FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES ENGINEERING

FINAL YEAR PROJECT REPORT

DESIGN AND CONSTRUCTION OF A VENTURI-BASED DRAINAGE CLEANING MACHINE

By

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A final year project report submitted to the Faculty of Engineering and Technology as a partial fulfilment of the requirement for the award of a Bachelor's of Science in Water Resources Engineering at Busitema University

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ABSTRACT

This paper proposes to design and construct a venturi-based drainage cleaning machine. Drainage systems are essential for ensuring efficient wastewater management. Over time, these systems can become clogged with debris, causing blockages that result in a range of problems, such as flooding and sewage backup.

The proposed machine utilizes the Venturi effect to create a vacuum that draws debris from the drainage system. The system comprises a series of nozzles that direct high-pressure water jets to dislodge the debris, while the vacuum created by the Venturi effect sucks it out, making it suitable for use in both residential and commercial settings. The construction of the machine involves sourcing and assembling the necessary components, such as the pump, motor, and nozzles. Once assembled, the machine was testing for its effectiveness in cleaning various types of drainage systems, but it failed to produce a suction force that sucks out the sediment and the water flushed for disintegration. This can be due to many different factors like pressure differences between the inlet and throat diameter was not created enough, there could also be inadequacies in fluid properties like temperature and viscosity of the fluid. The main objective of this machine was to create a suction force and also the disintegration of the sediment.

DECLARATION

I declare to the best of my knowledge that this research proposal report is as a result of our own effort and knowledge. I hereby affirm that it has never been submitted for any award of a degree or any academic qualification in any academic institution or university.

Signature: ……………………………………………

Date :……21/03/2024……………………………

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APPROVAL

I hereby certify that this final year proposal report as original and individual work of **AKELLO SHARON, BU/UP/2019/1837.** It has been done under my supervision and it is ready for submission to the board of examiners of Busitema University.

Signature: ....

Date: 22nd/3/2024

MR. KIMBOWA GEORGE

Main Supervisor

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With great honor and appreciation, I am highly indebted to the Department of Water Resources Engineering and all my lecturers for professional guidance and mentorship they have given me.

Great thanks go to my supervisor, Mr. Kimbowa George for the tireless efforts rendered to me during the preparation of this piece of work, may the good Lord bless u so much.

Lastly, I would like to thank Water Resources (WAR) 4 of Class 2019 for all the encouragement during the preparation of this piece.

DEDICATION

I dedicate this work to my family, friends and supervisor for guiding me through this project proposal. May the Almighty God bless and reward them abundantly.

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CHAPTER ONE

1.0 INTRODUCTION.

This chapter includes the background of the study, a statement of the problem, the purpose of the study, the objectives of the study, the scope of the study which includes the conceptual scope, geographical scope, time scope, and finally the justification of the study.

1.1 Background of the study

Sedimentation is a natural process that has been occurring on Earth for millions of years. The deposition of sediments has played a crucial role in shaping the Earth's landscape and creating geological formations. Sedimentation is the process by which particles settle out of a fluid due to gravity(Background, n.d.).

Provision of sufficient drainage is an important factor in the location and geometric design of transport infrastructure. Drainage facilities on any highway or street should adequately provide for the flow of water away from the surface of the pavement to properly designed channels (Gerges & Ph, n.d.).

Drainage must handle water of different origins: domestic waste water (or sullage), rainwater (or storm water, runoff), floodwater, and water from natural sources (Disease, n.d.).

Subsurface drainage systems are hydraulic structures that are used for directing the flow of water usually from one side of a road, railroad, or similar obstruction, to the other side. These types of hydraulic structures are used to form a bridge-like structure to carry traffic, manage and route runoff along, under, and away from the roadway. Occasionally, drainage systems are utilized for the management of excessive runoff (Najafzadeh, 2016).

Over time, sedimentation in drainage systems has become a challenge, which occurs through the natural process of erosion and transportation of sediment by water or wind. When water flows in a channel, it has the power to pick up and carry sediment particles. The speed and direction of water flow determine the amount of sediment to be transported. When the water flow slows down, the sediment particles lose momentum and settle out of the water. Sediment deposits are most detrimental as they often seriously reduce the culvert’s capacity to convey flows. Sediment deposition in drainage systems is influenced by many factors. Anthropogenic activities and climate change have significantly altered river systems around the world with immediate implications for stream channel stability and riverine infrastructure security, including the size and geophysical characteristics of the channel material, the hydraulic characteristics produced by different hydrologic events, the channel geometry, channel transition design, and the presence of vegetation in the vicinity of the channel (Ho et al., 2013).

From (Xu et al., 2019), drainage system design must account for a large range of flow rates but most of the time, they convey flows that are smaller than the design flow. Sedimentation in culverts is quite an involved process, therefore, it is important to design culverts that allow for the efficient flow of water.

By regularly maintaining and cleaning drainage systems, transportation infrastructure can remain functional and safe and the basic responsibility is to ensure "the proper flow of water" by preventing any obstructions and also ensuring that it doesn't attract vermin or cause health hazards. These could be done by keeping the growth of vegetation such as trees, weeds, reeds, and grass, removing excess silt that naturally builds up in watercourses, and culvert entrances and exits often have protective grilles to prevent debris from entering the pipe (Council, 2018). Cleaning the inside of a culvert is likely to cost more than carrying out maintenance of an open watercourse therefore, blockages can be reduced by regular inspection, especially during periods of heavy rainfall when debris can accumulate very quickly(Guide, 2020).

Municipalities can take proactive measures to protect their communities and ensure the safety of their residents. It is therefore crucial for municipalities, contractors, and other stakeholders to prioritize regular drainage systems maintenance and cleaning to ensure the proper operation of drainage systems and the safety of the public(Drainage & Alternatives, 2003).

This project aims to demonstrate a novel approach to tackle closed drainage system maintenance challenges.

1.3 Problem statement

Sedimentation in drainage systems is a prevalent issue caused by factors such as soil erosion, urbanization, and improper land management practices. The build-up of sediment in drainage channels has significant effects on the functionality and efficiency of the system, leading to educed flow capacity, increased flood risk, and compromised drainage performance. Existing drainage cleaning techniques, include manual cleaning, jetting, and sediment traps, have been employed to mitigate sedimentation. they often fall short in achieving optimal results due to limitations such as inadequate reach, limited effectiveness, resources and time-consuming processes. This project aims to design and construct a venturi- based drainage cleaning machine which will be non-consumptive.

1.4 Justification

There will be continued socio-economic losses resulting from costly and labor-intensive cleaning of drainage channels. By implementing the venturi-based drainage cleaning machine, the project will aim to improve the efficiency and effectiveness of drainage system machine. The machine's powerful suction capabilities, created through the venturi effect, enabled the removal of sediment, debris, and obstructions more effectively, thereby restoring the drainage system's optimal capacity. This design solution promised to enhance a non-consumptive approach to cleaning, eliminating the need for excessive water usage during the cleaning process. This water-saving aspect aligns with sustainable water management practices and conservation efforts.

1.5 Objectives

Main Objective

To design and construct a venturi-based drainage cleaning machine

Specific objective

- To design the components of a venturi-based drainage cleaning machine
- To fabricate the prototype of the machine components.
- To test the performance of the machine.
- To perform a cost benefit analysis of the machine

1.6 Significance

The project is in line with Uganda's Vision 2040; the country will develop the road infrastructure to improve transport connectivity, effectiveness and efficiency to comparable levels of the developed countries.

The Venturi-based drainage cleaning machine was designed to efficiently clean clogged drainage system using the principle of creating a pressure differential. By harnessing the Venturi effect, these machines can generate a strong suction force that effectively removes debris and obstructions from the drainage system. This efficient cleaning mechanism can contribute to SDG 6 (Clean Water and Sanitation) by ensuring the proper functioning of drainage systems, preventing blockages, and reducing the risk of waterborne. The machine was designed to optimize water usage, water recycling systems, the design can help conserve water resources. This aligns with SDG 12 (Responsible Consumption and Production), which emphasizes efficient use of water resources and sustainable practices.

The design of venturi-based drainage cleaning machine This was achieved through the use of eco-friendly materials, energy-efficient components. By reducing noise pollution and using sustainable materials, the machine design can align with SDG 11 (Sustainable Cities and Communities) which emphasizes the development of inclusive and sustainable infrastructure.

The design of the drainage cleaning machine was taken into consideration accessibility and affordability factors. It was designed to be easily operable, lightweight, and compact, allowing for its efficient use in various environments and by different user groups. This relates to SDG 9 (Industry, Innovation, and Infrastructure).

1.7 Scope

This project is intended to design and construct a venturi-based drainage cleaning machine and it is limited to small diameter closed drainage channels.

This project study will be limited to a period of three months

CHAPTER TWO: LITERATURE REVIEW

2.0 Design machine components

2.1 A venturi-based drainage cleaning system

A Venturi system is a system that uses the Venturi effect to create a vacuum in the suction pipe and draw water from a source. The system is powered by a compressed fluid.

According to (Yadav et al., 2019), when compressed air passes through an initial chamber, a smaller portal then opens into a larger chamber that is similar to the original chamber. When fluid flows through is constricted pipe, the pressure of the fluid decreases. This decrease in pressure causes the fluid to increase its speed and create a partial vacuum, which pulls in water from the source. The fluid's pressure increases back to ambient pressure when it leaves the constriction.

