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# TOPIC: STANDARDISED DESIGN OF A TOOL FOR BOREHOLE CHECKS AND SINK OUT DRAWN SUBMERSIBLE PUMPS IN BOREHOLES.

BY:

**TSATSA CLIVE T**

**B190113B**

BSc Hons. AGRICULTURAL ENGINEERING

SUPERVISOR:

**PROFFESSOR ISNEL RODRIGUEZ**

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# DECLARATION

I, **TSATSA CLIVE T.**, **B190113B**, I declare that, with the exception of what is noted in the acknowledgement and references, all of the research and work for this study was done by me. According to my knowledge NO other university has received this project, in whole or in parts.

Student´s Signature:_ _ Date: 05/06/2024

Academic Supervisor´s Name: I. Rodríguez Signature: _ Date: 20/06/2024

Project Coordinator´s Name: I. Rodríguez Signature: _ Date: 20/06/2024

## ABSTRACT

The provision for the manufacture of submersible pumps is still being a challenge especially in developing countries like Zimbabwe. This has result in high costs of these pumps since they are being imported from the Asian and European countries. The purpose of this study was to design and fabricate a tool that can be used for fishing out drawn submersible pumps which has fallen into the borehole due to loose connections and many other reasons. The tool is also to be used for borehole checks, checking depth of casing and borehole depth as number of crooks have increased in the borehole drilling industry. The goal was to minimize the costs of buying new pumps as they are expensive hence, just fishing it out and re-use the pump will be cheap. Another goal was to do borehole check just after the drilling process so that the client would verify if the job has been done perfectly by checking depth of borehole and checking depth of borehole casing before the installation process. The tool has been fabricated using some recycled material and very few new components so as to reduce cost so that it becomes affordable.

## DEDICATION

I dedicate my project to my numerous friends and family. I am very thankful to my wonderful parents, Mr and Mrs Tsatsa, whose support and insistence on perseverance have left a lasting impression on me. They have been my pillars of strength and have always believed in me, even during my toughest times. My siblings Dennis Tsatsa and Samantha M are incredibly dear to me and have never left my side.

In addition, I dedicate this project to my church family who have helped, encouraged and prayed for me along the way through. I dedicate this work to my amazing closest friends Queenrose Ruva Mhembere, Vimbai Chaka L and Farai Manza and express my gratitude to them all. Their encouragement and motivation have made my college experience memorable, and I am grateful for their unwavering friendship. I am really appreciative of all of your help in shaping who I am now.

May you always be blessed by the all-powerful God Jehovah with his boundless grace and love?

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## List of Acronyms and Abbreviations

1.UNGA - United Nations General Assembly

2.UNICEF - The United Nations Children's Fund

3.SDG - Sustainable Development Goals

4.NDS2 - National Development Strategy volume 2

5.HDPE - High Density Polyethylene

6.PVC - Poly Vinyl Chloride

# LIST OF APPENDICES

# CHAPTER 1: INTRODUCTION

## 1.1. Background

A borehole is a narrow shaft bored or drilled in the into the earth surface. It is drilled either vertically or horizontally. A borehole may be constructed for many different purposes, including the extraction of water, other liquids such as petroleum or gases for example natural gas. As surface water is depleted by climate change, groundwater reached by boreholes has become the main water source for 38% of Zimbabweans, says the Ministry of Environment, Water and Climate change. Harare the capital city, is especially dependent on boreholes .Here, about 80% of the people depend on groundwater, using some 28000 registered boreholes (Carruthers, 1999).

The rate of borehole drilling is increasing daily in Zimbabwe, several communities will benefit from a water supply project recently launched by the government. The authorities have approved the release of Z$1.1 billion (over US$3 million) to drill 1,800 wells. The future facilities will be used to capture groundwater to supply schools and high-traffic areas in vulnerable areas of Zimbabwe. According to Anxious Masuka, Zimbabwe's Minister of Agriculture, Lands, Fisheries, Water and Rural Resettlement, the country currently has some 41,754 wells. These facilities, located in rural areas, are operating at just 55% of capacity. The sites for the new boreholes will be identified by local communities and will be subject to hydro-geological studies before work begins.

Access to safe drinking water is crucial in any area in Zimbabwe. And climate change, mostly causing droughts, is not making things any easier. Long periods of drought also bring more conflict between humans and wildlife. Many people get their water outside their villages and have to walk long distances to find it. This is especially so for people living near protected areas where encounters with wild animals easily occur.
However, it is not only people who need fresh water - many wild animals also have to move long distances to find water. This brings them increasingly close to human settlements - and the potential for conflict increases. Counteracting this is part of an ambitious WWF project in two trans-boundary nature conservation areas – one that covers Zimbabwe being the Kavango Zambezi Transfrontier Conservation Area (KAZA). The aim is to improve people's livelihoods, strengthen communities, adapt them to the effects of climate change and mitigate human-wildlife conflicts. One

practical way of supporting communities is the construction of drinking water boreholes in Zimbabwe.

Most of the boreholes being drilled uses different sources of power for pumping water from underground to the surface, some boreholes uses solar energy, electric energy and some are bush pump which uses manual power to draw water. The bush pump is wholly Zimbabwean. It was first designed, by Tommy Murgatroyd, a government water supply officer operating in Plum-tree district of Matabeleland, in western Zimbabwe, (Morgan, 1989). This pump is mostly found in rural areas. On electric pumps are only used by those who has access to electricity, but most people are running away from electricity and opting to use solar because there is too much load shedding and also to cut cost by avoiding ZESA monthly tariffs. Solar energy is abundant and free, making it an excellent long-term investment for those who install it. Moreover, solar-powered systems do not produce any emissions, making them environmentally friendly.

## 1.2. Statement of Problem

Due to climate change and depleting of surface water, the rate of borehole drilling will continue to rise as underground water is one of the safe and trusted source of water both for human consumption, for agricultural purposes and also for wildlife. The number of people getting into this borehole business has also increased, some of the trades and companies are operating legally and some are not, thereby we are having challenges by some installers and companies who are not doing the job professionally. These people or companies are using untrained installers who are not doing proper jobs and also cheap fake materials which end up causing the pumps to sink into the boreholes as there will be weak connections, they lie about the depth drilled and also the depth of casing. Therefore, the aim of the project is to design and manufacture a tool which can be used for borehole checks just after the drilling purpose and before installation to check depth of casing and depth of the borehole before to the next stage. The tool can also be used to fish out drawn submersible pumps in boreholes.

## 1.3. Main Objective

To design and manufacture a tool which can be used for borehole checks and to sink out drawn submersible pumps in Bindura farms.

### 1.3.1. Specific Objectives

i. To design a tool for borehole checks and to draw out sunk submersible pumps.

ii. To fabricate a low cost tool using locally available material in Bindura and recycle material.

iii. To prove the performance of the system

1.3.2. Hypothesis

i. To design a tool which is cost effective and high operating efficiency for borehole checks and to sink out drawn submersible pumps in Bindura farms and producing results.

ii. The tool for borehole checks and to sink out drawn submersible pumps must be easy to operate and cheap in terms of maintenance

**1.4. Justification**

Boreholes are now the reliable source of water in Bindura thereby the rate of borehole drilling is increasing daily in every parts of the country. However, the industry of borehole drilling is also increasing hence some companies are providing poor material and services to the clients. This results in lying the drilling depth, lying casing depth and lastly providing poor quality materials which may results in sinking of submersible pumps inside the boreholes. This may be a risk to the client cause at any time the borehole can collapse ,the borehole may run dry due faked depth and also the pump may sink due to poor material or experience of the installer which may results in extra cost as the client may need to drill another hole or to buy new pumps.

To mitigate the potential risks associated with the problems above therefore checks will be necessary to minimize such activities in the industry. This research aims to come up with tool which will be used for checking borehole depth and casing depth. The tool can also to be used to remove sunk pumps in a borehole.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Introduction

A water borehole is a hole that is bored beneath the ground to retrieve water from a natural source deep underground. It may be horizontal or vertical in direction and is used to collect water from the pathway along which the final hole will be drilled (Meinzer, 1923). Due to the deeper penetration into the ground, a water borehole provides a consistent, reliable source of water even in drought conditions.

A machine slotted casing in a borehole is what allows water to come through from the aquifers into the hole. Borehole can have depth ranged from 150ft to 1000ft. The deeper the borehole, the more casing needed and the more water that is able to pass through. The size of your property and the amount of water you expect to use will determine the borehole depth, (Rowley, 1987). After the drilling process, a borehole pump is needed to draw water from underground. A borehole pump typically consists of a motor and impeller that work together to pump water to the surface. Borehole pumps are commonly used for domestic, agricultural, and industrial purposes. Borehole pumps are a type of submersible centrifugal pump of multi-stage design which can be submerged at large depths. They are typically designed to fit in narrow holes called boreholes which are drilled to extract water from water tables or aquifers deep below ground, (Hussein, 2023).

