University of Southern Queensland

School of Engineering

A Capable and Effective Watering System for an Intensive Beef Cattle Covered Housing Arrangement

A dissertation submitted by

Lachlan James Davis

in fulfillment of the requirements of

ENP4111 Professional Engineer Research Project

towards the degree of

Bachelor of Engineering (Honours) (Mechanical)

Submitted November 2024

2024

University of Southern Queensland

School of Engineering

ENP4111 Dissertation Project

(This is a 2-unit research project in Bachelor of Engineering Honours Program)

Limitations of Use

CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Student Name: Lachlan James Davis
Student Number: [redacted]

[redacted]
Signature

7/11/2024
Date

ABSTRACT

The Australian beef cattle feedlot industry is continuing to expand. New systems, technology and software are being adopted by the industry, in particular covered housing systems. By advancing and innovating current systems that are crucial to intensive feeding operations, operational efficiency which improves production to accommodate the increasing demand, will be realised. This project focuses on a small but integral section of intensive feeding, being the development of a novel water trough for a covered housing system. By developing a working concept of a water trough that delivers benefits through increased production efficiency and performance, system optimisation and advancement, and sustainable and ethical animal welfare practises, this project will succeed. Conventional water troughs that are used in uncovered outdoor feedlots (concrete and plastic troughs) do not meet all of the beneficial intentions underlined above and are not easily adapted to a covered housing system. Recognising that new systems are being adopted, adaptations are needed to more closely suit these arrangements, hence bolstering the timing and importance of this project. By utilising engineering methods a viable solution can be presented, but first a methodical approach must be adopted in order to work through the objectives and answer the research questions effectively. The approach that was undertaken was a waterfall method commonly used for design and conceptual engineering projects; it encapsulates a step-by-step procedure that essentially entails a flow on effect for each step of the process in an orderly manner.

The end goal for this project was to have a working prototype of a water trough installed in a covered housing system. This was achieved in the form of a gate mounted tipping water trough that incorporates effective use of space, has quick and easy cleaning ability and met all the design considerations and requirements set. The prototype water trough proved that this arrangement is practical and commercially viable in a large-scale intensive feeding operation. The system offers a more adaptable and sustainable system than using conventional water troughs. Reduction in water usage was one of the benefits of this system with a significant reduction in cleaning water wastage after 3 months as compared to a conventional water trough, Overall, after observing its implementation into the covered housing arrangement, it showed positive outcomes and results. These include, but are not specifically limited to, ease of maintenance, ease of cleaning, less spoiling of water by cattle and reduced wastage of water. The system has a large opportunity for adoption in covered

housing systems and in conventional beef cattle feedlots, in particular within areas such as cattle handling facilities.

Overall, this system will prove extremely beneficial to the Australian beef cattle feedlot industry and can help push change for a more sustainable charge towards a more efficient and 21st century conscious future through the adoption of covered housing systems.

ACKNOWLEDGEMENTS

Firstly, is an acknowledgement to the project lead and owner of Struggle Downs Feedlot, Mr Darren Hamblin, who gave me the opportunity to complete a project of importance and practical and commercial use. As well as supplying crucial elements to allow the completion of this design such as funding the prototype, site access and additional design ideas. For this I am grateful for the opportunity, and your time and resources that have been used upon myself.

Secondly, is an acknowledgement to Steven Goh, my supervisor, for taking myself on board and being extremely helpful in providing the appropriate details necessary to achieve a quality project, as well as outlining all the crucial insights on how a dissertation should be prepared and organised according to industry and academic formats.

Thirdly, I would like to acknowledge Rod Davis from RDC Engineers Pty Ltd, who provided insight into the Australian beef cattle industry, which assisted in the formation and development of this project and dissertation. This included the supply of images, in depth analyses of industry principles and cohesion addons.

Lastly, I would like to acknowledge and thank everyone else that supported myself in the duration of this project, such as friends, peers and family members for ongoing assistance and motive.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

CHS – Circular Hollow Section

Intensive feeding – large density of animals that are fed in penned arrangements

MLA – Meat and Livestock Australia

SHS – Square Hollow Section

Strathdale Wagyu – Premium brand of Australian Wagyu. Owned by Mr Darren Hamblin

Struggle Downs Feedlot – Site name of the project’s environment

1 Introduction

Australia depends heavily on the beef industry for economic growth and food security, with the industry projected to "*rise by 19% to 16.3 billion dollars in 2024-2025*" (Wong, 2022). Beef production in Australia comprises both extensive pasture based grazing systems and intensive feeding systems (feedlots). After significant involvement in the Australian cattle feedlot industry over the past several months, a substantial appreciation and respect for the operations and value that this sector provides to the community have developed. This industry not only supports business owners but often serves as the lifeblood of rural communities, creating local employment opportunities and contributing directly to community life, which subsequently impacts the regional economy. It is therefore essential to expand and enhance the knowledge of systems and practices within this industry to improve efficiency and environmental performance. Understanding the significance and role of intensive feeding in the beef production sector, as well as how it evolved in Australia—a country now heavily invested in its implementation—is crucial. The catalyst for adopting intensive feeding of systems in Australia was climatic variability and price fluctuations which led to supply issues within the extensive pasture-based systems.

The intensive beef cattle production system has evolved over more than 40 years but still primarily operates as an outdoor, uncovered system where cattle are mechanically fed and watered in open-air environments. Various issues such as animal welfare and the environment are making it necessary to reconsider traditional approaches to intensive beef cattle feeding practices. While the industry's longstanding traditions are challenging to overcome, changes are inevitable due to modern issues such as climate variability, social and environmental concerns, population growth, and the need for economic sustainability in Australia. Progress has been slow, and a strategic approach is required to address these issues.

Mechanical engineers have the capacity to create, innovate, and develop more efficient and practical systems. Numerous areas within intensive beef cattle feeding systems rely heavily on mechanical engineering, but this discussion will focus on components within a covered housing system where advancements are needed to transition the sector into the 21st century and beyond. One particularly relevant advancement is the implementation of autonomous systems. Autonomous systems offer precise data collection, reduced labour inputs, increased efficiency, and minimise human interaction with cattle, thereby allowing time and resources to be allocated to other critical areas. Such systems can benefit operations across scales, from small farms to large industry players, while addressing significant challenges such as climate change and environmental sustainability.

The essential components of an intensive feeding system are the feeding and watering systems. These systems rely extensively on labour and infrastructure and components, which are currently simple, labour-intensive, and expensive to maintain efficiently. The components and arrangements developed for conventional intensive feeding systems are not easily adapted to covered housing systems. There is, therefore, a need to develop alternative solutions to reduce costs, minimise downtime, and increase overall system effectiveness.

These issues are being addressed by Darren Hamblin the owner of Strathdale Wagyu. Darren, who grew up in Leyburn and graduated from the University of Southern Queensland in 1991 with a degree in mechanical Engineering, has experience in the mining industry, where he ran his own mining business. He now operates a large-scale beef production enterprise specialising in high-performance Wagyu cattle. Darren is currently developing an intensive beef cattle feeding facility utilising a covered housing system in Leyburn. The development is known as Struggle Downs Feedlot. This system will incorporate automated robotic technology imported from Europe. A watering system must be developed and optimised for this covered housing system and integrated with the autonomous robots to achieve production efficiency and environmental sustainability.

The focus of this project is to provide a practical solution for delivering water to cattle through an alternative system, which has the potential to greatly benefit the industry. This endeavour challenges traditional methods and seeks to drive innovation, ensuring advancements in production efficiency to meet emerging challenges effectively. Darren will oversee both the technical and practical aspects of the project.

1.1 Objectives and Aims

This project aims to enhance production and cost efficiency by developing an alternative solution for watering the cattle in an intensive beef cattle housing system. The objective is to create a solution that is novel, practical, requires less maintenance, reduces cleaning time, and effectively maximises production.

The project will address two primary aspects: understanding what is needed and why. It involves developing a watering arrangement for a covered housing system with consideration for key applications and potential future advancements.

Although both aspects have their own sets of requirements and developmental paths, they are unified under the overarching themes of mechanisation and optimisation in intensive beef cattle production systems. Maintaining this broader perspective is essential throughout the project, as these aspects are interrelated in various ways.

To ensure the project is well-guided, specific objectives have been compiled as follows:

1. Identify areas for adaptation in developing an innovative and practical watering system compatible with the layout and operations of a covered housing system.
2. Address potential advancements that could significantly impact the industry and engage in discussions with the owner to develop a customised solution tailored to the specific needs of the operation.
3. Generate design concepts, refine the final concept, provide all necessary details, and prepare fabrication drawings for construction.
4. If construction is completed, analyse the system's functionality and usage, documenting any modifications that may be required following implementation.

1.1.1 Expected Outcomes

1) Develop a practical and functional arrangement for a watering system within the covered housing system.
2) Create detailed fabrication drawings to ensure the system can be constructed according to the designed dimensions.
3) Monitor the construction and implementation process and evaluate the system's effectiveness.
4) Conduct life cycle analyses and provide comprehensive descriptions of how this innovation could transform the industry both within and beyond this specific operation.

1.1.2 Work Plan

Month	Stage	Objectives
1	Project Proposal	▪ Develop a proposal that includes aims, objectives, and other essential components. ▪ Obtain the necessary approvals and permissions from the project lead, Darren Hamblin, and the academic supervisor, Steven Goh.
2-3	Client Brief, Knowledge Collation	▪ Understand the requirements for the designs. ▪ Gather all relevant designs and information necessary for developing a strong conceptual design.
4-5	Information Analysis and Conceptual Designs	▪ Demonstrate the implementation of research information and evaluate its viability. ▪ Outline the development of the concept designs by correlating the changes to identified needs and wants, as well as standard information. ▪ Justify the changes and specific aspects of the designs.
6-7	Finalisation of Design and Fabrication Drawings	▪ Refine the final design and develop a prototype design after it has successfully passed inspections using visualisation tools such as Autodesk Online Viewer ▪ Ensure the creation of fabrication drawings for the construction and implementation stages.

8-9	Analysis and in-depth explanations for Report Writing	▪ Provide a comprehensive explanation of the designs and the overall process of the project. ▪ Ensure that no information is omitted and that sufficient details are included for all stages to thoroughly document the development process.
10	Presentation and Final Report version	▪ Conduct a thorough review of the report. ▪ Finalise a presentation that highlights the key factors of this project.

Table 1: Work plan

1.2 Project plan

The project plan sets out the goals, tasks and timeframes and must align with the objectives and aims of the project. Maintaining a structured plan is crucial to ensure that good results are delivered within the designated timeframe. Establishing minimum and maximum goals is essential.

- The minimum goal is to develop a 3D model and prepare working drawings suitable for manufacturing of prototype water trough. This requires comprehensive engineering documentation, ensuring that detailed analysis supports the design decisions and provides the fundamentals to address design questions.
- The maximum goal is to produce a working prototype that can be analysed for operational functionality, enabling practical answers to the design questions.

The design methodology will progress through multiple phases, yet certain factors, such as the allocation of time for each segment of the design process, must be carefully considered. Creating a time schedule will facilitate achieving the maximum goal, provided that all available technology, resources, and funding are fully utilised. In this case, since the project is in effect a commercial project and will serve as a critical operational component, a design solution is necessary, and the required resources can be secured. Consequently, to develop a working prototype, all theoretical work must be completed efficiently. The time dependencies for each section of this report are outlined in the section 1.1.2.

1.2.1 Required resources

1.2.1.1 Equipment:

- It may be possible to implement 3D printing equipment to generate a scale model if construction is not completed prior to the finalisation of the dissertation.
- Utilise sketching paper along with all necessary rulers and pens.
- Acquire measuring equipment for onsite visits, such as a survey device (Trimble DA2), tape measure, vernier callipers, and other tools.
- A workshop may be required to address specific questions.

1.2.1.2 Software:

- Autodesk Inventor
- Excel spreadsheeting
- Citation tools
- Word documents
- Emails for communicational purposes
- Google and academic sources

1.2.2 Dissertation Chapter Summaries

1.2.2.1 Chapter 1 Summary – Introduction

This chapter introduces the foundational expectations of the project. It provides a concise overview of the objectives and aims that will be explored throughout the dissertation, allowing the reader to understand the significance and rationale behind the project. The chapter outlines the scope of the project, detailing the specific areas of focus while affirming the overall achievability of the proposed solutions. By establishing these key elements, this chapter serves to validate the project's viability from an engineering perspective, setting the stage for the in-depth analysis and discussions that will follow in subsequent chapters of the dissertation.

1.2.2.2 Chapter 2 Summary – Background

Building upon the project introduction, this chapter provides a thorough examination of the information necessary to support design decisions and gather insights into the intensive beef cattle industry. It outlines the relevant background information required to effectively address design criteria and emphasises the importance of understanding existing practices and innovations.

1.2.2.3 Chapter 3 Summary – Literature Review

This literature review serves as a critical foundation for identifying effective engineering solutions that not only meet the current demands of the industry but also advance upon prior studies. By synthesising available knowledge, the chapter aims to inform the development of innovative solutions that are both practical and viable for use within Struggle Downs Feedlot.

1.2.2.4 Chapter 3 Summary – Methodology

The methodology chapter delineates the design process, emphasising the specific steps necessary to achieve a functional design. It establishes a framework for addressing the design questions and objectives outlined earlier, ensuring that these elements are systematically integrated into the subsequent design phases. By detailing the required steps, this chapter serves as an effective engineering technique that facilitates a smooth design workflow. The structured approach allows for the preliminary organisation of relevant information, guiding the decision-making process and ultimately solidifying the final design choices. This cascading effect, where each section builds upon the preceding one, fosters a comprehensive understanding of the topics and broader processes essential for reaching the project's objectives.

1.2.2.5 Chapter 4 Summary – Design

This section synthesises the information presented in the preceding chapters, transforming theoretical concepts into practical models for application. It meticulously addresses each component necessary for the successful completion of the project, presenting this information in a clear and accessible format that facilitates reader analysis. This organised approach prepares the groundwork for the subsequent development of a prototype, ensuring that all elements have been considered and effectively integrated into the overall design strategy.

1.2.2.6 Chapter 5 Summary – Results and Discussion

This chapter provides a comprehensive overview of the entire design process, culminating in the presentation of the final solution to the project. It highlights the achievements made through prototype testing, design refinement, and the assessment of overall operational functionality and usability. The chapter reiterates the significance of the project, supported by tangible evidence rather than purely theoretical hypotheses. By comparing and justifying the outcomes based on critical data and finalised figures, this section effectively underscores the legitimacy of the project’s findings and its contribution to the field.

1.2.2.7 Chapter 6 Summary – Conclusions

This chapter serves as a conclusive summary of the entire report, revisiting the project's initial objectives and aims. It discusses how the project has effectively addressed the set design questions and provides a final justification for its relevance and value to the industry. Additionally, this section outlines how the principles established in this project will inform future work, ensuring the long-term viability and adaptability of the solution within the dynamic landscape of engineering advancements.

2 Background

2.1 Scope

The scope of this project encompasses the design, development, and implementation of an effective watering system tailored for an intensive beef cattle covered housing system. This initiative aims to address the unique challenges associated with cattle hydration in a controlled environment, enhancing both animal welfare and operational efficiency. The project will explore innovative solutions that integrate seamlessly with existing infrastructure while meeting industry standards and requirements.

Key elements of this scope include conducting thorough research into current watering practices, assessing the technological advancements applicable to cattle feedlots, and identifying gaps in existing systems that can be improved. Additionally, the development of a prototype will play a crucial role in testing the effectiveness of the proposed system, with field trials planned to validate its functionality and performance in real-world conditions. Through this comprehensive approach, the project seeks to deliver a practical solution that not only meets the immediate needs of Struggle Downs Feedlot but also contributes to the broader goals of sustainability and efficiency within the beef cattle industry. Ultimately, the outcomes of this project will provide valuable insights and methodologies for future developments in cattle management systems.

2.2 Background

It is important to understand the background of the applicable systems, as this knowledge aids the reader in comprehending the primary arguments for the significance and benefits of this project to the industry. Establishing a strong foundation to rely on later in the design process serves as a valuable tool and can influence reasoning and design choices.

2.2.1 Australian lot feeding industry

It is important to understand the industry into which this project will integrate, specifically the lot feeding industry of Australia. For those unfamiliar with this process, it involves a plot of land where livestock, predominantly beef cattle, are fattened for the consumer market (www.merriam-webster.com, 2024). Other livestock, such as sheep, pigs, and even chickens, are also produced under similar intensive systems. This approach accelerates and enhances the efficiency of mass growth in animals to prepare them for sale. Lot feeding of beef cattle was first introduced on a larger scale in the 1960s, driven by the demand for higher-quality beef that arose due to drought conditions (Wikipedia Contributors, 2019). Today, the beef feedlot industry in Australia contributes approximately '$4.6 billion to the economy and employs around 28,500 people, both directly and indirectly' (FutureBeef, n.d.). This figure only represents the beef cattle sector and does not account for the other livestock mentioned above. The significance of the beef cattle feedlot industry in Australia is evident, as it plays a crucial role in rural communities by injecting essential financial support into local businesses such as grain growers, livestock breeders, service providers, and suppliers. There are currently around 450 accredited beef feedlots in Australia that supply certified grain-fed beef, with the majority located in Queensland and New South Wales. Queensland accounts for 60%, followed by New South Wales at 30% (World Animal Protection Australia, 2023). It is, therefore, common for new cattle feedlots to be developed in Queensland, which is also where this project will be situated, specifically near a small rural town called Leyburn, approximately 66 km southwest of Toowoomba (Wikipedia, 2023).

However, this does not imply that this beef cattle feedlot will be identical to others. The distinguishing feature of this feedlot is that it will be entirely covered, with cattle housed in a large shed, known as a covered housing system. This approach contrasts with the traditional feedlot, which is an uncovered system consisting of an open yard, sometimes supplemented with a narrow overhead shade structure that does not cover the entire yard, as illustrated in the figure below.

Figure 1: Australian Feedlot – Typical shade system (Animals Australia, n.d.)

2.2.2 International industry

Cattle feedlots are not only prevalent in Australia but also internationally. In Europe, their presence is limited compared to the overall cattle sector, although this sector is experiencing growth. Conversely, feedlots are very common in North and South America, with the US and Canada currently leading in this area (Bechtel, 2018). The northern hemisphere has a markedly different climate, and environmental conditions compared to Australia. Countries such as Mexico, Brazil, and Spain also have a rising feedlot sector (Behrendt and Weeks, 2009).

In the US most feedlots consist of an uncovered open yard system. In Canada and Europe most beef cattle are kept in a covered housing system. The rationale behind many housing arrangements in the Canada and Europe primarily relates to weather; winter temperatures can be significantly cold, necessitating the permanent movement of cattle indoors for the season. As a result, these regions tend to maintain tighter stocking densities (4–5 m^2 per head) than those observed in Australia to help keep cattle warm (MLA, 2023). Below are images of cattle in Canada utilising a covered housing system.

Figure 2: Typical Canadian covered housing system (Media, 2022)

In environments like this, roof shapes may vary to accommodate snowfall, and additional reinforcement and different types of ventilation would also be necessary. Below is another example of a covered housing system, this time in Spain, which may present a climate more similar to that of Australia.

Figure 3: Typical European covered housing system (www.farmersjournal.ie, n.d.)

As demonstrated in both images, the cattle exhibit very clean hides, and the reduction of dags is evident on a global scale. Understanding the benefits of covered housing systems is crucial for advancing this project.

3 Literature Review

A review of the current methods of intensive feeding of beef cattle within Australia was undertaken. There are basically two types of systems, being the traditional approach of feeding cattle in pens with the pen area partially covered by a shaded system or uncovered. Alternatively, cattle may be fed in a covered housing system in which the pen area is partly covered or fully covered by a solid roofed structure. The cattle in fully covered systems are not exposed to rainfall. Each type of system offers positives and negatives. An in-depth exploration of each type of system is now presented.

3.1 Uncovered System

This is the traditional beef cattle feedlot system and is characterised by an arrangement of pens in the open-air environment. This system may or may not have shade installed. Historically, all feedlots were uncovered. Several factors influence the decision to implement uncovered pens, including cost, animal breed, and climate. For instance, there are no additional costs associated with building shade infrastructure when it is deemed unnecessary, such as in colder climates like southern or central New South Wales. However, the Australian Lot Feeders Association (ALFA) is now advocating for the installation of shade in every feedlot. The ALFA shade policy is "*encouraging all unshaded facilities to investigate and install shade*" (Sarah, 2022).

However, this system has several major drawbacks. These include reduced beef production due to climatic conditions, such as rainfall and heat, and animal welfare concerns like heat exhaustion and wet manure accumulation in pens, which leads to odour generation and dirty cattle. Overall, this setup provides a poor environment for the cattle, which is why ALFA has adopted a shade policy. Another significant issue with this system is the formation of dags, defined as "*accumulated balls of manure and soil that adhere to the coat or hair of cattle, and are most prevalent on the brisket, underbelly, tail, and sides (ribs, flank)*" (Rod Davis per comms, 2024). The ground surface's susceptibility to environmental conditions, such as rain and mud, often drives the creation of dags (Bennet, Deyzel, and Davidson, 2022), particularly during extended periods of wet weather.

Dags pose a problem at slaughter and can cost up to -$16 per head to mitigate, as they risk contaminating the carcass. "*Reducing the manure, dirt, and dags on the hides of cattle being presented for slaughter lowers the risk of meat contamination when the hide is removed after slaughter. Subsequently, meat processors require that the hides of cattle are visibly clean before slaughte*r" (Davis, Rod, as per comms, 2024). Current methods for removing dags include water soaking followed by high-pressure cleaning systems, which are often stressful for the cattle and costly to implement (Bennet, Deyzel, and Davidson, 2022). Below is a layout of an uncovered feedlot. In an uncovered system, it is impractical and uneconomical to provide an environment that prevents dag formation, resulting in inevitable losses.

Figure 4: Australian Feedlot - Typical unshaded feedyard (Condon, 2021)

3.2 Shaded System

This section will discuss the evolution of shade systems. Several types of shade systems are implemented within Australian feedlots. The selection of a shade system for a feedlot is often influenced by specific location factors. Climate is the primary consideration, as aspects such as sun exposure, heat exhaustion, cold weather, wind, and rain protection play significant roles in determining the most suitable type of shade.

Shade systems can either cover the entire pen or only a portion of it and may be constructed from waterproof or permeable materials (MLA, 2016). Partial coverage is the most common configuration. Permeable shade systems allow rainfall to filter through, whereas waterproof systems, although effective, are becoming less favourable due to high construction costs and the potential risk of animal injury during storms. Shade systems provide significant sun protection throughout the day, reducing heat stress and greatly improving animal welfare. As previously mentioned, animals experiencing less stress are more likely to consume food, drink water, and gain weight. From an animal welfare perspective, shaded systems are far more effective than uncovered ones.

Even in colder climates, cattle are still exposed to harsh sunny conditions, which is why ALFA is advocating for all feedlots to incorporate shaded systems as a minimum standard. Research in this area has produced key findings, such as: "*Cattle with access to shade had 3% greater dry matter intake – 36 kg extra – and a 1.9% increase in hot carcass weight, which amounted to an additional 6 kg per head at the processing plant*" (House, 2019). This clearly demonstrates that shaded systems enhance animal performance. Furthermore, it has been reported that "*Payback on commercial shade installation is approximately three to four years*" (House, 2019), and "*The average life of shade sails is approximately 15 years, with the capital cost of shade ranging from 1–2c per head per day*" (House, 2019). Shade is fundamentally an investment, adding value to the overall operation.

However, even with shaded systems, issues such as dags and the risk of carcass contamination during slaughter remain. Permeable shade systems, in particular, do not prevent mud formation when it rains, as the materials used are not waterproof, as illustrated in Figure 3.

Figure 5: Australian Feedlot – Typical shade arrangement system (www.abc.net.au, 2019).

3.3 Covered Housing

This section is directly related to this project. Understanding the concept of a covered housing system and its relevance to this project is crucial.

Covered housing systems have been in use for over twenty years, primarily associated with small feedlots or those owned by Japanese interests, as these systems are more commonly employed in the northern hemisphere (MLA, 2023). Recently, however, they have gained popularity in Australia due to shorter return on investment periods, as production gains are being realised and profitability in the lot feeding industry increases. This trend has made it easier for proprietors to cover the associated costs (A. Smith, Rangers Valley Feedlot, pers comms 2024).

Covered housing systems are relatively uncommon in Queensland, with only two fully covered feedlots currently in operation for over 12 months: the Four Daughters Feedlot at Meandarra (Four Daughters, n.d.) and the Canning Downs Feedlot near Warwick (Elbow Valley, n.d.). Both are depicted in Figures 4 and 5 respectively. Additionally, the Lemon Tree Feedlot at Millmerran comprises both uncovered pens and fully covered pens.

Figure 6: Australian Feedlot – Covered housing system western Queensland (Four Daughters, QLD n.d.)

Figure 7: Australian Feedlot – Covered housing system Darling Downs (Elbow Valley, QLD n.d.).

There are various reasons for implementing a covered housing system, some of which may not be as straightforward as they initially appear. The three Queensland leaders in covered housing systems have all highlighted the benefits of their arrangements and their objectives for implementing them. As noted by Beef Central, "*Could shed structures move feedlots into new areas?*" (Barker, 2023), which is a fundamental question for the owners of Struggle Downs, whose goal is to revolutionise the feedlot industry through the adoption and implementation of new systems and technologies.

With a greater focus on covered housing systems, it is worth outlining some of the benefits and advantages of such arrangements. These include:

- Improvements in meat quality (Elbow Valley, n.d.).
- Significant enhancement of animal welfare (Elbow Valley, n.d.).
- Minimisation of environmental impacts (Elbow Valley, n.d.).
- Reduced exposure to weather-driven events (Barker, 2023).
- Cleaner animal hides, which reduces excess labour for cleaning, as animals need to be clean before heading to slaughter (Sarah, 2024).
- A low-stress environment that boosts feed conversion (Sarah, 2024).
- Decreased feed wastage (Sarah, 2024).
- Less labour-intensive feeding processes (Sarah, 2024).
- Higher stocking rates: "*Stocking density in open feedlots is typically around 15 m^2/SCU, but when undercover, this can be reduced to 9 m^2/SCU*" (Sarah, 2024).
- Better bedding management (Sarah, 2024).
- Opportunities for solar panel installation to reduce electricity costs (Sarah, 2024).

As demonstrated, there are substantial benefits to this system, making it clear that it is a highly viable option for the future. Although there are significant challenges associated with dags on cattle, a covered housing system protects the animals from rain, resulting in minimal wet manure formation and virtually no dag accumulation. This translates to considerable cost savings for the industry. However, there is one drawback: the capital cost and construction of the system. Covered housing systems typically involve one or more large sheds—over 200 meters long and approximately 30-50 m wide. As expected, the expense of constructing such a large shed can be substantial. Nevertheless, this investment can be offset by the improved production efficiency gained once the system is operational.

3.4 Industry Standards and Requirements

The feedlot industry in Australia is a regulated sector, with numerous rules and regulations governing the specifics of establishing a feedlot with a covered housing system. Various agencies across Australia enforce regulations that primarily focus on animal welfare and needs, including standards for food and water to ensure ethical practices across all operations. Other requirements pertain to the construction of the covered housing arrangements, which involve sustainable practices such as flooring type, shed positioning, drainage, and available size. These elements ultimately contribute to sustainable animal management practices. These points will be discussed further in the subsequent subheadings. Note: Requirements and standards vary from state to state in Australia, though the principles remain the same. However, for site specification all requirements and standards will be considered for Queensland only.

3.5 Animal Welfare

Animal welfare is an increasingly important issue. With the growing number of animal activists over the years, there has been a rise in vocal opposition and actions against cattle feedlots. As a result, owners are seeking ways to enhance animal welfare while also advocating for stricter penalties for trespassing, particularly in Queensland (Beef Central, 2019). Therefore, special care is required when managing these animals; otherwise, production may decline, and complications may arise due to activist actions.

Specifically for beef feedlots, the requirements are as follows, directly quoted from the Queensland Government Cattle Code of Practice (Department of Fisheries, 2011): Ensure cattle kept in a beef feedlot have a minimum floor area of 9 m^2 for each standard cattle unit (equivalent to 600 kg live body weight) in the feedlot. Ensure cattle in a feedlot are inspected daily to assess their welfare.

The owner or operator of a beef feedlot must complete an annual risk assessment regarding the risk of heat stress at the feedlot and establish, implement, and maintain a risk management system to manage the ongoing risk of heat stress.

High levels of animal welfare also positively impact the production and quality of beef. The straightforward equation that has emerged from this review is that if an animal experiences less stress, it will gain weight more quickly and produce higher-quality meat. Consequently, the shed system not only promotes better animal welfare but also aligns well with its benefits when compared to uncovered systems.

3.6 Food and Water Requirements

3.6.1 Food requirements

As this is a feedlot, there is an expectation for cattle growth. This necessitates that the feed energy intake must exceed what is referred to as maintenance energy intake. The formulation of their diet is based on the nutritional requirements needed to achieve a specific desired level of performance (FutureBeef, n.d.). It is crucial to monitor and control the amount of feed distributed to each animal within a certain timeframe, as this impacts quality and, consequently, longer-term factors such as the duration of their stay in the feedlot. Some lot feeders aim to finish cattle at a quicker rate to expedite their movement to slaughter, which is influenced by the market demand for those cattle.

Nonetheless, there is a fundamental requirement to maintain an animal's energy levels, in addition to the extra energy allocated for weight gain and performance (Gomes et al., 2012). The specific feeds available—such as sorghum, molasses, and silage—can vary in energy content and nutritional type (FutureBeef, n.d.). Additionally, the feed requirements for an animal are heavily influenced by its genetics and specific breed, as these traits determine how effectively they process energy (Okine, McCartney, and Basarab, 2003).