Venturi system was designed to clean a drainage and comprises of component parts that will aid in the functionality of the machine, these include an electric motor, an impeller or centrifugal pump, a narrow orifice or jet, and a Venturi tube, high-pressure hose and nozzle for cleaning, a suction hose to draw water and debris from the system, and a filter to prevent debris from clogging the system to be removed, and the required flow rate of the system.

2.1.1 Components of the machine

The venturi- based drainage cleaning machine consists of water supply system that includes a water pump, hoses and connectors; the venturi system which is the heart of the cleaning machine and it includes the venturi nozzle and the suction hose; the filtration system that will remove solid particles and debris from the water before it is conveyed back to the drainage system.

2.1.2 Existing cleaning drainage equipment

The common strategies that have been used and implemented are the drainage trencher, drain pipe, high pressure water jetting, CCTV Inspection, chemical cleaning involving chemicals to break down and dissolve blockages, biological cleaning where useful bacteria is used.

2.1.3 Drainage system specifications

(Gerges & Ph, n.d.) Explains, drainage facilities on any road infrastructure should adequately provide for the flow of water away from the surface of the pavement to properly designed channels.

Subsurface drainage systems specifications depend on the size, slope, length and catchment area of the drainage system.

2.1.4 Identify sediment accumulation

The presence of sediment in the drainage system was determined by visual inspection, there are indicators showing presence of sediment such as; reduced water flow, stagnant water, flooding of the drainage system during periods of heavy rainfall.

It may as well be necessary to conduct a physical inspection by excavating the area around the drainage employing specialist tools, such as CCTV cameras or remote sensing technology.

2.1.5 Measurement of sediment load

Apparatus and instruments have been developed in the attempt to measure each process of erosion-sediment transport sequence for instance; total collective tanks, suspended sediment samplers, samplers for bed material discharge.

1.1 2.2. FABRICATION OF THE COMPONENT PARTS

2.2.1 Material selection

This will depend on the system components available. The material selected will resist the different forces and loads imposed on the system. The mechanical properties that will be considered include; smoothness, durability and strength. Other factors like surface finish, density, interaction with environment, fabrication cost, maintenance cost, availability of materials, ease of fabrication and safety of materials will be considered.

2.2.2 Pump

From (*Classification of Pumps*, 2017), pumps are designed for various specific applications. However, most of them can be broadly classified into two categories;

i. positive displacement
ii. dynamic pressure pumps

The type of pump, as well as how it is selected depends primarily on the purpose of its use, the type of liquid to be pumped, the desired distance to move the liquid, and the amount you need to obtain a certain time frame, however it is not easy to determine the type of pump according to its use, says (Saeed, 2022).

Using the wrong pump can lead to processing slowdowns or shutdowns. Just as costly, the wrong pump can result in inconsistencies in product or the wrong product altogether. Before pump selection, one must know; the total head or pressure against which it must operate, the desired flow rate, the suction lift and characteristics of the fluid.

Multiple nozzles

The parameters needed for using multiple nozzles to clean a drainage system or disintegrate sediments include:

1. **Nozzle Type:** Selecting the appropriate nozzle type is essential for the specific application. Different nozzle designs produce different spray patterns and impact forces. For sediment disintegration and drain cleaning, rotary nozzles or penetrating nozzles are often used.

2. **Nozzle Quantity and Arrangement:** Determine the number of nozzles to be used and their arrangement. Placing the nozzles strategically can ensure thorough coverage of the drainage system or sediment.

3. **Nozzle Size:** The size of the nozzles affects the water flow rate and pressure. Larger nozzle orifice sizes can handle higher flow rates, which can be beneficial for dislodging tough sediments or debris.

4. **Water Pressure:** The water pressure at the nozzle is a crucial parameter for effective sediment disintegration and cleaning. Higher pressure can provide greater force to break apart and flush out the sediment. Pressure is usually measured in pounds per square inch (psi) or bar.

5. **Water Flow Rate:** The water flow rate determines the volume of water delivered to the nozzles and affects the cleaning efficiency. Flow rate is typically measured in gallons per minute (GPM) or liters per minute (LPM).

6. **Operating Distance:** The distance between the nozzles and the sediment or debris affects the impact force. The closer the nozzles are to the target, the more intense the impact.

2.3 Testing the performance of the machine

Testing is the critical aspect of product development and research, quality, control and research. There are different types of testing such as water and air tests. The purpose of these tests is to ensure that all components and systems are in a satisfactory and safe condition before start up (No, 2017).

2.4 Performance of Cost-benefit analysis

Preliminary economic evaluation will be conducted for the drainage project in order to analyze the feasibility of the proposed measures from the viewpoint of national economy. The Project will be analyzed by quantitative method by cost-benefit analysis(Report, 2002).

According to (Ha, 2019), the cost benefit analysis process estimates the benefits and costs of an investment for two reasons:

1. To determine if the project is viable; if it is a good investment

2. To compare one project investment with other competing projects, to determine which is more feasible. It allows decision makers to appraise projects in a consistent and comparable manner.

CHAPTER THREE: METHODOLOGY

3.1 DESIGN OF MACHINE COMPONENTS AND MATERIAL SELECTION

Design of the Venturi Tube

This water pump is based on the Venturi principle. The Venturi effect is the result of Bernoulli's principle of fluid dynamics, that is when the fluid is passing through the pipe and the pipe suddenly gets smaller, the fluid has to speed up to for the fluid behind it to keep moving at the same speed. It takes energy to accelerate, and the energy for the increased in speed comes from the force of pressure on the fluid. Since the energy is being used, the pressure has to decrease as the fluid accelerates. A decrease in pressure creates vacuum. The more speed the fluid has before it travels through the smaller section pipe, the faster it will have to go it once it enters, the pressure will drop, the greater the vacuum effect will be. In terms of design, a Venturi water pump is a pumping device that uses an air compressor to supply pressure to converging suction which can create vacuum. The pressure difference creates a vacuum at suction where it is placed in water then this device is called a "water vacuum pump." Basic vacuum pump components are shown.

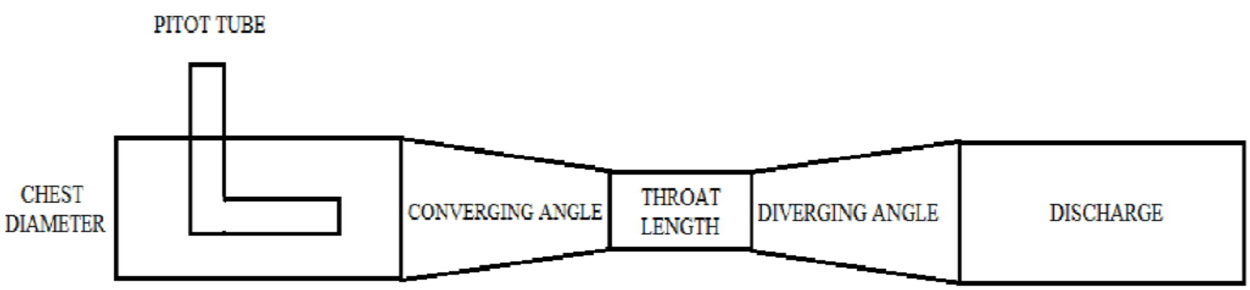


Figure 1 showing venturi water pump parts

It includes two parts: the main tube and the suction tube, the suction tube is located in the throat of the main tube.

When medium flows through the main tube, the water inside is carried away and the static pressure drops as the flow velocity increases. A negative pressure effect is formed once the flow velocity reaches a critical value, which helps to absorb material from the suction port. The velocity increases rapidly in the process from inlet to throat since the diameter convergence. The maximum velocity appears in the throat tube and thus causes a maximum negative pressure. Therefore, solid particles such as steel balls and abrasive powders, and debris can be sucked into the main tube by the negative pressure effect. Finally, the transportation of the solid material or mixed abrasive can be realized.

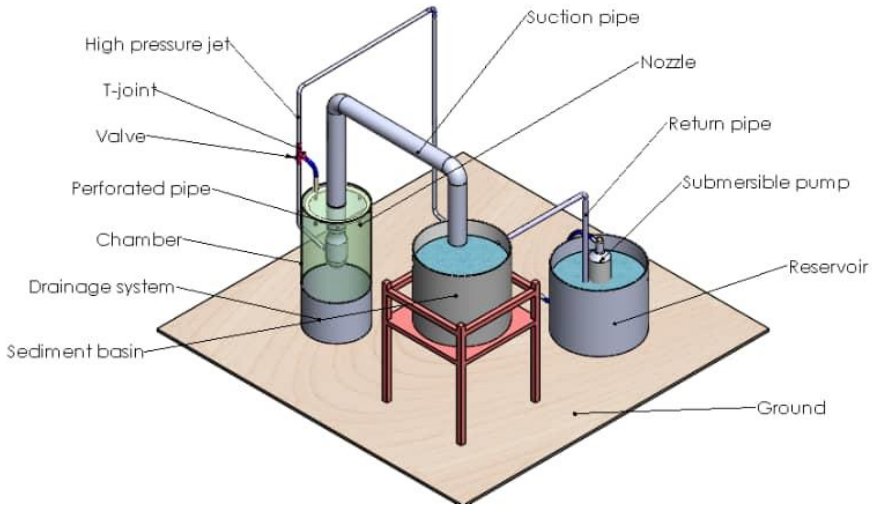


Figure 2 showing the conceptual diagram

The pipeline pressure versus flow velocity is described by the following Bernoulli equation.

$$p = C - \frac{1}{2}\rho U^2 - \rho g h$$

where P is the pressure, U is the flow velocity, ρ is the fluid density, g is the gravitational acceleration, h is the height of the flow and C is a constant.