## 2.2. Background and Context

Access to safe water is also a human right recognized by the UNGA, (Gupta, 2010). Water is fundamental to development and well-being. Access to safely managed water is not only a goal in its own right but is critical in the achievement of other developmental objectives such as adequate nutrition, gender equality, education and the eradication of poverty, (Ray, 2007). Borehole drilling has been identified jointly by UNICEF and Zimbabwean government as one of the critical interventions needed to responds to SDG call. The specific test was to engage private drilling companies in Zimbabwe to provide drilling services, including survey for water and installations of the boreholes then hand over to their communities, (Note, 2016).

To overcome the water scarcity and water problems Zimbabwean government is setting goals in borehole drilling programs, as it is a safe and reliable source of which may take the country and its people to the next level, (Mukuhlani, 2014). In May 2021

Zimbabwean government did set a goal of drilling 44600 wells by year 2025, several communities will benefit from a water supply project recently launched by the government? The boreholes would be drilled nationwide including Mashonaland Province, where Bindura town is located. The future facilities will be used to capture groundwater to supply schools, hospitals, agricultural purposes and high-traffic areas in vulnerable areas of Zimbabwe.

According to Anxious Masuka, Zimbabwe's Minister of Agriculture, Lands, Fisheries, Water and Rural Resettlement, the country currently has some 41,754 wells. The new boreholes will also supply horticulturist these facilities will improve water supply to 35,000 people, including 9,600 rural school children. As the number of boreholes will be increasing in the country, the borehole problems associated with pumps falling into the boreholes will be also increasing. This will be caused by cheaters in the industry who will do substandard jobs leading to problems like the one mentioned above. Schemes like Presidential Schemes has also been launched to increase the borehole drilling process to counter the problems of in all parts of the country including Bindura town located in Mashonaland Central province. The Presidential borehole drilling scheme has started as Government seeks to provide clean water to urban areas after successive opposition led councils have failed to ensure potable water for residents. Harare and Chitungwiza are expected to get over 200 solar-powered boreholes under the scheme while Marondera will have 20. Schemes will also help in agricultural sector for people in rural areas hence fulfilling government's aim of everyone being a middle earner by the year 2030, NDS2.

The types of pumps used in boreholes in Zimbabwe. Firstly, the Bush Pump, (De Laet, 2000). It is a robust conventional lever action hand-pump, developed and standardized in Zimbabwe (SAZ 881:2004). It is designed for heavy-duty use, serving communities of 300 persons. Three different cylinders are available, the smallest one extend the range to a maximum recommended depth of 80 m. The Bush Pump is not corrosion resistant. It requires special skills for installation as well as for the maintenance (Morgan, 1995)

Figure 2: 1 Bush borehole pump (source: www.rural-watersupply.net)

Secondly, the other type of pump used in Boreholes is submersible pump, (Chen, 2019). A submersible pump is a device which has a hermetically sealed motor close coupled to the pump body and the whole unit of the pump is submerged in fluid to be pumped. This is now the common pump used in Zimbabwe. These pumps are powered by either electricity or solar, (Sharma, 2022). In Zimbabwe solar powered pump are being preferred mostly because of increased rates for power cuts in the country and also solar system is cheap in a long run period. The pump does not need manual power to pump water. The disadvantages is that the water cannot be pump during cloudy days and also at night will be needed hence storage tanks (Gouws, 2012).

Figure 2: 2 a solar powered borehole (source: www.aqliquidtransfer.co.za/solar.)

## 2.3. Borehole Drilling and Installation Process

Engineers and environmental consultants use the term 'borehole' to collectively describe all of the various types of holes drilled as part of a Geo-technical investigation or environmental site assessment, (Matthews, 2002). Typically, a borehole used as a water well is completed by installing a vertical pipe (casing) and well screen to keep the borehole from caving. This also helps to prevent surface contaminants from entering the borehole and protects any installed pump from drawing in sand and sediment. There are four steps in borehole drilling namely ,geophysical survey, drilling and construction, determination of yield of borehole and lastly piping and pumping the borehole, (Tudor, 2018).

### 2.3.1. Geophysical Survey

The first thing that need to be determined is where the water is and how you will get to it. That is where the services of hydro-geologists are employed. They make use of a variety of borehole drilling methods to assess the geophysical properties of the underlying area, (Keys, 1990). The first decision of the water borehole drilling process is to determine where to drill. The geological features of hydro-logical importance, include faults fractures and lithological contact zones, are targeted for drilling. There is 60 to 85% success rate in ideal conditions. These hydro-geologists ensures that you are not drilling into natural hazards or man-made infrastructure for example pipelines, cables and phone lines, (Riyaz, 2017).

Borehole surveying involves the analysis of geophysical data that are collected within boreholes, wells, or test holes. Boreholes provide access to the sub-surface, and borehole methods can produce continuous, in situ record of the properties of intersected formations, formation fluids, borehole fluids, and well construction. Data collected using borehole methods are diverse and may provide more physical and chemical information about the subsurface than available from drilling, sampling, or surface geophysics alone. Borehole geophysics can provide a wealth of information that is critical in gaining a better understanding of subsurface conditions needed for groundwater and environmental studies. Borehole methods can be subdivided into seven broad categories, and those are electrical, electromagnetic, nuclear, seismic physical and imaginary methods, (Mussett, 2000).

Figure 2:3 picture showing person doing borehole sitting (source: boreholesiting.co.zw)

### 2.3.2. Drilling and Construction

The first step in drilling a borehole is determining the proper location. This entails taking into account elements including the geology, potential impediments, and the kind and depth of groundwater. Drilling starts as soon as a drill rig is assembled at the chosen location. This entails drilling a hole into the ground with a drill bit utilizing percussive or rotational drilling techniques. Drill cuttings are extracted from the hole by drilling fluid as the drill bit progresses, (Mahoud, 2020). Drilling for water wells includes drilling for water boreholes. To access the water below, it basically entails boring a hole deep into the earth. After installing steel or PVC casing and a borehole pumping system, you can draw natural water straight out of the earth, (Misstear, 2017.).

It's not as easy as Moses and the rock, unfortunately and contrary to popular belief, an endless supply of water won't just surge to the surface following the drilling of the borehole, hence there are still steps to follow and processes to be completed. Drilling and construction is next step after the survey process. Once the hydro-geologist has helped to prepare a path for the borehole drilling, the construction of the borehole starts. Once the borehole has been drilled, the necessary unstable lengths of the borehole are steel cased in an effort to reinforce the tube, (Hamelin, 2002).

Figure 2:4 Borehole drilling (source: globaldrilling.co.zw)

2.3.3. Determination of yield of borehole

It is also known as capacity testing which is done soon after drilling or construction process, (Thasnanipan, 2002). In order to most accurately gauge the yield of borehole water, an aquifer test is performed. This involve installing a test pump and pumping borehole water for a fixed set of variables at a given time, at a given rate and then assessing the test's impact on the water level in the borehole. Maximum yield is achieved by increasing the abstraction rate, ensuring optimum draw down of water in the borehole, (Rusli, 2020). Apart from the boring and building process, there are a few additional factors that need to be taken into account. The borehole capacity is one. The capacity affects the amount of water that can be pumped out of the borehole at any given moment and is based on the hydrology and geology of the area. The water pump's power source is an additional factor to take into account. The pump will typically be powered by electricity, however in isolated or off-grid areas, solar panels or a generator may be used to power it, (Rushton, 2004).

A test is used to determine a borehole yield by comparing the maximum volume of water that can be pumped out of the hole to the volume of water that recharges the hole from the nearby groundwater source, (Van Tonder, 2001). A procedure known as a pumping test can be used to ascertain an underground groundwater wells yield. In a pumping test, a constant flow of water is pumped out of the well, and the rate at which the water level falls over time is recorded. This makes it possible to determine the wells yield, or the fastest rate at which water may be drawn from the well without running out of aquifer, (Messar, 2006). Water testing is carried out to meet the regulatory requirements and adhere to the safety procedures that are needed for pollutant-free water and also to know the amount of water deep underground as it helps on pump and pipe sizing and also the demand.

Figure 2:5 Borehole capacity testing (source: Mimishacirrigation.online)

### 2.3.4. Pumping and Piping the Borehole

This process is called the installation process. The kind of pumping system and piping installed in your new domestic water borehole depends solely on the intended use of the borehole water, (Lamarche, 2010). The water needs to be raised to the surface and dispersed to the appropriate areas after the borehole has been dug. The usual method for doing this is called "pumping and piping". The pipelines that carry the water to its destination are connected to a water pump that is positioned at the boreholes surface. A number of variables, including the depth and capacity of the borehole as well as the distance over which the water must be moved, will determine the kind and size of the pump and pipelines, (Barlow, 2017). The pipes mainly used now days are either PVC or poly-pipes, they have low weight and also there property of not rusting is also an advantage of using them, (Einarson, 2002).