3.6.2 Water requirements

Feedlot water requirements can be divided into two categories: fresh, clean water necessary for cattle drinking and water needed to meet various other demands, such as feed processing, washing trucks, cleaning cattle handling facilities, maintaining water troughs, washing cattle, dust suppression (on roads), sprinkler systems for hot days, and human consumption. These additional water requirements are primarily related to food safety and general hygiene during operations (Water use in the paddock, n.d.). However, the primary focus will be on the water required for cattle drinking, as this is a fundamental aspect of implementing a covered housing arrangement and presents the most potential for technical advancements. According to Meat and Livestock Australia (MLA), the daily water consumption of lot-fed cattle can vary from 14 L/head/day to 75 L/head/day, depending on the season (Davis and Watts, 2016). Additionally, Davis and Watts (2016) identify several criteria that influence water consumption in cattle, including:

- Environmental factors (e.g., higher temperatures, humidity, etc.)
- Breed (Bos indicus cattle typically drink significantly less water than Bos Taurus)
- Diet composition (the drier the food, the more likely cattle are to drink)

All these factors will be evaluated further later in the dissertation.

3.7 Building Requirements

A shed is a key component of a covered housing system. Constructing a shed of this size necessitates careful consideration of various factors. These factors are outlined in the table below, which is taken from the manual titled "*MLA Feedlot Covered Housing Systems v03 (Feedlot Covered Housing Systems Best Practice Design and Management Manual, 2023)*" (MLA, 2023).

Item	**Consideration**
Approval	Various legal obligations need to be met when building any type of structure. This is usually done through local councils.
Siting	This essentially pertains to the location of the housing, the distance from nearby dwellings, and the soil structure on which it is constructed. This is a crucial factor to consider.
Building orientation	As previously mentioned, an east-west orientation is preferred. This orientation helps to alleviate heat load within the shed by optimising wind flow through the longest axis of the structure, thereby enhancing natural ventilation.
Pen configuration	The design should be practical, addressing needs such as ease of access for the movement of feeding equipment, pen cleaning equipment, cattle, and staff.
Water and power	The design must effectively accommodate these two systems. Additionally, it can provide benefits in terms of roof space for solar panels or targeted water harvesting. This introduces extra options that are not available in uncovered feedlots.
Internal environment	This essentially involves maintaining optimal internal conditions within the shed for the cattle, such as minimising humidity and heat.

Ventilation	Ventilation is a crucial consideration in building design, as it must effectively remove excess moisture and gases and supply fresh breathing air. Natural ventilation can often be sufficient; however, specialised advice may be necessary to evaluate proper ventilation requirements. Additionally, all design dimensions of the shed impact ventilation effectiveness.
Lighting	Adequate lighting is essential to ensure worker safety, facilitate cattle handling, and provide general visibility for all operations. Furthermore, lighting can be utilised to promote artificial day lengths, which may positively influence animal performance.
Building height	The building height will be designed to provide adequate clearance for working machinery and to ensure effective ventilation. A height of 5 meters or greater is generally considered sufficient when taking both of these factors into account.
Building width	The building width is a critical consideration. A wider shed may lead to ventilation challenges; however, various roof systems can be employed to mitigate these effects in wider structures. Ultimately, the final width selection depends on the desired pen size by the lot feeder. Additionally, sheds may be retrofitted to existing outdoor pens, necessitating a wider design to accommodate the existing infrastructure.
Building length	The building length is determined by the number of cattle to be housed by the lot feeder; longer structures can accommodate more pens. It is not uncommon to encounter sheds exceeding 200 meters in length.
Support structures	These structures must be professionally engineered to meet the specific requirements of the desired design and tailored to the particular site conditions. Selecting appropriate materials is essential for this aspect of construction.
Roof	Roof designs can be either mono-slope or gable. Mono-slope roofs are often utilised for narrower sheds, while a wider configuration may require multiple mono-slope roofs arranged in a sawtooth

	pattern. For gable roofs, steeper pitches of approximately 15 degrees are necessary to ensure adequate ventilation.
Vents and roof caps	These elements are crucial for promoting effective ventilation within the shed system. The specific design of these features can be complex and necessitates careful consideration and evaluation. For instance, open vents may be placed over feed roads, while closed vents should be implemented over cattle pens.
Roof materials	Corrosion protection is essential when selecting roofing materials. However, the choice of paints or finishes may be subject to council approvals, which can influence material selection and compliance with boundary regulations.
Roof drainage	Given the substantial size of these sheds, they can generate significant rainwater runoff, necessitating careful planning and management to control this runoff and prevent adverse effects on the surrounding areas.
Flooring	The flooring in a covered housing system must be designed to support the weight of both cattle and machinery. Additionally, because the environment is more controlled in a covered system, the flooring experiences less wear and tear from weather conditions, resulting in reduced maintenance needs compared to uncovered systems.
Fences and gates	The flooring in a covered housing system can be designed similarly to an open system but can incorporate specific features like feed bunks and nib walls. These design variations help optimise space and facilitate feeding, while also ensuring that the flooring remains durable and easy to maintain.
Feeding	In covered housing systems, pre-cast or cast-in-situ bunks are typically preferred for their ease of installation and durability. While self-feeders are also an option, the use of slip-forming for bunks is less common. This is primarily because the support columns within the shed can obstruct the equipment needed for slip-forming, making it impractical. Therefore, choosing the appropriate bunk design is

	crucial to ensure efficient feeding and to accommodate the structural layout of the housing system.
Water requirements	A well-designed water reticulation system is essential to ensure the required volume of water can be delivered to the cattle. Locations of water troughs needs to be considered so that they don't impede on machinery and are easy to clean. Uncovered systems typically have a pre-cast concrete trough 5.1m long and about 600mm wide with a capacity around 750L.
Drainage	Drainage of both clean water and dirty water (effluent) can be effectively separated in a covered housing system due to roof collection. Consequently, smaller effluent ponds can be utilised, and drainage for water runoff can be collected in a separate system.
Bedding	Covered housing typically has loose bedding for some of the year. It will be replaced and changed at regular intervals. The type that will be used will be dependent on availability and cost etc. Some of the common options are sawdust, woodchips, straw or composted manure. It's important to consider bedding as it is optimal to keep suitable conditions for the cattle, keeping them clean, and healthy and can control emissions.
Manure management	Manure management is crucial to animal welfare and general hygiene and needs to be cleaned regularly following approval conditions. The manure needs to be removed and placed in a controlled drainage area.
Welfare	This is crucial to achieving good cattle performance, and if all items mentioned above are addressed and implemented properly, good animal welfare can be achieved and maintained. There are minimum space requirements that are mandated per head, and the food and water requirements are outlined in the previous sections.
Animal health	Since these animals are not exposed to sunlight, Vitamin D supplementation is required. Otherwise, the regular operations of feeding, watering, and veterinary care are conducted as usual.

Table 2: Covered housing systems– Important considerations (MLA, 2023)

3.8 Current Trends and Developments

3.8.1 Present knowledge of practice

This section will explore the specifics of the practice that the project will impact. It will address aspects such as how the operation functions currently, what changes are being implemented regarding this practice, and the anticipated future outcomes. This essential information will relate closely to the specific site, the project, and the requirements and expectations of the owners of Struggle Downs Feedlot. By focusing on these details, it will become possible to narrow down more in-depth requirements and establish important goals and aims for the project.

3.8.2 How does Struggle Downs Feedlot operate currently?

Currently, Struggle Downs Feedlot is not yet in full operation, with its primary component, the covered housing arrangement, still under construction. The main components of the feedlot will be 6 sheds which have a pen area of 200 m long by 41 m wide and a 4 m roof overhang on each side. The owner of this feedlot is Darren Hamblin, who is a grazier from north-central Queensland. Understanding how the operation will be conducted is essential for forming objectives and research questions. Most feedlots operate in slightly different ways, each exhibiting specific aspects that vary, including feeding times, feed types, cleaning methods, and water trough designs. The breed of cattle being introduced into the feedlot is the Wagyu breed. Australian Wagyu is originally a Japanese breed of cattle known for its unique growing ability that produces exceptionally tender marbling in the beef. This characteristic makes Wagyu cattle highly desirable and consequently very valuable in the market (The Cattle Site, n.d.).

Figure 8: Typical appearance of Wagyu bull (The Cattle Site, n.d.)

These cattle are extremely high value and can be genetically and genomically focused to produce efficient livestock. Darren Hamblin states that there is a significant difference in value between low- and high-quality animals, and he "*wanted to reach the high end*" (www.google.com, n.d.) of these values. Darren has specifically developed his Wagyu cattle through targeted genetic breeding and has successfully attained a position in the higher end of the grain-fed beef market with marble scores in excess of 8. For comparison, at slaughter, the value of these animals can reach $15/kg or more when they have a marble score of 7 or higher, whereas other breeds typically command around $6/kg with a marble score of 1-2. AUS-MEAT is used to grade marbling based on visual and reference standards, with scores ranging from 0 to 9, where 9 indicates the most abundant marbling (MLA Corporate, 2024). Wagyu is therefore considered a high-value animal, which makes investing in a covered housing system even more advantageous and justifies the majority of the upfront costs associated with the covered housing arrangement. Previously, cattle bred by Strathdale Wagyu have been custom fed, which involves sending the cattle to a traditional feedlot where they are finished on behalf of the owner (Gill et al., n.d.). This practice currently takes place at Kerwee Feedlot in Jondaryan and will discontinue once Struggle Downs Feedlot becomes operational, at which point all cattle being fed will be Strathdale Wagyu in the new and innovative covered housing system.

3.8.3 What is in the future for Struggle Downs Feedlot?

It is essential to understand what the Struggle Downs feedlot will look like in the years following construction. Darren aims to create a system that requires minimal human interaction while implementing technology that significantly enhances beef production. All components necessary for engineering this system will consistently consider several criteria, including, but not limited to:

- Ease of use;
- Recording of relevant data;
- Efficiency and effectiveness;
- Increase in beef production;
- Minimal human involvement;
- Synergetic connections between processes; and
- Automation potential.

These criteria outline some of the key considerations for implementing various systems within this covered housing feedlot. One system that is currently under review by Darren is the watering system for the cattle. This system is a crucial element of the operation, as it will help optimise beef production in this arrangement and can be adapted and advanced to meet the listed criteria. Another critical system is feeding, with feed robots being implemented, which will represent a revolutionary advancement for the Australian lot feeding industry. Consequently, the design of the watering system must also account for these robots and their associated systems, ensuring that an optimum solution is engineered that is compatible with the entire system. Some background information will be provided about this robot to outline its processes.

3.8.4 Autonomous feed robots

Figure 9: Autonomous Feed Robot - Lely Vector in action - (Lely, n.d.)

Figure 9 illustrates the Lely Vector autonomous feed robot. This robot is relatively new in creation, but it provides exceptional service for feeding cattle. It incorporates advanced mechatronic and mechanical engineering to deliver an effective system and offers many benefits that may make it viable for Australian beef production. Some of the benefits that the Lely Vector autonomous feed robot can provide are as follows (humans.txt, n.d.):

- Frequent feeding can improve health by allowing cattle to eat more often, effectively replicating grazing patterns; the machines can operate 24/7, while feed trucks are typically only in operation two to three times a day and require operators to drive them.
- The correct quantity of rations is provided, producing higher feed efficiency, which is especially beneficial in the feedlot industry and genetic feeding.
- Precision feeding and mixing ensure that nutrients are delivered effectively, which also reduces feed waste.
- Real-time results can be generated, offering insights into cattle intake and feed costs; this information is useful for monitoring feed success and makes it easier to identify necessary modifications or adaptations for feed.

- Lower operational costs are achieved, as the system is energy efficient and uses low power to operate, which can result in significant savings on fuel prices compared to other alternatives, such as trucks and tractors.
- Flexibility allows it to perform well in many different types of layouts, feed types, and locations, making it a versatile tool.
- Time savings occur, as reducing the time spent on feeding throughout the week enables more energy to be focused on other areas of the feedlot, such as genetic analysis.

Overall, it is a promising system that will prove useful in Australia; however, it requires some adjustments to suit large-scale feedlot operations, as it is typically used overseas in smaller facilities, such as dairy barns. This factor will be an important consideration in the broader context of this project.

3.8.5 Watering systems

Conventional water troughs used in traditional uncovered systems will not be adaptable to the covered housing system implemented at Struggle Downs Feedlot. Therefore, a new type of watering system for the cattle needs to be developed. Conventional water troughs are typically 5.1 metres in length, approximately 600 mm wide, and are usually located along the dividing fence line between pens, in the middle of a pen, or along the rear fence line, perpendicular to the fence on the floor of the pen. These locations hinder the implementation of some of the innovations that are desired for this covered housing system, such as the autonomous feed robots mentioned earlier. Furthermore, the pen area is smaller, making the manoeuvrability of equipment more difficult with larger concrete troughs, and they are not compatible with other innovations, such as varying pen sizes and roof-dispensed bedding. Thus, the immediate focus is to develop a watering system that will conform with the current and future technologies.

Figure 10: Australian Feedlot – Typical pen concrete water rough - (Grieger, 2020)

The water trough depicted in Figure 10 is positioned in the middle of the pen, perpendicular to the fence line, which creates uneven angles and edges that machinery must navigate. This arrangement also complicates servicing; if the trough malfunctions, it can leave the cattle in that pen without adequate access to water until repairs are completed, a process that often proves to be lengthy and difficult.

3.8.6 Prior studies

Evaluating previous research in this industry is essential, particularly studies and research papers that may provide valuable insights for designing a more suitable or effective system. Equally important is identifying what has not been explored, recognising existing gaps, and understanding how the research and design landscape is evolving within this field. Numerous research papers could be considered relevant; however, to maintain focus, literature related specifically to cattle watering systems will be discussed. This literature is expected to not only enhance the design process but also provide clarity on the depth and analytical methods necessary to effectively present a design project in this sector.

Multiple criteria will guide the selection of useful literature and published articles:

1) Relevance to the design project
2) Coverage of significant topics
3) Inclusion of numerical data or conclusive evidence that supports design aspects
4) Potential to aid in the analysis of concepts.

Based on these criteria, the published studies listed in Table 3 have been identified as relevant to the project.

Relevant Literature and Research papers that will assist in design applications
"*Designing better water troughs: dairy cows prefer and drink more from larger troughs*" (Pinheiro Machado Filho, L.C. et al., 2004)
"Water trough management system." (Isabirye, 2019)
"*Designing better water troughs: 2. Surface area and height, but not depth, influence dairy cows' preference*" (Teixeira, Day et al., 2006)
"*Drinking behaviour of dairy cows under commercial farm conditions differs depending on water trough design and cleanliness*" (Burkhardt, Franziska et al., 2022)
"*Effect of water trough type on the drinking behaviour of pasture-based beef heifers*" (Coimbra, P.A.D et al., 2010)
"*Designing Better Water Troughs: Does Trough Color Influence Dairy Cows' Preference?*" (Lemos Teixeira, D et al., 2017)
"*The influence of season and of providing a water through on-stream use by beef cattle grazing hill-country in New Zealand*" (Bagshaw, C.S et al., 2008)
"*Water Borne Diseases Control in Livestock Through Water troughs management system*" (Ocen, G et al., 2022)
"*Effects of social dominance, water trough location and shade availability on drinking behaviour of cows on pasture*" (Coimbra, P.A.D. et el., 2012)

Table 3: Reviewed relevant literature that will assist in design

A substantial body of published literature exists on topics such as cattle behaviours, trough cleanliness, the effects of trough size, and various management techniques. This existing body of research provides a foundation that can guide design decisions by offering insights into how cattle interact with different watering systems. Understanding these aspects is crucial, as design choices must account for factors that impact cattle welfare, water consumption efficiency, and system durability. Moreover, integrating findings from these studies will help establish informed design constraints and ensure that the new system aligns with proven management practices. By referencing this literature, the design process can be more methodical and grounded in evidence, enhancing the system's overall effectiveness and reliability.

3.9 Critical Analysis of Literature

This section is essential for understanding the reliability of the information used in the report. As evidenced by the reference list at the end, a multitude of sources from various institutions and businesses have been consulted. When seeking this information, it is crucial to assess its viability, particularly regarding numerical figures. Reliable sources typically consist of governmental or organisational bodies within the specific industry. Fortunately, this project frequently references MLA (Meat and Livestock Australia), which can be considered a reliable source due to its status and contributions to the industry. MLA is known for its world-class research, accreditation of developments and projects within the industry, and has been active since 1998, amassing significant experience as the leading body of the cattle industry in Australia (MLA Corporate, n.d.).

Other sources used in this review include businesses that invest in or are directly involved with cattle production. The reliability of these sources is often tied to their credible statements regarding their products or services, including insights from other feedlots and organisations like Action Steel, which provides well-considered details.

Another aspect of reliability stems from the beef industry community, which contains a wealth of information not typically found on websites but known through years of practical experience in the field. This information can be trusted and deemed reliable, as it often includes crucial insights derived from hands-on experience with feedlots. Some of this knowledge can be attributed to Rod Davis, an Agricultural Engineer and owner of RDC Engineers, who offers insights based on approximately 25 years of experience in the feedlot industry (RDC Engineers, 2024) and is the author of numerous industry guidelines and manuals (e.g., MLA 2016, MLA 2023). Another valuable source is Darren Hamblin, owner of Strathdale Wagyu and a Mechanical Engineer, who has provided deep insights into the lot feeding of Wagyu cattle, cattle handling processes, and systems, and oversees both the technical and practical aspects of the project (www.hamblin.com.au, n.d.).

3.9.1 Knowledge gaps

This section aims to identify the areas of research that this project intends to address. Typically, engineering processes begin with the formulation of a set of research questions, followed by justifications for their importance. In this case, the goal is to substantiate the benefits that this project will bring to the intensive beef cattle industry. As discussed above, there is a wide variety of watering systems available on the market, ranging from small plastic tipping troughs to large, fixed concrete troughs. Ideally, this project will move away from these conventional options, seeking a solution specifically tailored for a covered housing arrangement that optimises various advantages. Before formulating the research questions, it is essential to outline several statements to summarise the known factors before addressing the unknowns.

3.9.2 Design questions

Firstly, a design must be developed that is unique and well-suited to the specific application, in this case a watering system for a covered housing system. As discussed, there are numerous differences between intensive feeding operations at different sites. However, it is also beneficial for aspects of this design to be adaptable for integration into other sites. This leads to the following overarching design questions:

Design questions

1. What types of factors can be integrated into a design solution to deliver a practical watering system within the covered housing arrangement of Struggle Downs feedlot?

2. What types of factors can be integrated into a design solution to satisfy the Struggle Downs feedlot requirements but also allow the system to be fundamentally adaptable for integration into covered housing systems and potentially uncovered feedlots at other sites?

3. How can engineering principles be combined with industry expertise to create an innovative and practical system that provides advantages over conventional water troughs currently available on the market?

4. Finally, how can this particular system help transform and increase adoption of covered housing systems within the intensive feeding industry, including demonstrating improvements in environmental impact and animal welfare.

Further research into these points will be addressed in this report. Answering these questions will be essential for the successful development of a capable and effective watering system for a covered housing system.

3.10 Chapter Summary

Building upon the project introduction, this chapter provides a thorough examination of the information necessary to support design decisions and gather insights into the intensive beef cattle industry. It outlines the relevant background information required to effectively address design criteria and emphasises the importance of understanding existing practices and innovations. This literature review serves as a critical foundation for identifying effective engineering solutions that not only meet the current demands of the industry but also advance upon prior studies. By synthesising available knowledge, the chapter aims to inform the development of innovative solutions that are both practical and viable within the context of the Struggle Downs Feedlot project.

4 Methodology

This section outlines the methodology for the project. This requires compiling a structured sequence for the overall process by which the project will be approached. A thorough understanding of mechanical design and design processes is necessary to achieve a viable system. The integration of well-considered design processes is crucial to this project, necessitating a comprehensive grasp of the needs of the system, design criteria, regulations, materials, manufacturing constraints, and environmental considerations, among other factors. Despite the extensive nature of the requirements and considerations for a design process, they can be addressed methodically. Within the engineering industry, design methodologies are available in various forms, some of which incorporate specific approaches to meet relevant goals.

4.1 Design Methodologies

It is important to establish a basis for a methodology to control the design process, ensuring that order is maintained, and mistakes are minimised. However, to begin, current design methods that are already prevalent in the industry and have proven effective can be referenced. The ones most likely to achieve the desired goal for this project will be (Engineering Design, n.d.).

- Design for manufacture;
- Axiomatic design;
- Interdisciplinary design; and
- Sustainable design.

All these design methods include aspects that are desirable for this project, encompassing crucial points that must be considered collectively. To further break down these design methods, the specifics that will be adapted or advanced upon from the above-listed methods can be outlined.

1. Design for manufacture, this means that anything that is designed specifically is also designed so that manufacturing/fabrication is easily accomplished, adding considerations such as cost, material availability, joining methods.

2. The Axiomatic design method relies on a set of functional requirements that relate to the project, these can fall under a few different categories such as operational goals, cost, or client/environmental requirements etc.
3. The Interdisciplinary design method involves the use and interconnection of different disciplines to converge and create a considerate project involving all the different backgrounds and skills that would be achieved by branching out to different disciplines. In this case there will be a mixture of background that will be used.
4. Sustainable design is helpful and intertwines with efficient design, it helps justify longevity and lifetime cycles of the project as well as the impact and uses it will continue to uphold in the future.

When each of these above listed design methods are applied sequentially this can be referred to as the waterfall design approach. The waterfall design approach encompasses, a systematic design that follows a step-by-step process which includes each of the main principles from the above listed methods. Each step will flow onto the next until a final answer is accomplished. This step-by-step process will be outlined once all the factors of the design methods have been established.

4.2 Methodology Criteria

The waterfall design approach has been selected as the overarching methodology as it is the most likely to achieve design success. An outline on how a final functional design will be achieved by the waterfall design approach is outlined below.

1. Establish the sustainable requirements for the project, including operational goals, cost, environmental impacts, industry standards, and design criteria. These requirements will help define the guidelines that the project must follow to remain on track and create a viable outcome that aligns with industry expectations and addresses innovation gaps. Since these requirements determine the project's feasibility within the industry, they must be addressed first, ensuring that all design considerations are consistent with them.
2. Next, determine the project's design criteria, which are governed by site-specific principles around equipment design based on cattle behaviour and performance. As

the project must be tailored to a particular site, these considerations are crucial in guiding design decisions. Identifying variable working areas is essential and must be completed second.

3. Analysing current market options from a design perspective will facilitate idea generation by revealing areas for improvement or potential faults. This analysis will also provide justification for excluding certain market options based on their unsuitability for the specific site.
4. The next part of the methodology should detail the process for generating ideas effectively, including the technology that can be utilised, viable materials, and potential manufacturing processes for prototype creation. Limitations in these areas can significantly impact design boundaries.
5. Implementing an interdisciplinary design approach will involve consulting with the owner of the development and collaborating with other engineers. This approach will aid in idea generation and refinement, contributing to the development of possible solutions for the project.
6. Finally, address the sustainability of the project by suggesting factors such as lifetime design, potential future adaptations, and applications across diverse industries.

Each of the steps of the waterfall design approach will now be expanded upon in the following sections. Each step is designed to flow sequentially, building upon each other to develop a comprehensive design methodology. An evaluation will be conducted at the end to assess adherence to the waterfall design approach and to provide a final assessment on the overall effectiveness of the approach and the completeness of the project.

4.2.1 Sustainable requirements

The functional requirements represent the essence of the project's initiation, summarised by the question, ‘What needs to be accomplished with these designs?’ Preliminary sustainable requirements were established earlier in the report but can be significantly expanded to provide a broader understanding. Various factors can differentiate functional requirements from design criteria, including operational capability, which must be prioritised before addressing less critical design parameters. Considerations such as needs of the owner of the development, cost, environmental impacts, and industry standards also play crucial roles. If these aspects are not identified and acknowledged prior to the design process, completing the project may become increasingly challenging, often leading to a situation where corrections are made reactively rather than proactively. For a mechanical engineer, this approach is far from ideal; it can ultimately become a time-consuming endeavour. Therefore, establishing a decisive set of sustainable requirements is essential.

4.2.1.1 Cost

For this project, the number of components, materials selected, complexity of manufacturing will impact costs, for example. In the context of creating solutions for the cattle industry, there is an expectation that the costs associated with the product will remain reasonable. This entails avoiding the unnecessary use of expensive materials, opting for generic and readily available manufacturing processes, and refraining from overengineering the structure. It is crucial not to enhance a design solely for aesthetic purposes. In summary, cost considerations will always be considered when evaluating factors that may impact expenses, and each decision will be assessed on a case-by-case basis. Consequently, cost will be a focal point during discussions surrounding design choices.

4.2.1.2 Environmental impacts

Environmental impacts have become increasingly important in engineering design processes, particularly due to concerns regarding carbon emissions and waste. This aspect is considered one of the primary factors for engineering projects in the current era. However, for this design process, no negative environmental impacts are anticipated concerning the physical products. The underlying goal of this project is to create more sustainable and environmentally friendly systems that contributes to cleaner drains, minimise emissions from machinery, and so forth. The environmental benefits will be thoroughly analysed throughout the design process.

4.2.1.3 Industry standards

This aspect is a crucial component of the operational requirements. In Australia, strict rules and regulations apply to various industries. Some regulations can be extremely complex and stringent, while others may function more as guidelines. Regardless, all regulations must be assessed to ensure that the outcomes achieved are legally acceptable. The relevant guidelines and regulations for this project are those relating to the intensive feeding of beef cattle in Queensland and Australia and animal welfare.

4.2.1.3.1 Standards for cattle fences and gates

Regarding the standards for cattle fences, it is stated by MLA that "*There are no specific mandatory requirements associated with the design of fencing, gates, and lanes*" (Watts et al., 2016). It is important to note that this 'freedom' is still constrained by established practices that are known to be effective, including considerations such as height above the ground, the number of rails/cables, and supporting structures. This aspect can be elaborated further, as it will be a crucial point in the design, with detailed specifications provided in the design section.

4.2.1.3.2 Standards for cattle troughs

For cattle troughs, there are no specific design requirements as long as the regulations for cattle water needs are met. Table 4 is reproduced from the Animal Welfare Standards and Guidelines Australia (Animal Health Australia (AHA) 2014), and outlines the requirements for cattle watering and troughs:

Point	Requirement
G2.10	Cattle should have reasonable access to water at least daily.
G2.11	Lactating cows, and all cattle in hot weather, should have access to water at least twice daily.
G2.12	Calves removed from cows should have access to water at all times.
G2.13	Where the water quality is known to be variable, it should be monitored regularly for harmful substances and managed to protect cattle welfare.
G2.14	Water infrastructure should be inspected and maintained to allow effective provision of water in a reasonable time.
G2.15	Medicated water systems should be closely monitored to ensure cattle are not overdosed.
G2.16	Assessment of water requirements for construction of cattle-watering facilities should consider: • daily requirements and total annual requirements • flow rates needed for peak, short-term demand. • constructed to prevent temperature build-up.

Table 4: Standards for cattle troughs (Animal Health Australia (AHA), 2014)

To determine the exact amount of water required, several factors must be considered, including the number of cattle, breed, season, evaporation rate, and others. To gain a greater understanding, MLA have conducted research that outlines these specific requirements. Davis and Watts (2016) outline the water requirements for feedlot design and construction. The specifications by Davis and Watts (2016) will be closely examined and used as a guideline for several aspects of this project.

4.2.2 Design criteria

The relationship between the requirements and design considerations can now be discussed. Many of the stated requirements shape and form the design considerations, akin to a skeletal structure that creates boundaries and a framework while necessitating additional elements for functionality. These additional elements may include industry practices, industry knowledge, and materials. Understanding the principles and considerations essential for a design project of this nature establishes a solid baseline. From this foundation, innovation and creation can occur to meet specific needs and environmental conditions. Below are the design criteria considerations for a watering system in an intensive covered housing system.

4.2.2.1 Theory for equipment design in the cattle industry

Designing an engineering project for the cattle industry may be perceived as straightforward or rudimentary, however, there are often aspects that need consideration which may not be initially recognised until one has experience working with cattle. This factor makes this design process unique compared to other mechanically oriented design projects, as it involves understanding animal behaviours and tendencies. Other considerations, such as structural techniques, material selection, site compatibility, weather resistance, and general mechanisms, are not specific to the cattle industry. Therefore, there are particular conditions and considerations that aid in integrating mechanical systems that cater to intensive feeding of cattle.

To discuss these conditions and considerations in greater detail, it is essential to first understand and analyse the behavioural traits common in operations such as this intensive feeding system. Many of these traits can be observed through hands-on experience with these animals, leading many experienced industry members to describe them as “very curious animals” (Cabot Creamery, n.d.). This curiosity directly impacts any moving mechanism that may be within their reach, as such mechanisms will ultimately attract their interest. For example, cattle have been observed licking various objects, tugging on chains and fences, and using objects as scratching points. Therefore, when designing mechanisms that will be in proximity to cattle, a concept akin to childproofing can be applied. The following list will outline common practices that not only help keep equipment out of reach of cattle to prevent damage but also ensure their safety.

1. Minimising exposed sharp edges to avoid cuts;
2. Creating ample space for their head to prevent it from being stuck in odd places;
3. Creating bump rails for them to hit instead of crucial mechanical elements;
4. Creating locks that are lockable by humans but impossible for cattle to unlock;
5. Swinging systems that will not greatly spook or intimidate cattle; and
6. Ensure that any materials or substances used will not cause harm if ingested by cattle.

An important factor in this design process is identifying areas that will benefit the cattle industry. This can be summarised in the following statements: increasing production performance, generating efficient industry optimisation and advancements, and implementing sustainable and ethical animal welfare practices. These three broad points were given significant consideration in this project and will serve as the basis for referencing each design point.

4.2.2.1.1 Cattle behaviour and wellbeing

Cattle are animals with behaviours that can change or evolve in different settings, and they can sometimes be unpredictable. Based on years of experience, a common comparison made regarding cattle is 'childproofing.' Predicting the unpredictable is a valuable principle to follow when designing infrastructure that directly interacts with cattle, and a watering system is one such example. Moreover, while the intensive beef industry plays an important role in society, it often faces criticism for being unsanitary or inhumane. Therefore, ensuring the safety of cattle is crucial; this not only maintains the well-being of the animals but also mitigates the need for human intervention when attending to wounds or caring for sick animals.