According to (Pressures, 2000), venturi calculations of incompressible fluids were made;

From the continuity equation

$Q = v_1 A_1 = v_2 A_2$

Bernoulli's equation

$$P + 0.5 * \rho * v^2 + \rho * g * h = constant$$

Assuming that $\rho = 1000kg/m^3$, Atmospheric pressure; $P_1 = 101{,}325Pa$, $P_2 = 76{,}400Pa$

Hence, change in pressure, $\Delta P = P_1 - P_2$

$$= 101{,}325 - 76{,}400$$

$$= 24{,}925Pa$$

Outlet Area, $A_1 = \frac{\pi}{4}.(38.1mm)^2 = 1{,}451.61mm^2$

Throat area, $A_2 = \frac{\pi}{4}.(25.4mm)^2 = 645.16mm^2$

To obtain the mass flow rate

$$\dot{m} = A_2.\sqrt{\frac{\frac{2}{\rho}(P_1 - P_2)}{\frac{A_2^2}{A_1^2} - 1}}$$

To calculate the inlet velocity

$$v_1 = \frac{\dot{m}}{\rho.A_1} = \sqrt{\frac{\frac{2}{\rho}(P_1 - P_2)}{\frac{A_1^2}{A_2^2} - 1}}$$

$$= \sqrt{\frac{\frac{2}{1000}(24{,}925)}{\frac{1{,}415.61^2}{645.16^2} - 1}} = 4.81mm/s$$

To obtain the throat velocity

$$v_2 = \sqrt{\frac{2 * \Delta P}{\rho}}$$

$$= \sqrt{\frac{2 * (24{,}925)}{1000}} = 14.10m/s$$

The suction force of the Venturi tube can be expressed as;

$$F_d = \frac{1}{8}\pi C_d \rho v_2^2 D^2$$

$$= \frac{1}{8}.\pi.(0.95).(1000).(14.10^2).(25.4 * 1000)$$

$$= 188.389MN$$

where $C_d = 0.95$ is the drag coefficient of the flow around the medium, ρ is the density of the ambient flow, D is the throat diameter.

It can be seen that the suction force of Venturi tube is highly depend on the flow velocity, which was impacted by the throat diameter (D), the convergent angle, and the inlet velocity

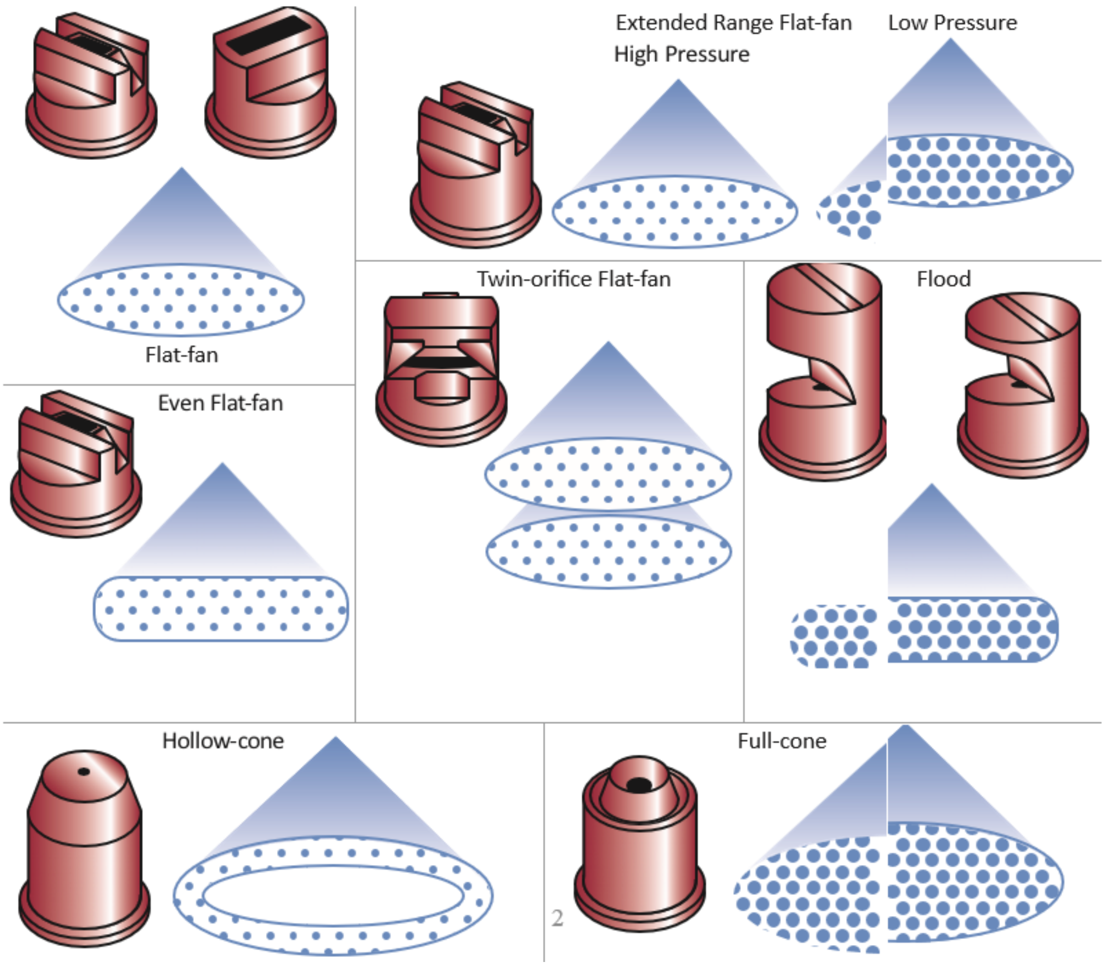
Perforated pipe system characteristics

The perforated pipe consists of nozzles. Its goal is to supply the desired amount of water to disintegrate the sediments as efficiently and uniformly as possible. Listed below are factors that determine performance characteristics such as droplet size, wetted diameter, water force, and application rate. These performance characteristics, in turn, affect the selection of a nozzle system and how well it will perform on a given drainage system (Scherer et al., n.d.).

- Nozzle type and size: Circular, rectangular, and triangular; to achieve the desired water application patterns and droplet sizes.
- Configuration: Trajectory angle, mounting location, and height, spacing,
- Operating pressure and flow rate: The flow rate and pressure at which the nozzle operates impact the intensity of the spray. Higher flow rates and pressures can lead to increased soil disintegration, but it's important to balance these factors with the potential for soil erosion or damage.
- Uniformity and overlap: Ensuring uniformity of application is crucial to avoid uneven treatment of the soil. Overlapping spray patterns from adjacent nozzles help in achieving consistent coverage and disintegration.
- Material compatibility: it's essential to choose nozzles made of materials that are compatible with the substances being sprayed, prevent corrosion or degradation.

Nozzle description

Nozzle types commonly used include: fan, hollow-cone, full-cone, and others. Special features such as air induction (AI) and drift reducing (DG) are available for some nozzles. These nozzles produce a tapered-edge, flat-fan spray pattern. On boom sprayers for broadcast applications, nozzles are positioned so that their output overlaps.(Hern et al., 2022)



1.1.1.1 Figure 3 showing different nozzle types ***(Scherer et al., n.d.)****.*

CP 360° nozzle: Variable single orifice ranging in diameter from 1.32 to 6.35 mm with a stainless-steel deflector. Droplet size was measured at pressures of 138, 207, 276, and 345 kPa.

CP 3-way nozzle: Variable single orifice ranging in diameter from 1.32 to 6.35 mm. Three stainless steel deflectors settings were available. Discharge distances for small (S), medium (M), and large (L) deflectors were about 6-, 10-, and 14-mm. Droplet size was measured at pressures of 138, 207, 276, and 345 kPa.

CP Floater Turbo nozzle: Two orifices in series, ranging in diameter from 1.32 to 6.35 mm (orifice) and from 1.85 to 6.35 mm (secondary orifice). Droplet size was measured at pressures of 138, 207, 276, 345, and 414 kPa.

CP Sprayer Turbo nozzle: Two orifices in series, ranging in diameter from 1.14 to 4.39 mm (orifice) and from 1.85 to 4.39 mm (secondary orifice). Droplet size was measured at pressures of 69, 138, 207, and 276 kPa(Grisso et al., 2013).

Design equations of the nozzle

The objective of the nozzle is to enable breakdown and make loose sediment and debris in the drainage channel by directing water at particular pressure to disintegrate the soil particles

Pressure of the water at the nozzle

The pressure of water at the nozzle is obtained using;

From the head of the pump; h=72m

From $P = hg\rho$, pressure of the water from the reservoir can be determined;

$$P = 72 * 9.81 * 1000$$

$$P = 706{,}320Pa$$

Impact Pressure by the Nozzle

The water from the water jet is approximated by a set of rays. The rays originate from the nozzle and have a pressure distribution that decays along the radial direction away from the center of the nozzle. The impact pressure is calculated at the points on the plate at which the rays hit the surface. Then based on the impact pressure, a quantity called the cleaning effectiveness is calculated.