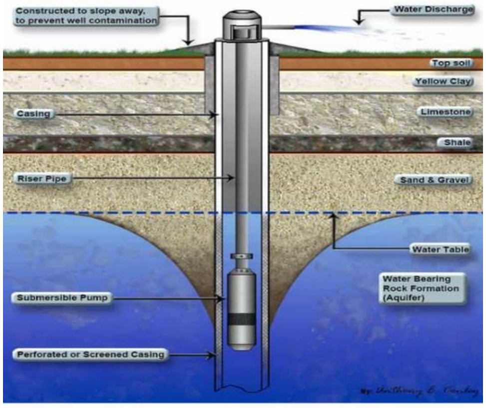



Figure 2:6 Borehole pump pipe set up (source: www.rpmdrilling.co.zw)

## 2.4 .Type of material to be used when installing boreholes

### 2.4.1. Nylon rope

Nylon rope to be used when putting the pump inside the borehole. This ropes to support the submersible pump so that it don't sink into the borehole. Due to its high strength, natural elongation, and abrasion resistance, nylon is a versatile and reliable rope material. This rope has also the ability to absorb tremendous shock loads, (Foster, 2002). This cannot be affected by water hence making it best for its purpose as it will be working water.

Figure 2:7 Nylon rope (source: www.genkingpowerservices.co.za)

### 2.4.2. Poly-pipes

The essential factor to consider is that the pipe material must be durable and long-lasting to avoid problems in the future. PE pipes are made up of polyethylene, which is a thermoplastic polymer. This type of material is known for its high strength-to-density ratio, as well as its flexibility, resistance to chemical and environmental damage, and low cost. PE pipes are often used in water systems because they are less likely to leak or burst than other types and kinds of pipes, poly-pipes are also locally available and they have easy joining mechanism, (Von Graszouw, 2016)

Figure 2:8 (HDPE) Poly-pipes (source: Mimishacirrigation.online)

### 2.4.3. Submersible Pump

Electric submersible pumps are multi-stage centrifugal pumps operating in a vertical position. Liquids, accelerated by the impeller, lose their kinetic energy in the diffuser, where a conversion of kinetic to pressure energy takes place. This is the main operational mechanism of radial and mixed flow pumps, (Gamboa, 2011). Submersible pumps are suitable for the conditions and can often be utilized from a bore diameter of 76mm because the boreholes are frequently relatively tiny, because the submersible borehole pumps are completely submerged, they can operate with high power inputs and maintain effective cooling, (Kuntz, 1980).


Figure 2:9 Submersible pump (source: www.desert-cartzimbabwe.co.zw)

2.4.4. Flex cable and Electrical accessories

A flex cable is a type of electrical cable that is designed to be flexible and bendable. It is often used in situations where traditional rigid cables cannot be used due to space constraints or the need for flexibility. Flex cables are often made of thin, flexible materials such as copper or aluminum and are insulated with a material such as PVC or TPE. They can be used for a wide range of applications, including electrical wiring. This makes it suitable to be used in boreholes for transmitting power from either solar or electricity to motor of the pump. Other accessories used are insulation tapes, joining kits pressure tanks pressure switch.

## 2.5. Conclusion

Due to change in climate there is now water scarcity in Zimbabwe and in urban areas the councils are failing to meet water demand required by consumers. These are the major reasons which has cause the increase in borehole drilling in the country since year 2000. Therefore the industry of borehole drilling was also increasing hence some small trading companies were end up doing unprofessional jobs trying recover the money they have undercharged the client when trying to convince him/her. These poor job quality has led to cases of the companies faking borehole depth during drilling process, faking casing depth and also unprofessional work during installations which has led pumps drawing inside the boreholes. The borehole check technology is need to check if the job done was perfect and also to remove the pumps which has fallen inside the hole.

# CHAPTER 3: DESIGN ANALYSIS AND CALCULATIONS

## 3.1. Introduction

For a number of reasons, it is crucial to concentration the design and analysis of a tool to sink out borehole pumps and borehole checks mainly in areas like Bindura where the rate of borehole drilling is increasing daily. The boreholes are being drilled in schools, hospitals, community areas, public areas like market places and also in farms for agricultural purpose like animal husbandry and horticulture production. Having this tool to sink out boreholes pumps in Bindura area will helps hell drilled working boreholes since they will be checked after drilling process before the installation process. This will also reduce the cost of farmer’s local people and different organizations from buying pumps as the pump are cost in Bindura. The used of locally available material and recycle material in construction of a tool to sink out submersible pump and borehole checks is also a sustainable one since the tool cheap orally hence it will affordable.

To make sure the tool is performing it purpose successfully, efficient and safe to use, it is crucial to design and analyze it. Effective design and analysis may minimize waste of material during fabrication, optimize efficiency and minimizing danger to the operators hence doing the perfect task required. A badly fabricated tool has a risks of mishaps and injuries to the operator hence it is important to design and fabricate the tool which is safe to use. This chapter will also focus on the process how the borehole will be checked and also how the pump will be removed from the borehole when it has separated with the pipe, flex cable and the pipe when it sinks. The chapter will also focuses on the calculations, procedures of fabricating the tool and design analysis will be covered in detail in this chapter. This chapter will helps to guarantee that the tool is perfect and will perform a great purpose when it released out there to people hence solving the purpose which is intended to do.

## 3.2. Key components of the tool to sink out borehole pumps and checks

The design of a tool to sink out drawn submersible pumps and borehole checks is mainly for Bindura areas where there is increased rates of borehole drilling both in town and the rural parts. The tool involves several key components. These components include supporting frame, the arm the rope and the camera and the hook. The system is going to be operated manually. The tool should be easy to use, easy to service and it should also be serviced locally to reduce operating costs. Some of the material used will be recycled material and few components will be new.

- ✧ The main frame

The main frame is the biggest component part of the tool. It is the part that holds other parts of the tool like the tool arm and the nylon rope holder. The size of the pump to be drawn out will depend with the size of the frame and its strength. Steel is the material used when making the main frame. When the size of the frame increases the size of arm will also increase hence bigger pump sizes will be drawn out.

- ✧ The arm of the tool

The arm is the key component that is attached to the main frame of the tool. The arm contains two pulleys where the nylon rope will pass by, it also supports the rope when drawing out the pump and when also when doing borehole checks so that the pump won't be damaged. Steel is used when making this arm.

- ✧ The rope

This one of the critical component of the tool. It is designed so that it will carry the pump hook in and out of the pump. The nylon rope will rolled on the mainframe and it will pass by the two pulley on the arm going into the borehole. Nylon is to be used due to its extra strength and light weight hence it does not break easily. The rope must be long as possible so that it reach the bottom of the borehole. Most of the boreholes in Bindura have a depth of 40m

- ✧ The camera

The camera will be attached to the pump hook it will there for borehole checks and also helps when trying to hook the pump so that the pump does not slip out when drawing out the submersible from the borehole. The camera should contain light so that you can see in the hole since there will be no light. It must also be water proof since it will be working in wet and water conditions. The camera must also be able to carry signal to depth of 40m. The camera will be linked to a router then the router will be linked to a mobile device or laptop.

- ✧ The pump hook

This one is the heart of the tool. This is the one which will hook the pump when drawing it out the borehole. This is also which camera will be attached to. The hook will be attached to the nylon rope. The hook must be strong to withstand pump weight.

### 3.3. Material and Component selection

3.3.1. Requirements and conditions for major components

a) The main frame and the arm

The selection of the material for a tool to draw out drawn submersible pumps and borehole checks depends on various factors, including the tool design, operating conditions and the overall costs. These factors may affect the performance and durability of tool which will have will impact on efficiency and lifespan of the tool.

- ◆ Corrosion resistant: The tool will be exposed to moisture, therefore it is essential to choose the material that can resist corrosion or which can be protected from corroding
- ◆ Cost: The cost of the material should be reasonable and within the budget of the manufacture, since this will have an effect on the selling price of the tool. Using the tool must be cheap than buying a new pump.
- ◆ Availability: The material must be locally available in the local markets. And accessories to service the tool must also be locally available.
- ◆ Strength: The material used should be of high strength so that they can withstand the weight when operating and also for the tool have a longer lifespan.

b) The rope (nylon)

The nylon rope is where the pump hook is attached to and is the one we pull when removing the pump from the borehole once it is hooked. Some of the key characteristics and the conditions of the rope need when fabricating the tool are;

  - ◆ Compatibility with the tool: the rope should designed to fit the specific function without affecting other components on the tool.
  - ◆ Resistant to change in low temperatures: when the temperatures are low the ropes have a tendency to shrink that property will not be best for a rope need on fabrication of the tool.