4.2.2.1.2 Cattle production

This is an important factor within the industry, as its goal is to produce as much beef as possible to meet market demand (Department of Agriculture, Fisheries and Forestry, 2023). Consequently, facilitating faster cattle growth will enhance production performance, which can be measured in terms of weight gain over a specific period. This process is resource- and time-dependent. Factors influencing production include food intake, food efficiency, and the overall refinement of supporting features, all of which can be summarised by an effective management system (McAllister et al., 2020). Anything that optimises feeding can improve production efficiency while allowing more time to focus on other areas within a feedlot. Attention to detail and data analysis in this field can significantly enhance monitoring and gauging of growth rates.

Although this project is not directly related to feed delivery, the watering system can be optimised to align with the site-specific feeding operation, thereby improving cattle comfort. Additionally, production performance can be enhanced by systems that address aspects often challenging for smaller operations, such as crop tending and maintenance. These processes can be time-consuming yet are essential to operations. If maintenance times can be reduced through design improvements, this could free up time for other activities that support production performance, such as food quality assurance, data analysis, and targeted feeding. Therefore, the design choices will prioritise timesaving and synergy with feeding operations, ultimately aiming to provide a definitive justification for improvements in production efficiency, such as increased growth rates or reduced time values.

4.2.2.1.3 Equipment adaptability

Another important consideration is the adaptability of the system, which aligns closely with various time-saving factors previously discussed. This adaptability will also support the system's justification for widespread industry use. Innovations in this sector can significantly enhance the industry's image, particularly when implementing sustainable systems. Making the design versatile is essential for facilitating its deployment across different sites and simplifying maintenance processes. Effective maintenance solutions can reduce downtime and maintenance costs, thereby improving overall production performance. As a result, the design will prioritise principles aimed at minimising maintenance requirements and ensuring the system can be quickly and easily modified for use in a wide range of feedlot environments. Throughout the project, special attention will be given to developing features that simplify system adaptation and promote efficient, large-scale implementation.

4.2.2.2 Site specific principles

Understanding the operation and management typically associated with precast concrete water troughs can be used to assist in the selection of design criteria. Precast concrete water troughs are extremely common in intensive feeding developments, as they can contain high volumes of water for a larger-than-normal population of cattle. However, these troughs often remain filled with water, which can become stale, algae-ridden, and dirty. All three factors are suboptimal for cattle and may have adverse effects on growth performance.

The objective for this project is to implement a design that deviates from the conventional approach - one that operates efficiently and offers increased benefits. This involves gathering a comprehensive understanding of the background factors that influence the design of an efficient water trough tailored to the specific site conditions.

4.2.2.2.1 Understanding cattle feed and water demand

Understanding the importance of water troughs in the intensive feeding industry is essential for determining the water requirements of cattle. It is known that increased food intake leads to higher water consumption (Davis and Watts, 2016). This is a critical consideration that must be assessed, as the feeding system directly influences the water demand of the cattle. Site-specific factors play a significant role in this context, particularly since the feeding system implemented at Struggle Downs Feedlot is unique and represents one of the first of its kind in Australia.

The goal for Struggle Downs Feedlot is to achieve autonomous optimisation wherever possible, thereby reducing labour hours spent on monotonous tasks. The initial step towards autonomy involves the utilisation of autonomous feed robots, such as the ‘Lely Vector’ (Figure 14; Figure 15), as discussed in the section 2. These robots operate under different conditions and require a distinct infrastructure setup.

As these robots originate from Europe, the bunk walls must be designed to align with European specifications. This contrasts with typical Australian operations, where feed is dispensed into a U-shaped trough-style bunk (Figure 11) by a feed wagon (tractor-trailer or feed truck (Figure 12) based on regular time intervals throughout the day. For instance, standard feeding frequency range from one up to three times per day (Beef Central, 2023), depending on operational constraints, supply availability, and workforce scheduling. In contrast, with the autonomous robots, feed will always be made readily available, aiming for a high degree of consistency. This approach eliminates the risk of feed shortages during the day.

The continuous feeding option is optimal, as it ensures that cattle have constant access to feed, reducing stress associated with hunger and minimising competitive behaviours during feeding times. This arrangement allows cattle to adjust their feeding schedules according to their needs, free from the competition that arises from timed feeding, which often forces them to jostle for position at feeding times.

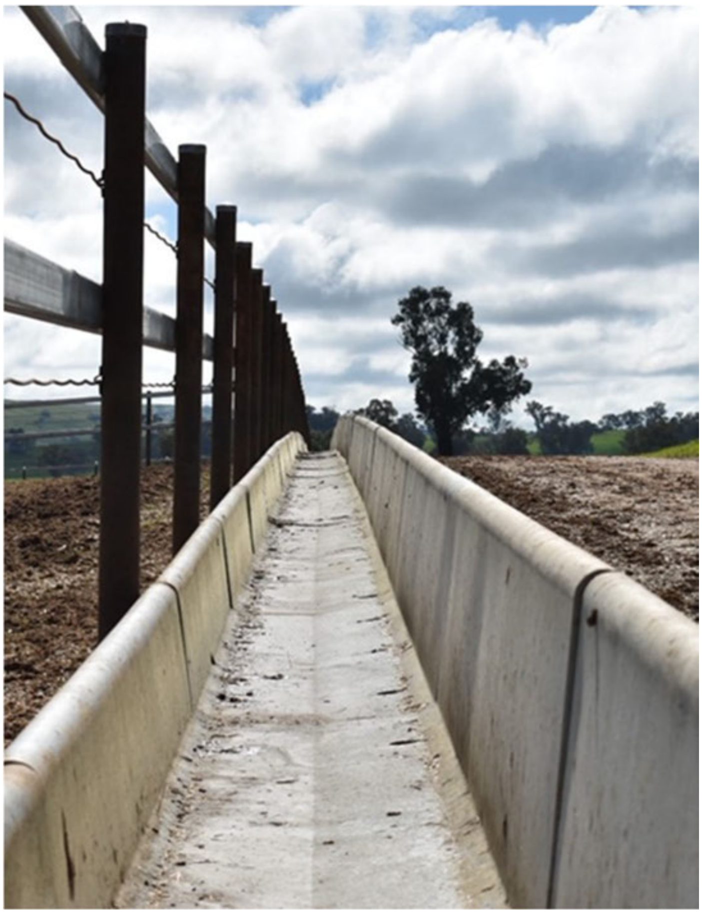


Figure 11: Australian Intensive Feeding – Typical open feed bunk (Conron Stock Crete, 2024)

Figure 12: Australian Intensive Feeding – Typical ration delivery to feed bunks via feed truck (MLA Corporate, 2019)

Figure 13: Australian Intensive Feeding – Typical amassing at feeding time (Beef Central, 2023)

As can be seen in Figure 13, cattle amassing at a feed bunk disallows some shyer and more timid cattle access to appropriate portions of feed, hindering growth performance.

Figure 14: Autonomous Systems - Teed organiser robot, for use on-site until 2025-26 (humans.txt, 2018)

Figure 15: Autonomous Systems - Lely Vector robot dispensing feed (Team Lely, 2017)

Figure 16: Struggle Downs - Feed dispensed against the European style bunk (RDC Engineers Pty Ltd, 2024)

Figure 16 illustrates the way feed is placed at Struggle Downs Feedlot. As observed, there are a few notable differences in the way feed is dispensed. The rationale for implementing this system, as opposed to the conventional feed truck approach, is entrenched in a broader vision. The integration of technology has proven to be highly effective in enhancing performance across various sectors, including parcel delivery, automotive, mining, and manufacturing. These autonomous systems have significantly benefited these industries by reducing the reliance on employees or operators performing simple, repetitive tasks, allowing those workers to transition into more adaptive and challenging roles while simultaneously improving the efficiency and effectiveness of those tasks.

Although the application of autonomous systems in the cattle industry is relatively new, the same principles apply. The objective for Struggle Downs Feedlot is to leverage this technology within the intensive feeding sector to facilitate effective data collection, enhance performance, and reduce monotonous tasks. This shift will enable greater focus on the advancements necessary for optimising cattle growth and overall outcomes. Consequently, it is crucial to develop the watering system to align with these principles. It would have been detrimental to assume that conventional feeding operations would suffice, as this would not support the optimisation of the overall operation.

Reverting back to the suitability of water trough systems, large concrete water troughs are effective for conventional feeding, as they accommodate significant numbers of cattle that tend to eat and then drink simultaneously. This design justifies the need for high volumes in water troughs, despite the associated drawbacks. However, once the initial surge of drinking is completed, there tends to be minimal eating throughout the day, resulting in limited water intake until the next feeding time. This pattern allows for water to stagnate and collecting grime such as manure.

This principle must be adapted to effectively support the automated feeding system to be implemented at Struggle Downs Feedlot, while also addressing the outdated and unsustainable nature of large precast concrete water troughs. The constant availability of feed necessitates a continuous supply of fresh drinking water. This principle, among others, will be analysed to introduce an effective watering system that aligns with the automated feeding system, which is integral to the operation and performance of the intensive feeding system as a whole.

4.2.2.2.2 Covered housing arrangement

The covered housing system plays a significant role in the design of the watering system. The Struggle Downs Feedlot covered housing system is shown in Figure 17. Displaying the layout and general appearance of the arrangement (Figure 18) will facilitate a clear visualisation of how the trough will be situated, along with the specific infrastructure available. Additionally, a key objective of this project is to design a system that thoroughly meets the requirements of the site.

Figure 17: Struggle Downs - Covered housing arrangement under construction (RDC Engineers, 2024)

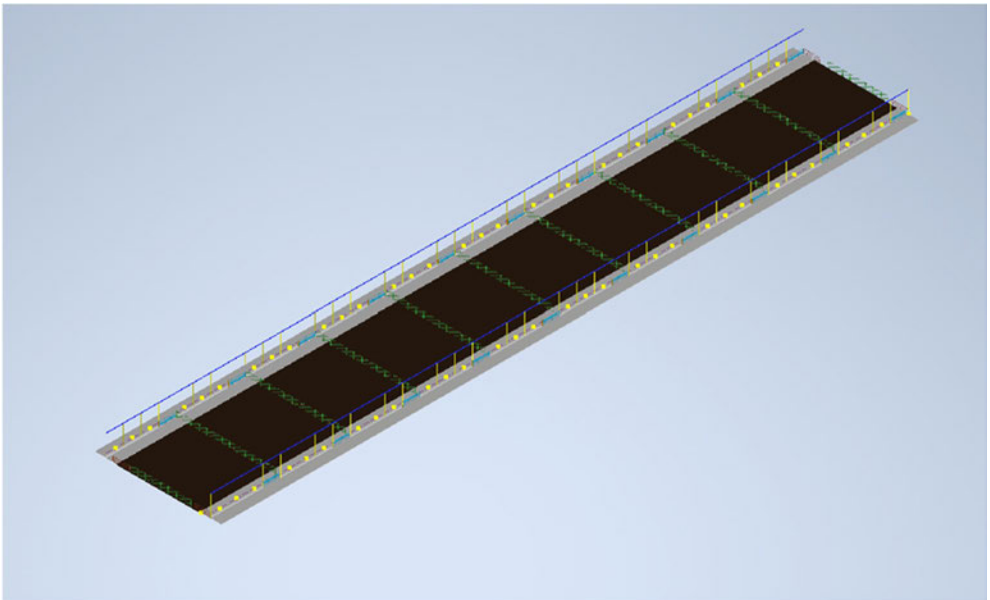


Figure 18: Struggle Downs – Spliced 3D Model of Infrastructure

Figure 18 illustrates the setup of the pens, along with the fence structures and the general dimensions of the shed. It is evident that segments are already included in the model to indicate pen sizes. Consequently, there is a need to implement a trough system that is compatible with this layout for each of the designated pens. The rest of the 3D models for the shed can be found in Appendix C – Methodology.

4.2.2.2.3 Drainage

Another important aspect of this project, considering the covered housing arrangement, is the water drainage system. The layout of the shed is strategically designed within a controlled drainage area (RDC Engineers Pty Ltd, 2024) where all water flow is directed towards designated runoff holding infrastructure. This controlled drainage is crucial for maintaining a clean and efficient environment for the cattle while preventing any water accumulation or contamination around the troughs and protecting surface waters from potential contamination.

4.2.2.2.4 Size and weight limitations

The water trough is to be mounted on a pen gate, not on the ground like conventional water troughs. Therefore, size and weight are design limitations. Size limitations are critical; the trough must be compact enough to allow the gate to open and close freely without obstructing cattle lanes or interfering with machine operations. Additionally, the weight of the trough is an important factor since it will be mounted on hinges, necessitating careful attention to ensure the gate remains functional and does not become too heavy to open.

These specifications will be thoroughly addressed in the design process.

4.2.2.3 Current market options

Understanding the limitations presented by conventional concrete troughs on the market is essential, as well as how these limitations can be overcome. The general design of pre-cast concrete water troughs commonly used in traditional feedlots have been outlined in 2. Table 5 outlines the advantages and disadvantages of pre-cast concrete water troughs in greater detail.

Advantages	Disadvantages
Large volume of water	Can entail stale non-fresh, heated water
Semi-weather resistant	Water loss due to evaporation
Durable to cattle	Quickly accumulates algae
	Typically, at a height for which cattle defecate in
	Inter-pen located, hence hard to access
	Difficult to clean, and large volumes of water lost during cleaning
	Difficult to maintain if trough was to break down

Table 5: Unsuitability analysis of large concrete water troughs

Now that the positives and negatives of pre-cast concrete water troughs have been established, each of the disadvantages can be considered further. The following sections outline how each of the disadvantages can be adapted, modified, overcome or is irrelevant in the water trough system in this project.

4.2.2.4 Stale and heated water

Stale water is regarded as a disadvantage, although it does not significantly impact the overall quality or nutrient content of the water. The reason it is considered a disadvantage relates to the preferences and behaviours of cattle when drinking water. Cattle tend to prefer water that is fresh (RDC Engineers, 2024), which typically means lower water temperatures, ideally between 16-18 degrees Celsius, but never exceeding 25 degrees Celsius (E.A Systems Pty Ltd, 2024). Additionally, they favour clean, flowing water, which is often why small streams are preferred for drinking due to their cooler and running nature. Unfortunately, large concrete troughs, which hold still water, can experience rapid temperature increases on warm days.

To mitigate this issue, reducing the exposure of water troughs to sunlight would help lower the high temperatures that can develop within these troughs. Furthermore, these troughs typically have larger capacities (approximately 350 litres to 750 litres) and tend to have larger surface areas that facilitate direct convective heat transfer.

For a more comprehensive understanding of the importance of providing fresh, cool water for the production and welfare of cattle, the report "*Cooling Water for Cattle*" by E.A Systems Pty Limited (E.A Systems Pty Ltd, 2004) offers extensive insights into temperature-related systems for cattle. This resource is valuable for gaining a deeper understanding of the previously mentioned discussion points.

In conclusion, the water trough designed for the Struggle Downs Feedlot covered housing system benefits from the ample shade available in the environment. Materials can also be selected to help mitigate water temperatures by utilising less heat conductive options. E.A Systems Pty Ltd (2024), state several objectives that can assist in achieving optimal design outcomes. These include:

- "*While supplying cool water for drinking has a limited direct cooling effect, other benefits associated with drinking cooler water have a significant impact in reducing heat stress*."
- Drinking water should be supplied at about 16-18 degrees Celsius and not above 25 degrees Celsius.
- The temperature of the drinking water should be consistent.
- An ample supply of water for each animal with adequate access is required.
- Modify trough design and practice measures to reduce heating at troughs.

Although these points relate to the broader context of the trough system design, they are crucial for understanding the importance of maintaining cool water for cattle. This aligns with the project's aims to increase production performance, generate efficient industry optimisation and advancements, and implement sustainable and ethical animal welfare practices.

4.2.2.5 Water loss via evaporation

Water loss due to evaporation can present challenges in most open-air intensive feeding systems, particularly in open water storages (water troughs, dams etc), where evaporation can remove at least as much water from dams as livestock can drink (Department of Primary Industries and Regional Development, 2017). While this principle applies on a smaller scale to water troughs, it can significantly impact performance factors and overall operational efficiency. There exists a strong correlation between preventing evaporation and maintaining cooler water temperatures. Several factors that can influence evaporation and be incorporated into suitable trough designs include the following (Emprende Jalisco, 2015):

- Placing troughs in covered areas
- Utilising light-coloured materials
- Implementing float systems

Positioning the water troughs in shaded areas will be straightforward due to the shed's orientation, ensuring minimal to no direct sunlight exposure on the body of the water trough itself. Thus, overall positioning is not critical. Employing light-coloured materials will aid in mitigating the effects of direct sunlight by increasing light refraction rates. A crucial component of this water trough design is the float system, which must be carefully integrated to align with the project objectives. Although its primary function may not be to prevent evaporation, its significance lies in ensuring a consistent supply of fresh water, as discussed in the previous section. Since the water trough design does not accommodate a large water volume, maintaining constant water flow will be essential to counterbalance the reduced capacity. The float system will serve as a cornerstone of the trough design and will be further addressed in subsequent sections.

4.2.2.6 Accumulation of algae

Accumulation of algae is a significant factor that is often overlooked, yet it can have detrimental effects on cattle. "*Not only does the water affected by algae (green water) taste bad, but it can also impact livestock health*" (Cocky Valve, 2024). Therefore, it is essential to avoid this issue at all costs. The phenomenon of 'green water' is particularly common in plastic or concrete troughs, arising from several contributing factors (Cocky Valve, 2024):

- Warm weather (which causes thermal stratification in troughs);
- Nutrients (such as those found in animal saliva, manure, or soil);
- Calm water (stagnant water allows algae to proliferate); and
- Sunlight (algae thrives on photosynthesis)

The characteristics of pre-cast concrete troughs holding large volumes of water and often being exposed to sunlight create optimal conditions for algae growth. Unfortunately, much of Australia experiences warm weather, including the Leyburn area in which the Struggle Downs Feedlot is located, which has average maximum temperatures as shown in Table 6.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Max (ºC)	30.4	29.6	27.9	24.8	21.2	18.5	18.1	20.2	23.6	26.1	28.0	29.5	24.8

Table 6: Average maximum monthly temperatures for Leyburn (Elders, 2024)

As shown in Table 6, the average maximum temperature across the year for Leyburn is 24.8 degrees Celsius which is a warm classification. Hence algae growth would be extremely likely in stagnant concrete or plastic water troughs out in the sun in the Leyburn region.

Figure 19: Conventional Concrete Trough - Example of algae contamination (Davis and Watts, 2016)

Given that algae growth is a significant concern at the Struggle Downs Feedlot site, it is essential to identify systems that can help prevent such growth. Table 7 outlines steps that can be incorporated into the trough design to mitigate algae proliferation and ensure that cattle have access to healthy drinking water:

Anti Algae Step	Justification or Tech Implementation
Inspection and identification of algae	Ease of viewing, possible implementation on outer fence lines. Instead of inter-pen.
Regular cleaning	Ease of cleaning (tipping), waste efficiency which means smaller overall volume.
Replace concrete or plastic with steel	Specific fabrication for a desired shape using waterproof steel would be desirable.
Place trough in shade	Should be considered, however covered housing provides ample shade around the day.
Utilise float valves	Float valves must be used effectively to help counteract for the potential lack of volume. And to keep fresh water available.

Table 7: Anti-Algae design ideas

The ideas in Table 7 will continue to be expanded upon as they may become crucial elements to this design project.

4.2.2.7 Difficulty of access

The difficulty of access to water troughs is not universally problematic, as it largely depends on the specific layout of the intensive animal pens. There are various options for positioning troughs within a typical pen arrangement. Figure 20 illustrates common locations for troughs within pens.

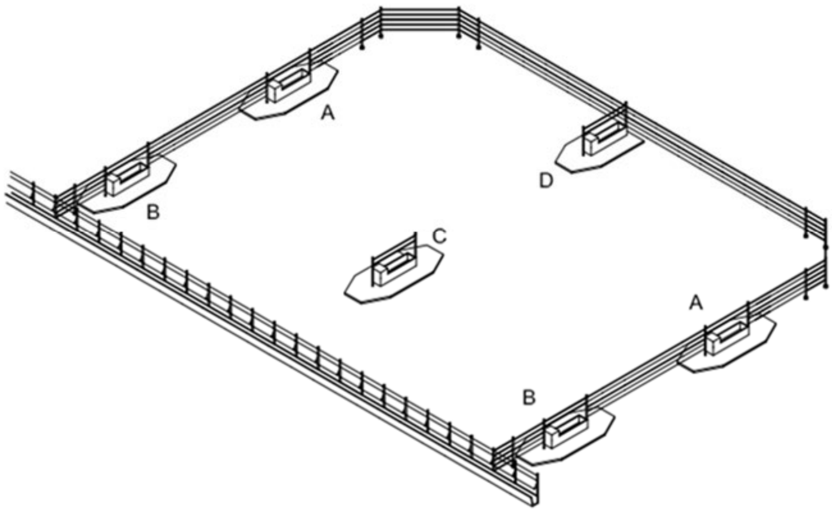


Figure 20: Conventional Concrete Trough - Traditional positioning schematic (Davis and Watts, 2016)

Figure 20 shows that water troughs are frequently positioned along the fence lines, as cattle follow the fences and can locate water quickly and easily. Option C is feasible but less common, as it may obstruct cleaning equipment used within the pen. For effective routine cleaning and essential maintenance, all positioning options necessitate that workers enter the pen.

Additionally, it is important to note the orientation of the troughs, which is aligned parallel to the slope of the pens. This orientation is critical for proper drainage and waste management, as it minimises the contact surface area for waste, facilitating unobstructed movement around the permanent concrete footings on which the troughs are installed. In an operational context, these troughs will always require such a footing or pad to safeguard the underground sewage infrastructure from potential trampling by cattle.

These systems may not be the most suitable due to the requirement for personnel to enter the pens for servicing, which can increase stress levels of the cattle and does not align with sustainable and ethical animal welfare practices. Consequently, the option of mounting the water trough becomes an attractive solution.

This approach involves positioning the water trough perpendicular to the slope angle and effectively mounting it onto the gate. This setup would elevate the water trough above the pen level, enhancing accessibility and versatility while minimising animal interaction and impact on the pen environment. Additionally, it allows for the elimination of underground plumbing, relying instead on an alternative method for cleaning and diverting water flow away from the pens.

A water trough located on a gate reduces the need for personnel to enter the pens and is readily accessible for maintenance which ultimately benefits operational efficiency and production outcomes. Further details on the cleaning and maintenance of the water troughs will be provided, to establish design criteria that will serve as a solid foundation for developing design concepts.

4.2.2.8 Difficulties in cleaning

Cleaning poses a significant challenge for large precast concrete water troughs, as they tend to accumulate contaminants from various sources, including cattle faeces and urine, muzzle grime etc. This issue is exacerbated by their low height of approximately 600 millimetres, which can result in contamination of the water even when the troughs are full, potentially affecting water quality for extended periods (RDC Engineers Pty Ltd, 2024). Additionally, these troughs are prone to the buildup of muzzle grime, which includes saliva and leftover feed, after the cattle drink.

Most cleaning methods for troughs rely on a simplistic sewer system that necessitates underground plumbing work, which can be costly. Figure 21 illustrates an overflow pipe in a water trough which is connected to a sewer system. This approach is intended to ensure that large volumes of water drained from the troughs are effectively redirected away from the pens, thereby preventing unwanted wet manure (which leads to odour) and erosion.

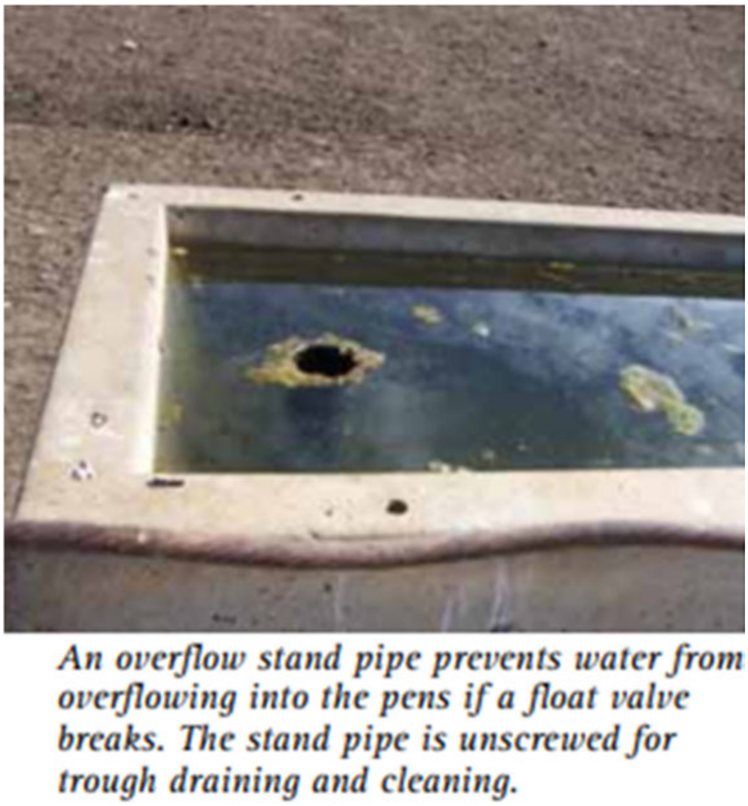


Figure 21: Conventional Concrete Trough - Overflow pipe (Davis and Watts, 2016)

This system inherently introduces additional costs and presents the potential issue of clogging of the sewer pipes which would be undesirable for maintenance purposes. This process will be discussed in further detail in the next section.

Figure 22: Conventional Concrete Trough - Cleaning example (RDC Engineers Pty Ltd, 2024)

Typically, pre-cast concrete water troughs are drained using a sewer system and manually scrubbed and cleaned multiple times per week, typically ranging from 1 to 3 times. Figure 22 illustrates cleaning of a pre-cast concrete water trough. From a workforce perspective, a quick analysis of the time required for this task can be conducted. Cleaning a trough is often a monotonous and labour-intensive job; therefore, setting a goal to streamline this process is desirable.

A brief time analysis is as follows: based on average values in feedlots with 5,000 head in an open pen arrangement, it is important to note that outdoor pens typically have a larger footprint, which increases the time required to clean each trough due to greater travel distances. In contrast, the covered housing arrangement will minimise excessive travel time.

For standardisation, each pen will have one trough, plus an additional trough at the end. Consequently, for a 5,000 head feedlot, there will be approximately 41 troughs (RDC Engineers, 2024). This value will be utilised in the following calculations.

Minimum 1 time per week (Low, undesired value)

If it takes approximately 4 minutes to clean one pre-cast concrete water trough plus 2 minutes travel time between troughs there are 41 (average) troughs in the example feedlot (obviously the number of troughs will vary with feedlot capacity) however in this case the maths becomes simple.

Minimum 1 time per week (minimum expectation)

Equation 1: Time analysis (minimum)

$$\text{Time Cleaning Troughs Minimium} = 6 * 41 * 1 = 246 \text{ minutes per week}$$
$$\rightarrow 4.1 \text{ hours a week}$$

Maximum 3 Times per week (Standard expectation)

Equation 2: Time analysis (Maximum)

$$\text{Time Cleaning Troughs Maximim} = 6 * 41 * 3 = 738 \text{ minutes per week}$$
$$\rightarrow 12.3 \text{ hours a week}$$

Therefore, the average ranges are from 4 to 12 hours per week simply cleaning troughs, this time could be best spent benefitting other areas of the feedlot, such as pen cleaning, feed delivery, silage growing, or data collection. The aim of this project is to also minimise time spent cleaning troughs, by hopefully introducing a quick method such as tipping, self-cleaning or autonomous prospects.

However, this is not the only number that can be acquired in relation to pre-cast concrete troughs. But water wastage is an issue, and if this can be improved it will already serve as a significant benefit to the industry. Some preliminary calculations can be shown to outline water wastage numbers. As discussed, a majority of the small pre-cast water troughs are around 350 litres, and the large ones are around 700 litres with the capacity dependant on the manufacturer and design. However, in relation to the cleaning times per week this is also how many times the trough will be emptied completely per week. Using the same parameters as above, so 41 troughs, for a 5000 head feedlot. Hence the calculations will be:

Minimum 1 time per week empty

Equation 3: Water Wastage Min

$$Minimum\ Waste\ water = 1 * 350L * 41 = 14350\ L\ per\ week$$

Maximum 3 times per week empty

Equation 4: Water Wastage Max

$$Maximum\ Waste\ water = 3 * 350L * 41 = 43050\ L\ per\ week$$

These values are very high and are based on the smaller water troughs and don't account for wash water. Hence this water usage can be double if the operation used 700 litre troughs. To avoid such large water loss values a solution to this is paramount.

4.2.2.9 Difficulties in maintenance

There may be some insights in the preceding sections that have established a perspective on the maintenance challenges associated with these troughs. The primary difficulty arises from their positioning within the pens, as they are often placed half inside and half outside, making access to the troughs problematic in certain configurations. To effectively clean these troughs, it is often necessary to enter the pen, as addressing issues from outside is not a viable option due to their large size, fixed fittings, and non-modular nature. These factors collectively contribute to the challenges of servicing the troughs.

The specific nuisances associated with maintenance include:

1. Fixed infrastructure: The troughs are supported by fixed infrastructure, including pipes, sewage, and containment systems. This design makes it increasingly difficult to address faults, and any downtime can render the troughs, and consequently the pens, unusable for hours or even days at a time.

2. Lack of versatility: Concrete is challenging to replace or repair quickly, particularly in a stocked pen. For instance, if a significant crack develops in the water trough, the repair process will require time to cure and set. This situation can hinder the ability to effectively stock cattle, leading to a decrease in production efficiency.