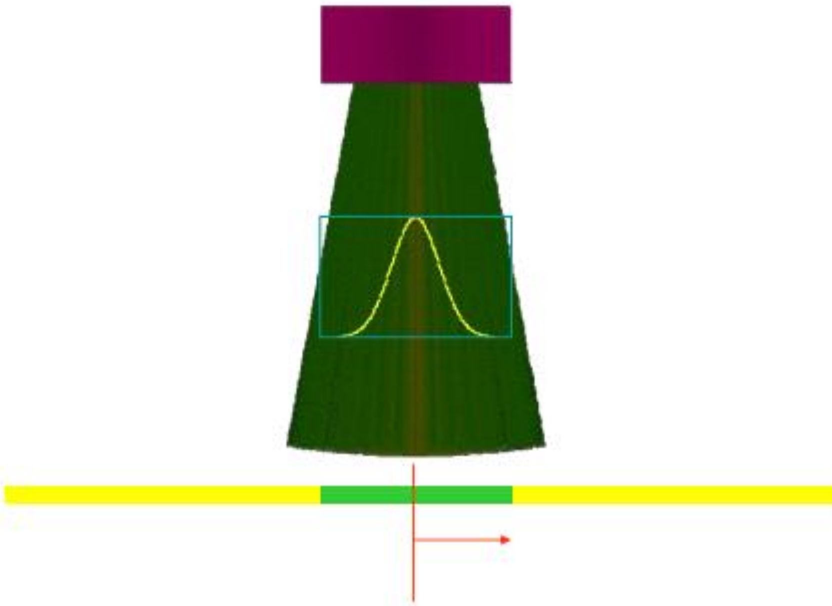


Figure 4 showing water nozzle approximated as a set of rays ***(Krishnamurthy & Li, 2016)****.*

The water from the nozzles is approximated by a set of rays. The rays originate from the nozzle and have a pressure distribution that decays along the radial direction away from the center of the nozzle. The impact pressure is calculated at the points the rays hit the surface.

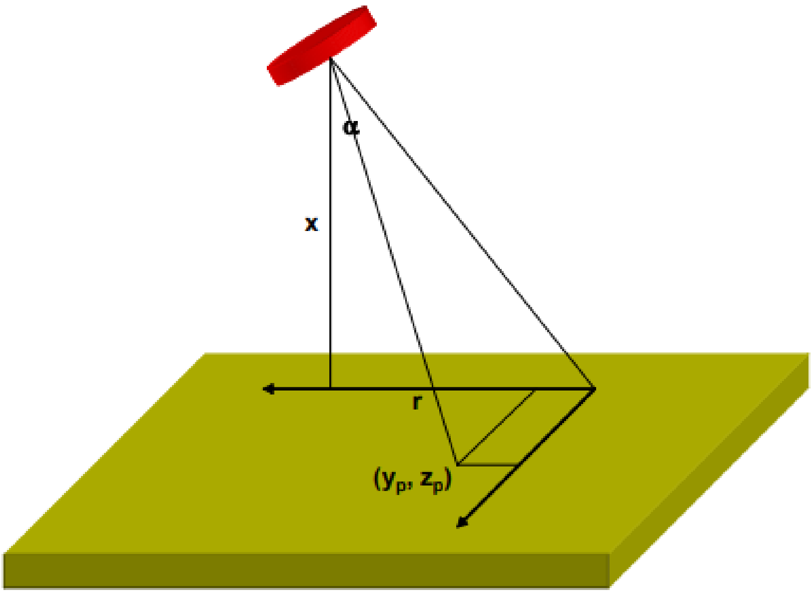


Figure 5 showing water nozzle positioned at an angle

Then based on the impact pressure, a quantity called the cleaning effectiveness is calculated.

This equation gives the impact pressure of the waterjet at any point (Krishnamurthy & Li, 2016).

$$P = 7.95\lambda k \Psi \sqrt{P_o \rho}\,\frac{{r_o}^2}{(Cx)^2}\left[1 - (\frac{r}{Cx^{1.5}}^{1.5})\right]\text{^}3$$

Where P- impact pressure

λ -Stress coefficient

ρ -density of water

Ψ -sound speed in water

P_o- water pressure from the nozzle

r_o −radius of the nozzle

C – Jet spreading coefficient

x- standoff distance

r- distance of the point of consideration from the waterjet centerline

Cleaning Effectiveness

The ability of the water jet for cleaning the surface is correlated directly to the impact pressure of the waterjet on the surface. Higher impact pressures correlate to higher cleaning effectiveness. We use a cumulative normal distribution to correlate the pressure of the water jet with cleaning effectiveness.

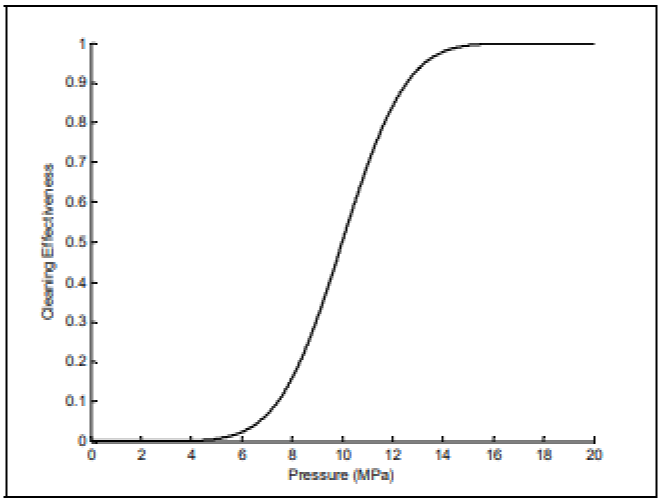


Figure 6 showing correlation between impact pressure and cleaning effectiveness

Based on this impact pressure, the cleaning effectiveness is calculated, maximizing the sum of the average cleaning effectiveness, averaged over the set of sample points S on the surface for all nozzle positions, N and the coverage fraction, which is the fraction of the total area accessible by water. This is given by;

$$E = \sum_{N} \int edA + \int cdA \approx \frac{1}{S} \sum_{S} \sum_{N} e + \frac{C}{S}$$

where C is the coverage fraction and e is the effectiveness calculated at each sample point of S.

Minimize the number of positions of the waterjet, which directly corresponds to the feed rate of movement of the nozzle. If there are more positions, then the cleaning effectiveness will be high but on the other hand, the time for the process will also be high.

$$t = k_t . n$$

where k_t is the constant time taken for each position and n is the number of positions. We assume that the distance moved in each step is constant and is inversely proportional to the number of steps. For the purpose of the simulations, we also assume $k_t$to be unity.

Water force applied on to the point of impact for sediment disintegration

From the water pressure, $P = \frac{F}{A}$, the force of water entering the nozzles can be calculated;

Since P= 706320Pa, therefore $F = PA$

$$F = 706320 * \frac{\pi}{4} * 0.0127^2$$

$$F = 89.4744N$$

Force applied= loss in energy or energy dissipation/ kinetic energy of water

$$E = \frac{1}{2} mc^2$$

Where $m = \rho * \ vol$; But vol. $=$ A $*$ L $\quad E = \frac{1}{2} \rho . Vc^2$

$$\frac{F}{L} = \frac{1}{2} \rho . \frac{A}{L} L \ c^2$$

$$F = \frac{1}{2} \rho . Ac^2$$

$$\frac{1}{2} \rho . Ac^2 = 89.4744$$

Diameter of the nozzle, d= 0.00424m

$$c^2 = 89.4744 * \frac{2}{1000 * \frac{\pi}{4} * 0.00424^2}$$

$$c = 112.578 m/s$$

From $Q = Ac; c = \frac{Q}{A}$,Q is the nozzle discharge

$$Q = \frac{\pi}{4} * 0.00424^2 * 112.578$$

$$Q = 1.589 * 10^{-3} m^3/s$$

Sizing of the pump

Pipe material selection

Comparison between the pipe materials were carried out through different properties like those in the table below, to determine which material be used.

Table 1 showing Pipe Material Comparisons

Properties	PVC	PPR	HDPE	GI	copper
Strength	Fair	High	Low	High	fair
Toughness	Fair	High	Low	High	fair
Fabricability	High	requires the technical know how	High	Fair	requires few people to install
Availability	High		High	high	low
Cost	Low	Low	High	slightly high	expensive
corrosion resistance	High	very high	high	improved	high

Table 2 showing PVC and CPVC Pipe Charts ***(Pipe et al., 2018)***

PVC and CPVC Pipes - **Schedule 40**					
Nominal Pipe Size *(inches)*	Outside Diameter *(inches)*	Minimum Wall Thickness *(inches)*	Inside Diameter*) *(inches)*	Weight *(lb/ft)*	
				PVC	CPVC
1/2	0.840	0.109	0.622	0.16	0.17
3/4	1.050	0.113	0.824	0.21	0.23
1	1.315	0.133	1.049	0.32	0.34
1 1/4	1.660	0.140	1.380	0.43	0.46
1 1/2	1.900	0.145	1.610	0.51	0.55
2	2.375	0.154	2.067	0.68	0.74
2 1/2	2.875	0.203	2.469	1.07	1.18
3	3.500	0.216	3.068	1.41	1.54
4	4.500	0.237	4.026	2.01	2.20
5	5.563	0.258	5.047	2.73	
6	6.625	0.280	6.065	3.53	3.86
8	8.625	0.322	7.981	5.39	5.81
10	10.750	0.365	10.020	7.55	8.24
12	12.750	0.406	11.938	10.01	10.89

Losses in the system

These can occur due factors like friction, bends, and turbulence in the pipes or fittings. The Darcy-Weisbach equation is commonly used to calculate head losses in a fluid system (Chaurette, 2009).

$$h_f = f * \frac{L}{D} * \frac{V^2}{2g}$$

Where h_f is the head loss (in meters)

F is the Darcy-Weisbach friction factor(dimensionless)

L is the length of the pipe or system (in meters)

D is the diameter of the pipe or system (in meters)

V is the velocity of water (in meters per second)

G is the acceleration due to gravity (approximately 9.81m/s^2)

Reynold's number of the flow

To obtain a greater suction force, the flow must be turbulent with Re >2000, which is expressed as;

$$Re = \frac{\rho v d}{\mu} \; where\ \mu\ is\ the\ dynamic\ viscosity\ of\ water$$

According to (Yunus A.Cengel, 2010), using the Colebrook- White Equation:

$$\frac{1}{\sqrt{f}} = -2.0\ log_{10}(\frac{\frac{\epsilon}{d}}{3.7} + \frac{2.51}{Re\sqrt{f}})$$

Assuming that the value of friction factor, f = 0.02. The value of friction factor varies based on factors like pipe material and surface roughness.