- Resistant to mildew: since the rope will be working in wet conditions is must be of high strength so that it cannot be affected by water. The rope must also have high strength to salt water as some of the underground water Bindura area is salty although the salts are very small quantities
- High strength to mass ratio: The rope must be strong enough to withstand the tension when the rope is being pulled out when the pump has been hooked.

c) The camera

When selecting a camera to use on a tool to draw out drawn submersible pumps in borehole, several conditions should be considered;

- Cost effectiveness: The camera must not be too expensive, as this can increase the overall cost of the tool significantly.
- Durability and corrosion resistant: The camera should be strong so that it last long and also since it will be working in wet conditions must not be affected so that it may have a long lifespan.
- Compatibility: The camera must be designed so that it can fit with the task to be carried out.
- Accessibility for cleaning; the camera will be deep inside the borehole the changes of the camera being in contact with mud are high therefore it should be easy to clean.
- Availability: The camera must also be locally available and also easy to fit and use.

d) The hook

When selecting the material to use for making a hook to use when drawing out the submersible pumps in borehole the following factors should be considered;

- High strength: The hook must be of high strength, if the material used is weak the pump may fall back into the hole and get damaged.
- Compatibility with the tool: The hook should designed to fit the specific function without affecting other components on the tool.
- Easy to use and control: the hook must be easy to control and easy to use so that it does not give complications to the operator.

3.3.2. Material comparison and selection

I. Selecting the type of frame and arm material to use.

Table 3. 1 Selecting the type metal.

| Material | Mild steel | Copper | Aluminum | Cast iron |
|---|---|---|---|---|
| | It can be easily cut, shaped and welded into various forms without requiring specialized tools, and lastly it is locally available. | high capacity to conduct electricity, Increased ductility, high thermal conductivity,<br>Excellent machinability, it's also corrode over a long period of time and lastly it is expensive hence prone to theft. | It has low density, is non-toxic, has a high thermal conductivity, has excellent corrosion resistance and can be easily cast, machined and formed,<br>Lastly it's expensive and prone to theft. | It is more fusible than steel, hard, brittle, and non-malleable that is, it cannot be bent, stretched, or hammered into shape. Due to its crystalline structure, it fractures easily and with little deformation when subjected to severe tensile strain. However, cast iron has excellent compression properties |

Overall the mild steel is the best material to use when constructing the frame and the arm due to its properties stated above compared to other materials.

II. Selecting the type of rope material needed.

Table 3. 2 Selecting the suitable rope

| Material | Nylon Rope | Polypropylene Rope | Jute Rope |
|---|---|---|---|
| | When it comes to conventional ropes, nylon is the strongest. Because it may revert to its initial length after being extended, it is utilized to absorb stress loads during lifting or towing. Additionally, it can endure several times longer than natural fibers and has good resistance to abrasion.<br>It is also locally available and it's cheap. It is not affected my moisture | Very lightweight, flexible and Can also be softened, it is also tough, durable all-round rope. Not as strong as Nylon rope. | Unique physical characteristics of jute fiber include its high tenacity, bulkiness, ability to insulate heat and sound, low thermal conductivity, antistatic qualities and lastly it can't be used in water as it may rote over time. |

From the above mentioned properties and quality of rope material, Nylon rope is the best type of rope which will compatibly with the task it will be caring out.

### 3.4. Design synthesis of the tool

3.4.1. The functional interrelation of the tool

A tool draw out drawn out sunk submersible pumps and borehole checks is a simple manual machine which variety of functions in borehole drilling industry. Its main function is to draw out drawn submersible pumps which could have drawn deep in boreholes. The functional interrelation of the tool is the overcome costs of buying new pumps as they are expensive and also job must be done as that shall be monitored by doing borehole checks. The tool shall also be safe to the environment.

- The main frame

It is the body of the tool, most parts of the tool will be attached to this part. The main frame must be strong enough and it must have a base so as to be mounted on trucks or mounted on the ground. Mild steel is to be used due to its good properties and should be painted to protect it from rust hence adding extra strength.

- The nylon rope

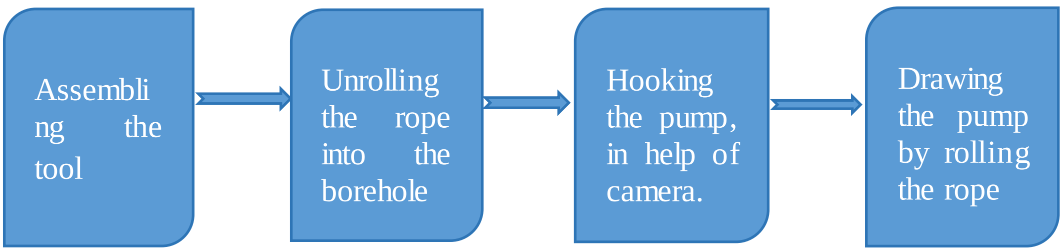
The pump hook will be attached to a rope which is the nylon rope. The rope will be rolled on the main frame and it will two wheel pullies then attached to the hook. The rope should be of extra length so that it reaches the bottom of the borehole. Using the nylon rope will add extra strength to the tool as the rope can withstand high loads due to its properties.

- The hook

It is the component which will hook the pump, hence it should be protected from rusting by painting it so that it don't pollute borehole water since borehole water in Bindura is considered as safe water hence it is also used as drinking water. By protecting the hook through painting it's not only making water safe but also strengthening the hook hence increasing the overall lifespan of the tool

3.4.2. Description process steps of the tool

Process flow steps of the tool




Detailed description of the steps

i. Step1: Assembling

The process start by setting up the tool and doing all the adjustments needed during operating the tool. The setting up and the adjustments depend either the tool is to be used for drawing out the pump or for borehole check. The tool can be mounted in a truck or on the ground.

ii. Step2: Unrolling the rope

Once the tool has been assembled, the process then continue. The rope rolled the main frame will then be rolled into the borehole with a hook at end of it. The unrolling should be done gently without damaging the tool.

iii. Step3: Hooking

As the process continues, once the hook reach the bottom of the hole or when it reaches the point where the pump is in help of the camera, the pump is then hooked

iv. Step4: Drawing out the pump

Finally, when the pump hooking is successful the rope will then be rolled hence drawing out the pump from the borehole. This point need extra care and attention to avoid pump slippery back to the hole.

Overall, a tool to draw out sunk submersible pumps and borehole checks is an efficient tool which can solve problems in borehole industry sector. The process of drawing out the pump are easy and also there is easy to operate hence making it an excellent to which shall solve problems out there.

**3.5. Design calculations**

3.5.1. Calculating the tension the nylon rope.

Let the tension in the rope be (Ft)

(Ft) = Force of gravity (Fg)

= mass (of pump) by acceleration due to gravity

=m (kg) by a (m/s^2)

Assume a submersible pump has a weight of 9kgs and acceleration due to gravity is 9.81m/s^2.

Therefore Ft= 9kg × 9.81m/s^2

=88, 29kgm/s^2

Tension in the rope is =88,29N

3.5.2. Calculating velocity ratio, mechanical advantage and the efficiency of the tool.

Assumptions

-tension Ft is 88,29Newtonsfrom the above calculation

-effort is 60Newtons

The number of pullies of the tool is 2

Calculating velocity ratio (VR),

VR= number pulley wheels on the system

Velocity Ratio (VR) =2

Calculating mechanical advantage of the tool (MA),

$$\mathrm{MA} = \frac{\mathrm{load}}{\mathrm{Effort}}$$

$$= \frac{88{,}29N}{60N}$$

$$=1{,}4715\mathrm{N}$$

To 2d.p mechanical advantage (MA) $=1.47$

Calculating the efficiency of the machine (EFF),

$\mathrm{EFF} = \frac{\mathrm{MA}}{\mathrm{VR}} \times 100\%$

$= \frac{1{,}47}{2} \times 100\%$

The efficient of the tool will be (EFF) =73.5%

3.5.3. Calculating the Resistance condition.

$\sigma \leq (\sigma)$

$$[\sigma] = \frac{\sigma_y}{SF}$$

The three possibilities are;

i. When the condition is OK $\sigma_a \leq [\sigma]$

ii. When there is some doubt $\sigma_a = [\sigma]$

iii. When there is no resistance $\sigma_a \geq [\sigma]$

The safety factor should be between 1.5 and 2.5

Hence am going to use 2 as my SF

Table 3.3 Information on steel property used

| PROPERTIES | METRIC |
|---|---|
| Density | 7.87g/cc |
| Hardness | 105 |
| Tensile strength | 365MPa |
| Tensile strength | 305MPa |
| Modulus of elasticity | 205GPa |
| Bulky modulus | 160GPa |
| Shear modulus | 80GPa |
| Machinability | 55% |
| Elongation at break | 20% |
| Reduction of area | 40% |

Area in front of the load

$= L \times W$

$=20m\times20mm$

$=400mm^2$

Stress which produces the load

$\sigma_a = \frac{P}{A}$

$\sigma_a = 56.58\frac{N}{mm^2}$

$= 56.58MPa$

Consideration about the resistance

$\sigma_a \leq [\sigma]$

$[\sigma] = \frac{\sigma_y}{SF}$

$[\sigma] = \frac{305MPa}{2}$

$[\sigma] = 152.5MPa$

Shear $[\tau] = \frac{[\sigma]}{2}$, hence the first condition is met, it means that the material will resist working conditions.