Figure 23 illustrates a cross-section view of a large precast concrete trough, highlighting their reliance on solid fixed infrastructure, which necessitates extensive earthworks and can introduce costly complications. Figure 24 illustrates an unsewered system where trough water is allowed to dispense into the pen.

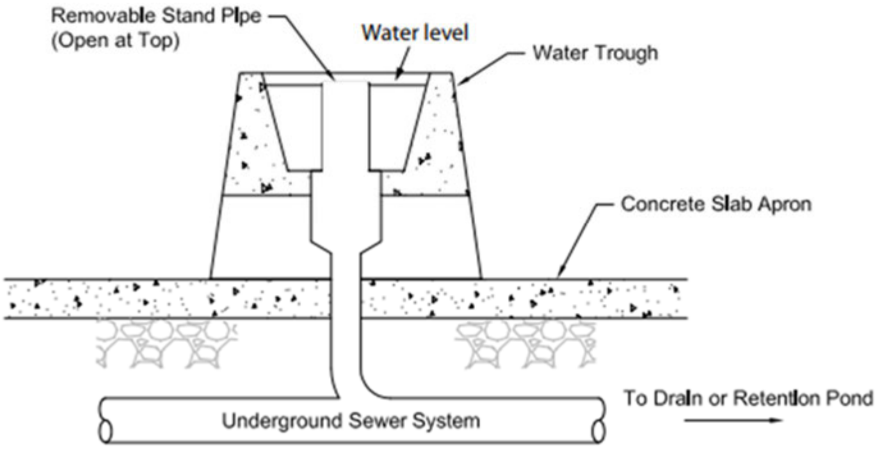


Figure 23: Conventional Concrete Trough - Spliced view of plumbing (Davis and Watts, 2016)

Figure 24: Conventional Concrete Trough – No proper drainage (Davis and Watts, 2016)

4.2.2.10 Summary and initial innovation recommendations

This section summarises the primary shortcomings associated with current options available in the market, outlining their drawbacks and the subsequent effects they have on operational efficiency. By analysing the issues and challenges posed by large pre-cast concrete water troughs, it becomes essential to correlate these faults with potential improvements in design. This connection is critical to ensuring that the objectives of this design project are achieved, which include enhancing production performance, facilitating efficient industry optimisation and advancements, and implementing sustainable and ethical animal welfare practices. Consequently, it is now appropriate to begin proposing and solidifying design solutions to address these identified problems.

4.2.3 Idea generation

4.2.3.1 Available technology and resources

The creation process is a critical phase of the project, during which conceptual and design ideas are translated into visual or physical components. Given the wide array of available technologies, it is essential to utilise a specific set of programs to maintain conformity throughout the project. The software selected for this project is AutoCAD Inventor, a widely used program in the industry for 3D modelling, which is also part of the University Learning program and is available for free use. Inventor is particularly beneficial for creating 3D models, as visual representation serves as an invaluable tool in the preliminary analysis phase.

Additionally, Autodesk offers an online program called Autodesk Viewer (Autodesk, 2019), which facilitates the uploading of files and assemblies, enhancing communication by enabling parts to be viewed anytime and anywhere. This functionality allows stakeholders to access files through a link in an email without needing to open the file itself, making it an essential tool for effective client-designer interaction.

Furthermore, an additional component that could enhance this design process is the incorporation of 3D printing technology. This advancement would allow for the creation of a physical prototype of the product, providing a tangible representation of the design.

4.2.3.2 Resource plan

A resource plan is an essential aspect to consider, as numerous engineering tools are available to display and analyse problems effectively. For this design project, the approach will remain straightforward during the theoretical phase, utilising AutoCAD Inventor. This software is a widely recognised mechanical engineering modelling tool, featuring various user-friendly options that can be deployed to create and showcase solutions.

AutoCAD Inventor is capable of producing 3D models, which can be presented through assemblies or professional 2D drawings. Both formats are beneficial for visualising component interactions and are applicable for real-world applications such as laser cutting or program-based manufacturing techniques. Additionally, the built-in finite element analysis (FEA) software allows for a seamless transition from model creation to theoretical analysis.

Moreover, the software provides an efficient means of client communication. Traditional methods for sharing 3D models typically involve sending files that require specialised software to open on a computer. In contrast, AutoCAD Inventor offers a cloud-based system that allows users to upload 3D models to AutoCAD servers. This enables easy sharing through a simple link, which can be attached to an email. This feature is particularly advantageous, as it allows designs to be viewed on laptops or, more conveniently, on mobile devices. This accessibility is especially useful in environments where carrying laptops is impractical, such as in paddocks or job sites.

This resource will be integral to the design process of the project. The link to the AutoCAD Viewer is as follows: https://viewer.autodesk.com/. This tool will be utilised extensively during the design phase and will transition to a fabricator who will have access to the additional resources necessary to complete a prototype. It is important to recognise that these tools function in a cooperative relationship within the engineering process.

4.2.3.3 Materials

In this project, the selection of materials plays a vital role in the design process. Different materials not only serve distinct purposes but also influence the shapes, positioning, and manufacturing processes involved. It is essential to understand the required properties and how specific attributes can be satisfied through the selection of appropriate materials. The properties necessary for this project are as follows:

1. The areas of the trough that will be exposed to water must exhibit rust resistance.
2. The trough must possess rigidity and durability to withstand the demands of use.
3. The gate must be robust enough to support the weight of the trough.

Several material-specific design choices will be considered when selecting a material for the water trough. Given Australia's strong focus on use of steel, it is highly probable that the water trough will utilise steel and its derivatives. Steel is well-suited to Australian conditions, as it is strong, durable, weather-resistant, and easy to maintain. Other materials that may be used for similar applications, such as concrete or plastics, present certain drawbacks. The advantages and disadvantages for several materials is provided in Table 8, leading to a conclusion regarding why stainless steel is likely to the preferred option.

Material	Advantages	Disadvantages
Concrete	Strong in compression, can be moulded to some degree.	Heavy, can crumble, has to be ground based.
Heavy plastics	Strong in some regard, light weight.	Environmentally degrades, hard to mould and manufacture. Is wear susceptible.
Steel or steel derivatives (stainless steel)	Strong in tensile, is easily moulded and manufactured to any shape, is environmentally resistant. Not too heavy not too light. Long life span. Is common in the industry. Stainless steel is corrosion resistant	Can have sharp edges. May be more expensive for higher grade steels.

Table 8: Viable material comparison

A quick analysis indicates that the most suitable material for the tasks is steel or a steel derivative. This material offers an optimal combination of benefits while presenting minimal drawbacks, which can be mitigated through appropriate processes.

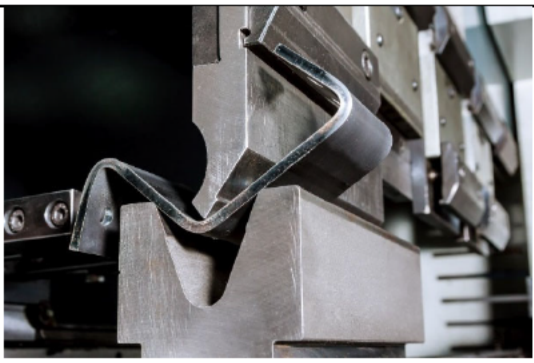
4.2.3.4 Manufacturing processes

Manufacturing will play a crucial role in the overall design process, particularly considering that manufacturing costs in Australia tend to be significantly higher than in other countries, such as the United States, where costs are roughly 30% lower (Admin, 2014). However, local businesses may be able to facilitate smaller-scale manufacturing, which has several advantages including:

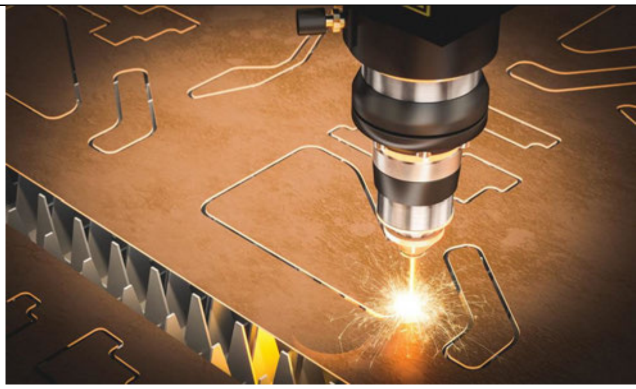
1. Supporting local businesses and contributing to the economy; and
2. Proximity reduces major shipping costs associated with international freight.

Conversely, there are important cost considerations when manufacturing within Australia.

Water troughs globally are produced using a variety of materials, but as established in the previous section, stainless steel will be the preferred material for the trough critical components, while mild steel will be utilised for the gate. Agriculture, marine and the food industry commonly employs stainless steel due to its anti-oxidisation properties. However, different manufacturing considerations must be addressed when working with stainless steel compared to aluminium or mild steel, as their properties vary significantly and must be handled accordingly for joins, bends, and other processes. Some common techniques for manufacturing components from steel are outlined in below.

Manufacturing process	Image & Use
Welding	 **Figure 25: Manufacturing Techniques -Welding (Austgen.vn, 2017)** Welding is used to join two pieces of metal together by fusing them with filler material. It is useful for its strength and transferable stress and strain qualities, as the join can make the 2 pieces behave as if 1.
Bending	 **Figure 26: Manufacturing Techniques -Bending (Hartech, n.d.)** Bending is useful for simple single piece shapes that can be moulded after a specific shape. It keeps material homogeneity

	and is not typically used to replace joins but for large specific shapes such as jagged edges or circular shapes.
Riveting	 **Figure 27: Manufacturing Techniques -Riveting (Eichinger, 2018)** Riveting is a semi-permanent type of joining, its commonly used to keep sheet metal tied down firmly, as can be seen in the image a large number of rivets are used but is useful in attaching pieces of shaped steel to more structural type emplacements. It not advised for high single load stress applications.
Bolting	 **Figure 28: Manufacturing Techniques -Bolting (Tobias, 2019)** Bolting steel is a commonly used practice it delivers a flexible and strong joining method of steel; bolts are optimal for high stress and strain applications and can withstand single load

	applications as well. Also has a tightening option which is good for maintenance with movements in structures.
Laser cutting	 **Figure 29: Manufacturing Techniques -Laser cutting (Canadian Fabricating and Welding, 2023)** Laser cutting is useful for creating clean 2D shapes, and within a short amount of time. It is based off programming and works in well with DXF drawings from 3D or 2D modelling software. It useful for creating bulk parts or specifically difficult parts.
Milling	 **Figure 30: Manufacturing Techniques -Milling (Ye, 2023)** Milling is becoming increasingly popular in the manufacturing industry, it can complete numerous amounts of tasks with different attachments such as cutting, facing, chamfering etc. It is an extremely versatile machine and can be used in tandem with CNC programming which makes operations quicker and more

	efficient. However, is predominantly used for smaller more solid intricate type parts.

Table 9: Steel component manufacturing techniques

All of these methods will be evaluated to ensure that, from an engineering perspective, the construction of prototypes aligns with a predetermined manufacturing process. This approach is essential for ensuring smooth workability and assisting manufacturers. Effective communication and collaboration between the design phase and the construction phase are crucial elements of mechanical engineering design.

4.2.4 Interdisciplinary design

This section will focus on addressing the specific design problems discussed previously by adhering to established engineering principles and methodologies, such as the waterfall approach. Certain steps within the selected methodology sequence will require a more detailed examination. This section will adopt a step-by-step approach to achieve an adequate solution to the identified problems. The process will encompass various stages that flow into one another, ensuring that changes are clear and justified. This approach aims to gather both theoretical and practical insights, incorporating crucial design considerations from experienced professionals. Ultimately, this will establish a solid foundation for design choices and practical applications within 3D modelling software.

4.2.4.1 Brainstormed ideas

Brainstorming was undertaking with the owner of Struggle Downs Feedlot and the Project supervisor to generate a range of ideas for the development of the water trough including design constraints and feasible solutions. This section relates those ideas some of which have been considered in the previous sections to engineering fundamentals and problem-solving attributes to discuss preliminary solutions before refinement.

Table 10 presents a comparison of the specific design constraints presented by conventional pre-cast water troughs and alternative solutions.

Specific issues presented by pre-cast concrete troughs (current market)	Already presented viable solutions via site specifications and arrangements
1. Warm and stale water	High flow rate to be utilised over high volume. Due to elevations from storage to dispensing point.
2. Stale water	High flow rate can mean smaller volume but refilled more often. Keeping it cool and fresh.
3. Algae growth	Smaller overall volume means less stagnant water. Will be desired to be in the shade. Relates to flow rate.
4. Difficult access	Needs to be in a place where it is easily reached for maintenance. And out of the road of other operations. Such as autonomous feed robots and possible future advancements.
5. Lengthy and difficult cleaning	No solutions presented yet.
6. Difficult to maintain	No solutions presented yet.
7. Lacks other applications and versatility	TBD

Table 10: Site specific design constraints

From the assessment of the design constraints and feasible design ideas were developed and are presented in Table 11.

Outlined design constraints	Feasible design ideas of these constraints
Utilisation of the high flow in a trough system.	High flow utilisation • Elevation differences (slope downhill) • Gravity fed over long distances from water storage tanks on site • Water flow fed from roof piping, attached to roofing structure of covered housing arrangement.
High flow rate again but decreasing the overall volume of the trough to promote freshwater drinking.	Reduction of overall volume in conjunction with high flow. • Use of a high-performance float system

	• Smaller volume of trough (high demand will be counteracted with higher refill rate)
Cleaner	Reduction in grime collection and algae growth • Create trough out of steel preferrable stainless grades to prevent rusting. • Offer a method for an effective method of cleaning. Smooth surfaces such as stainless will also benefit this. • Placed in the shade to reduce warm water and algae growing conditions
Wishes for it to be mounted on a swivel pen gate, hence out of road of robots, cleaning equipment etc.	Improved access • Mounted on gate for the pens • Fabrication is needed for gates; hence this will be a small addition with no need for underground works. • Will be completely out of the road of the feed robots if feeding is required on both sides of shed. • Cleaning equipment will have easy access to pens due to it not impacting pen shapes.
Needs to be quick to clean, Tipping is the preferred method suggested. Can be used in conjunction with some already present cleaning equipment such as cordless drill with brush.	Quick cleaning • Should use a tipping mechanism to empty all water and grime out in one go. • Can be used with a cordless drill brush, simply
Versatility, so that maintenance is easy achieved. Refitment and replacement is quick and easy.	Versatility • If something was to break down, it needs to be adaptable and modular enough to

	be replaced and fixed elsewhere easily without disturbance. • Simply switch out with spares, to minimise downtime.
Can be adapted to suit future advancements withing the covered housing arrangement. Smaller scale uses, autonomous applications such as self-cleaning etc.	Future Advancement options • Autonomous cleaning options, water jets, auto brushes, auto tipping etc. Smaller scale fence mounted troughs for smaller pens to work in conjunction with future technologies.

Table 11: Feasible design ideas

Incorporating these design constraints can lead to componentry designation within the project. As a form to split up and critically analyse finite details.

4.2.4.2 Idea refinement

The feasible design ideas have now been established to address the specific issues associated with conventional options, considering design constraints alongside operational and site suitability expectations. It is important to acknowledge that these design ideas and general concepts may be subject to change throughout the design process. Last-minute adjustments are also possible, reflecting the realities of engineering. The initial goal of these ideas is to generate a highly plausible design before prototyping; however, adaptations may only become apparent after field testing. At that stage, a field analysis of various advantages and disadvantages can be conducted to evaluate overall functionality in the intended environment.

Once complete refinement is achieved, a finalised design will be presented. This aligns with the methodological approach outlined in previous sections of this report. In this section, the design idea refinement process will begin, involving the compilation of suggested ideas, analysis of necessary components, assessment of manufacturing feasibility, evaluation of mechanical practicality, and consideration of how the systems will meet the project goals of increasing production performance, generating efficient industry optimisation, and implementing sustainable and ethical animal welfare practices.

Throughout this process, extensive communication with the owner of Struggle Downs Feedlot has taken place, including numerous discussions to assess potential designs, systems, and operations required for the project's success. Recognising that the project must be tailored to the site is a critical initial factor. The main requirements identified were:

- The implementation of a trough mounted to a gate.
- The trough must be tipping in nature.

These fundamental requirements provide practical and logical applications, aligning well with the project's objectives and the potential for mitigating the design faults associated with conventional options. From these core elements, optimal systems can be designed to fit. A list of components required to integrate and synergise the primary requirements will be created, facilitating a division of labour and enabling thorough analysis and justification.

The assessment of core components will commence. Table 12 outlines a list of components required, along with the order for their design development.

Component	**Justification and design points**
Gate frame	• Needs to be able to mount a water trough amongst its structure. • Easy to manufacture • Still be able to swing as per a usual gate without extra impedance. • Strong enough to support the weight generally of the fully laden trough.
Gate hinges	• Needs to be able to effectively clamp onto the current support systems of the shed • Adaptable to different sizes of gates. • Allows for versatility and easy disassembly for gate maintenance.
Trough body	• Needs to be able to hold a decent amount of water considering. • Have a geometry that is compatible with tipping and easy cleaning.

	• Needs to be constructed out of suitable material for weather resistance, cleaning and manufacturing supply. Easy to manufacture.
Trough mounts	• Strong enough to support the weight • Durable to uphold multiple tipping cycles
Trough tipping mechanism	• Needs to be strong and durable • Simple in nature • Designed for quick use • User friendly • Limited mechanisms
Trough locking system	• Must be cattle proof • Has to hold the trough in a non-tipped position • Must be quick and easy to lock and unlock
Trough float system	• Quick refills • Must be positioned so that the tough can tip seamlessly with its implementation • Must be thoroughly protected from cattle interactions • Must be versatile for maintenance.

Table 12: Component breakdown

4.2.4.3 Lifecycle anticipation and sustainability

The lifecycle of structures largely depends on the needs and preferences of the use and the environment in which it is located. Some applications require troughs that can last as long as possible, whilst in other applications troughs may be replaced every few years. This variability is influenced by the design of the troughs, which can be either permanent, like concrete troughs, or more easily replaceable, like plastic round troughs. Therefore, the aim for the water trough design in this project is to create a system that offers durability while also allowing for retrofitting with other components for future use, thereby enhancing modularity and ease of maintenance to extend its longevity.

The intended future use of the water trough is also crucial in determining its design, particularly whether it is to be built for a lifespan of five years or twenty.

The incorporation of autonomous options within the Struggle Downs Feedlot opens up possibilities for fully autonomous or semi-autonomous operations in future advancements. This evolution will enhance the longevity of the design, aligning it with emerging advanced systems and further increasing operational efficiency. Potential future advancements may include autonomous cleaning and tipping mechanisms, which would reduce the need for human interaction and optimise cattle watering processes.

These advancements contribute to the overarching goal of achieving maximum efficiency and synergy within a covered housing system. Additionally, minimising human contact or impact could open numerous avenues for the industry, such as regional diversification. Intensive livestock operations could be established in more remote areas, enabling enhanced data collection for animal welfare monitoring and improving animal growth efficiency, which would benefit the Australian economy.

As a smaller population country, Australia should concentrate on areas of strength, leveraging its vast expanses of land. By focusing efforts on robust industries, the nation can work toward financial security in the future through the adoption and innovation of methods like these. Incremental advancements are the most effective way to facilitate evolution within the sector.

4.2.4.4 Methodology evaluation system

To properly assess the design process, evaluation criteria are essential for validating and supporting design work. Creating a prototype without a defined evaluation framework would be futile. Therefore, specific checkpoints will be established to facilitate a successful design project. Understanding the requirements and all design considerations is a critical aspect of this evaluation scheme. To ensure that subsequent sections continue to align with the design questions, applicable requirements, and functional considerations outlined in this methodology, factors will be implemented to continuously evaluate the process.

This approach will uphold the identification of critical numbers, allowing for numeric values to serve as benchmarks for comparison against conventional systems. This serves as a method of evaluation to justify the effectiveness of the current design approach relative to known standards. Consequently, the first criterion will be to evaluate critical numbers where present and applicable to gauge the importance and success of the methodological approach. Additionally, each design choice section will incorporate a reference back to the design questions, objectives, and aims of the project, ensuring that these processes remain aligned with the methodological framework. As a result, every design choice will be linked and justified in relation to this methodology.

4.2.5 Chapter summary

The methodology chapter delineates the design process, emphasising the specific steps necessary to achieve a functional design. It establishes a framework for addressing the design questions and objectives outlined in Chapter 2, ensuring that these elements are systematically integrated into the subsequent design phases. By detailing the required steps, this chapter serves as an effective engineering technique that facilitates a smooth design workflow. The structured approach allows for the preliminary organisation of relevant information, guiding the decision-making process and ultimately solidifying the final design choices. This cascading effect, where each section builds upon the preceding one, fosters a comprehensive understanding of the topics and broader processes essential for reaching the project's objectives.

5 Design

Chapter 4 outlined several major components deemed necessary for the design process. This section outlines the design procedure for each of these components, aiming to establish a solid foundation based on design ideas, standards, trends, requirements, and general needs associated with each component. This approach will aid in deducing and fine-tuning a design prototype.

Certain components are highly dependent on others, influencing factors such as shape, hole positioning, and overall spacing. Therefore, design solutions will be discussed as independently as possible, followed by compiling them into a cohesive conceptual design suitable for engineering drawings and subsequent fabrication. Numerous iterations of the components will be required due to changes influenced by neighbouring components, ensuring that synergy is maintained throughout the design process.

Utilising Autodesk Inventor will facilitate the display and modification of these iterations. The software's assembly features will enable precise sizing assessments and analysis of component synergy. Once the design is refined and polished, it will be submitted for approval by the owner of Struggle Downs Feedlot for manufacturing. After approval, the design will be fabricated, installed and commissioned in the field to evaluate its operational performance.

5.1 Available Area and Site Constraints

5.1.1 Applicable infrastructure

The initial constraints for the water trough will focus on overall sizing and positioning, including factors such as length, width, and height. The area designated for the water trough is between two upright support columns of the shed. Figure 31 presents the 3D CAD model of the proposed water trough location to illustrate the fixed boundaries that must be considered in the design, as these columns are already constructed within the covered housing arrangement.

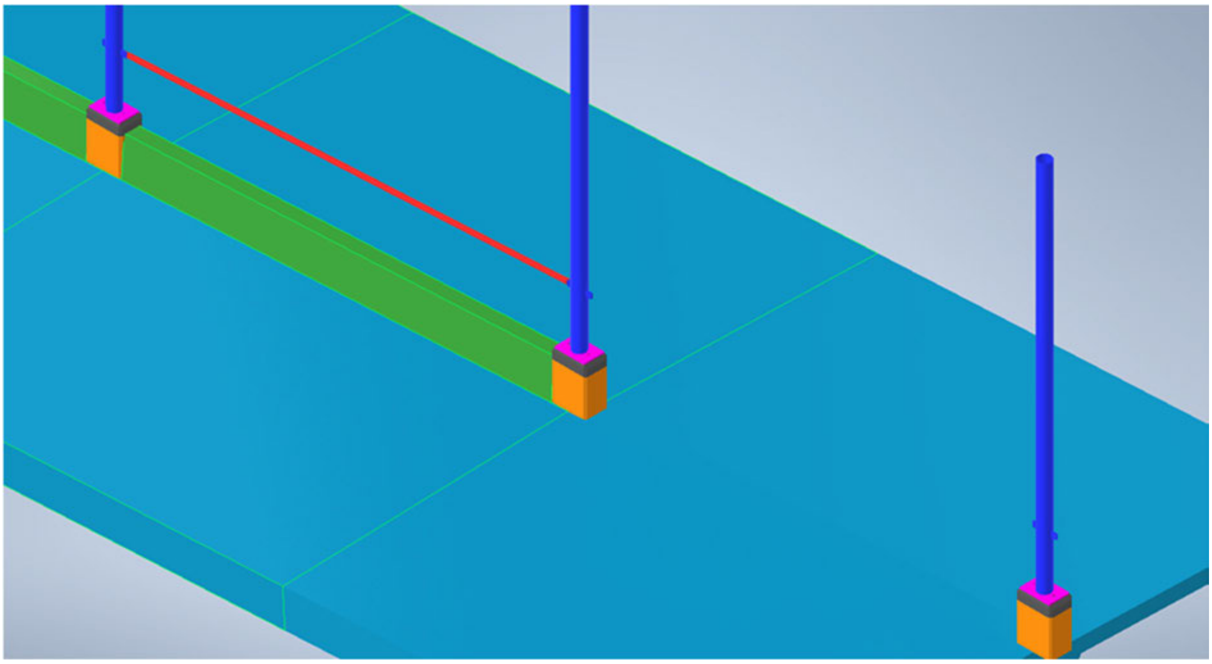


Figure 31: Applicable Infrastructure - 3D model

A 2D drawing was prepared of the site infrastructure from the 3D model to show the dimensions and space available. The 2D drawing is presented in Figure 32.

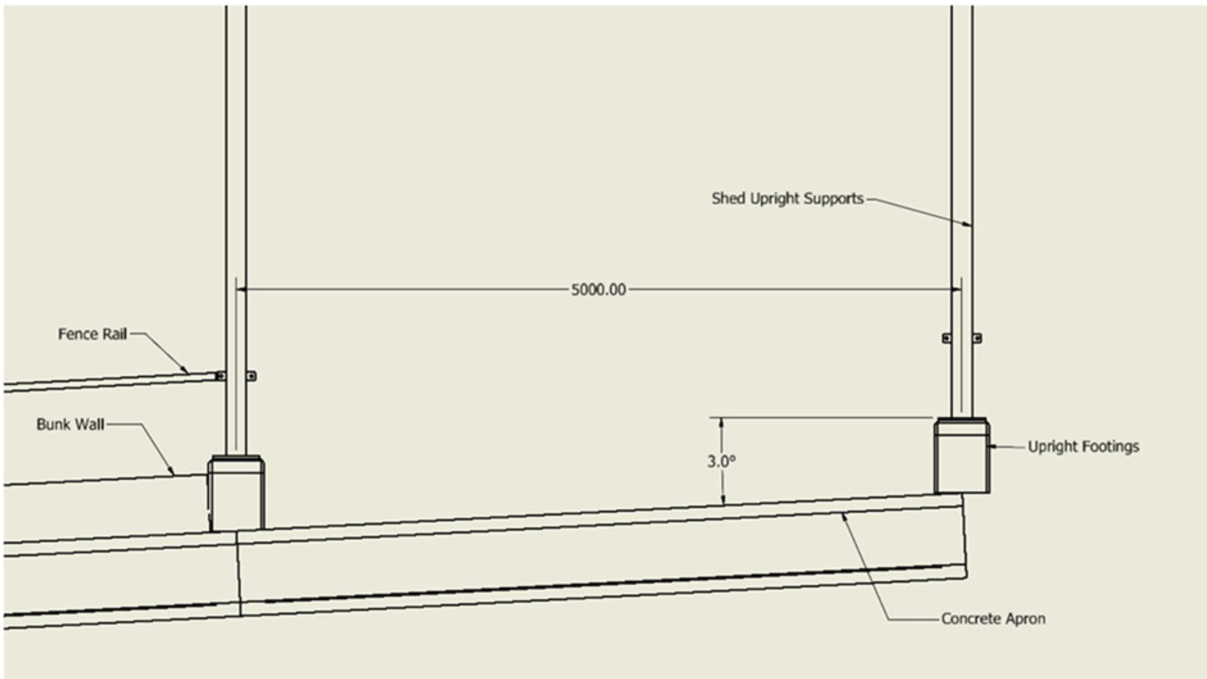


Figure 32: Applicable Infrastructure - 2D drawing

Figure 32 shows the position of the fixed constraints of the water trough location. A brief explanation of each of the components is outlined below.

- Fence rail – this is the rail that is positioned above the bunk wall as a method to keep cattle in, this is different to other arrangements due to the alternative European feeding style. It allows cattle to stick their head down between the rail and the bunk wall while retaining them in the pen.
- Bunk wall – This is a large concrete plinth that helps organise feed, however, again is different to conventional feed bunk systems. As been already discussed as per the feeding method.
- Shed upright – shed roof supports in this case are structurally important and are spaced 5 metres apart from centreline to centreline. They are CHS 139.7 x 3.2 mm in size and grade S235 (Brisko, 2024). They are roughly 6 metres in height.
- Upright footings – these are simply to support and firm up the shed uprights. Ensuring strong structural integrity. They are also made with one concrete pour in conjunction with the bunk wall. An intricate steel mould was used as the formwork.
- Concrete apron – this is a reinforced concrete pad that everything was built up from, it is graded down away from the bunk, as well as a step down. One side of the bunk is the cattle side, which is where the cattle will be situated inside of the pen. That side of the apron offers a step down of roughly 100 mm when compared to the feed side, which is the side where the feed is distributed, and is the higher of the two levels. So, this information will become important for when the water trough heights will be analysed

For a more detailed and spliced image of the step down, footings and apron refer to Appendix C – Methodology.

This exercise serves as a valuable reference for assessing site compatibility regarding the creation and assembly of 3D components. It will facilitate the efficient analysis of factors such as available space, gaps, lengths, heights, and tolerances.

5.2 Design Components

5.2.1 Gate frame

This serves as the foundation of the project. The concept of mounting the water trough on a gate has been discussed, but it is essential to recognise that such an implementation has not been previously undertaken in Australia. This is largely due to the challenges posed by large-scale operations, including concerns about positioning and weight. Consequently, the gate was designed to support this trough must possess sufficient strength to bear the weight of the water, which will necessitate limiting the trough's volume. Nevertheless, fundamental gate principles must still be adhered to in order to ensure functionality for the intended operation.

The primary constraints associated with gate design that affect operational performance include gate size, location, weight, strength, and latching mechanisms. These factors will be addressed in the following sections.

Designing a gate that is tailored to a specific operation can be challenging, as components that are conventional within the industry may not be suitable in this context. However, maintaining the practicality of this project is paramount, which is why many established techniques for gate design will be incorporated to ensure usability, cost-effectiveness, and ease of maintenance.