From the principle of conservation, achieve the total energy (head) of the pump

$$H = \{\frac{P_B}{\gamma_W} + Z_B + \frac{V^2}{2g}\} + h_f$$

But $P_B \approx 0$

$Z_B \approx 0$ (Negligible elevation difference)

Since, $h_f = f * \frac{L}{D} * \frac{V^2}{2g}$

Therefore; $H = \{\frac{V^2}{2g}\} + f * \frac{L}{D} * \frac{V^2}{2g}$

H= $\frac{3.28*10^{-11}}{2*9.81}\left(1 + \frac{0.02*0.09}{0.0127}\right) = 1.9020722 * 10^{-12} m$

Table 3 showing cohesion and friction angles of different soil types ***(Yang H. Huang, 1983)***

Table 3.1 Average Effective Shear Strength of Compacted Soils.

UNIFIED CLASSIFICATION	SOIL TYPE	PROCTOR COMPACTION MAXIMUM DRY DENSITY pcf	PROCTOR COMPACTION OPTIMUM MOISTURE CONTENT %	AS COMPACTED COHESION c_0 tsf	SATURATED COHESION c_{sat} tsf	FRICTION ANGLE ϕ deg
GW	well graded clean gravels, gravel-sand mixture	>119	<13.3	*	*	>38
GP	poorly graded clean gravels, gravel sand mixture	>110	<12.4	*	*	>37
GM	silty gravels, poorly graded gravel-sand-silt	>114	<14.5	*	*	>34
GC	clayey gravels, poorly graded gravel-sand-clay	>115	<14.7	*	*	>31
SW	well graded clean sands, gravelly sands	119±5	13.3±2.5	0.41±0.04	*	38±1
SP	poorly graded clean sands, sand-gravel mixture	110±2	12.4±1.0	0.24±0.06	*	37±1
SM	silty sands, poorly graded sand-silt mixture	114±1	14.5±0.4	0.53±0.06	0.21±0.07	34±1
SM-SC	sand-silt-clay with slightly plastic fines	119±1	12.8±0.5	0.21±0.07	0.15±0.06	33±3
SC	clayey sands, poorly graded sand-clay mixture	115±1	14.7±0.4	0.78±0.16	0.12±0.06	31±3
ML	inorganic silts and clayed silts	103±1	19.2±0.7	0.70±0.10	0.09±*	32±2
ML-CL	mixtures of inorganic silts and clays	109±2	16.8±0.7	0.66±0.18	0.23±*	32±2
CL	inorganic clays of low to medium plasticity	108±1	17.3±3	0.91±0.11	0.14±0.02	28±2
OL	organic silts and silty clays of low plasticity	*	*	*	*	*
MH	inorganic clayey silts, elastic silts	82±4	36.3±3.2	0.76±0.31	0.21±0.09	25±3
CH	inorganic clays of high plasticity	94±2	25.5±1.2	1.07±0.35	0.12±0.06	19±5
OH	organic clays and silty clays	*	*	*	*	*

*denotes insufficient data, > is greater than, < is less than
(After Bureau of Reclamation, 1973; 1 pcf=157.1 N/m³, 1 tsf=95.8 kPa)

Pipe size determination

The types of pipes that were used in this study were dependent on the different stages through which the water travelled. Pipe size determination involved selecting the diameter of a pipe type, which could carry a given flow at or below the recommended velocity limit i.e., from the source to the pump coupled on the motorcycle rotary shaft, to the turbine, through the hose pipe and

The pipe size also depends the velocity of the water flowing through it, as well as the water pressure. Other factors in pipe selection included the availability of the pipe in the market and their price. The pipe networks used in the study were as follows

Delivery hose pipe

This pipe was from the outflow of the pump through the $\frac{1}{2}''$ PVC pipe. It was composed of a GI pipe fittings and HDPE connected through an elbow connection.

Table 4 showing the materials that were used

Component	**Materials**	**Specifications**
Venturi tube	HDPE Reducers	1½’’*1’’
	HDPE pipe	1/2”
	PVC pipe	1”, ½”
Pipes and fittings	HDPE pipe	½”, 1”
	HDPE fittings	½”, 1” reducers, elbows, nipples, straight connectors AND GATE VALVE
	PVC pipe	6’’, 1½’’, ½’’
	GI fittings	½”, 1” reducers, elbows, nipples, straight connectors
Drainage system	Sedimentation basin	135 liters
	Storage tank	120 liters
	Hose pipe	3 meters
	Wire mesh to act as sieves	1 meter

3.2 FABRICATION OF THE DRAINAGE CLEANING MACHINE

Selection of materials

The materials selected were based on their ability to resist the different forces and loads imposed on the system. Fluid properties such as pressure differences and flow rates were considered. Other factors like surface finish, density, interaction with environment, fabrication cost, maintenance cost, availability of materials, ease of fabrication and safety of materials were equally considered.

Below are the materials that were used;

The construction of the prototype was done following the design procedures and materials readily available while taking into account the costs. The fabrication of the machine was done by measuring, marking out, cutting, drilling, welding, assembling, bending, fastening, and grinding.

Material sizing

The pipes, sprinkler, pump and turbine were sized according to the required amount of water for irrigation in accordance to FAO specifications and guidelines.

Safety equipment

To ensure safety during the fabrication and construction phase, workshop boots, hand gloves, overalls were used.

Equipment required

The following equipment were used during the construction; adjustable spanners, tape measure, scribers, hack saw, welding rods and angle grinder, thread tape, wire mesh, axel.

System construction

The connection of the pump consisted of a set of adaptors and pipes. The connection between the pump and the tubing was made using pipe fitting. A global valve is attached at the GI tee (half inch) directing the flow of water through the pitot tube to the constricted pipe and to the nozzles to control the flow of water. Water flow through the nozzles is directed with a force to disintegrate the sediments in the drainage system. The suction created by the constricted pipe sucks the water and removed sediments through a one-inch hose pipe into the sediment basin, that contains a screen to trap some sediment A filter was attached at the inlet hose pipe to prevent debris from getting into the pump and backflow of water which may damage the system.

From the outlet of the pump through the half inch pipe, the water flow was directed to the nozzles for sediment disintegration and the constricted pipe to produce a suction effect.

3.3 TESTING OF THE PROTOTYPE

Unit testing

This involved testing of different unit components or sections of equipment, and the purpose of this was to verify that each component can function properly when isolated from the rest of the units. Some of the components included;

The venturi/ suction tube; this includes a constricted pipe whereby there is a reduction in pipe diameter from 1½'' PVC pipe as a convergent to 1''HDPE as a throat then back to 1½'' PVC pipe as the divergent.

The drainage system; this includes the reservoir tank from which where water is pumped to the nozzles to disintegrate the sediment particles and the constricted pipe, so as water and the sediments are sucked out through a vacuum created.

System testing

This was carried out after the completion of the system so as to determine the functionality, inter-dependence and communication of the entire system.

The purpose of system testing includes the following;

Response of the system to the presence of the suction effect

> The venturi tube that was fabricated failed to produce a suction effect in order to suck the disintegrated sediment, this could be due to improper design, the material selection, inadequate fluid properties and the inadequate pressure differential.

- ✓ Determination of the sediment disintegration due to the water force from the nozzles
- ✓ Determination of system accuracy
- ✓ Determine the performance of the system

3.4 Performing cost benefit analysis for the drainage cleaning machine

The payback period and benefit-cost ratio were used to calculate the cost benefit analysis of the prototype.