## 3.6. Diagrams of the tool to remove drawn submersible pumps and borehole checks

i. Diagram showing the pipe representing borehole casing

Note;

1-The PVC pipe 110mm

2-Metal base for supporting pipe

All dimensions are in mm

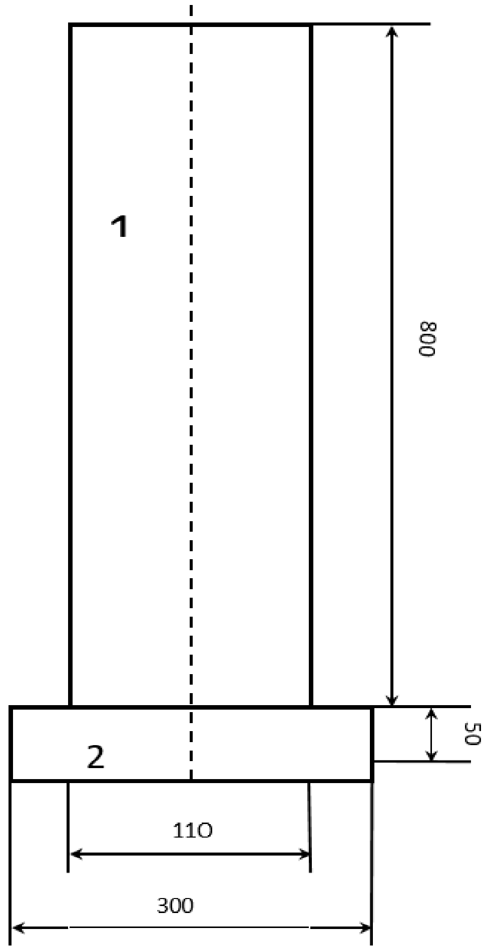



Figure 3. 1 Drawing showing the pipe representing borehole casing

ii. The full diagram of the tool

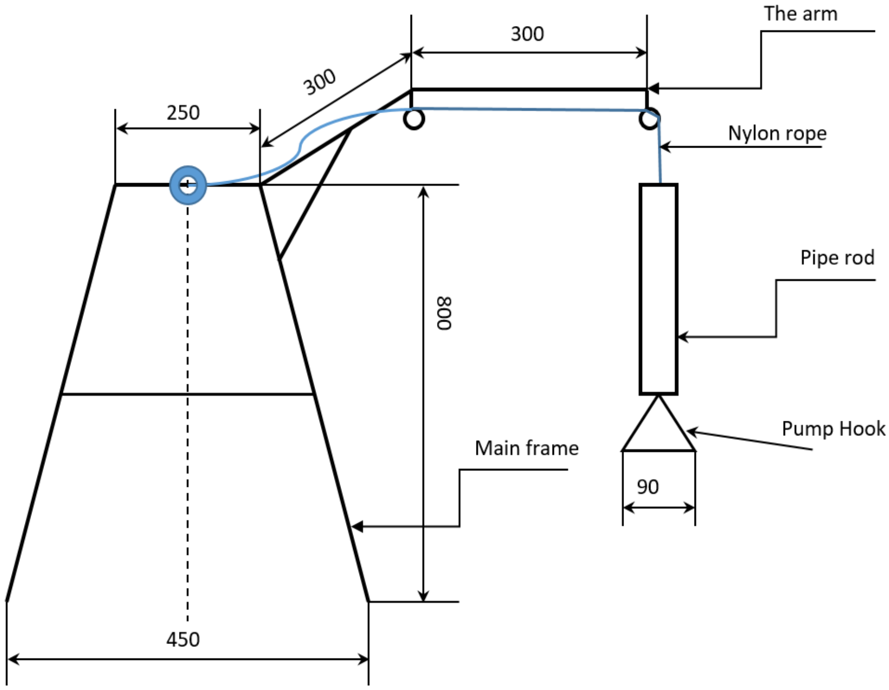



Figure 3. 2 full drawing of a tool to remove drawn submersible pumps

## 3.7. Fabrication of the tool to sink out borehole pumps and checks

Step 1(one) : Fabricating the main frame and the arm.

-The main frame must be strong enough to withstand the load coming from the borehole and must be supported enough so that it won't swing when the pump is being removed from the borehole.

-The material needed recycled steel, welding rods, nylon rope, camera, hooker, pipe, submersible pump and supporting stumps.

Figure 3. 3 Scrape metal at BUSE dumpsite

-Cut, shape, and bend the material according to the specified dimensions in the diagram, use a cutting disc to cut the steel to the appropriate size.

Figure 3.4 Picture showing student markings at BUSE workshop

Figure 3.5 Picture showing a student cutting using a cutting disc BUSE workshop

-Assemble the steel bars to form the main frame of the tool and the arm of the tool.

-The steel pieces are joined by using a welding machine.

-Protective clothing should be worn during the process of welding

-Once the main frame and the arm is fully assembled, fabricate the pullies will be added to the component and also the supporting are also to be added on the main frame.

Figure 3.6 Picture showing a student assembly pieces by welding BUSE

Step 2(two) : Fixing the rope to the main frame and applying the protecting material.

-After the fabricating of the main frame and the arm, the rope should be attached to the main frame.

-The rope is mounted on a wheel which will be attached to the main.

-The rope wheel will be attached to the wheel by welding the two parts together, the main frame and the rope wheel.

-After attaching the two components the rope will be fixed rolled to the rope wheel so that it will not be completely removed when unrolling it to the borehole.

-Insulate the rope wheel handle so that it won’t hurt the operator when the work is in progress.

Step 3(three): Attaching the hooker to the rope.

-The submersible pump hooker should be attached the rope.

-After the rope has been attached the rope wheel, the hooker is supposed to be attached to the rope.

-As the fabrication process, protective clothing should have been wore, safety shoes, gloves and welding glasses or safety glasses.

-All connections and joints are to be checked at this stage before moving to the next stage.

-since the tool will prone water chance of rusting is high due to the properties of steel to oxygen, protective measure are also done at this stage.

-The tool is then painted, the whole component except the rope and the insulated handles will be painted.

-Spray paints is to be used as it cannot washed away by water.

<u>Step 4(four)</u>: Assembling the pipe and its stand.

-110mm PVC pipe is going to represent borehole casing.

-The 110mm PVC pipe will be fitted on its supporting stand so that it balances.

-The supporting stand of the pipe is also painted to protect it from rusting.

-Mortar will be added to the bottom of the pipe so as to seal it.

-The component will be left for some days for the cement to dry.

-Water will be added to a certain level into the 110mm PVC pipe representing the borehole casing.

-A well pump 250W is going to be used representing a submersible.

-The well pump will put into the pipe which had been add so that it act as submersible pump which has drawn in the borehole.

<u>Step 5(five)</u>: Connecting the camera.

-After all other assemblies has been done, then camera is the last thing to connect.

-The camera will be mounted on the pump hooker as it will helps to visualize what will be taking places in the borehole during the withdrawal of the pump and the borehole check process.

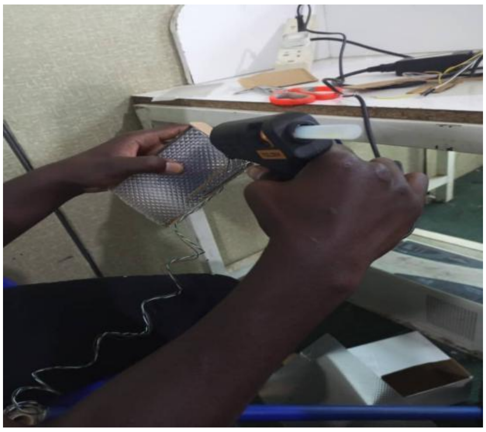


Figure 3.7 The picture showing covering the router for safety reasons using a glue gun.

-The camera should be properly insulated as it will be working in wet conditions inside the borehole hence water must not enter as it may cause to malfunction.

**3.7. Testing the prototype**

After the tool is fully assembled, the testing is then to be done, so as to see if the tool is working properly and also to obtain results.