To gather pertinent information, input will be sought from industry personnel who possess significant knowledge of cattle handling and gate components. This includes collaboration with the owner of Struggle Downs Feedlot (Darren Hamblin), who will provide insights on practical considerations for the integration of the water trough into the site and discussions with RDC Engineers Pty Ltd who have experience designing and construction of beef cattle feedlots. References such as the Meat & Livestock Australia report "*15. Fences, gates and lanes*" (Watts et al., 2016) were also reviewed to ensure that the design choices are well-supported by industry standards.

Another key point raised by Watts et al., 2016) is that "*gates should not have any sharp protrusions, such as badly positioned hinges and latches that cattle can bump into and be bruised by them moving in and out of the pen*". Adhering to this principle will be integral throughout all aspects of component design in this project, ensuring that design goals are met while prioritising the safety of the animals.

The essential considerations for a gate frame are as follows:

5.2.1.1 Gate location

The location of a gate is typically a significant decision factor for conventional feedlot gate placement, this factor is mitigated in the covered housing arrangement. The available area is already designated for the gate, comprising one large entrance for each pen. Generally, positioning troughs can be challenging due to considerations related to cleaning or feeding machinery; however, in this case, these factors are not a concern, as they are already established. Therefore, this design must conform to the existing constraints.

5.2.1.2 Gate size

The dimensions that are crucial for an effective gate are based on the distance from the centre to the centre of the shed uprights, which serves as the reference measurement. The overall allowable length can be calculated by subtracting twice the radius (essentially the diameter) from this reference distance. In this instance, the diameter of the shed upright is 139.7 mm, which is an imperial measurement. Therefore, rounding will be necessary to arrive at a more suitable metric value.

Note all values in the foreseeable calculations will be rounded down to the nearest whole number. The maximum allowable gate size is determined by Equation 5.

Equation 5: Maximum allowable gate size

$$5000\,mm - 139.7\,mm = \mathbf{4860\ mm}$$

This value represents the absolute maximum length of the gate, with zero tolerances applied. However, several factors will reduce this maximum length, including the size and type of hinges used, as well as the necessary tolerances on both ends to allow for clearance and unimpeded swinging. A preferred tolerance greater than 120 mm will be sufficient as a reasonable assumption, with a range of 60 to 70 mm recommended for each side. Therefore, a middle value of 65 mm will be selected as the tolerance for each side of the gate. The theoretical gate size is determined by Equation 6.

Equation 6: Theoretical gate size

The new number entailing these tolerances each side.

$$4860\ mm - (65\ mm * 2) = \mathbf{4730\ mm}$$

This will be the starting point for the overall length of the gate frame.
This implies that the maximum length of the trough is directly linked to this measurement and is highly dependent on it. Numerous components within this design project intersect and require various considerations simultaneously. However, since the fence gate represents the first step in the process, it is optimal to design the gate first, with subsequent components being designed around it.

5.2.1.3 Gate materials

To visualise the design of this gate and determine the standard material sizing that may be utilised, solutions can be derived from existing gate models. This approach provides insight into various aspects of cattle gates, including structural integrity, dimensions, and material selection.

Figure 33: Australian Feedlot - Typical pen gate (RDC Engineers Pty Ltd, 2024)

Figure 33 illustrates a typical gate arrangement at a conventional feedlot. As can be seen the gate consists of 4 upright rails comprising 2 end rails and 2 centre rails, and 4 horizontal rails which are there for spacing and to keep linear strength. The rails are commonly made from the following sizes.

Square Hollow Section (SHS) 50 x 50 mm for the gate heads, generally with a thickness of 3 mm. This size provides solid strength to gates. It not too large and is in a manageable size for fabrication. It is stated that its - "*ideal for structural, general fabrication, manufacturing, fence posts*" (The Metal Warehouse, n.d.). It is also an extremely popular size and can be bought from a variety of steel suppliers. Many options of length and finish are also available. Galvanised would be preferred for this application due to the fact the gate frame needs to be weather and corrosion resistant to some degree. The cost of these pieces is based on weight, for 2 m of galvanised SHS 50x50x3mm is $35.68. A full cost analysis will be completed after the protype has been made.

Cattle Rail 115x42mm is as per the name states applied for cattle rail and fences. Due to the rounded edges which is beneficial as per - "*less bruising and less rails can be used due to the wider profile*" (The Metal Warehouse, 2022). The thickness is available in 2 mm, which will sufficient enough for ease of joining and welding. These rails are available in 6.1 m lengths and cost $79.99 per length. It is also important to note they are galvanised inside and out, for a solid all-round resistance. These two sizes will make up the main structure of the gate. A cross-sectional profile of Square Hollow Section and Cattle Rail can found in Appendix D – Design.

5.2.1.4 Rail configuration

The arrangement of the rails will be crucial in determining the overall design of the gate frame. One of the primary considerations is the weight of the trough, which will contribute to the swinging resistance and the overall strength requirements of the gate. Many standard gate structures are capable of withstanding axial loadings in excess of 200-300 kilograms without additional strengthening. This resilience is inherent to cattle gates, which are designed to be robust and sizable. Therefore, for the initial iteration of the gate frame, no extra strengthening will be implemented unless it is determined that the total weight of the trough exceeds 200-300 kilograms.

5.2.1.4.1 Gate frame iteration 1

Figure 34 illustrates the gate configuration that was created as a starting point to base the water trough system on. Components of the water trough can be assembled onto it to create iterations as the design process continues.

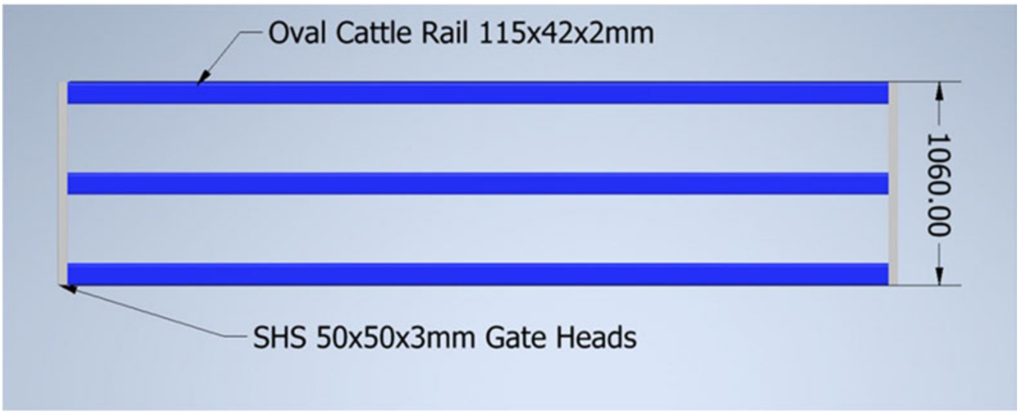


Figure 34: Prototype Design - Gate frame iteration 1

It is important to note that this iteration is subject to change, which may include adjustments to overall length, height, or the addition or removal of structures. Therefore, any modifications will be clearly classified and justified. However, considering the maximum length determined previously, the length of the horizontal cattle rails can be calculated by taking the overall length and subtracting twice the thickness of the gate head posts (2 × 50 mm). The length of the horizontal cattle rails is determined by Equation 7.

Equation 7: Current length of gate

$$Current\ lengths\ of\ inside\ cattle\ rails = 4730\ mm - (50mm * 2) = \mathbf{4630\ mm}$$

This design aligns with standard post and rail configurations. 3 horizontal cattle rails were chosen initially based on conventional gate configurations in the industry.

The vertical lengths of the gate heads are set at 1060 mm, representing a sufficient height without excessive material use. Considering the elevation of the post footings, of approximately 500 mm, the gate frame is therefore recommended to have a minimum height of 1000 mm. While most fences are generally stated to be "*1.5 m high but may need to be higher for cattle not accustomed to handling*" (Watts et al., 2016), the cattle in this instance are accustomed to handling and belong to a quiet breed. Thus, a total height of 1.5 m will suffice for functional purposes, with adjustments made only if technical adaptations become necessary. The additional 60 mm above the 1000 mm frame height will accommodate a post cap, which is designed to prevent water from entering the hollow section of the post.

With the working size and general platform established, it is essential to focus on creating an effective attachment solution for the gate to the 139.7 mm posts. One of the project goals is to develop a solution that is adaptable and suitable for various arrangements. Therefore, a flexible and innovative attachment method is required to ensure compatibility with both the current setup and potential future configurations. This will facilitate seamless integration while maintaining the functionality and stability of the gate.

5.2.1.5 Gate hinges

A gate typically features a method of attachment to a solid foundation structure, ensuring stability and enabling smooth swinging. Numerous variations of gate hinges are available, and this section will explore the optimal method for enhancing gate performance. Hinges are widely accessible off the shelf, providing ample options that can be varied or adapted to suit specific needs.

After conducting discussions and research, a particular type of hinge has emerged as a popular choice, making it imperative to incorporate this hinge type into the design. According to the MLA report "*15. Fences, Gates and Lanes*, - "*welded on round barrel hinges are simple and effective*" (Watts et al., 2016). Utilising this configuration will likely resonate with other lot feeders, as they will recognise its value and trust in its performance. The hinge selected was the weld on 27 mm diameter with 12 mm thick male and female hinge sets (W27mm). They are manufactured in a variety of finishes including zinc coated and galvanised. An image of this exact hinge can be viewed in Appendix D – Design.

These hinges are desirable for cattle industry applications for their simplicity, adaptability with welding, and fundamental strength. As per 'CanDoo Rural' a seller of these hinges, they state that the 20 & 27mm weld on hinges are optimal for "*stock yards, yard gates, large farm gates, stock crates cattle crushers and other heavy-duty applications*" (CanDooRural, 2022). Meaning these hinges should be more than adequate for an adaptation option via welding.

5.2.1.5.1 Attachment technique

While it was previously mentioned that the shed uprights consist of 139.7 mm posts, directly welding the hinges onto these posts may not be the most practical solution due to its rigid and structural nature. Although this standard practice is common in the industry, the objective of this project is to create a design that is as adaptable and versatile as possible, allowing for quick replacement and maintenance of components.

To address this, a proposal for a collaring system has been developed. This system would essentially clamp onto the 139.7mm posts at any variable point along the upright, creating a sleeved surface for the 27 mm hinges to be welded onto. This design allows for flexible hinge spacing as needed. Additionally, this collaring method can be applied to various post uprights, accommodating different arrangements. Initial sketches were created, followed by 3D modelling in Autodesk Inventor to visualise and refine this approach. Figure 35 illustrates the 3D model of a half section of the post collar.

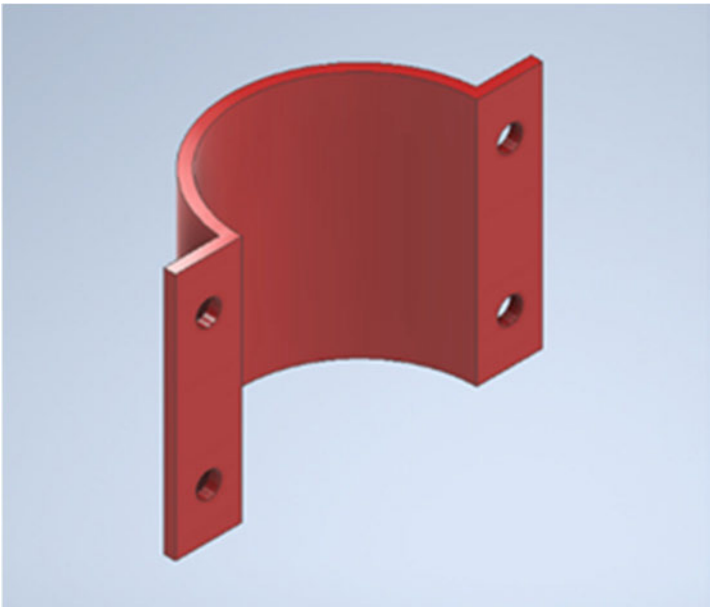


Figure 35: Prototype Design - Post Collar Half 3D Model

Key aspects of this design include the provision for a minimal tolerance of 2 mm around the post, ensuring a snug fit that enhances stability. The collaring system incorporates a four-bolt hole configuration, which is crucial for transferring both tension and compressive loads effectively. To achieve this, robust M15 size bolts will be employed.

Additionally, a slight gap between the two flat faces of the collar allows for the bolts to tighten and compress securely, ensuring a firm grip around the collar without any risk of slipping. This design feature enhances the overall strength and reliability of the hinge attachment, making it well-suited for the operational demands of the gate system.

The W27 mm hinges will be welded directly onto the respective sides of the collar, providing a strong and secure connection. Correspondingly, the other parts of the hinges will be welded to the gate heads, ensuring a stable pivot point for the gate's operation. The assembly has been meticulously designed to facilitate ease of movement while maintaining structural integrity and is illustrated in Figure 36. This configuration allows for smooth swinging motion and minimises wear on the hinge components over time.

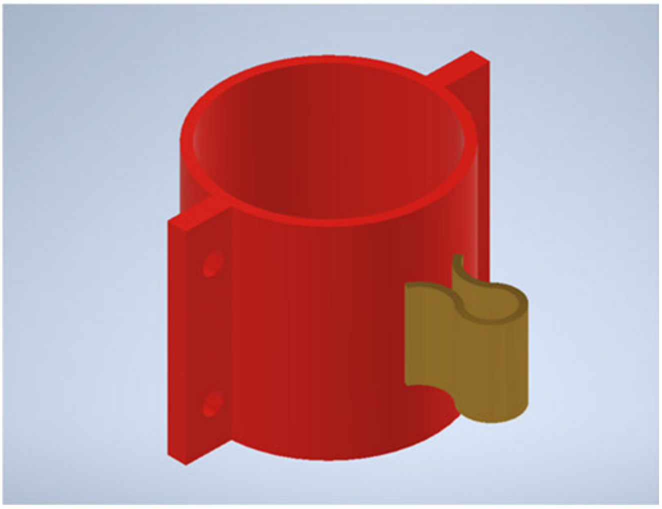


Figure 36: Prototype Design - Assembled Collar with female 27mm hinge assembled

These components will enhance maintenance versatility, particularly important in environments where cattle are present in pens. Maintenance tasks on gates can often be challenging; therefore, simplifying this process is crucial. The proposed design allows for straightforward maintenance, as it only requires loosening 8 or 4 bolts, depending on which hinge needs replacement. This can be executed strategically while the gate remains in place, reducing disruption.

Furthermore, there is no need for welding or detaching the gate entirely for maintenance, which helps avoid distressing the animals. This approach mitigates the drawbacks associated with rendering pens non-operational during maintenance and eliminates the need for inadequate temporary solutions.

Regarding weight and load-bearing considerations, the specific weights and forces acting on these collars will need to be calculated based on the volume of water the gate will support. Additionally, strategies to counteract any moments created by the weight of the water will also be explored, ensuring the design can handle the operational demands effectively.

5.2.1.5.2 Entire gate assembly iteration 1

The next step is the integration of these components into the 3D gate model as shown in Figure 37 and Figure 38. This process follows standard engineering principles and incorporates a design flow of refinements aimed at achieving a final assembly.

As shown in Figure 37, the post collars have been arranged in the assembly as they would appear on-site. Positioning the hinges as far away as possible from the gate head is advantageous for force distribution, as it helps reduce the moment around a single hinge. This approach enhances the overall stability and functionality of the gate.

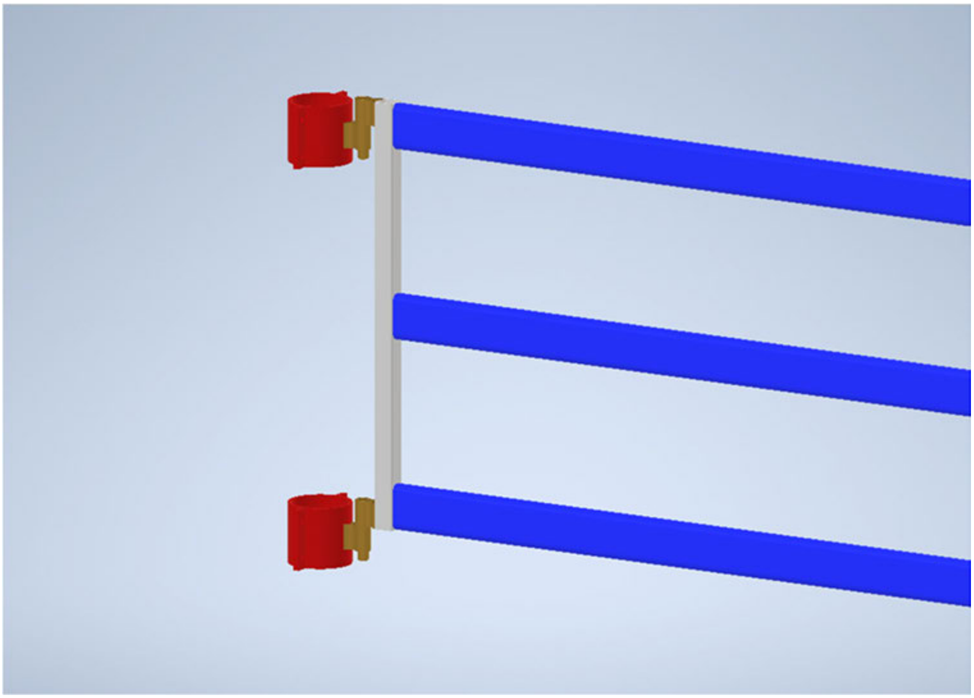


Figure 37: Prototype Design - Entire gate iteration 1, hinges assembled

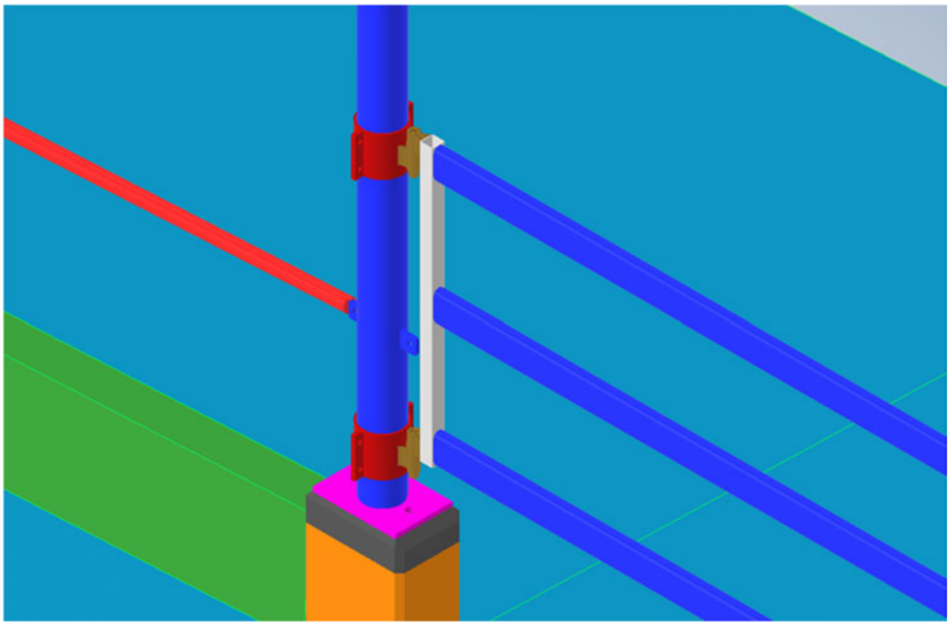


Figure 38: Prototype Design - Entire Gate Iteration 1 attached to site

As observed, there are limitations associated with this type of system, particularly regarding the positioning of the post collars. The footings of the posts restrict the collars from being positioned closer to the ground, resulting in a gap beneath the gate. This issue was anticipated during the selection of the gate head size.

The resulting gap of 500 mm is manageable, as the bottom rail will effectively prevent large cattle from accessing that space. This design consideration ensures that the gate remains functional and secure while accommodating the structural constraints imposed by the post footings.

Further iterations will be based on the same process, changes will be made and then displayed to show the progress and problem-solving thoughts that have gone into the iterations. Further iterations are presented in the Appendix D – Design.

5.2.2 Trough body

This component represents a crucial cornerstone of the water trough, as it will define the entire process and ideally serve as an effective and functional system. The size and shape of the trough body are critical considerations. Multiple elements must be addressed for the mechanism to operate efficiently, including its tipping functionality and the method by which it will be braced or positioned on the gate. However, the initial focus will be on the body of the trough, which involves considerations such as shape, volume, manufacturing processes, and materials.

5.2.2.1 Profile and length

From a mechanical perspective, the optimal tipping shape would be circular; however, a semi-circular design will be employed. This configuration allows for top access and maximises cleaning efficiency, as it eliminates edges where debris may accumulate. The design facilitates the use of tools like pipe brushes for thorough cleaning. Additionally, a half-pipe design is advantageous from a manufacturing standpoint, further streamlining the production process.

From a design perspective the length of the trough body was determined by the length of the inside horizontal rails of the gate with a reduction tolerance. The overall length of the trough body was calculated by Equation 8.

Equation 8: Tolerance Allocation to overall length

$$Tolerance\ Allowed = approx\ 6 - 7mm\ each\ side$$

$$Overall\ length\ of\ trough = 4630\ mm - (7mm * 2) = \mathbf{4616\ mm}$$

The tolerance allows for consistent unimpeded tipping in conjunction with the selected mounting options to the gate.

5.2.2.2 Materials

Given that this trough will be constantly exposed to water, stainless steel is the ideal material choice. The reasoning behind this decision lies in the limitations of other 'water-resistant' materials, such as galvanised steel, which is not entirely oxidation resistant. Galvanisation is merely a coating that can be scratched or worn off due to wear or cleaning processes. In contrast, stainless steel can withstand scratches or welding without compromising its water resistance, ensuring minimal rust formation. This is crucial, as it is undesirable to introduce rust contaminants into the water consumed by cattle or to face the need for frequent maintenance and replacement of the trough body.

Another advantage of stainless steel is its surface properties, which make it difficult for algae to grow and adhere. The microstructure and smoother surface finish of stainless steel are far less conducive to algae formation compared to industrial plastics or concrete. Reducing algae growth is beneficial for maintaining the quality of drinking water for cattle.

While the initial investment in stainless steel may be higher than that of other materials, its longevity and contribution to water quality make it the superior option. Various grades of stainless steel are available, each with different costs associated with surface finish and application. The choice of grade may depend on piece availability, as the manufacturing process will significantly influence the selection of the appropriate shape and grade of stainless steel used in the design.

5.2.2.3 Manufacturing

The fabrication process is a critical consideration when designing a specifically shaped object, particularly one that may not have off-the-shelf supply options. Unlike the readily available square hollow section (SHS) and oval rails for the gate, creating the half-pipe shape of the trough will likely require specialised fabrication techniques. It is essential to simplify the design while keeping all fabrication constraints in mind, including welding, bending, and cutting.

Obtaining stainless steel piping with suitable wall thicknesses and internal diameters can be challenging, as larger sizes are typically reserved for high-flow industrial applications, such as oil pipelines. Most large stainless-steel pipes come with wall thicknesses of 6 mm or more, which would be excessive for this application. An alternative approach is to use reasonably thick stainless-steel sheet, approximately 2 mm thick, and bend it into a half-pipe shape. Bending the sheet also allows for the incorporation of additional features without the need for welding.

Finding a single piece of stainless-steel sheet long enough for a 5-metre trough may be difficult; however, combining two pieces of 2 metre and 3 metre length through welding will suffice. Suppliers like Atlas Steel offer various grades of stainless steel in different lengths, making it a viable option for this project (Atlas Steels, n.d.). A supply sheet can be found in Appendix D – Design.

With the main fabrication process determined, final considerations must address the trough's water-holding capability. The overall inside diameter remains the only unanswered variable, which depends on size requirements, preferences, and the capabilities of the fabricator's machinery. After discussions and calculations with the owner of Struggle Downs Feedlot, it was determined that an inside diameter greater than 340 mm would be more than adequate to ensure ample water supply for the cattle.

Preliminary calculations using a diameter of 340 mm, combined with the previously advised length of the trough, can provide a rough estimate of the working volume. This information will also facilitate the calculation of the weight of the trough when filled with water and determine the desired flow rate. Understanding these factors will help establish the maximum working weight for the trough. The water holding volume of the trough body was calculated by Equation 9.

Equation 9: Initial volume

$$V = \frac{\pi * r^2 * h}{2}$$

$$Where, \quad r = radius, \ r = \frac{300}{2} = 150mm = \mathbf{0.17m},$$

$$h = length, h = 4616\ mm = \mathbf{4.616\ m}$$

$$Hence\ V = volume\ Therefore\ V = 0.209\ m^3\ @\ 100\%\ capacity$$

$$In\ Litres = 209L = \mathbf{209\ kgs}\ water\ weight\ (Maxium\ posible\ working\ weight)$$

This volume is smaller than that of other conventional water troughs; however, a plan is in place to counterbalance the reduced volume by increasing the flow rate. This strategy will be elaborated on in the section 5.2.4.4, which will provide a more comprehensive evaluation of the design's effectiveness and functionality.

5.2.2.4 Trough body iteration 1

Figure 39 illustrates isometric view of the first iteration of the trough body. Figure 40 illustrates the section view of the first iteration of the trough body.

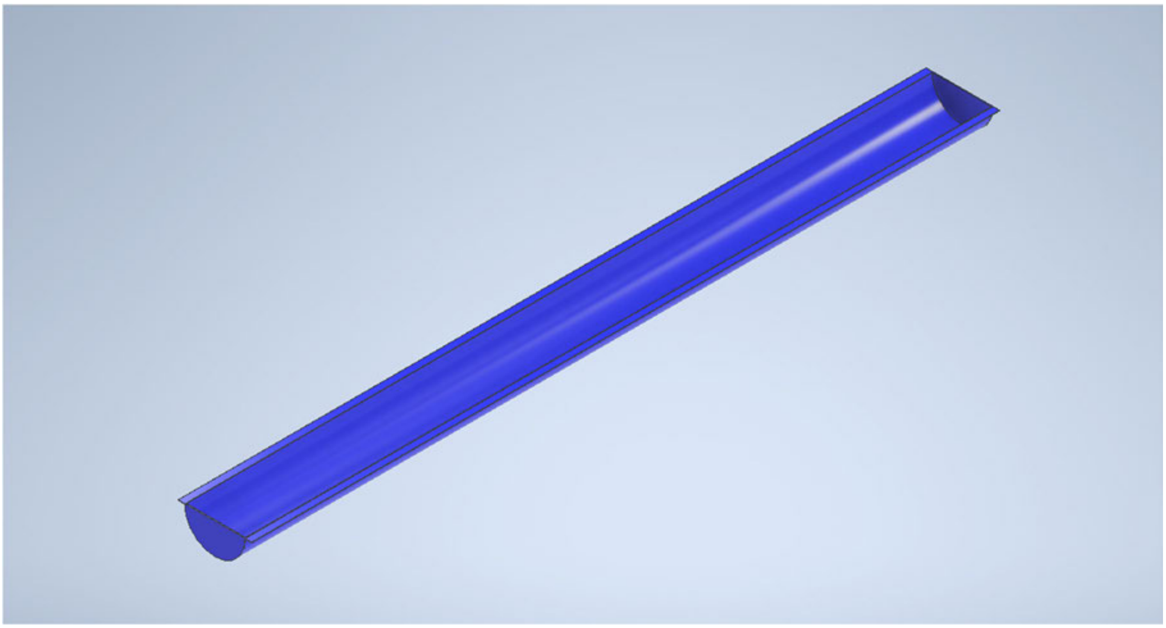


Figure 39: Prototype Design - Trough body iteration 1, isometric view

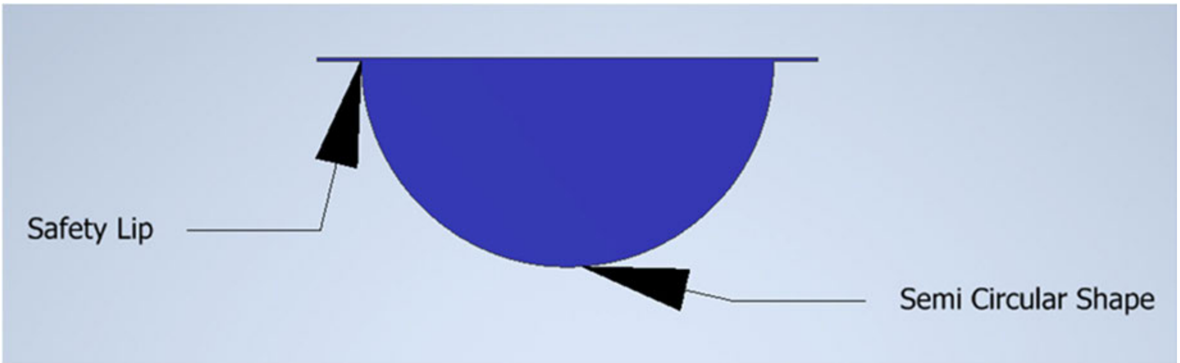


Figure 40: Prototype Design - Trough body iteration 1, section view

To enhance the design and promote component synergy, additional features will be incorporated into the trough. The straight edges may not be optimal, considering the potential for sharp edges, so it may be beneficial to implement a lip or chamfer to round off these edges. This adaptation will improve safety and ensure compliance with the design principle of minimising any risk of injury to cattle.

5.2.2.5 Weight and stress counteraction

The weight of the water trough will significantly impact the gate's hinges, introducing additional stresses that need to be mitigated to extend the lifespan of the collars and welded hinges. To address these challenges, two solutions have been proposed to alleviate the effects of weight on the moment created at the end of the gate.

The first solution focuses on counteracting sag, which is likely to develop over time due to the excessive weight and stress placed on the top hinge. This hinge experiences constant tension from gravitational forces, while the bottom hinge is subjected to constant compression. Regular gates often exhibit sagging over time, making them difficult to operate, resulting in issues with closing, opening, latching, and aligning other components.