Table 2 showing the bill of quantities

BILL OF QUANTITIES

S/N	Item Description	Quantity	Rate	Amount (UGX)
1	**Venturi tube**			
	high-velocity water creates a vacuum to suck the sediments			
a	1½'' PVC Pipe	3	1500	4500
	1" HDPE pipe	10		
	1½''* 1" reducers	2	20000	40000
	½'' PVC pipe	1	18000	18000
b	**Drainage System**			
	water is pumped through the reservoir tank to the venturi tube and the nozzles to clean the drainage system, the sediments are washed from the drainage and later sucked into the sedimentation basin through the hose pipe and channeled back to the reservoir tank.			
	thread tape	1	2000	2000
	GI sockets ½''	4	1500	6000
	GI elbows ½''	5	1500	7500
	GI Nipple ½''	5	1500	7500
	hose pipe 1"	3	1000	3000
	PVC 6" end cap	1	20000	20000
	PVC reducer 6" *4"*1½''	1	20000	20000
	plastic tank 120liters	1	20000	20000
	plastic tank 135 liters	1	25,000	25000
	Sub total			**169000**
3	**Fabrication cost and labor**			
	Labor			80000
	purchase of extra materials and general labor cost			150000
	Sub total			**230000**
4	**Transport cost and others**			
	Transport cost			100000
	Airtime, data and feeding			150000

	Sub total			**250000**
5	**Report preparation**			
	proposal report printing, internet, consultation,			150000
	final report writing and binding			120000
	Sub total			**270000**
	GRAND TOTAL			**919000**

Table 3 showing the cost and benefits of the project

	BENEFITS			
	Item description	costs incured	interval of cleaning yearly	amount
1	reduced maintenance costs	230000	2	460000
2	Fewer emergency repairs	400000	3	1200000
	other cleaning methods			
3	manual methods			
	employment cost	250000	2	500000
	safety equipment	130000	1	130000
4	high pressure jetting	1500000	2	3000000
	labor	150000	2	300000
	BENEFIT GRAND TOTAL			5590000
	BENEFITS	5,590,000		
	COSTS	919,000		
	PROFIT	4671000		
	B/C=			
	B/C>1, Therefore, the project is viable.			

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This section presents the result of the input and output data. The results were obtained base on both the evaluation of the models presented in chapter three and the fabricated design. The input and output data are tabulated for clarity, also, graphs were used where necessary to show the dependence of some parameters on the others.

4.1 Results

Specific objective one

Table 4 showing design of the Venturi tube and the perforated pipe

Velocity of the water through the nozzle inlet	**$v = Q/A$ =6.6m/s**
Pipe diameter	0.5'' = 0.0127m
Pressure of water at the nozzle	**76400.28 N/m^2**
Force of the water through the nozzle outlet	9.678 N
Discharge of the nozzle	175.423 Gpm

Specific objective two

Figure 6 showing the perforated tube

Figure 7 showing the venturi tube

Specific objective three.

- Effective Flow rate at the nozzle =1.589*10^-3 m3/s
- Pressure difference at the venturi tube, = $P_0 - P_1$

  =0.8MPa- 0.3MPa

  =0.5MPa

- Suction effect was produced at pressure of 300kPa, when the venturi tube was tested individually using an air compressor.

4.2 CONCLUSIONS AND RECOMMENDATIONS

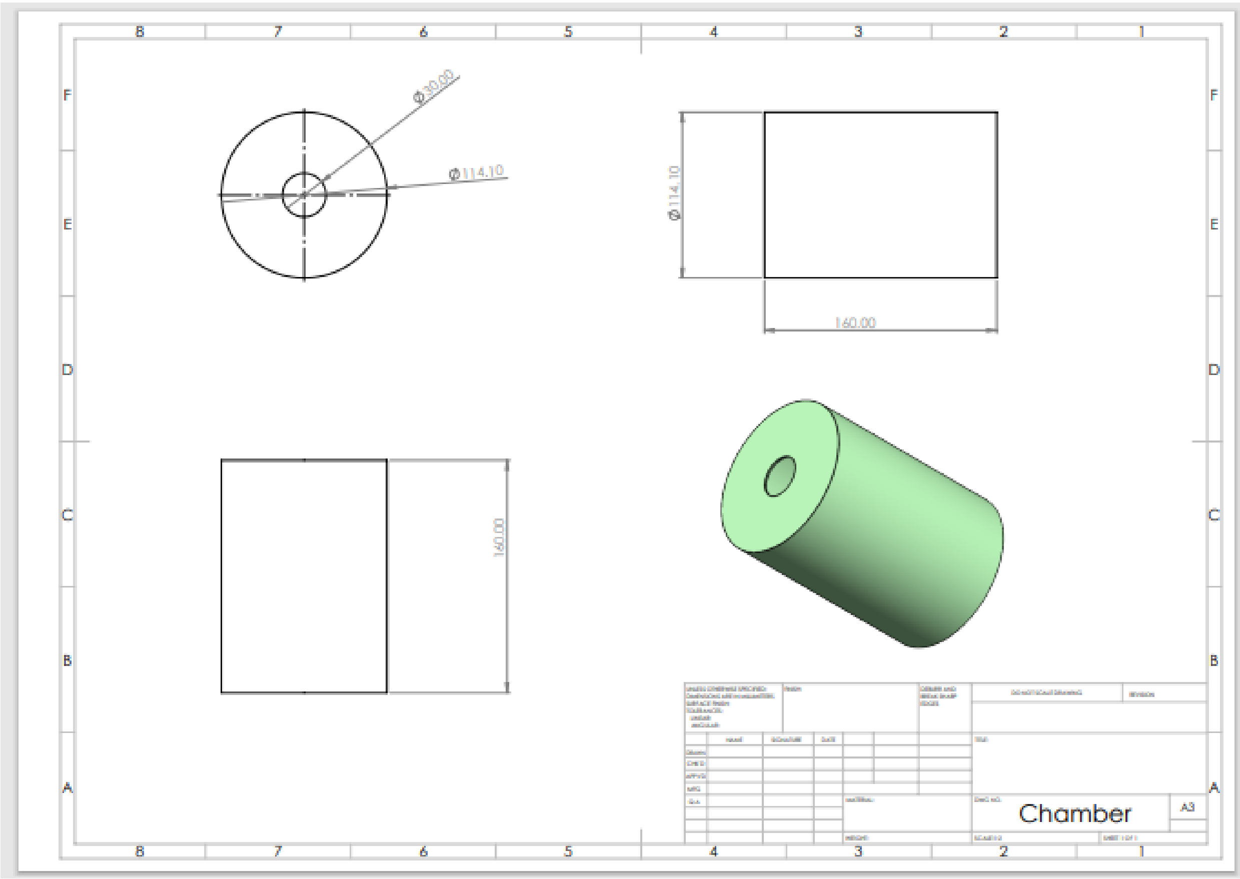
CONCLUSIONS

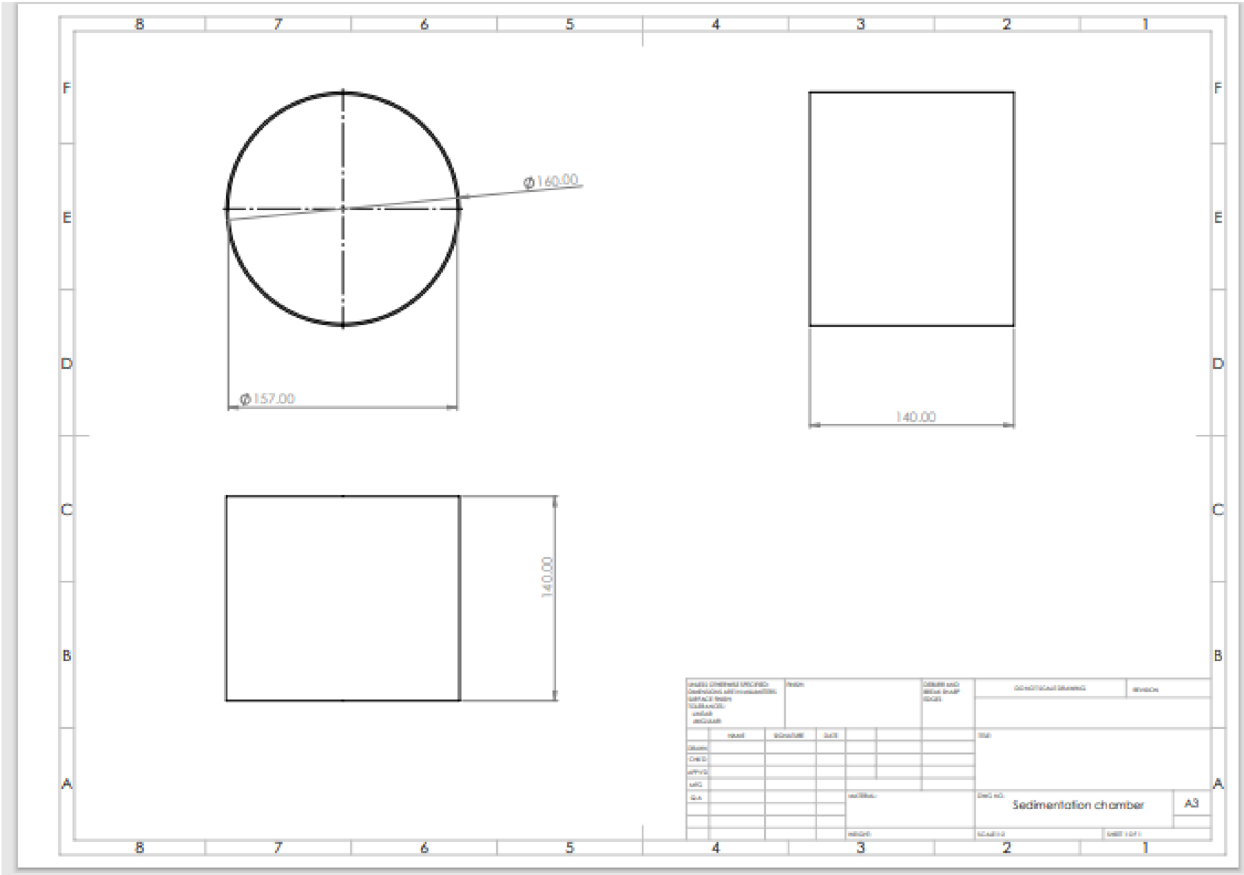
- The venturi tube could not produce a suction force to suck out the sediments.
- The machine is not as portable to be easily handled.
- Investigations need to be made to understand the conditions needed for the suction force to be created, if there are fluid properties and environmental impacts that affect its mechanism.
- Pumps of different head were tested to investigate the creation of the suction force; pump of 10m head, 15m head, and 72m head.
- I also used an air compressor as every literature state in the creation of the suction force, unfortunately the suction was not created during the system testing, but it was created when the venturi tube was individually created.