3.7.1. Drawing out submersible pump from borehole

-Set the tool and do all adjustments necessary.

-Put supporting blocks on the main frame to avoid the tool from tilting when the pump is being drawn out.

-The rope is then unrolled moving the pump hooker into the borehole.

-The rope is using a rope wheel moving it in clockwise direction.

-The camera should be checked to see if the hooker has reached the position where the pump is.

-The pumped is then hooked in help of the camera to see if the pump has been completely hooked.

-The rope is then pulled back by rolling the rope wheel anti clockwise.

-As the rope will be rolled the pump will be moving out of the borehole

-This should be done cautiously to avoid the pump from slipping.

-Hence the submersible is drawn out of the borehole.

3.7.2. Borehole checks

-During borehole check the hooker is removed at the end of rope and the camera is left at front of the rope and an extra weight left so at to make the rope since when it reach level with water.

-Check the point which is marked inside the PVC pipe which is acting as borehole casing.

-Mark the point flashing with the borehole casing outside the casing pipe.

-Remove the rope from the pipe casing then measure the length of the rope.

-Tape measure is used to measure the length in m.

-The distance will be the meters of the casing of the borehole.

-When checking the total length of the borehole the procedure is repeated but this time the rope is supposed to reach the bottom of the borehole.

# CHAPTER 4: RESULTS

## 4.1. Introduction

The first section of this chapter provides an overview of the specifications that were ultimately utilized in the tool's design for both borehole inspection and drawing out submersible pumps. The design and fabrication process are then shown in detail, along with the parts and materials required for the fabrication. An evaluation of the system's functionality and possible effects on the borehole drilling and installations sector round off this chapter. Overall, the study's findings offer insightful information that will help with the tool's design and will be very beneficial to the relevant field industry.

## 4.2. Tool Specifications

-frame size 0,8m high.

-frame has a base area of $0.12m^2$

-110mm PVC pipe used as casing is 0.8m long.

-the pipe will be supported by a metal base of $0.4m^2$.

-the nylon rope is 8mm thick and 10m long.

-a well pump 250watts was used.

## 4.3. Fabrication Process

### 4.3.1. The main frame

Steel bar from the scrap were used to make the main frame of the prototype. The steel was cut into the required sizes using the cutting disc. A protractor was to mark angles. Arc welding was then used to join the steel pieces to come up with the frame. On the top part of the frame a drilling machine was used to drill holes for the rope axle, 10mm drill bit was used. After welding the grinding disc was then used to remove unwanted edges to make the frame safe handle and also for better looks. The frame was then painted, adding extra strength to the frame by protecting it from rusting thereby adding value to the tool.

Figure 4.1The picture showing the main frame of the tool

### 4.3.2. The pipe and its supporting base

Figure 4.2 The picture show the pipe and supporting metal base

Material used to make the pipe supporting frame was also from the scrape. The supporting frame of the pipe was assembled by cutting the required dimensions using the cutting disc then joined using arc welding. 110mm PVC pipe was used to present the pipe for borehole casing. The pipe was then connected to the pipe and masonry mortar was add to make the object stronger and to avoid the leaks. The base frame of was also painted to protect it from rusting.

### 4.3.3. Other units

Nylon rope was rolled to its axis on the main frame it passed through the two pullies. The pump hooker was assembled using PVC pipes 25mm, wire and soft wire. A camera was also added to pump for visibility during the hooking process. A steel sensor was also added as for alternative in case water will be dirty. A cell application was also programmed to give results during the hooking process. The application was to give feedback of what happening inside the casing

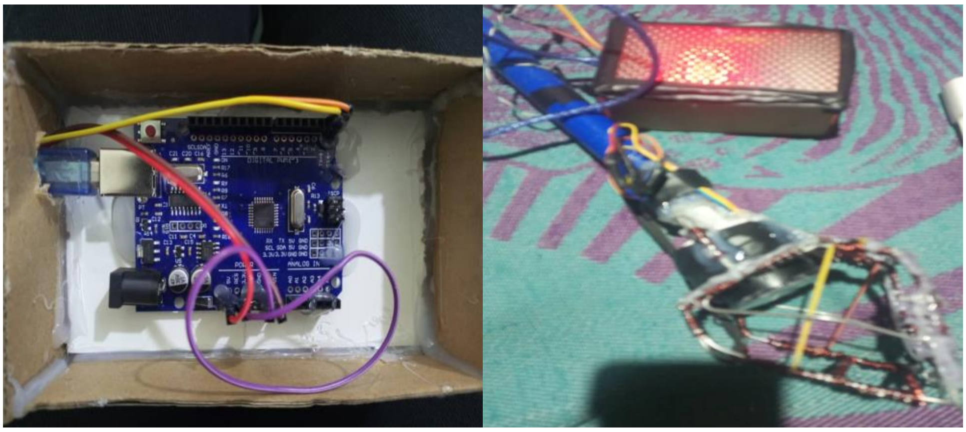


Figure 4.3 The picture showing a router and a pump hooker

### 4.3.4. The whole diagram of the tool

Figure 4.4 Standardised tool for borehole check and to remove drawn submersible pump

Laptop was supplying power to the router then router was link to mobile phone via hotspot then the view of what is inside the was seen on the specific site for the tool. inoder to login to view, 'http://192.168.226.144' this link is used. After you have seen where is the pump it is then hooked manualy using a small rope attached to the tool then the big nylon rope will be used to remove the pump form the borehole

### 4.4. Results calculations

The weight of the pump was 3kgs

Assume the experiment was done in vacuum and the acceleration due to gravity was 9.81ms^2

a) Calculating tension in the nylon rope

-Tension in the rope is equal to force in rope

-Force (F) = mass (m) × acceleration due to gravity (g)

= 3kgs × 9.81ms^2

Force (F) =29.43N.

b) Calculating the effort

-Effort is equal to force multiply be perpendicular distance

-the perpendicular distance from the frame to the far end of the arm is 0.4m

- Effort = length × load

= 0.4 × 29.43

Effort =11.772N

c) Calculating rope tension frequency

Tension frequency (f) =12l√Fμ

F= tension of the rope = 29.43N

L= length of the rope = 10m

μ= mass per unit length of rope = 0.1kgs

f=12(10) √ (29.43×0.1)

=120√2.943

Tension frequency =205.86CPM

d) Calculating efficiency of the tool

Efficiency $=\frac{mechanical\ advantage}{velocity\ ratio}\times 100\%$

-Calculating mechanical advantage$=\frac{load}{effort}$

$=\frac{29.43}{11.773}$

$=2.5$

-velocity ratio is equal to the number of pullies=3

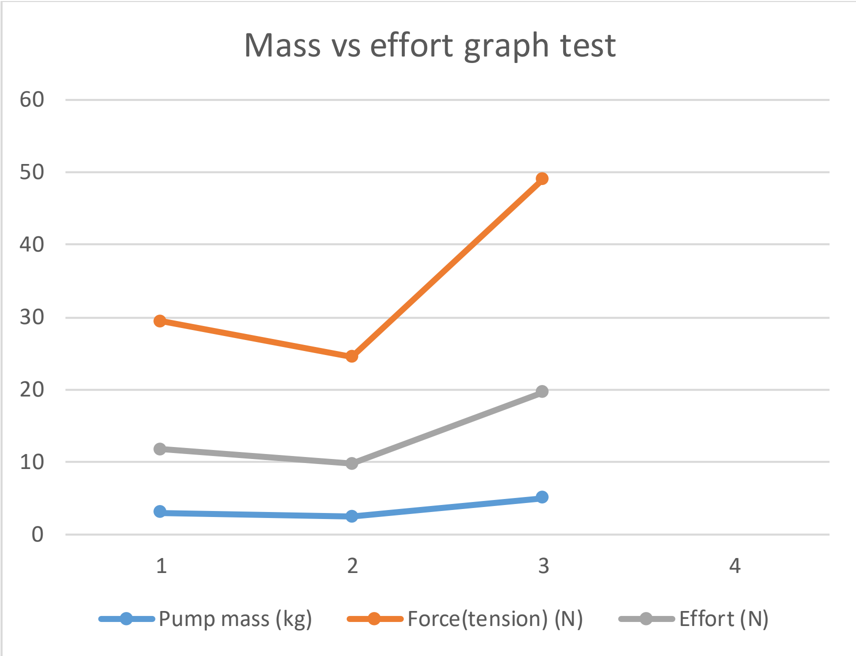
Hence, Efficiency $=\frac{2,5}{3}\times 100\%$

$=83.33\%$

-The experiment was then done using different pumps

Table 4 1Table showing the experiment result

| Pump mass (kg) | Force(tension) (N) | Effort (N) |
|---|---|---|
| 3kg | 29.43 | 11.77 |
| 2.5kg | 24.53 | 9.81 |
| 5.5kg | 49.05 | 19.62 |




Graph 4.1 representing experimental results

# CHAPTER 5: DISCUSSION AND PROJECT EVALUATION

## 5.1. Introduction

This chapter discusses the findings obtained from this project. It also implies a cost benefit analysis, the availability of resources, easy functioning and maintenance of the tool and job adaptation. The project evaluation is a critical process that helps to determine whether has achieved its objectives at the end of its life span. The evaluation process involves a systematic and objective assessment in the project, focusing on various parameters such as cost, schedule and performance of the proto-type.