To prevent sagging, the top hinge can be modified to incorporate a re-tensioning mechanism. This can be achieved by replacing the standard weld-on 27mm male side of the hinge with an L-shaped pin featuring a threaded end. The threaded section would be inserted through the gate head, allowing a bolt to be tightened to reduce the angle between the support uprights and the gate head. This innovative design, which has been modelled in Autodesk Inventor, is illustrated in Figure 41.

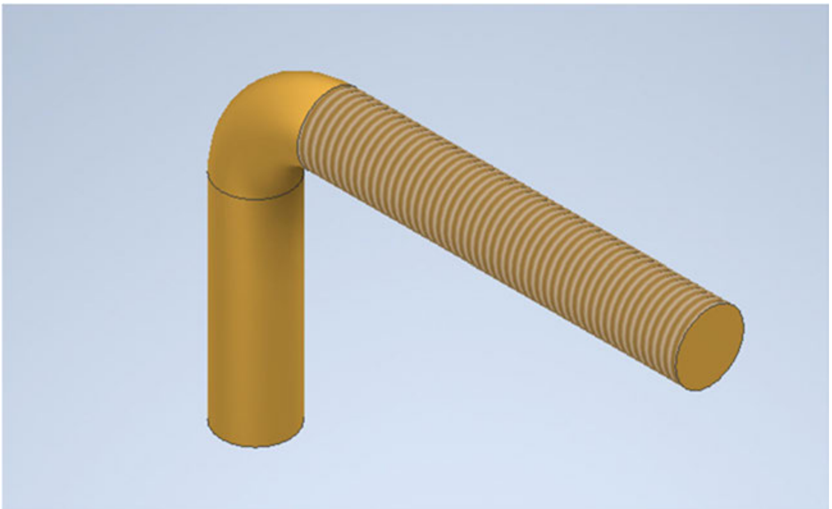


Figure 41: Prototype Design - Top hinge, L-shaped tensioner pin

To accommodate the re-tensioning mechanism, the design of the gate heads has been modified. The gate heads were extended to provide the necessary space for the bolt, positioning it as far away from the bottom hinge as possible. This extension not only facilitates the placement of the bolt but also enhances the overall structural integrity of the gate.

Additionally, a gusset has been introduced to protect the bolt while providing extra directional strength to the assembly. This gusset will help distribute forces more evenly, minimizing the risk of failure at the connection points.

While the finalisation of the gate frame and all major components is ongoing, the principle behind these changes is illustrated in Figure 42. Figure 42 outline the modifications made to the gate heads, highlighting the placement of the L-shaped pin. Figure 42 will serve as a valuable reference for understanding the adjustments made in the design.

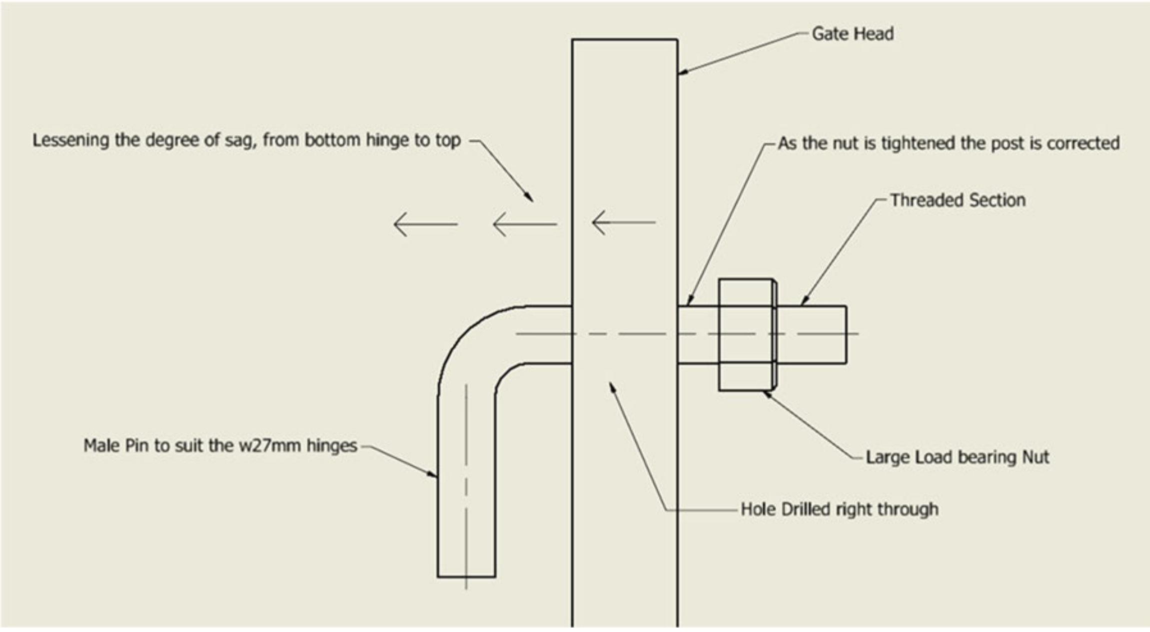


Figure 42: Prototype Design - Tensioner System dynamic diagram

The second modification involves leveraging the existing footings of the uprights for added support and stability. Currently, there are two large bolts that protrude from the footings, serving as ground anchors. However, the design allows for the gate to overhang these footings due to the height adjustments provided by the collar system as shown in Figure 43.

By positioning the hinges correctly, the bottom rail of the gate can be lowered slightly below the level of the footing. In this configuration, when the gate is in the closed position, it can be lifted just enough so that the gate head rests on the footing. This creates a load-bearing feature, distributing the weight of the gate more evenly and reducing the strain on the top hinge.

This innovative approach not only mitigates the effects of sagging but also enhances the overall durability and functionality of the gate. This modification is shown in Figure 44. and highlights the relationship between the gate, footings, and the collar system. Figure 44 will help visualise how the gate's weight is effectively supported by the footing, thereby improving the operational performance of the entire assembly.

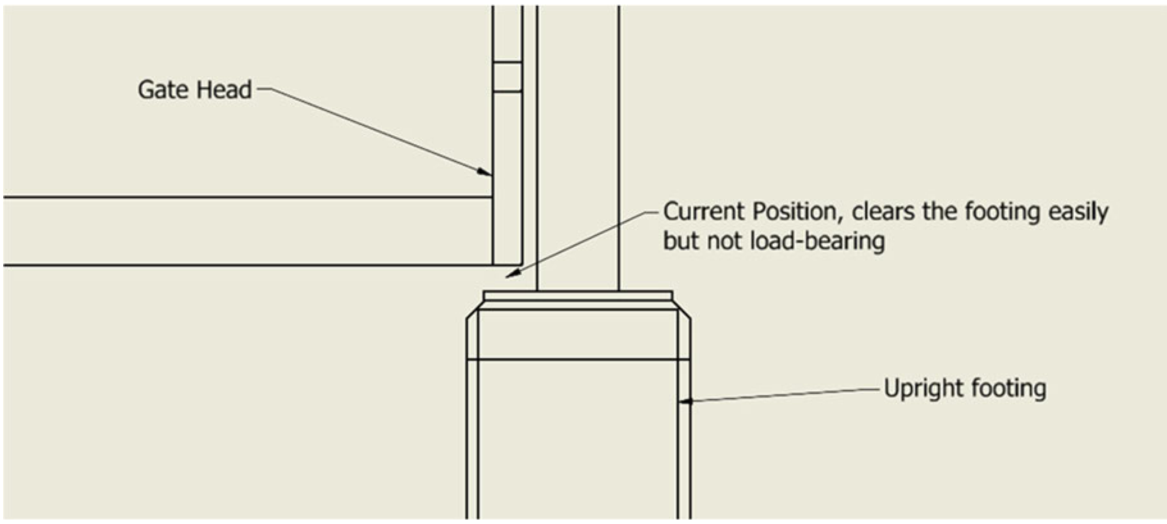


Figure 43: Prototype Design - 2D drawing of current gate height

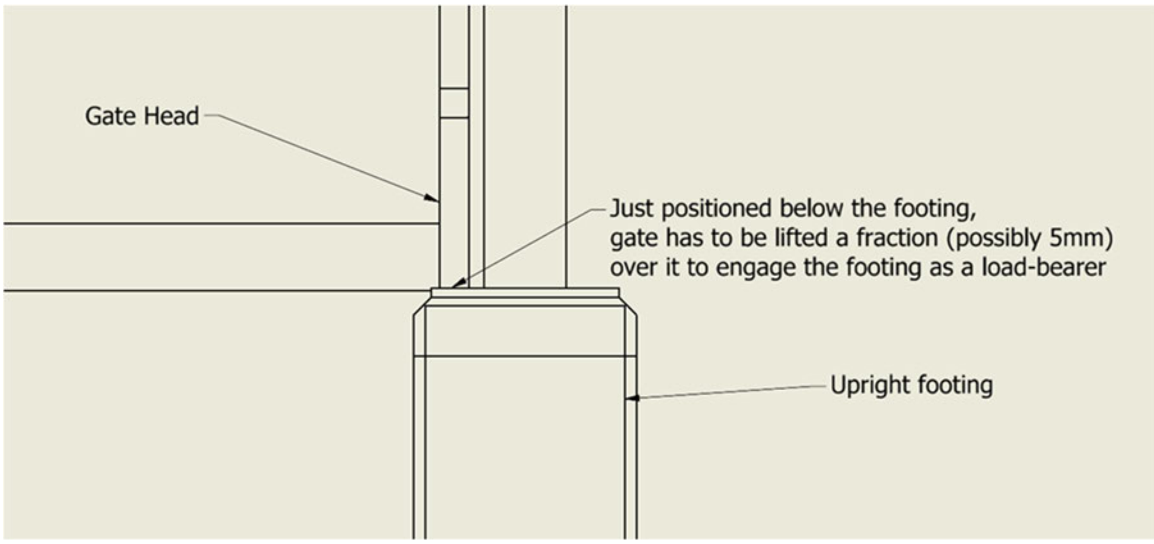


Figure 44: Prototype Design - Revised height of gate to incorporate load-bearer footing

This method is simple yet will decrease the load significantly on the hinges. Increasing the longevity of the hinges.

5.2.3 Trough mounts

The trough mounts are designed to position and strengthen the trough body to accommodate the added weight of the water. Since the gate cannot change width, the trough mounts will utilise the existing members to support the trough body. Important considerations must be taken into account when selecting this mounting solution for the trough, including its height, the side of the gate on which it will be installed, geometric considerations for strength, and how it can be effectively utilised for a tipping solution.

5.2.3.1 Trough position – Height

The height of the water trough relative to the ground is an important consideration. In conventional water troughs, the positioning on the ground limits the height to the height of the structure which is typically 600 mm. However, a gate mounted water trough can be strategically targeted for specific breeds and ages of cattle that require access to water. An appropriate height for a water trough is between 0.5 m and 0.7 m, according to the Agriculture and Agri-Food Canada research paper "*Troughs for watering range livestock*" (Agriculture and Agri-Foods Canada, n.d.). This range accommodates different ages and breeds, with some requiring shorter heights and others taller. In this project, the breed in question is Wagyu, a Japanese dairy breed of medium height. The general dimensions for this breed are shown in Figure 45.

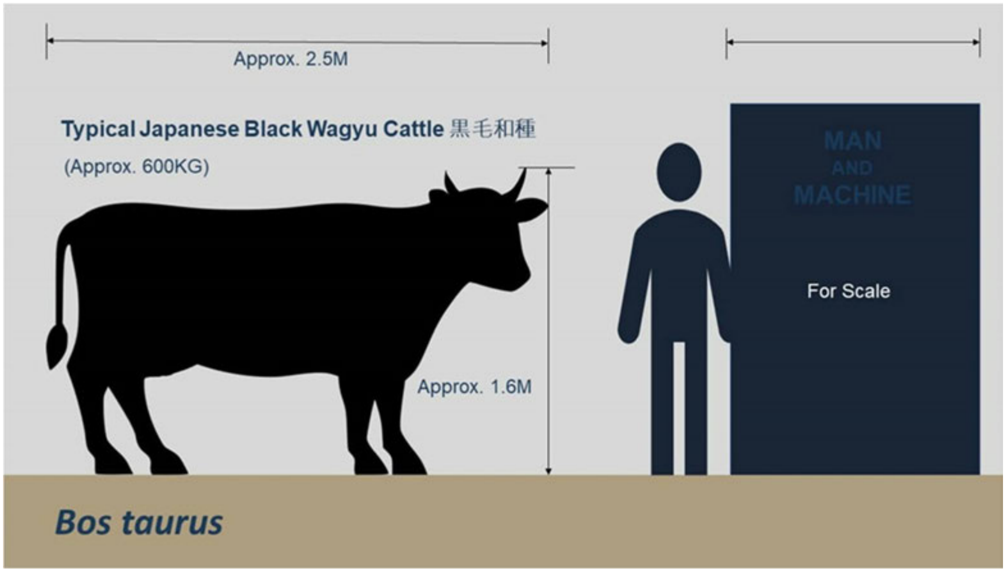


Figure 45: Prototype Design - Conceptual dimensions of Wagyu cattle, (Facebook.com, 2014)

As shown in Figure 45, the average height is around 1.6 m. It is anticipated that there will be minimal deviation from this height in this arrangement due to the growth rates and similar ages of the cattle. Consequently, the optimal watering height for the cattle in this covered housing arrangement can be tailored to their height and does not need to conform to the conventional 700 mm height. This allows the trough to be positioned anywhere from 700 mm to approximately 1000 mm above the ground surface.

5.2.3.2 Trough position - Side

The position of the trough on the gate is a consideration. There are three options for the trough's positioning: entirely on the cattle side, entirely on the feed side, or centred between the two. Each option presents its own advantages and disadvantages as shown in Table 13 and a clear conclusion will be drawn regarding the most suitable choice.

Trough side	Advantages	Disadvantages
Cattle side	• Closer to cattle	• Harder to tip the water away from the pen • Difficult to access without entering the pen • More exposed components to cattle interaction
Feed side	• Allows easy maintenance • Components can be far away from cattle interaction • Easier to tip onto concrete apron which will lead the water to a drain	• Cattle will have to stick head through gate
In between (middle of gate)	▪ Good centre of motion	• Limited room • Complication for tipping arrangement • may become cumbersome with latches and levers etc

Table 13: Positioning of water trough – Advantages and disadvantages

It is evident from this brief analysis which option is preferred. Ultimately, the feed side (the side outside of the pen) emerges as the option with the fewest and most manageable disadvantages. Engineering solutions can be implemented to address the identified disadvantages, such as raising the gate height to facilitate easier access for cattle to place their heads through.

5.2.3.3 Trough support structure

Now that the side position has been determined, it is necessary to generate solutions for the trough support structure. This support structure should include a framework that extends the trough away from the gate, positioning it at an optimal distance for cattle access. Additionally, it should provide ample space for the tipping mechanism to operate smoothly. From a strength perspective, a triangular configuration would be ideal, as this design aligns with the weight of the trough itself. It would also be advantageous for the structure to be constructed from the same material as the gate, specifically 50x50x3 mm SHS. If a structure of this nature is welded to the gate, there should be minimal risk of fracturing or failure, given that the maximum weight will be 209 kg distributed across two heavy-duty reinforced points. To provide a clearer understanding of this structure, a 3D model has been created as shown in Figure 46.

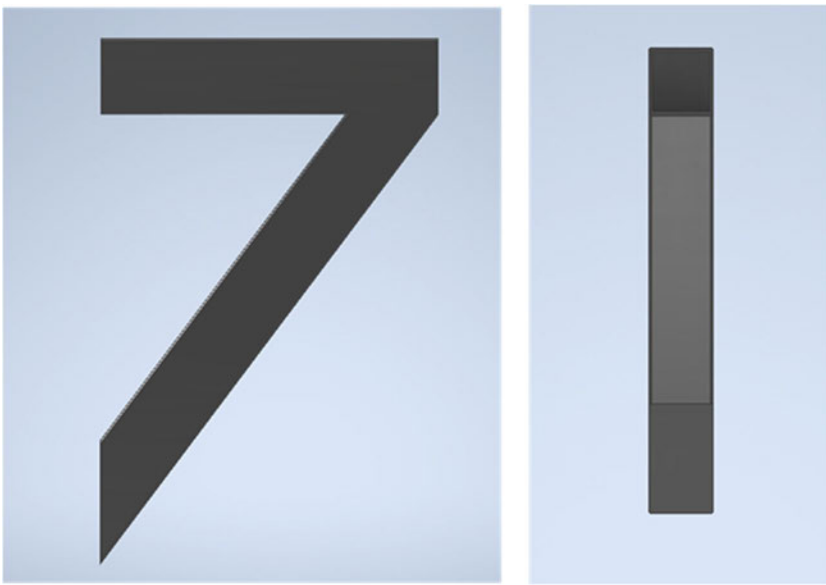


Figure 46: Prototype Design - Trough Support Structure, Side and Front 3D views

The general shape of these mounts will primarily maintain the triangular design; however, adjustments may be necessary regarding the distances based on the trough's tipping mechanism and the overall height of the trough. These modifications can be incorporated into the gate assembly for demonstration purposes, along with the adaptations required to ensure that cattle heads can fit through comfortably.

5.2.3.4 Trough position – Length

Due to the positioning and protrusion of the trough support structure, there may be limitations on the swinging arc of the gate (of only around 200 degrees), as potential interference with adjacent shed infrastructure, such as the column uprights and footings, would not be ideal. To address this concern, a gate extension was developed to enhance the operational functionality of the design.

The proposed solution involves adding an extension to the gate frame, which will create a buffer zone to ensure that it can swing more freely without obstructing the surrounding infrastructure. The minimum length for this extension has been determined to be 300 mm. This adjustment requires the introduction of an additional (dummy) gate head and filler gusset pieces to the gate frame. Consequently, the length of the trough body will also be reduced by 300 mm to avoid interfering with the swinging motion. This adaptation can be found in Entire Gate Iteration 2 in Appendix D – Design, however for analysis purposes the newly revised swing angle was modelled in Autodesk Inventor and displayed in Figure 47.

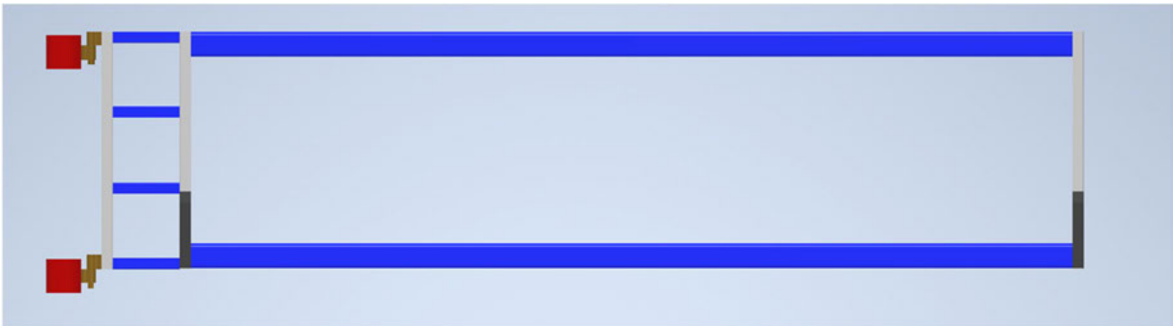


Figure 47: Prototype Design - Entire Gate Iteration 2, gate extension showcases

The gusset pieces will also be made from SHS 50x50x3 mm, 300 mm in length. This buffer will now allow a maximum 260-degrees swing arc as shown in Figure 48.

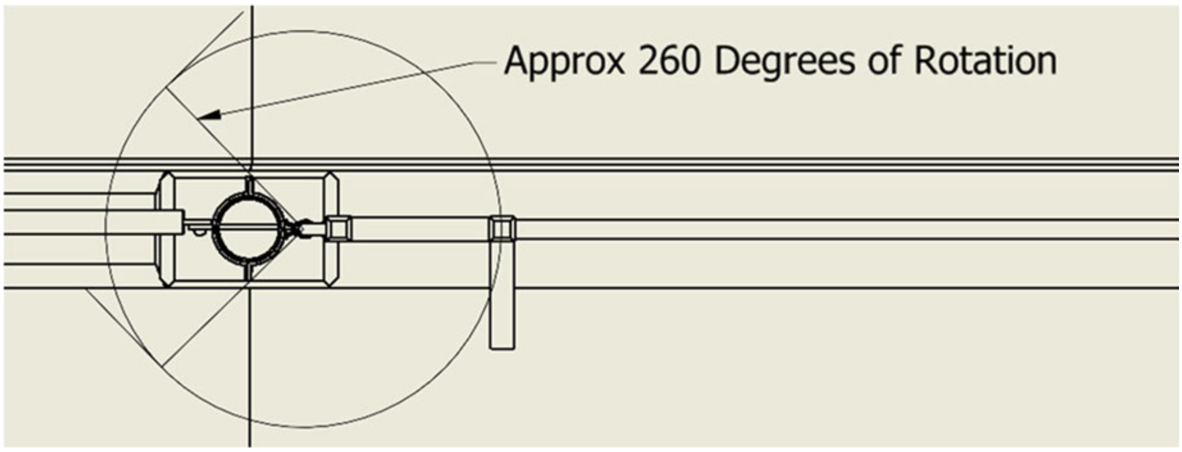


Figure 48: Prototype Design - Schematic of allowable swing angle

Additionally, it is important to note that the middle rail has been removed to provide sufficient space for cattle to pass their heads through the gate unhindered, thereby reducing the risk of them getting stuck.

Given the adjustment in the support location for the trough, it is necessary to shorten the trough body accordingly. This reduction in length will also require an updated calculation of the volume and weight. While a decrease in volume might initially seem detrimental to the overall design, it can provide advantages in terms of structural strength. Below are the revised dimensions and volume of the trough body at maximum capacity.

Length was shortened by 300mm plus the additional gate head. Meaning a total of 350 mm is taken off the original length. The revised length of the trough body can be calculated as seen in Equation 10.

Equation 10: Revised Volume for trough

$$Hence, \quad 4616mm - 350mm = \mathbf{4266mm} \text{ or } \mathbf{4.266m} \text{ is the new length}$$

Hence utilising the volume formula again:

$$V = \frac{\pi * r^2 * h}{2}$$

$$Where, \quad r = \frac{340}{2} = 170mm = \mathbf{0.17m}, \quad h = 4066\,mm = \mathbf{4.266\ m}$$

$$Hence\ V = 0.193\,m^3\ @\ 100\%\ capacity$$

$$In\ Litres = 193L = \mathbf{193\ kgs}\ of\ water\ weight\ (New\ maximum\ working\ weight)$$

5.2.4 Trough tipping mechanism

This section will develop a solution for draining water from the troughs through the implementation of a tipping arrangement. Unlike conventional concrete troughs, which necessitate in-ground plumbing that can be costly and difficult to maintain, a tipping arrangement will drop trough water directly outside of the pens onto the concrete drains which also direct roof runoff to the stormwater collection pond. This method is feasible due to the presence of the concrete drains in place. Additionally, the covered housing has a 3% grade over a length of 200 m, ensuring that water tipped from the trough will flow effectively away from the shed into designated catchment areas.

Implementing such a straightforward process will significantly reduce cleaning and maintenance time, allowing for increased attention to other areas of the intensive feeding operation and enhancing overall production efficiency. Consequently, it is essential to develop a quick and effective system to meet these objectives. Critical thinking is necessary, as the introduction of engineering principles and general rotational techniques can provide a simple yet effective solution. Over-engineering this solution could lead to an excessive number of moving components that may not withstand the harsh environment.

The rotation of components typically involves an axle-type setup, commonly found in equipment such as cars, trailers, cement mixers, and kitchen blenders. A proposal has been made to introduce a static axle at the ends of the trough, guided by a bearing hub system attached to the trough supports. This approach offers a simple solution that does not require intricate or non-standard fabrication techniques. Thus, the two system components can be categorised as Axle Design and Axle Hub Design.

Firstly, the centre of gravity of a semi-circle formula also known as the centroid was determined for the axle as shown in Figure 49. The centroid can be calculated using Equation 11.

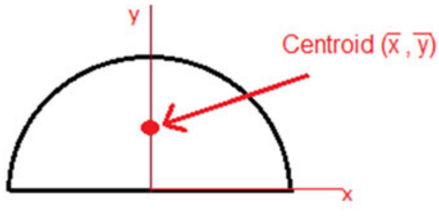


Figure 49: Mathematic Theory - Illustration of Centroid (Study.com, 2022)

Equation 11: Centroid for Axle

The radius of the semi-circle shape is 0.17m (170mm). Hence the centroid –

$$y = \frac{4 * 0.17}{3\pi} = 0.072m = 72mm$$

Note: If the radius of the trough is to change, this calculation will be required to be completed again.

Now that the centre point has been established, the available working position on the surface of the trough body end plate can be accommodated. The maximum axle diameter has been determined to be 120 mm to ensure proper fitment through welding. However, a smaller outside diameter can also be utilised, as it will still function for this application. Upon analysing various sizes, the optimal choice is a 3-inch (76 mm) brushed 304 stainless steel circular hollow section (CHS) with a 1.6 mm wall thickness (Bend Brothers Guarantee, 2024). This material is available from multiple suppliers, an image of the circular hollow section can be found in Appendix D – Design.

The length of the axle will be determined once the axle hub design has been finalised. As a placeholder, a standard axle length of 100 mm has been selected, which can be definitively analysed once the axle hub design is generated. The 3D model of the axles attached to the trough body is presented in Appendix D – Design.

5.2.4.1 Strength analysis

To determine whether the axle attached to the 3 mm end plate is sufficient from a general strength perspective, a simple stress analysis involving the water load on the axle points can be performed. The force can be calculated as the weight of half of the trough at full volume multiplied by gravity. The calculation can be performed using Equation 12.

Equation 12: Total Force on Axles

$$Force\ on\ Axle = \left(\frac{193}{2}\right) * 9.81 = 946.7\ N$$

Since this analysis accounts for the maximum load that could be experienced at this length and inner diameter for the trough body, any adjustments to reduce the size of this component would indicate that it is inherently strong enough.

This stress analysis can be done through Autodesk Inventor. The process of this operation was as follows:

1. Applying pin (rotation in the x-axis) joints to the axles at the furthest point;
2. Assigning material as stainless steel;
3. Applying an appropriate all round shell thickness as 3mm will give a good estimate of the displacement and pressures this trough body will experience at full capacity;
4. For which the simulation button can be pressed.

The results are as shown in Figure 50 and Figure 51. The analyses focus on the overall displacement on the trough, to assess rigidity and movement of the entire component at maximum load.

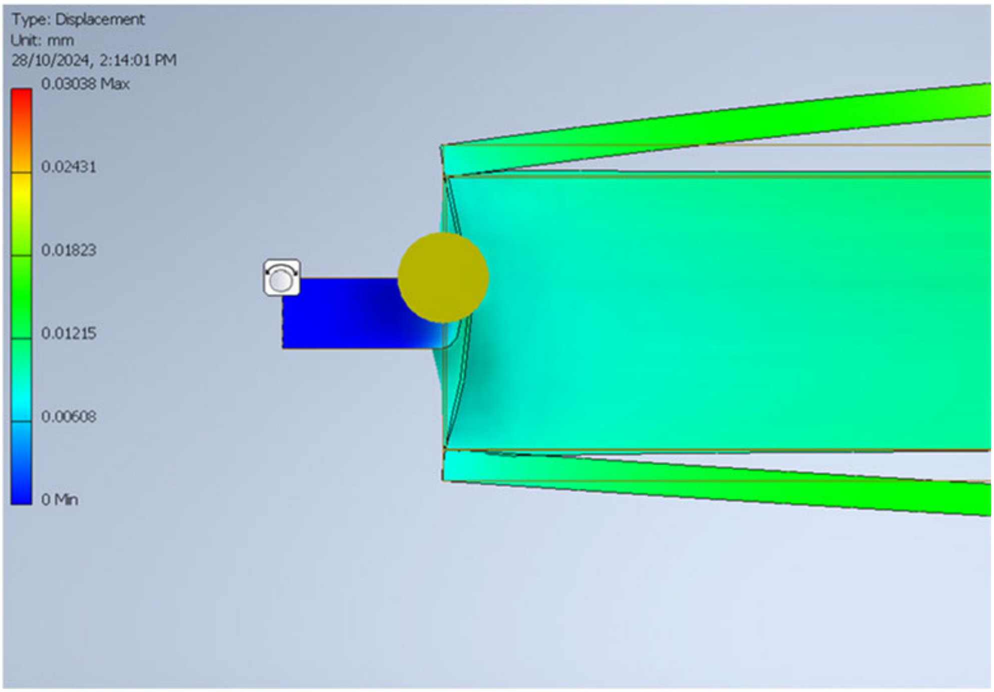


Figure 50: Stress Analysis 1 - Top View of Trough - Radial Loading on the axle

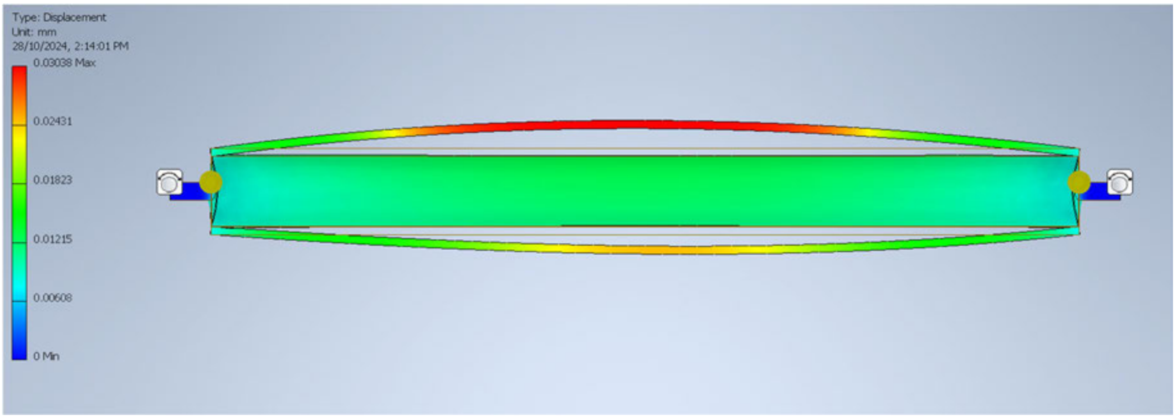


Figure 51: Stress Analysis 1 - Top view showing where the most displacement occurs.