RECOMMENDATIONS

- Considerations should be made in making the machine portable
- Investigations need to be made to understand the conditions needed for the suction force to be created, if there are fluid properties and environmental impacts that affect its mechanism.

APPENDIX





Ø160.00
Ø157.00
140.00
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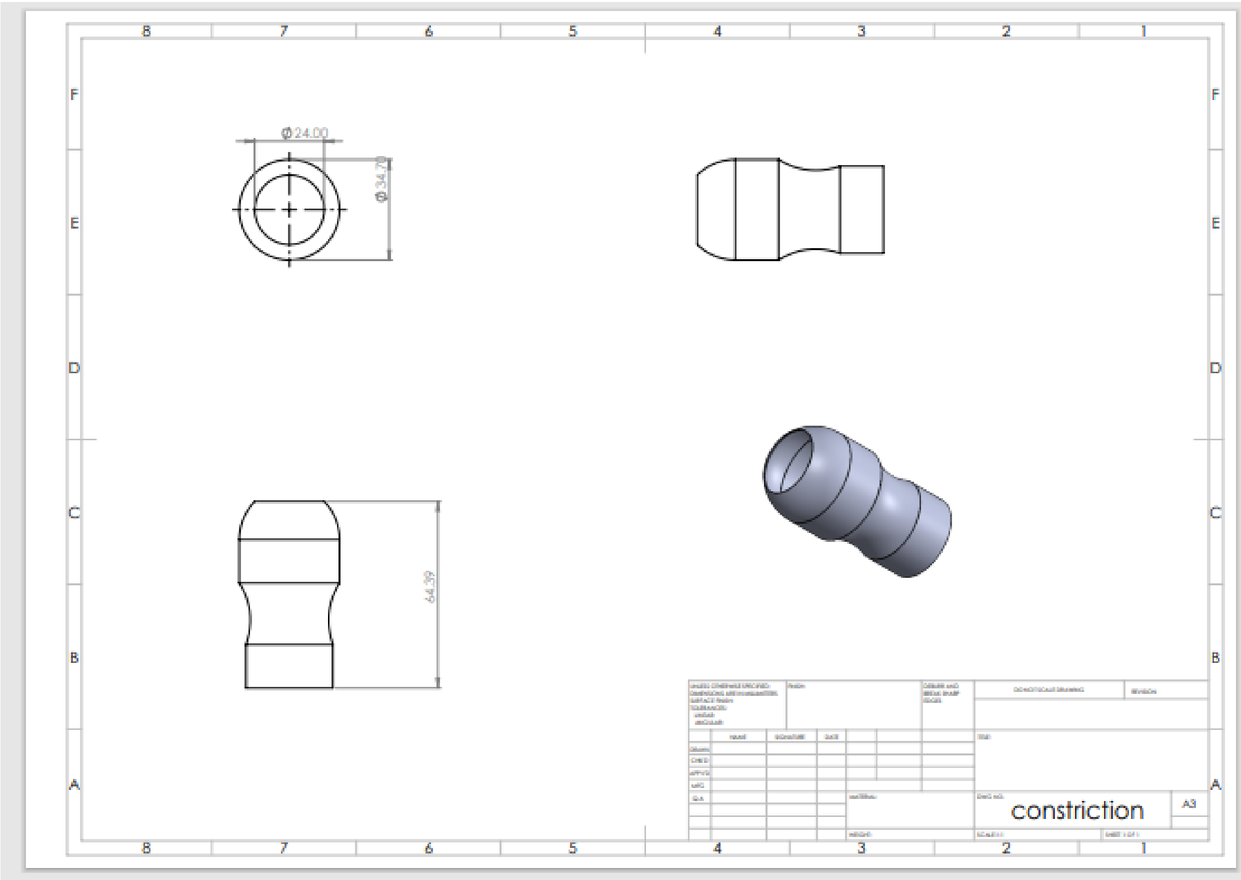
Sedimentation chamber
A3