## 5.2. Discussion of results

5.2.1. Objective 1: to design a tool for borehole checks and to draw out sunk submersible pumps.

The objective of designing a tool for a system to do borehole checks and to draw out sunk submersible pump was successful as the system designed got to be as planned. Though it was just a small prototype than the actual things, the idea of doing borehole checks after drilling and drawing out drawn submersible pumps in boreholes was proved to work as desired.

The system design demonstrated that it was functional and user friendly, with simple controls and little servicing overall costs. The system has actually use less labour during the operation making it best for the specific task to be performed. The system is also user friendly to the environment as it don't cause pollution or destroying the environment. The test results has also add valuable information on potential adjustments and improvements that could be made to increase the system's usefulness and efficiency in the future. This project design demonstrated the feasibility of innovative and environmentally friendly cooking solution for improved livelihoods in Mashonaland province area where Bindura is located.

5.2.2. Objective 2: to fabricate a low cost tool using locally available material in Bindura and recycle material.

In addition, the other aim of this project was fabricating a cheap tool and this successfully accomplished. The goal of this project was to used locally available material in Bindura and also recycle material from dump areas. The tool has a simple design which has to accommodate the use of cheap components from the shop and recycled materials were also efficiently utilized during the tool fabrication. The simple design will add advantage to the tool as they will be less complications when operating the tool. The use of recycled material substantially reduce production costs, hence making the tool affordable hence achieving the goal because the tool becomes expensive people will not afford it hence opting to buy new pumps. The recycled material shows resilient, thus ensuring a long lifespan and reliability eliminating replacement costs and low costs things like respraying will be necessary to protect the tool from being damaged for example by rust. The tool's performance was successful hence adding value to the borehole industry hence contributing to the physique of knowledge on eco-friendly and low priced tool paving the way for further advancement in the borehole drilling and installation industry.

5.2.3. Objective 3: to prove the performance of the tool in terms of efficiency using my prototype.

The results for borehole check and removing drawn submersible pumps in boreholes shows that the tool is relatively efficient in performing its purpose. After the prototype has been tested, the results showed that the goal has been accomplished. The aim of the thesis to design both an inexpensive simple tool but perfecting well the required purpose was achieved. The tool is going to play a big pivotal role in borehole drilling and installation industry, it will help to do the borehole checks just after the drilling process and also help to draw out sunk submersible pumps, which had sunk due different reasons like weak and unprofessional connections hence the tool will help the clients not to buy new pumps as they are expensive hence using the existing pump and cut costs.

Additionally, the tool was designed using cheap locally available material and recycled material hence its overall cost will be low then it will be cheap to purchase for those who need it and cheap for hiring for those who want to use temporary. Due to recycle material and locally available material the tool will be easy to maintain, operate and servicing hence it will have a long a lifespan. The results from the tested prototype show that the tool to do borehole check and to remove sunk submersible pumps will play a big pivotal role in boreholes industry benefiting the clients mostly by doing a perfect task and low cost.

5.2.4. Comment on the tool.

Less time is required when setting out the tool to perform the required job and also the processes are so fast both borehole check and pump removal hence time management factor is covered. During the results obtain the tool can work out through without being affected seasons or daily weather conditions. The tool is also corrosion resistant since it will be operating in water hence giving it high life span and become favourable in industry as everyone something that last long.

**5.3. Project Evaluation**

Project evaluation is a critical process that helps to determine whether a project has achieved its objectives and goals at the end of its life cycle. The aim of project evaluation to determine the relevance and level of achievement of the thesis objectives, development effectiveness, efficiency, impact and sustainability. It also focuses on various parameters such as cost, schedule, quality and performance. The evaluation of the tool to do borehole checks and to draw out sunk submersible pumps is going to consider cost benefit analysis, cost of labour, materials and the cost of production of 100 tools.

5.3.1. Cost benefit analysis

It is a systematic way or approach to estimating the strengths and the weakness of alternatives, and also a way of comparing the costs and benefits of an intervention, where both are expressed in monetary units. In this of a tool to do borehole checks and to draw sunk submersible pumps, a cost analysis would weigh the costs and potential benefits of assembling the tool. A cost benefit evaluation of this tool can supply valuable insights into its practicable advantage and cost.

Table 5.1 Bill of quantity for the fabrication of the tool for borehole checks and to draw out drawn submersible pumps

| Item Description | Unit | Quantity | Unit price $(usd) | Total price $(usd) |
|---|---|---|---|---|
| ESP camera | | 1 | 15-00 | 15-00 |
| Arduino | | 1 | 8-00 | 8-00 |
| Gun glue | | 1 | 2-00 | 2-00 |
| Mild steel | Meters | 1lenght/6m | 1-50 | 9-00 |
| Nylon rope | Meters | 10 | 0-40 | 4-00 |
| Spray paint | milliliters | 500 | 5-00 | 5-00 |
| Cable tiers | | 20 | 0-20 | 4-00 |
| Bolts and nuts | Milliliters | 12 | 0-50 | 6-00 |
| Labour | | 1 | 50-00 | 50-00 |
| Total (overall cost) | | | | 103-00 |

Cost of production of 100 tools

=100 × $103-00

=$10 300-00

Benefits;

1. Lower costs: one of the significant advantages of the tool to do borehole checks and to draw out sunk submersible pumps is the potential for cost saving. Such a system has overall low cost hence its affordable hence the clients will choose to use rather than buying new pump since submersible pumps are expensive.

2. Environmental benefits: the tool for checking the borehole and drawing out drawn submersible pump uses manual labour therefore it does not cause pollution to the environment.

3. Low servicing costs: since the tool is made from simple different components therefore there is nothing complex about hence it will be easy to do servicing for example respraying to protect the tool from rusting. The tool is also made up of strong components hence they don’t break easily making up a strong which will last long there by cutting servicing costs.

# CHAPTER 6: RECOMMENDATIONS AND CONCLUSIONS

## 6.1. Introduction

The primary goal of this chapter is to provide an overview of the key findings and recommendations of the research project named "standardized design of a tool to sink out drawn submersible pumps and for borehole check." It will also assist in providing an organized and thorough summary of the tool's efficacy to readers such as researchers, students, and others. This chapter will also address the efficacy of the solution and offer suggestions for enhancing its manufacturing and design to encourage broader adoption.

## 6.2. Summary

The summary from the study on the standardized design of the tool to sink out drawn submersible pumps and for borehole check are as follows;

- ❖ The design was successful and the aim of assembling the tool using locally available tools in Bindura and use of recycled materials was accomplished without any challenges.
- ❖ The purpose of borehole check was achieved and also the aim of drawing out drawn submersible hence things worked according hence producing the right tool although it was a prototype.
- ❖ Since the tool was assembled using a simple design therefore there was nothing complex about it hence making it simple to assemble and easy to use to perform the required task.
- ❖ The aim of making something cheap was also achieved as the tool was made using some recycle material hence making the affordable in industry while doing a perfect task.
- ❖ The prototype was tested to pick a bottle inside the pipe which was representing the pump and the aim was successful in help of the camera for making sure so that the bottle won’t drop.
- ❖ The tool was tested to pick the bottle in water hence the test was successful hence making suitable for the desired task since there will be water in boreholes.

- ❖ The prototype was also tested to pick a bottle inside a 110mm pipe since most of the boreholes are of that similar size and the test was successful.
- ❖ Mostly inside the borehole will be wet hence tested in water since it has to be water prof it was successful.
- ❖ The camera used during the picking up of the bottle representing the pump on the prototype was being viewed via a cellphone and it was successful.

**6.3. Conclusions**

- ❖ The system is quite effective in providing its purposes of removing drawn submersible pumps inside boreholes and also doing borehole checks.
- ❖ The system designed is adaptable to different sizes of pumps and can be customized to reach the required depth of the borehole because although most of the boreholes in Bindura area has depths of 40m there are also some which may reach 60m and 80m depth.
- ❖ The amount of material needed are not that costly hence the tool's overall cost will be low hence it will be affordable.
- ❖ Since the tool has simple design hence the cost needed to service it will be low therefore making it favourable in the industry.
- ❖ The fabrication of the tool requires basic welding skills, grinding and this can be achieved by using the locally available material.