This analysis indicates that the plate connecting the axle to the trough body may not possess sufficient strength to support the load on its own. Minimising flex and wear on the stainless-steel plate is essential to ensure the longevity of the structural integrity of the trough system.

5.2.4.1.1 Trough body strengthening

5.2.4.1.2 Axle strengthening

To address this issue, a strengthening structure was proposed for the plate, maximising the surface area on the axle attachment points (welds) to distribute pressure and reduce reliance on the single 3 mm plate. This was achieved through the addition of a hollow box extension that encases the axles at either end as shown in Figure 52 and Figure 53. This design increases the surface area for the welds and material interaction, allowing the joints to theoretically withstand twice as much stress before compromising the overall displacement at the attachment to the trough body.

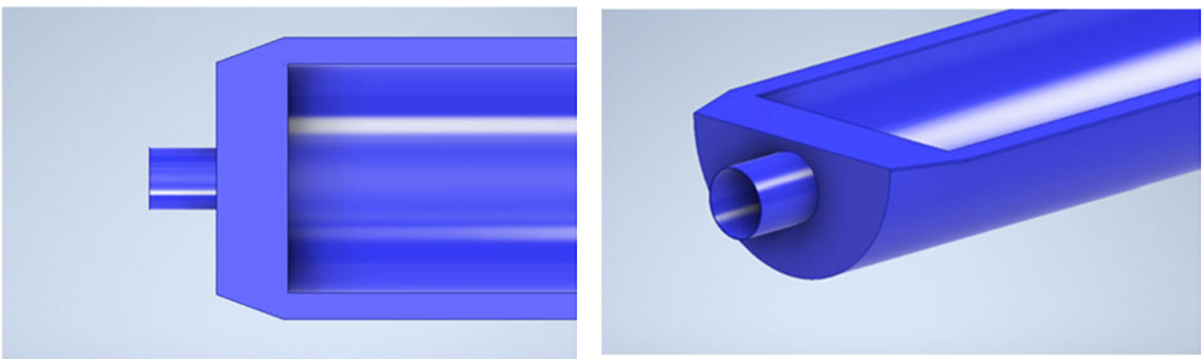


Figure 52: Prototype Design – Trough body iteration 2 Top and isometric views respectively

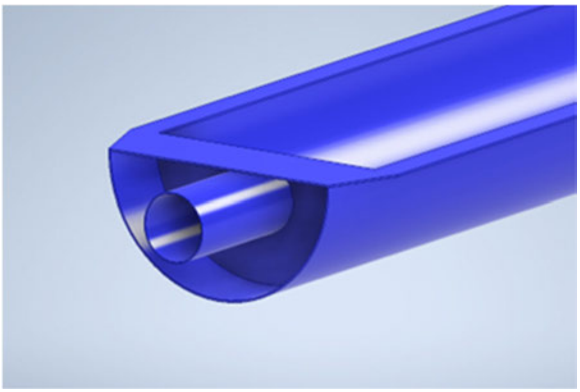


Figure 53: Prototype Design – Trough body iteration 2 spliced isometric view

5.2.4.1.3 Lateral strengthening

The trough body was also strengthened laterally which aimed to strengthen the middle section where displacement is greatest (indicated in red on Figure 56). This approach aligns with engineering principles, as the largest moment will occur at the point farthest from the supports. Incorporating some welded structures within the body will suffice, while minimising external structures to avoid interference with other components. A viable solution involves welding strengthening plates along the interior of the trough and creating strategically placed holes to allow for unobstructed water flow as shown in Figure 54. This design principle also helps to reduce forced splashing caused by any current movement, similar to how petroleum haulage tanks utilise dividers to prevent significant momentum-based sloshing. For analysis and visual purposes, a stress analysis was conducted again to illustrate the impact of the strengthening structures. Another view of this can be found in Appendix D – Design.

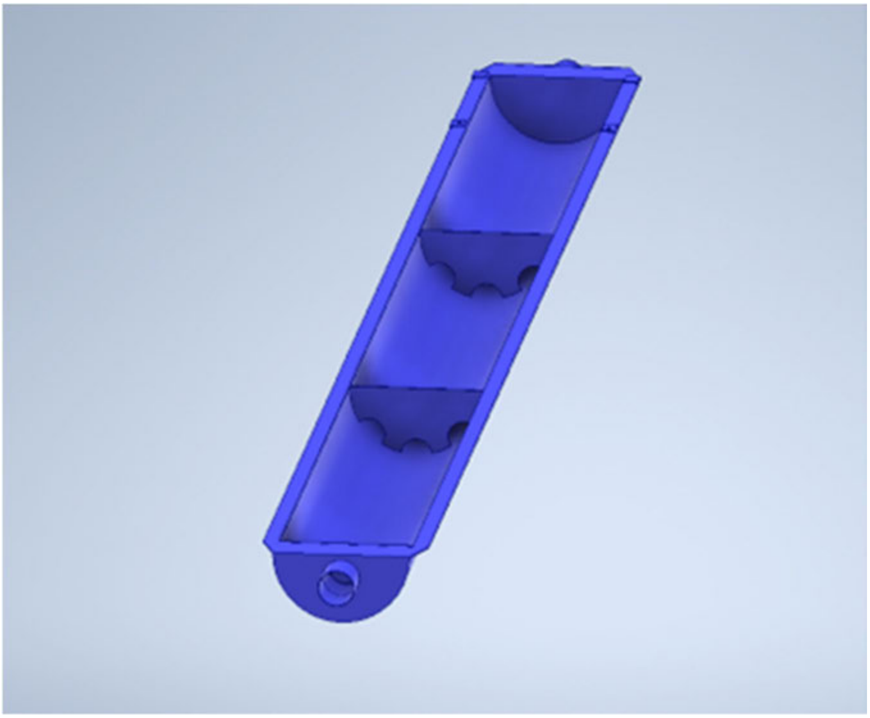


Figure 54: Prototype Design – Trough body iteration 2 with lateral strength plates

A stress analysis was undertaken on the revised trough body using Autodesk Inventor. The results are shown graphically in Figure 56 and Figure 57 and tabulated in Table 14.

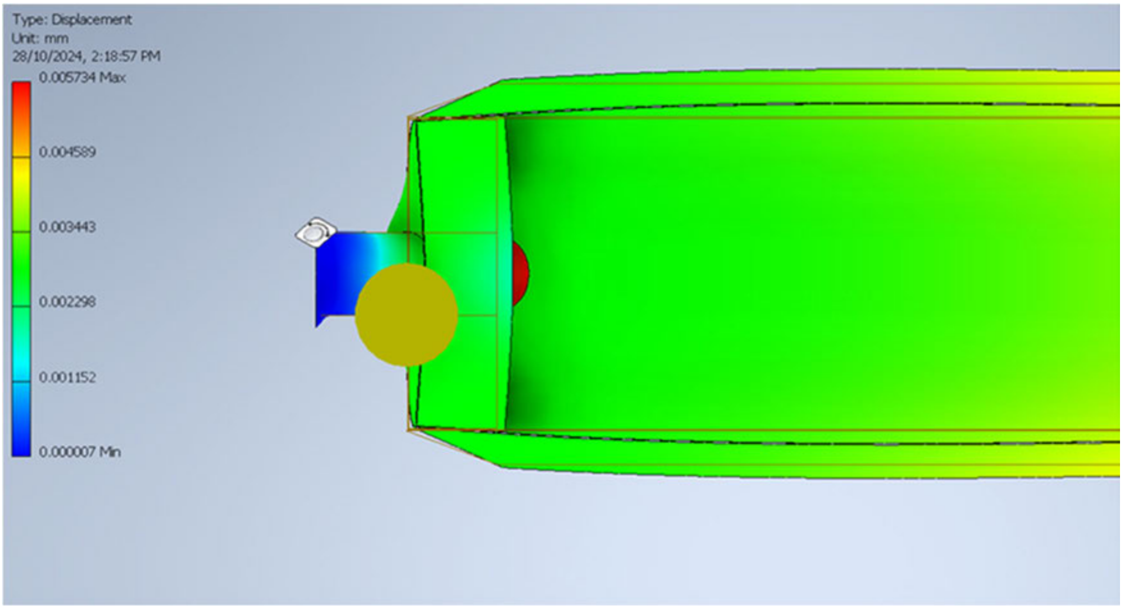


Figure 55: Stress Analysis 2 - Revised stress analysis focused axle displacement

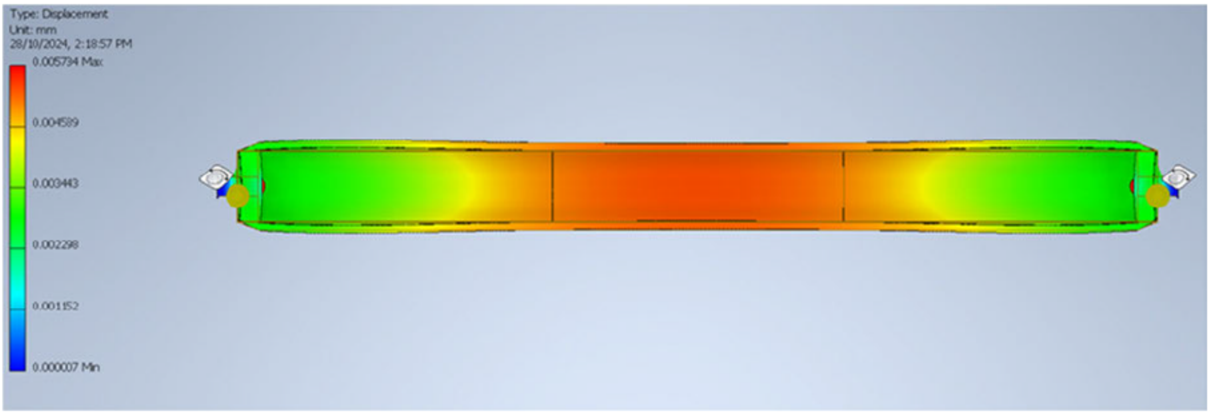


Figure 56: Stress Analysis 2 - Revised stress analysis entire body displacement

	No strengthening attributes	Strengthened attributes	Difference (%)
Max displacement	0.03038 mm	0.005734 mm	Approx 81.1 % Reduction in displacement.

Table 14: Stress analysis results comparison

This reduction in displacement means there will be less movement in the system for where would create higher stress points over time. The application of these strengthening attributes has decreased any displacement and movement in the material by roughly 81% which is a more than acceptable outcome from this exercise.

However, due to modifications made to the length of the trough body and the addition of boxes for axle support, both the length and weight of the trough will decrease. This reduction implies that the forces applied in the stress analysis will be rated higher than what will actually be experienced in the field, resulting in less displacement of the axles and the plates to which they are attached. Furthermore, the inclusion of the strengthening boxes, which introduced 200 mm of material that prevents water entry, necessitated an additional shortening of the trough. The revised water volume of the trough can be calculated using Equation 13.

Equation 13: Revision of Water Volume 2

$$Hence, \qquad 4216mm - 200m = \mathbf{4066}\boldsymbol{mm}\ or\ \mathbf{4.066}\boldsymbol{m}\ \ is\ the\ new\ length$$

<u>Hence utilising the volume formula again:</u>

$$V = \frac{\pi * r^2 * h}{2}$$

$$Where, \qquad r = \frac{340}{2} = 170mm = \mathbf{0.17}\boldsymbol{m}, \qquad h = 4066\,mm = \mathbf{4.066\ m}$$

$$Hence\ V = \ 0.193\ m^3\ @\ 100\%\ capacity$$

$$In\ Litres = 193L\ = \mathbf{193}\ \boldsymbol{kgs}\ of\ water\ weight\ (New\ maximum\ working\ weight)$$

5.2.4.1.4 Axle hub material and design

The purpose of the axle hub is to regulate the tipping movement, ensuring that it remains stable and allows for uniform rotation. Therefore, the axle housing must match the axle size, allowing for small tolerances whilst incorporating a method to minimise significant friction. Additionally, a bracket system will be necessary to connect this component to the trough supports. This bracket should also be constructed from stainless steel to withstand potential exposure to water. Fabrication of this component will require various sections of stainless steel, with modifications based on available materials, while maintaining the same fundamental principle. A general shape of the bracket has been developed and is illustrated in Figure 57.

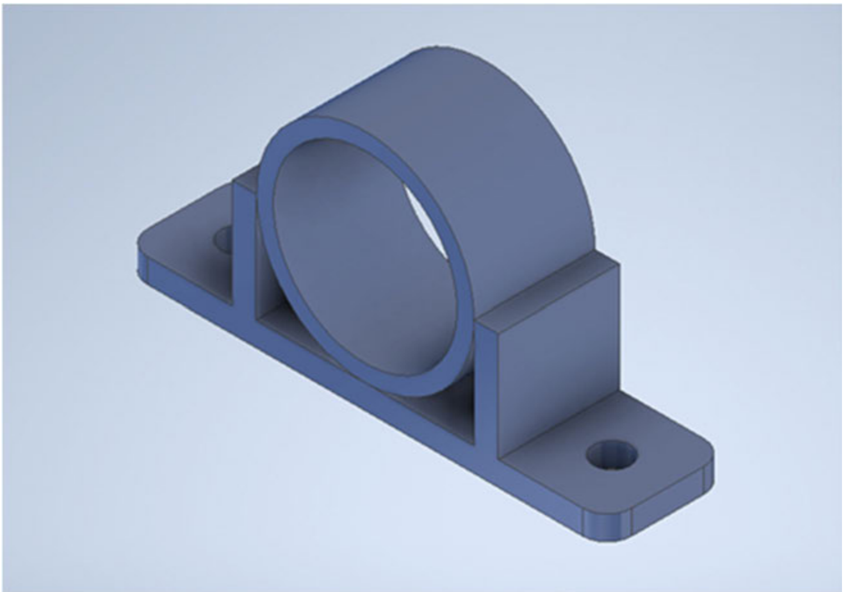


Figure 57: Prototype Design – Axle Hub 3D model

The bracket designed for this application features a fully welded construction with support plates made from thick 10 mm stainless steel, providing optimal strength. It includes two M15 bolt holes for fastening to the trough supports, facilitating ease of maintenance or disassembly. Two axle hubs will be utilised, one at each end of the trough body. To ensure smooth rotation, a grease nipple will be positioned on top of the encasement for lubrication. The length of the axle hub can be determined using Equation 14.

Equation 14: Axle hub length

$$Width\ of\ Hub = 50mm$$

$$Tolerances = 50mm$$

$$Therefore,\ \ length\ of\ axle = \ 100mm$$

This confirms the original length determined from the stress analysis.

As a secondary consideration, the axle rotation allows for 360 degrees of movement. This means that when the trough is level, it can tip in either direction, relying on balance to maintain stability. To prevent tipping in the undesired direction, a bump stop is necessary. A design proposal includes the addition of a small bump rail on the gate, which, when used in conjunction with the lip of the trough body, will mechanically restrict movement in the opposite direction. This bump rail will also enhance the strength of the gate. It does not need to be as large as the oval cattle rails; a 50x50x3 mm SHS length will be sufficient, as it is compact, strong, and features flat edges.

5.2.4.2 Finalised major structure

With all major structural components addressed, now the compatibility of these components can be finalised. It is crucial to outline all required frames and their positioning before addressing the minor components. Minor components refer to parts that do not significantly impact the overall structural positioning and strength of the system and can be more easily adapted to the major components. This section will address minor and miscellaneous issues arising from the creation of these components.

5.2.4.2.1 Modifications to the trough supports

The first modification involves lowering the height at which the trough will sit, creating more space between the trough body and the cattle rail. This adjustment can be achieved by modifying the heights of the trough mount supports. This allowed more room for the cattle to get their head through.

Secondly, it has been observed that the supports do not efficiently position the trough, particularly regarding the placement of the anti-tip lip over the rail. Therefore, the supports were lengthened and repositioned directly beneath the centre line of the axle hub as shown in Figure 58 and Figure 59.

These modifications can be implemented simultaneously, as they pertain to the trough supports. The final structure reflects these adjustments, with a decreased support height and a 45-degree support positioned to ensure that force is applied through the centre of the support. The bolt holes have been strategically positioned so that the axle hub places the trough just before the bumper rail, as shown in Figure 60.

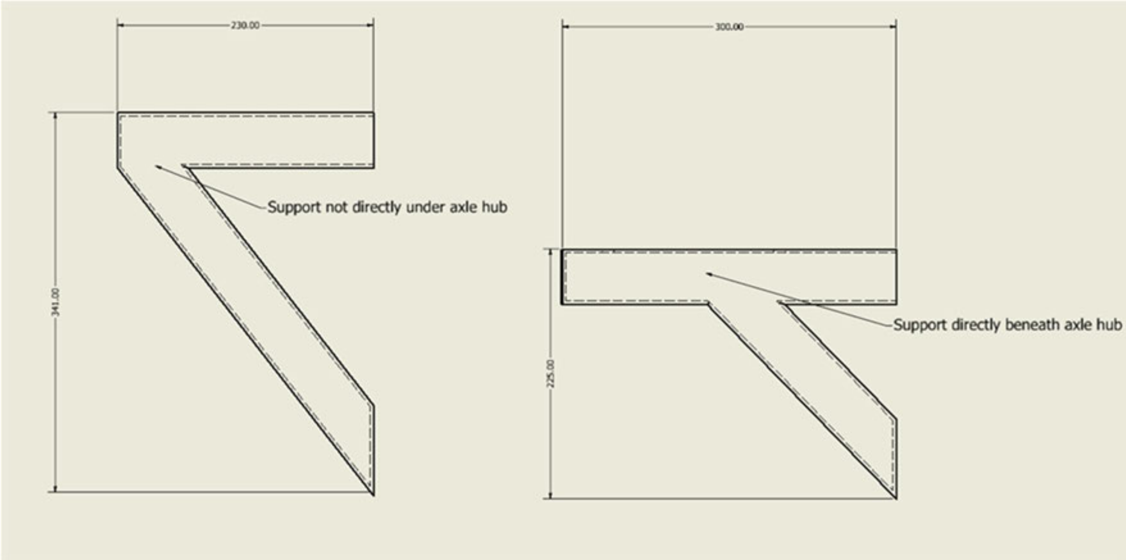


Figure 58: Prototype Design – 2D Drawing of trough support comparisons

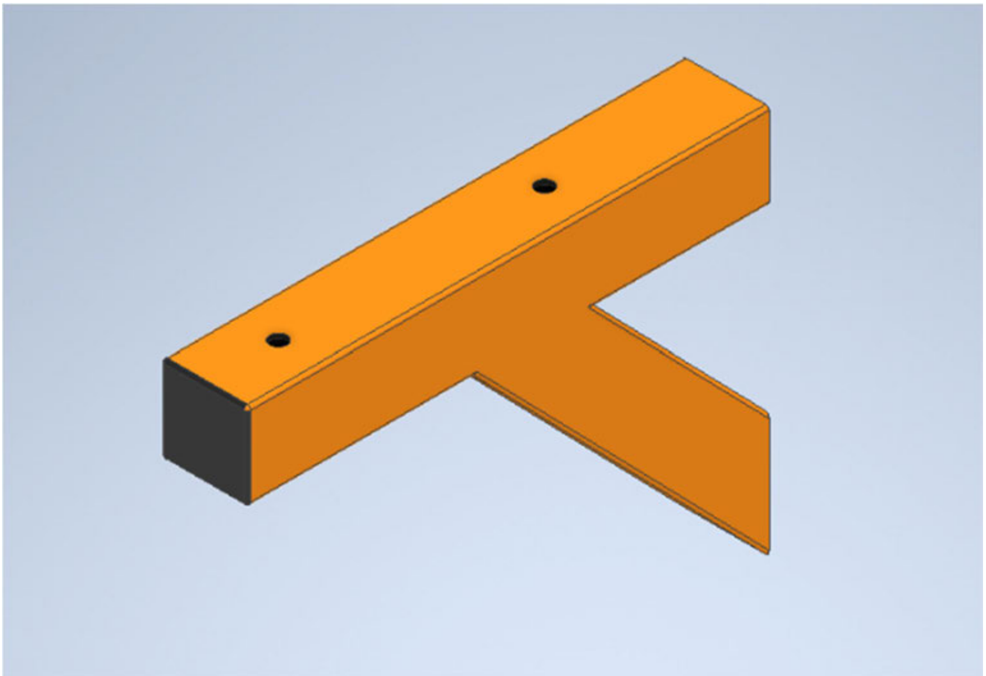


Figure 59: Prototype Design – Revised trough body support, isometric view

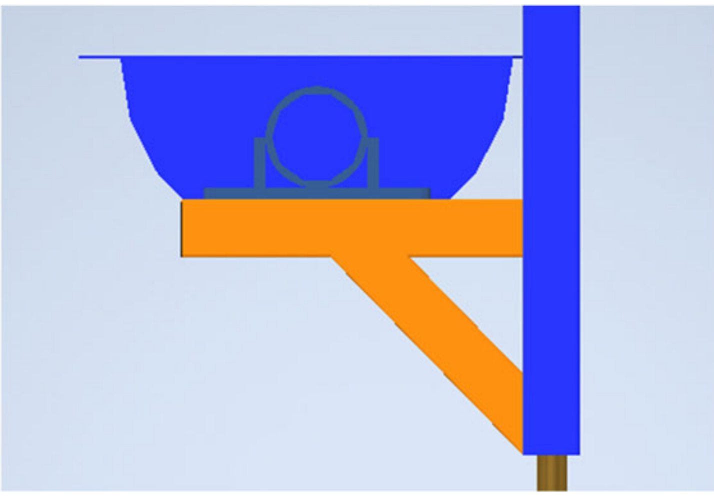


Figure 60: Prototype Design – Revised trough body support, side view of assembled components

5.2.4.2.2 Adaptations to the trough body

The 40 mm wide lip on the trough body currently does not adequately cover the surface area of the 50x50x3mm SHS bumper rail. To address this, the width of the lip can be easily increased to utilise the bumper rail more effectively. The lip has been extended from 40 mm to 65 mm, as shown in Figure 61 providing sufficient clearance and allowing it to sit securely over the 50 mm bumper rail.

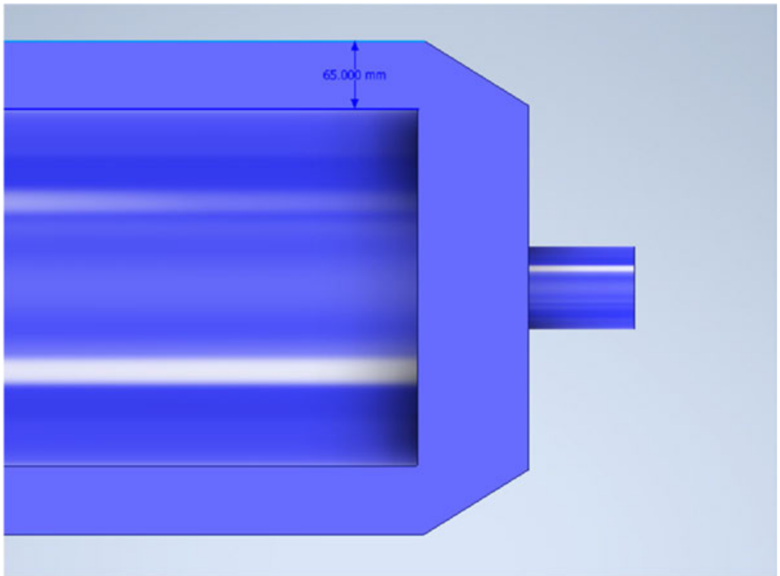


Figure 61: Prototype Design – Revised trough body lip, top view of revised lip size

The integration of the tensioner hinge into the gate frame will be executed, along with the addition of a support system to incorporate this feature effectively as shown in Figure 62. This principle was discussed earlier, but an assembly was not presented due to the uncertainty regarding the finalised frame design. Now, the focus will be on incorporating this system into the gate frame as shown in Figure 63.

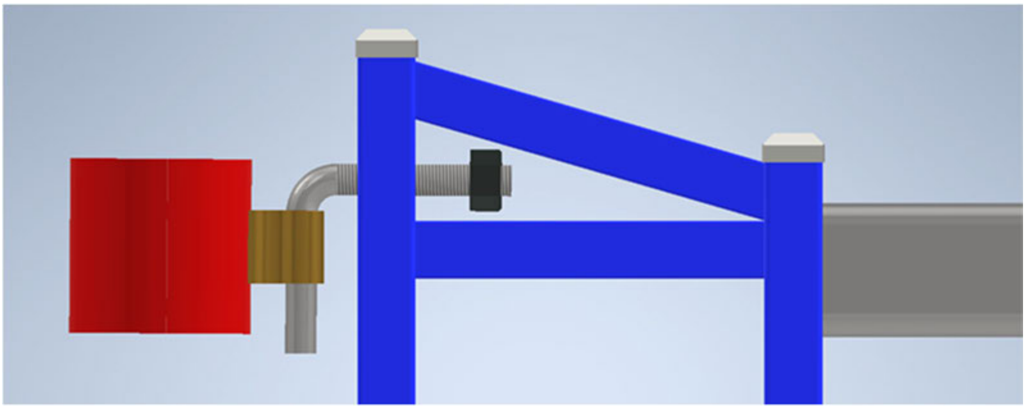


Figure 62: Prototype Design – Gate hinge tensioner, top hinge, side view

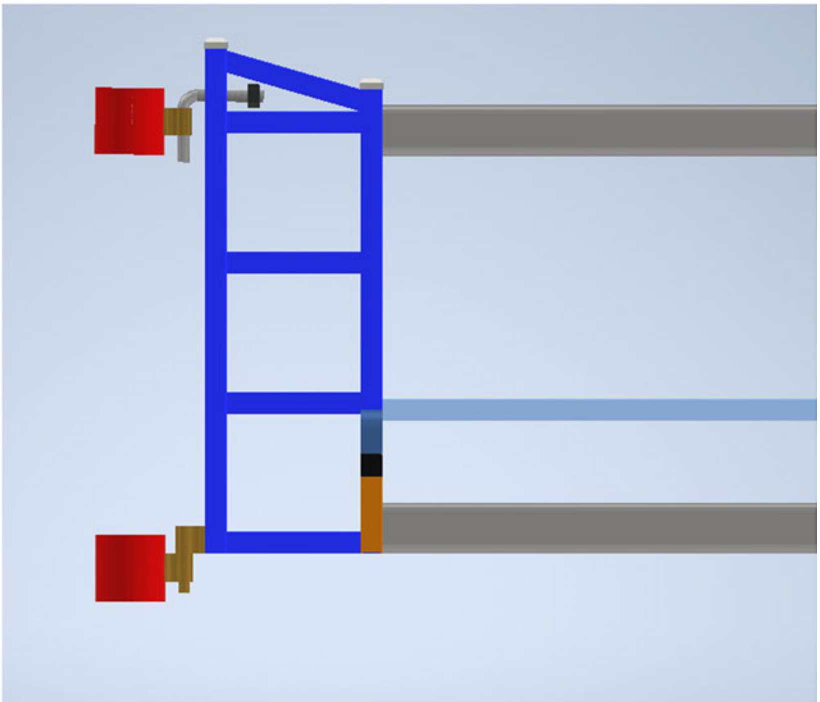


Figure 63: Prototype Design – Gate hinge tensioner, top and bottom hinge, side view

This section concludes the major structure of the gate, for which component design can now continue to integrate more component dependant designs.

5.2.4.3 Trough locking mechanism

Since the trough cannot physically tip backward due to the presence of the bumper rail, it is essential to implement a mechanism that prevents it from tipping pre-emptively the correct way. This solution will resemble a latch system that can be easily disengaged to allow tipping and then secured again afterward. A handle will facilitate the tipping process, making it easier for operators to manage.

A critical consideration for this mechanism is its resistance to cattle interference. Cattle tend to play with dangling or moving parts throughout the day, making it vital that the system is designed to withstand such interactions, especially since it is crucial for ensuring the well-being of cattle by providing water. Chapter 15 of Watts et al. (2016) states that gate latches, or in this case, trough latches, "*should prevent curious cattle from working out how to open the gate.*" The same principle applies here, where a simple yet effective mechanism is optimal, ideally consisting of only two components.

The first component could be a lever that enhances the ease of use for the trough tipping feature. The design should be straightforward, as the dirty conditions typical in feedlots—characterised by the accumulation of saliva, dust, and hair—can shorten the lifespan of intricate mechanical components. Therefore, the mechanism will prioritise simplicity and durability.

The lever may take the form of a bent or angled upright, constructed from smaller stainless-steel tubing to provide a firm grip for the operator's hand as shown in Figure 64. The bent design can facilitate a locking mechanism that involves a steel ring placed around the handle and one of the gate heads as shown in Figure 66 and Figure 67. When the ring is slid upward, it disengages from the handle, allowing the trough to tip. To secure the system, the handle can be positioned near the gate head, and the ring can be squeezed back onto the handle, tightening as it moves downward due to the bend. This design offers a simple yet effective method to prevent curious cattle from tampering with the trough while ensuring its solid security.

Figure 64: Prototype Design – General shape for tipping handle

This handle will be securely attached to the trough body through a combination of bolting and welding to ensure strength and durability as shown in Figure 65. This component has been integrated into the trough body and is illustrated in Appendix D – Design, which includes accompanying views of the handle's integration.