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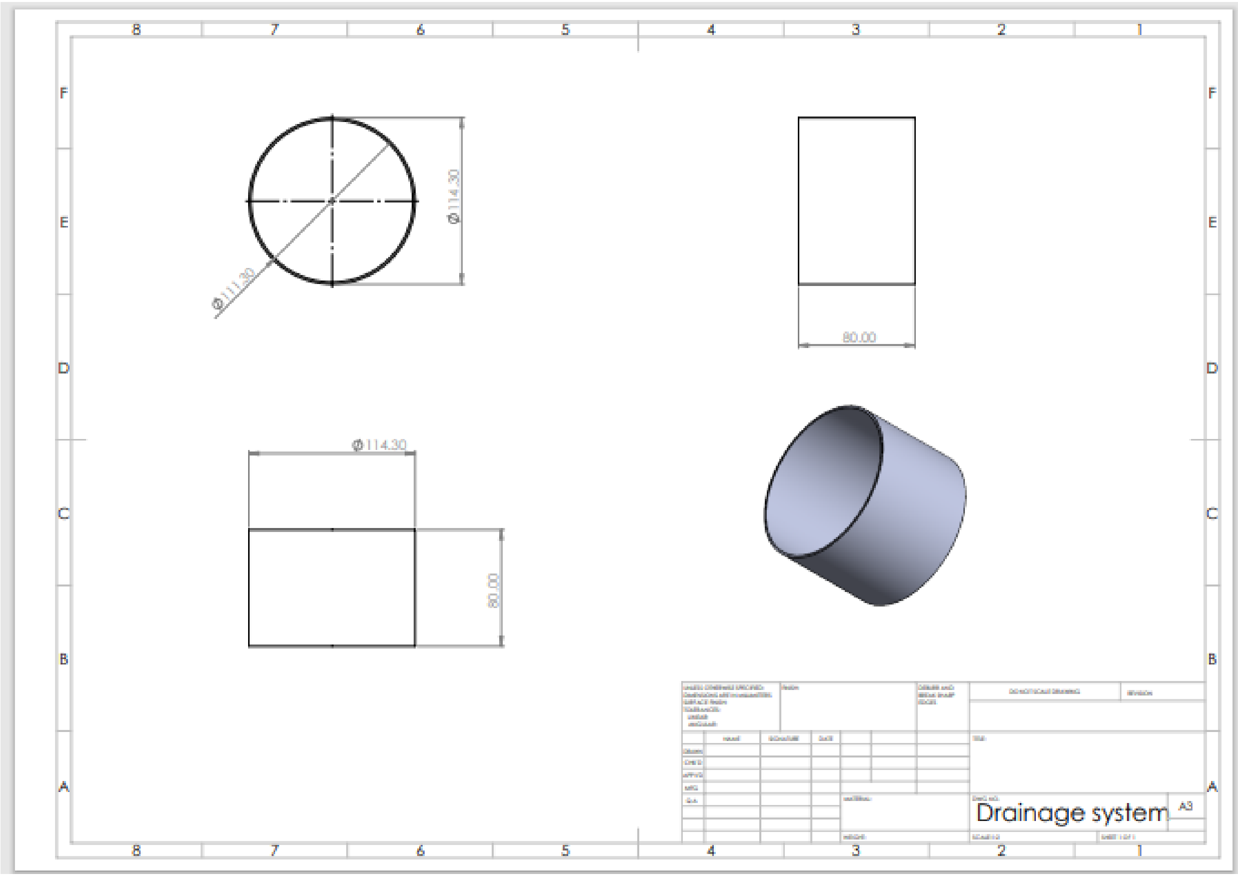
constriction
A3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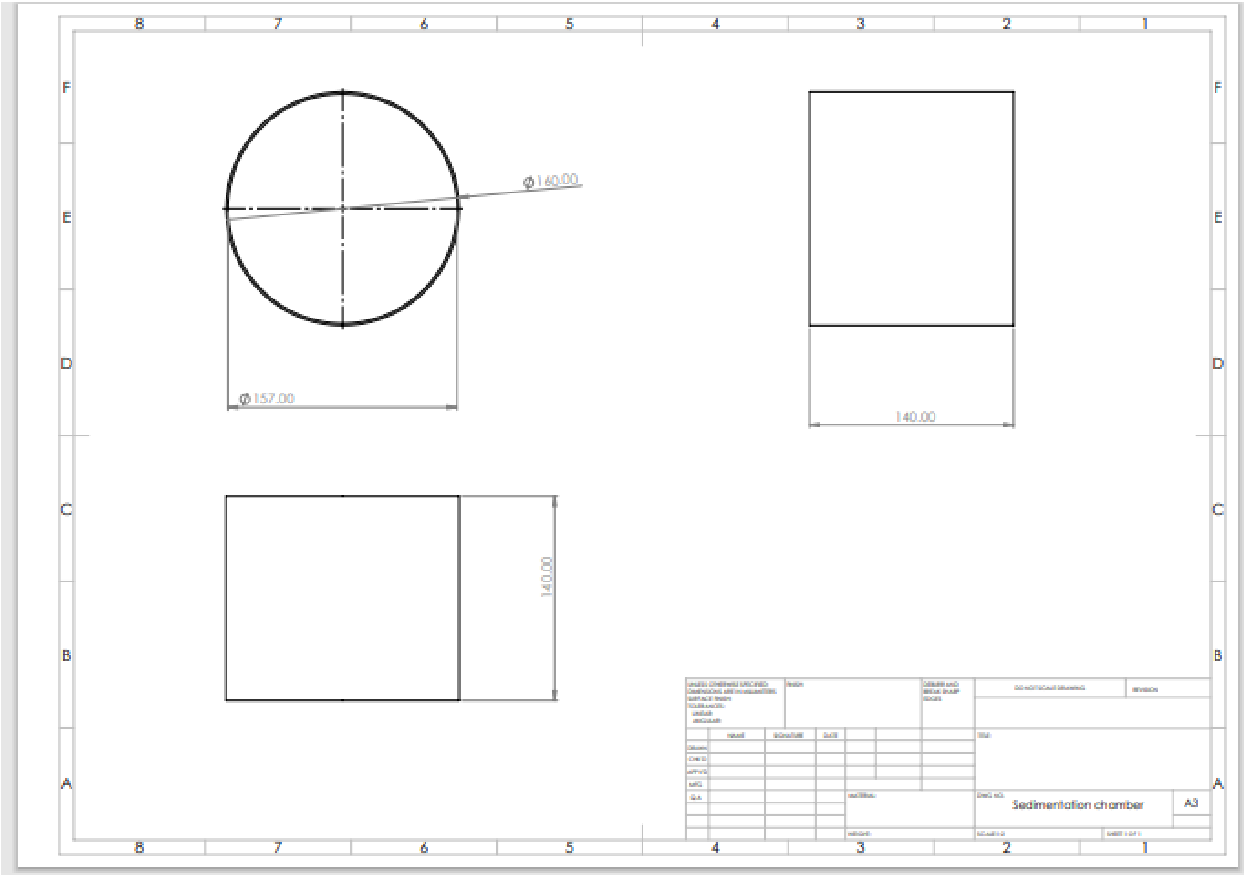
Drainage system
A3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Sedimentation chamber
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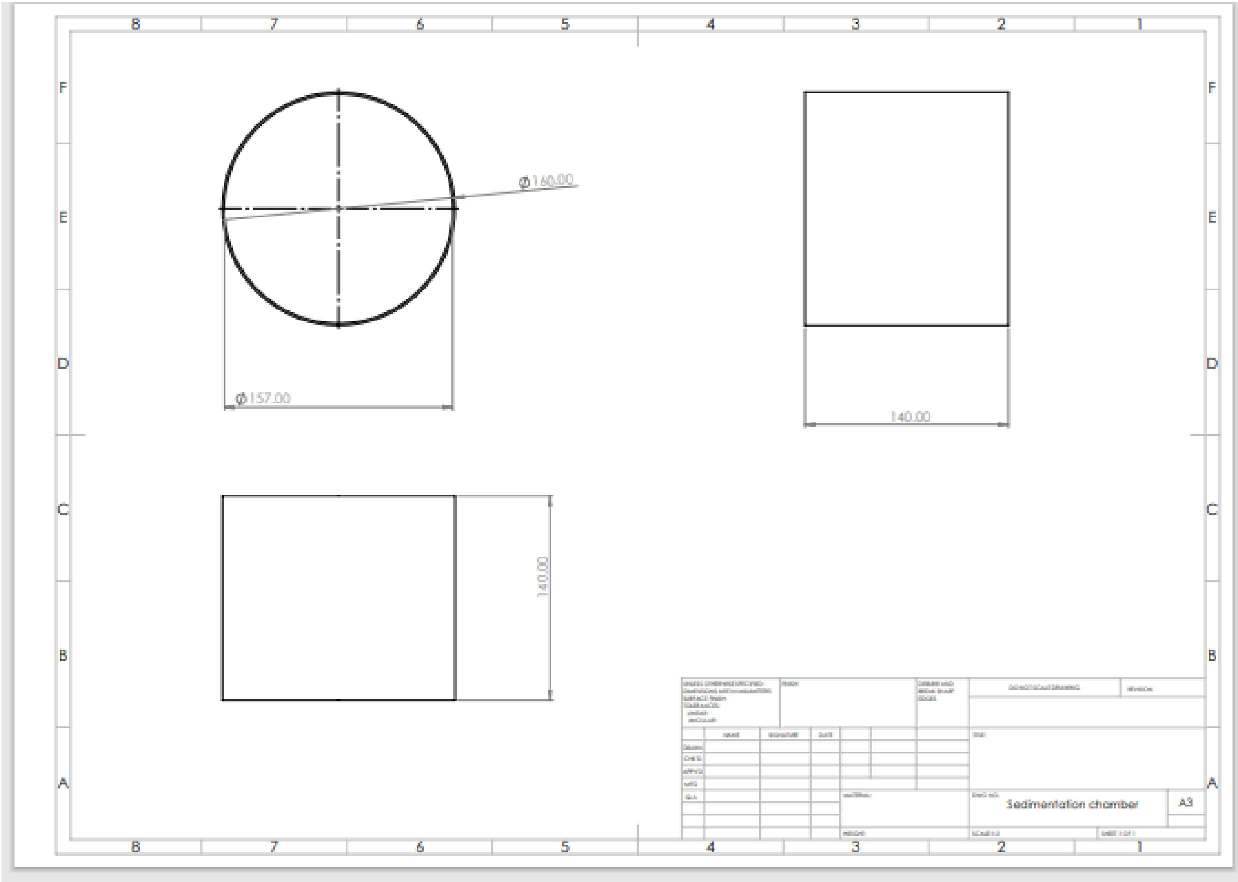

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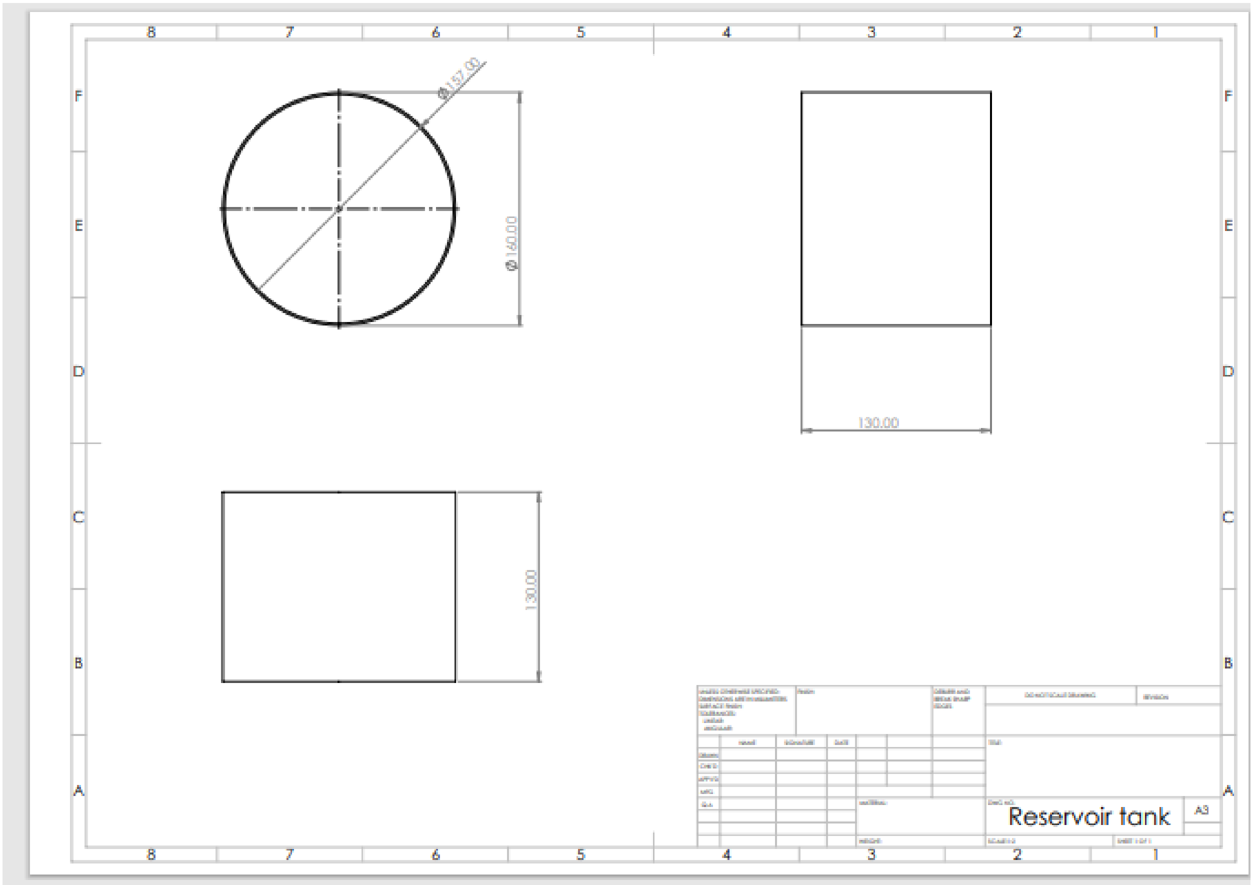
Sedimentation chamber
A3


Ø157.00
Ø160.00
130.00
130.00
Reservoir tank
A3

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