**6.4. Recommendations**

- ❖ The tool must be operated according to the correct protocols in order for it to function correctly.
- ❖ For the tool to work best supporting is need on the main frame so that the tool will not fall down when lifting heavy pumps

- The correct maintenance strategies must be followed at correct time interval for the long term performance and efficiency of the system.

- The improvement on the design of the tool may improve the capacity of the pump hence it will then be used for bigger pumps for example 20Hp submersible pump.

- Improvement on using mechanical means on removing the pump maybe necessary so as reduce manual labour therefore enhancing the easy functioning of the tool.

- Since the tool will be working in dump conditions it will necessary for the tool to be protected from rusting so as to increase its life span and this can be achieved by painting the tool and also insulating other components.

- Although the tool to do borehole checks and to fish-out drawn submersible pumps is assembled using strong material and components, routine checks are necessary to make sure if the tool is in good condition to perform the required task.

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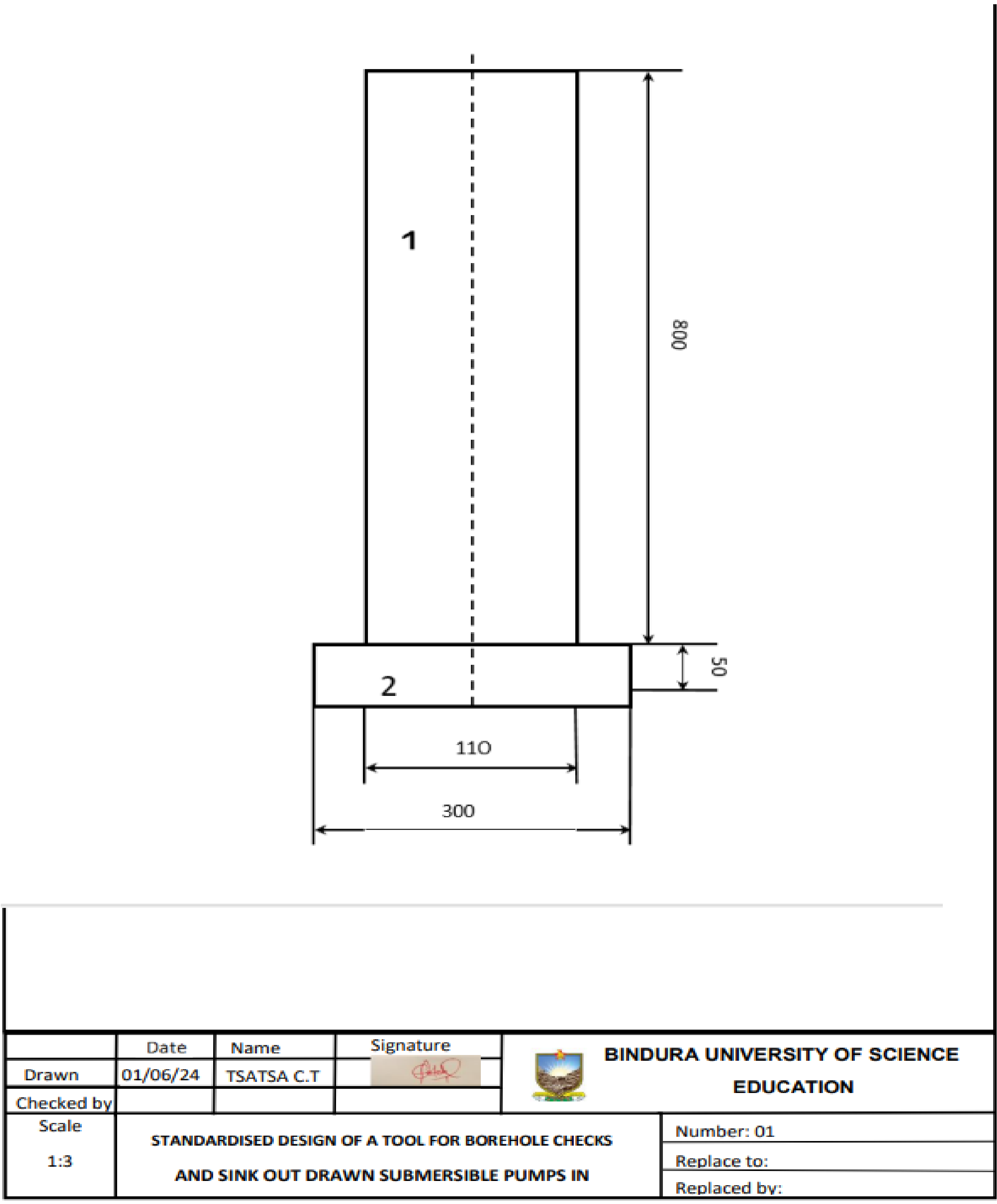
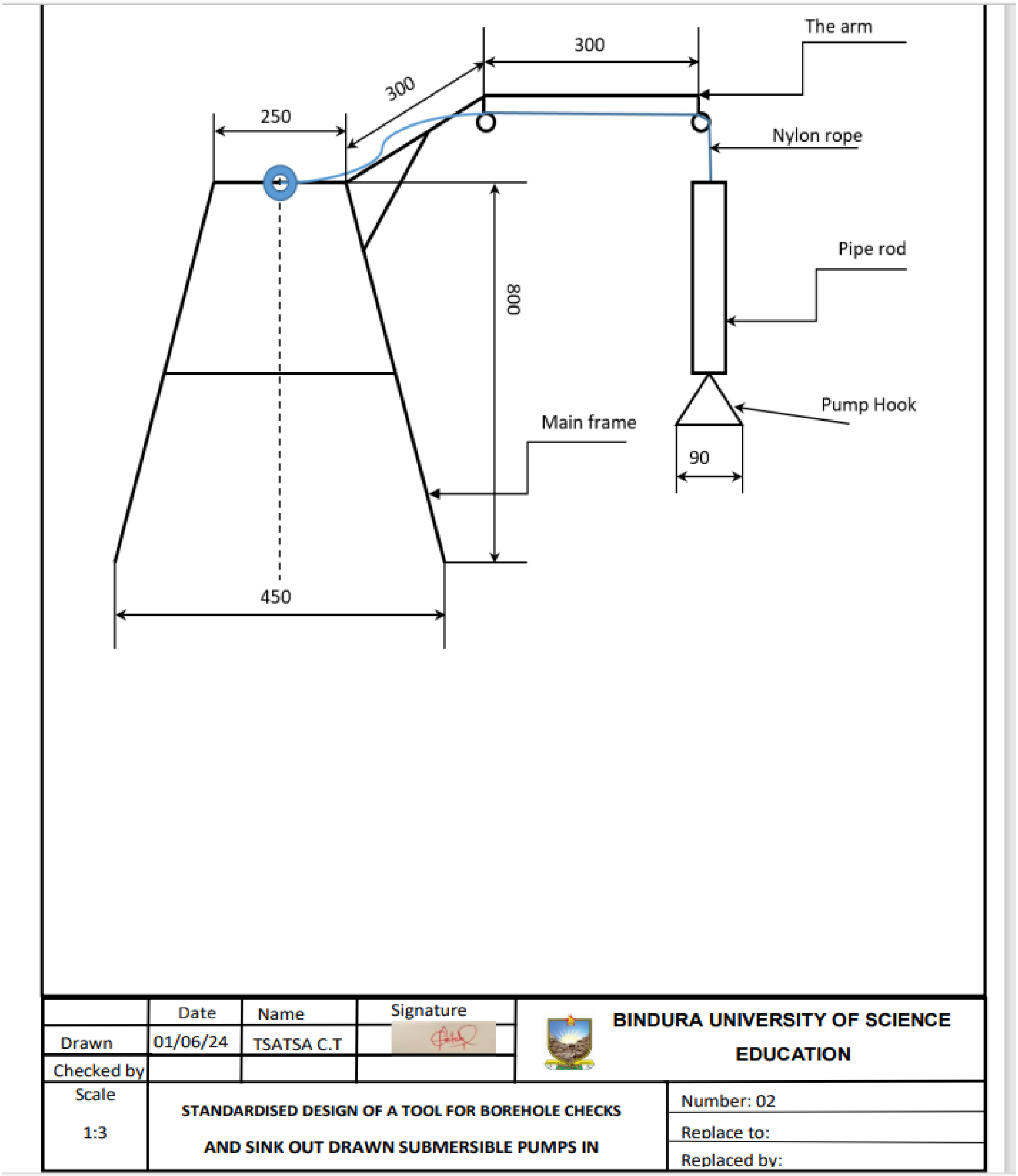
# APPENDICES




Appendices 1. 1The diagram showing the pipe and its base representing borehole casing




Appendices 1.2 The diagram above is showing the tool

Appendices 1.3 The picture showing student carrying out an experiment