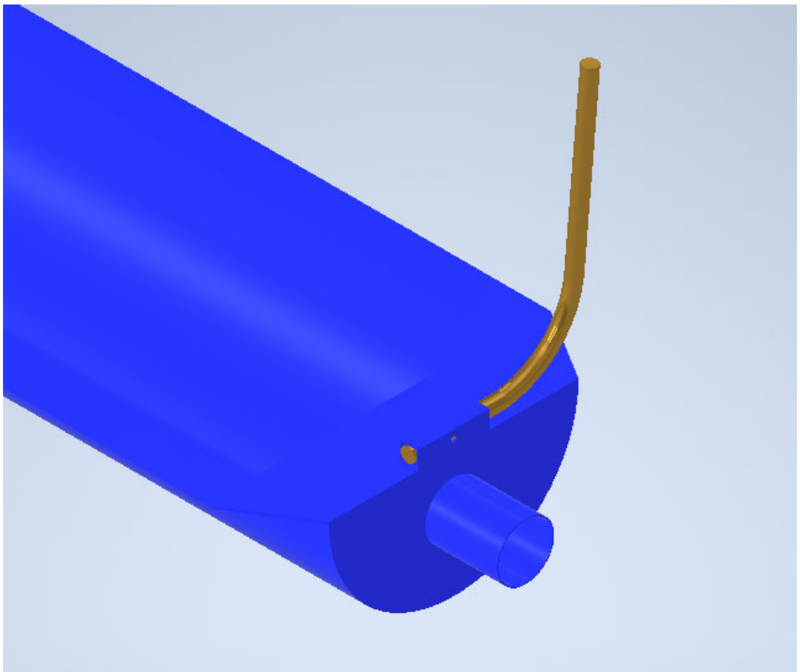


Figure 65: Prototype Design – Isometric view of handle attached to trough body

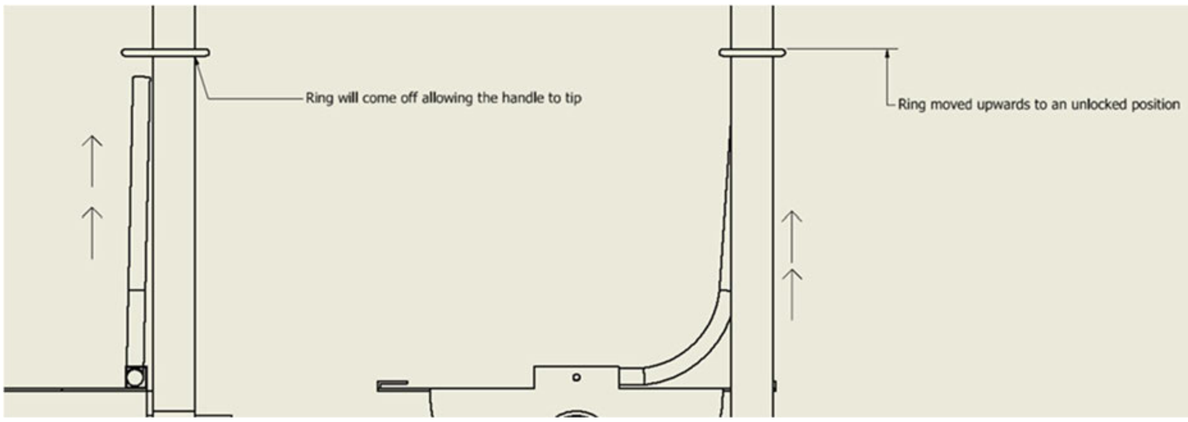


Figure 66: Prototype Design – Trough locking mechanism, schematic of unlocking process

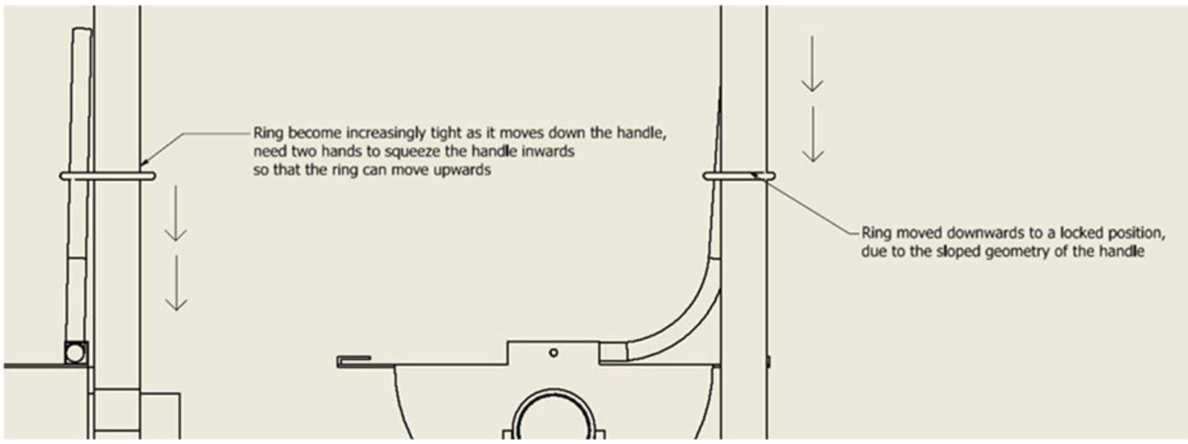


Figure 67: Prototype Design – Trough locking mechanism, schematic of locking process

5.2.4.4 Trough Float system

The final component involves integrating a float into the tipping trough system, which is essential for maintaining a full volume of water in the trough at all times. In conventional troughs, the float operates under static conditions, keeping the water level constant. However, since this trough will be tipping, the float system must be compatible with this dynamic scenario. This challenge has not been previously addressed, resulting in a lack of established standards or materials to guide the implementation of a float in this context. This section involved the development of a reverse engineered system that will be both beneficial and functional for the operation.

To facilitate reverse engineering, several key parameters must be established:

- The system must fill the trough quickly to compensate for the reduced volume. This consideration includes evaluating the water carrier systems, pipe sizes, and types of floats to be utilised.
- The float mechanism must be positioned to avoid interference with other operations and the swinging gate. The placement needs careful consideration.
- Maintenance must be straightforward, and the float system should be designed to protect against cattle curiosity.

These questions will be addressed systematically to develop a viable solution.

5.2.4.4.1 Water pipe delivery system

The delivery of water to the trough system is a crucial factor as it will determine whether any additional systems are necessary to ensure that the trough can be filled at the desired rate. Understanding the existing infrastructure will also help narrow down the options for components such as the type of floats that can be used and the size of fittings required. The current setup of the covered housing arrangement is straightforward. Water is pumped to large tanks (Figure 68) positioned at a high elevation on the site, and water is then gravity fed to the covered housing system by pipes.

Figure 68: Struggle Downs Feedlot - Water storage tank (RDC Engineers Pty Ltd, 2024)

5.2.4.4.2 Pipe Sizing

There are 3 pipe sizes that are used in this system, the water main from the storage to the bottom of the shed is a steel 100mm inside diameter pipe, the next is an 80mm inside diameter PVC pipe that connect the water main to 6m suspended pipes that run parallel with the roof of the shed, and lastly is 50mm inside diameter PVC piping which runs perpendicular downwards for which the valves and hoses are connected to service the troughs. For analytical reasons the flow rate could be calculated through each one of these pipelines to address the possible flow rates in each this will not be necessary as the elevation will be the same for the water main as the 50mm ID perpendicular pipe for which the trough float can accesses. Therefore, analysis for the 80mm pipe is not critical.

The entire piping system is shown more adequately in Appendix D – Design

5.2.4.4.3 Pipe Elevation

The shed has a 3% grade over its entire length, resulting in a total elevation change of 6 meters from one end to the other. The starting point of the shed is approximately 4 meters below the bottom of the water storage tank.

This configuration allows for a gravity-fed system throughout the entire shed. Understanding the volumetric flow rates available with this setup is essential for analysing the maximum time required to theoretically refill the trough's volume.

Hence, the final diameter is needed, along with the velocity of the flow in the 100mm pipe. To find the flow rate coming out of the 50 mm perpendicular piping Equation 15 was used.

Equation 15: Flow Rate Calculations

$$Pipe\ diameter\ =\ 50mm = 0.025m$$

$$Cross\ Sectional\ Area\ of\ pipe\ 2\ =\ \pi * r^2 =\ 0.00049\ m^2$$

$$Height\ Difference\ =\ 10m\ (max)$$

$$Velocity\ formula\ from\ Bernoillis, v =\ \sqrt{(2gh)}$$

$$Where\ v\ is\ veclotity, g\ is\ gravity, and\ h\ is\ height\ difference$$

$$Velocity\ from\ Bernoillis, v =\ \sqrt{(2 * 9.81 * 10)} = 14.007 \frac{m}{s}\ , through\ water\ main$$

$$Flow\ rate, \qquad Q = A * v = 0.00049 * 14.007 = 0.006 \frac{m^3}{s} * (1000 * 60)$$
$$= 411.6\ L/\min\ (without\ frictional\ affects)$$

This means the flow rate is exceptionally high to begin with, not including frictional effect however it can be assumed that this number will drop accordingly, however will still be a relatively large number. This is much above regular water systems where anything above 35L/min would be sufficient to fill this trough in under 3 minutes. The float that will be used will have to accompany for this higher flow rate, hence after some research and delving into the market a float valve company named ‘Cocky Valve’ (Cocky Valve (2024a) proved to have the most robust, simple and highest allowable flow rates on the market. Which accompany for different sizes and flow rates. With some flow rates ranging from 240L/min to 720L/min (Cocky Valve, (2024b) such as the ‘Ulti Flo Float Valve kit’ which will more than easily account for the maximum flow rate through the piping system at Struggle Downs.

5.2.4.4.4 Float positioning

The positioning of the float is a critical consideration that requires innovative thinking to ensure functionality without interfering with operations. Several parameters can help narrow down the selection process:

- The trough must be out of the way of operations: An optimal location for the float is on the gate, which eliminates any fixed exterior options that might obstruct feed robots or general cleaning equipment

- It must maintain clear contact with the trough body: The float should be positioned close enough to react promptly to changes in the water level. This necessitates its attachment directly to the trough body.
- Must be easily accessible: The float should be positioned where it can be easily monitored and serviced, allowing for quick fixes of any faulty components.

To achieve these goals, an arrangement that allows the float valve to be mounted on the tipping trough body itself was developed. This design will enable the float to move with the trough when tipping while ensuring it remains clear of the gate's swing arc, enhancing both maintenance access and protection for the float valve.

5.2.4.4.5 Float protection

Given the curious nature of beef cattle, it is essential to implement protective measures for the float. A commonly utilised design for float protection includes a robust enclosure that prevents cattle from tampering with the float mechanism while allowing adequate access to the float for maintenance. This design typically features a wire mesh (Figure 69) or perforated metal covering that provides visibility and access while deterring cattle from reaching the float directly. Additionally, the enclosure should be securely mounted to the trough body or gate, ensuring stability and minimising the risk of damage from cattle interactions. Such protective measures will help maintain the functionality of the float system while ensuring the well-being of the cattle.

Figure 69: Conventional Concrete Trough – Typical wire cage float protection (RDC Engineers Pty Ltd)

Alternative methods also incorporate the principle of encasing the float within a protective structure, whether through a panel or cage-like design. This concept can be adapted to the tipping trough design, enhancing the overall functionality. However, conventional methods often lack versatility, as they are typically fixed to the system. Developing a modular protection system would significantly improve maintenance efficiency and operational flexibility.

The system will be designed for quick removal from the trough body, allowing it to be placed out of the way during tipping procedures, thereby facilitating a seamless operation. While the specific shapes and geometries may not be critical, maintaining some conformity with the trough body will simplify manufacturing. A semicircular dome-type hood made from the same steel as the trough body meets all of the above criteria as is shown in Figure 70.

This protective hood could be fixed to the lip of the trough body, supplemented by tabs or a rail system featuring holes for secure pinning. The attachment process would involve:

1. **Attachment mechanism:** Utilising the existing lip on the trough body to create a secure attachment point, ensuring stability during operation.
2. **Modular design:** Designing the hood to be easily removable, allowing for straightforward maintenance and operation without impeding the tipping mechanism.
3. **Flexible operation:** Enabling the hood to be placed aside during tipping to allow unobstructed movement while still providing protection from cattle interactions when in place.
4. **Material consistency:** Ensuring that the hood is constructed from the same material as the trough body to maintain uniformity in strength and durability.

This approach will promote ease of use while effectively safeguarding the float mechanism from potential damage. The procedure for removing the float protection system for tipping or maintenance is as follows:

1. Undo the connection pin: Begin by detaching the connection pin that secures the hood to the trough body.
2. Slide the hood out: Carefully slide the hood out of the rail system, which will free the entire component, including the hose, float, and protection system, as a single unit.
3. Position the component safely: Place the complete system next to the trough, either dangling or resting on the ground, to avoid any obstruction during the tipping process.
4. Complete the tipping feature: With the protection system removed, proceed with the tipping feature as intended.
5. Reverse the process: Once the tipping is complete, reverse the steps to reattach the protection system. Slide the hood back into the rail system, reinsert the connection pin, and ensure everything is secure for operational use.

This method provides a straightforward approach to maintenance and operational flexibility while ensuring the float remains protected during standard operations.

This approach enables quick replacement of the entire float protection system in the event of a failure. It allows for the use of spare components, including the hood and float. If a malfunction occurs, the faulty system can be easily detached from the trough and the water supply, allowing for a seamless interchange with a new unit. This means that the defective float can then be taken to a workshop for repairs without causing any downtime for the trough.

With this principle established, designs can now be developed using a 3D model. Simple adaptations will also need to be made on the trough body to accommodate this system effectively.

5.2.4.4.6 Float hood iteration 1

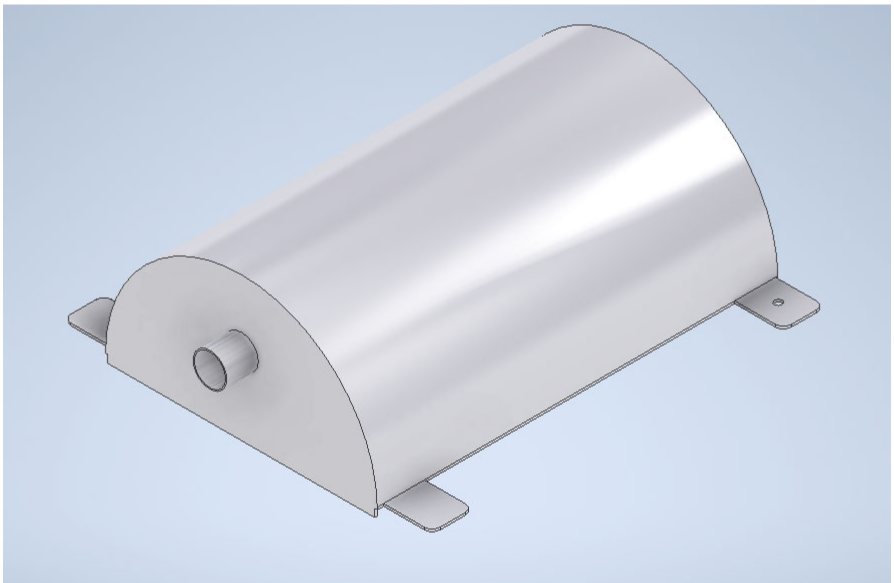


Figure 70: Prototype Design - Float hood, isometric view

The following feature of this float is as follows:

1. A hole for the float attachment, with a diameter of 50mm to match the size of the piping that will be used;
2. Small flat tabs that serve as rails and guidance features; two of these tabs will have holes for pins to secure the system;
3. A length of 500mm to accommodate the desired float assembly; and
4. The diameter matches that of the trough body to ensure aesthetic and functional compatibility between the two components.

More images of this float hood can be found in Appendix D – Design.

5.2.4.4.7 Trough body iteration 3

The trough body was modified to accommodate the float hood. The modification incorporates four simple tabs to effectively secure the float hood in place, complemented by two pin holes that facilitate quick locking and unlocking without the need for a complex mechanism as shown in Figure 71.

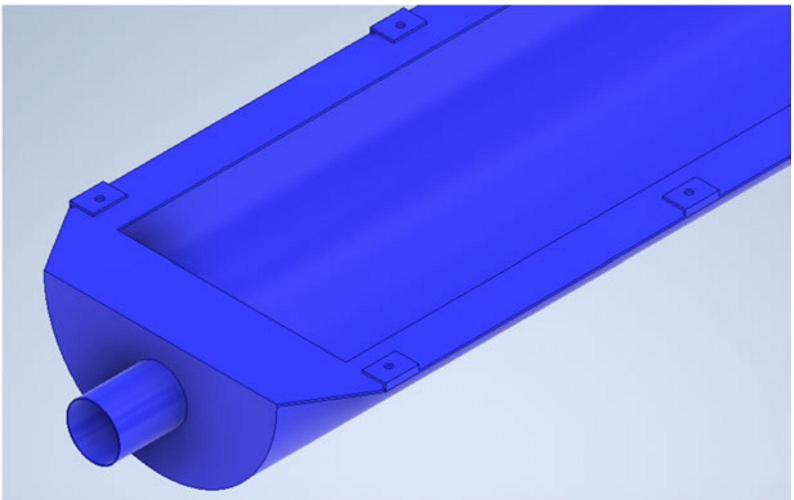


Figure 71: Prototype Design – Trough Body iteration 3, isometric view of tabs added for float hood attachment

To better illustrate component compatibility, the two pieces can be assembled together in the 3D model as shown in Figure 72. In Figure 72 each component is represented in distinct colours to clearly highlight the differences between them. This visual representation aids in understanding how the parts interact and fit within the overall system.

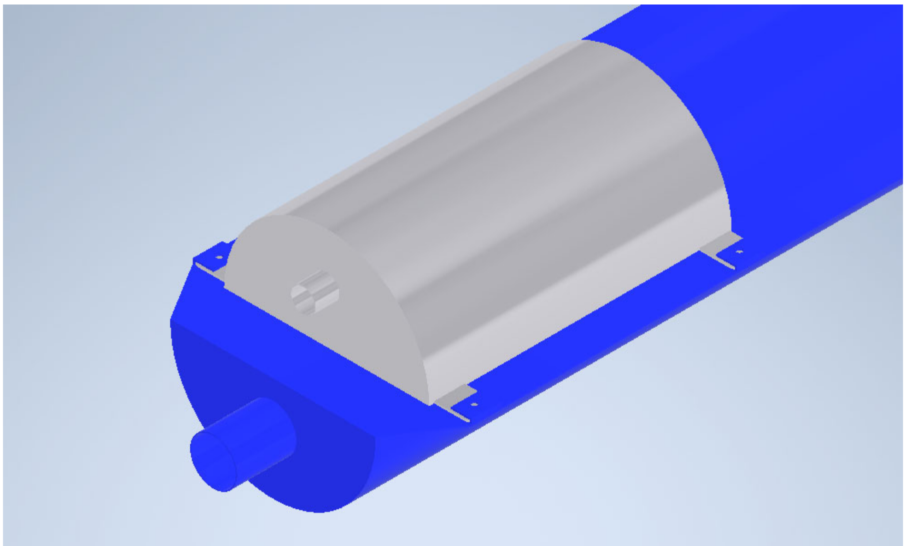


Figure 72: Prototype Design – Trough body & Float hood assembly, isometric view

More images of this attachment can be found in Appendix D – Design.

5.2.4.5 Prototype design summary

With all major components now designed, all the components were assembled in AutoCAD Inventor. Figure 73 illustrates the 3D assembly. This assembly visualises how the design will physically appear and assesses its compatibility with the existing site infrastructure prior to construction. More views of this first prototype assembly can be found in Appendix D – Design.

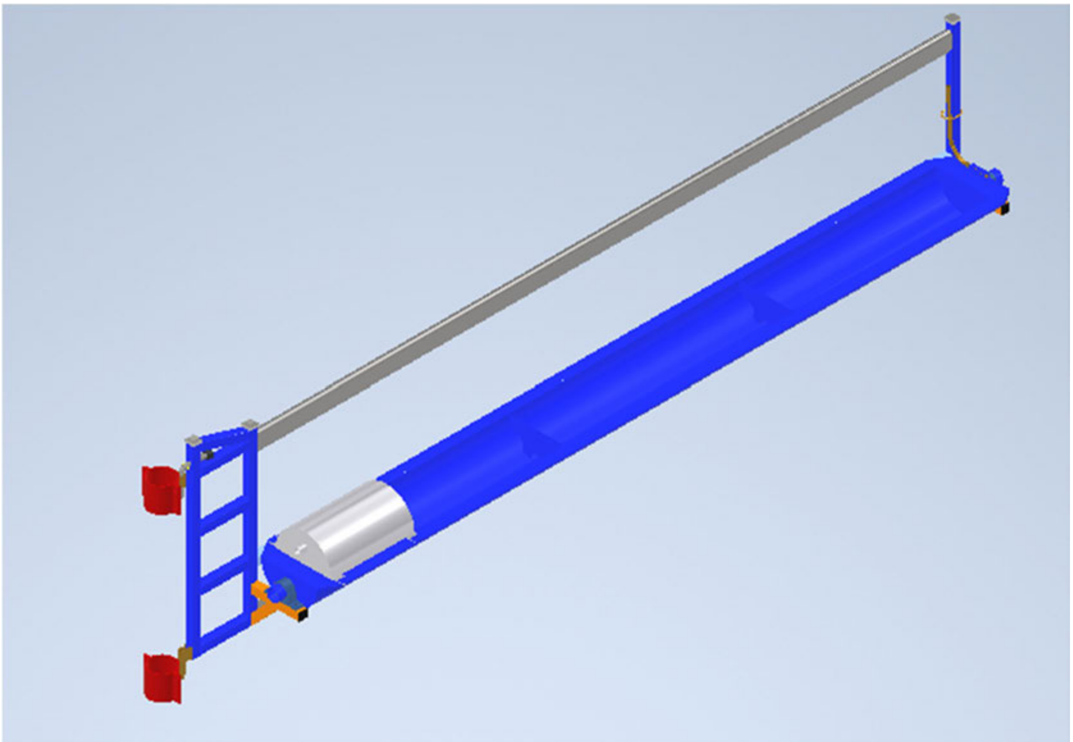


Figure 73: Prototype 1 - Trough and Gate assembly, isometric view

5.2.5 Fabrication drawings

The next steps involved the preparation of detailed construction engineering drawings from the 3D model to allow fabrication of a prototype. The fabrication drawings were prepared using Autodesk Inventor.

The fabrication drawings are provided in Appendix F – Fabrication drawings.

5.2.6 Construction

The fabrication drawings were provided to a local fabricator for fabrication of a prototype.

The prototype water trough shown in Figure 73 was manufactured within three weeks by a local fabricator, with a total cost of $2,400 for materials and labour. This initial expenditure demonstrates significant cost savings compared to conventional water trough systems, which can cost upwards of $6,000 to construct and install. Traditional systems often require concrete slab installation and the use of cranes, leading to prolonged setup times.

5.3 Chapter summary

This section synthesises the information presented in the preceding chapters, transforming theoretical concepts into practical models for application. It meticulously addresses each component necessary for the successful completion of the project, presenting this information in a clear and accessible format that facilitates reader analysis. This organised approach prepares the groundwork for the subsequent development of a prototype, ensuring that all elements have been considered and effectively integrated into the overall design strategy.

6 Results and discussions

This chapter on outlines the observations gathered during the prototype testing phase of this project.

6.1 First prototype

6.1.1 Installation

The water trough was installed at Struggle Downs Feedlot. The water trough was lifted by three men and bolted to the uprights in one hour. The water supply hose was then attached to the float hood and float, and the trough began filling with water.

This quick and efficient implementation immediately highlighted an advantage over conventional plumbed concrete troughs which take 4-5 hours to place and plumb up. Additionally, the ease of replacement for maintenance purposes, even in field conditions, was evident. To provide further insight into the testing phase, images of the first field prototype will be presented, accompanied by explanations of specific observations, overall functionality, and how the design met the intended project goals.

6.1.2 Field operation

A visit to Struggle Downs Feedlot was undertaken to observe and analyse the field operation of the first prototype water trough which is shown in Figure 74. Figure 75 illustrates the float hood installed on the first prototype. The first prototype had been in use for approximately two weeks before refinement work began to develop a second and final prototype. Figure 76 illustrates the tipping action of the first prototype. Before detailing the final prototype, it is necessary to evaluate the performance of the first prototype and address any design concerns identified.

It is important to highlight that the first prototype functioned exactly as intended, meeting performance expectations. The proposed adaptations are not essential for the fundamental operation of the system but are aimed at improving usability and optimising the design for day-to-day operations.

Figure 74: First prototype - water trough in operation

Figure 75: First prototype - Float hood

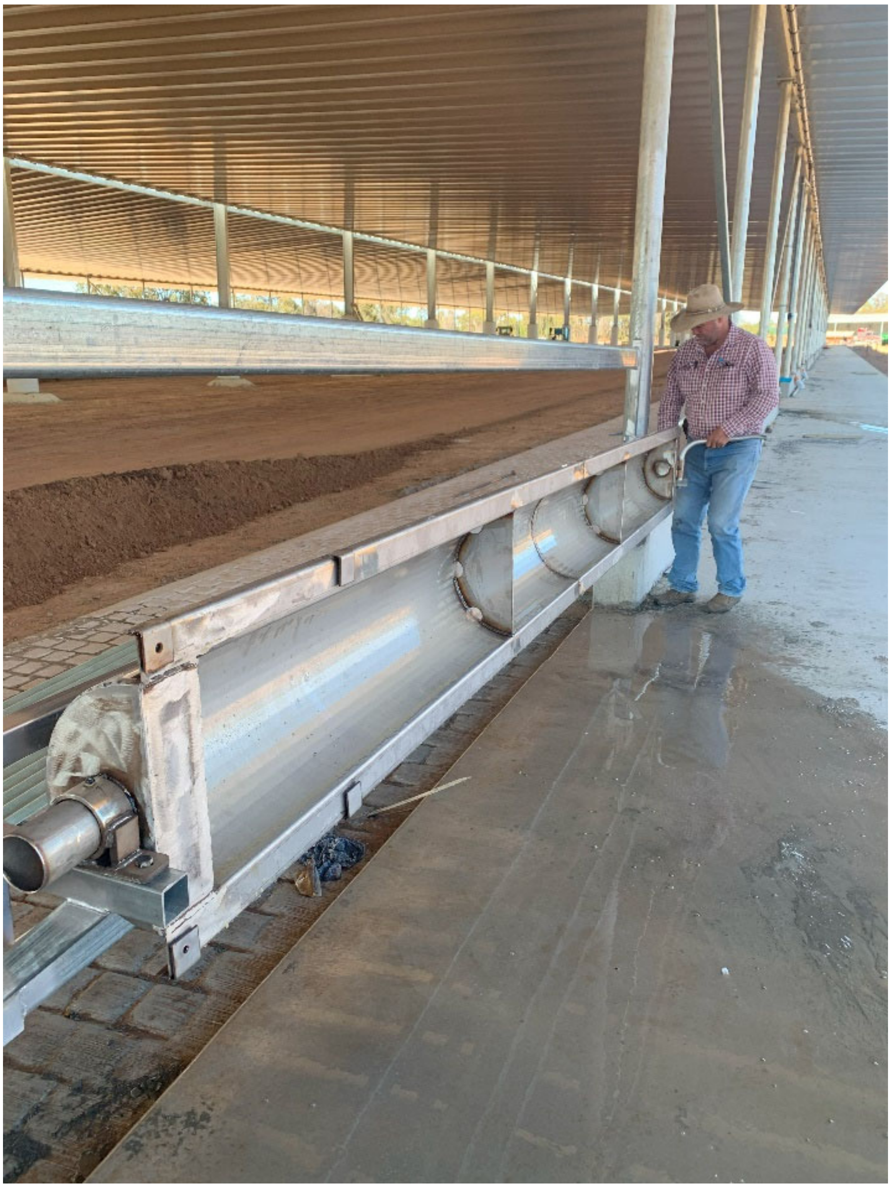


Figure 76: First prototype - Tipping mechanism in action

More images on the first prototype installed in the Struggle Downs Feedlot are presented in in Appendix E – Results

6.1.2.1 Discussion and evaluation

The prototype water trough includes numerous components that warrant detailed discussion; however, it is more effective to first review key observations regarding which factors and systems performed well and which aspects require improvement. These observations will be broken down for a more thorough evaluation, highlighting both the strengths and limitations of the initial design.

6.1.2.2 Design feature evaluation

6.1.2.2.1 Gate functionality

1. The gate's swinging mechanism functioned exceptionally well, providing a smooth and stable motion on the hinges.
2. The weight distribution did not pose any issues, as the gate could be easily swung with moderate effort, even when fully loaded.
3. Cattle were able to drink effectively through the gate rails, and the trough height presented no access problems.
4. The chosen height of the trough also promoted cleanliness, as minimal to no faeces were observed in the trough after one month of use. This is a marked improvement over concrete troughs, which are often at a level where faeces regularly accumulate and require cleaning.
5. The float pod could be removed swiftly and repositioned to facilitate the 260-degree swing rotation of the gate. However, it was noted that extending the hose would allow the float to remain attached to the trough body during gate movement, enhancing efficiency.

These outcomes represent the ideal performance for this feature of the project, and implementing a longer hose could improve operational convenience.

6.1.2.2.2 Locking system

1. The system demonstrated excellent sturdiness, effectively securing the trough in place.
2. During the trial, cattle were unable to dislodge the ring.
3. The ring proved to be simple and efficient to remove, facilitating the tipping feature.
4. The lever was robust and felt securely attached to the trough body.
5. The gate could be closed with ease using the lifting technique, which helped align it on the footing and significantly reduced stress on the hinges.
6. Adding a 90-degree lip to the trough body would enhance the fit over the bumper rail, providing a snugger connection and serving as an additional locking feature or guide for positioning the trough.

Other than the proposed addition of the trough body lip, no further modifications to the locking system are necessary.

6.1.2.2.3 Tipping system

1. The overall system principle performed effectively.
2. The trough cleaning process took only about 2 minutes.
3. There was a minor issue with friction between the axle and axle hub, as the rotation felt 'sticky' even with the use of a grease nipple.
4. The trough successfully emptied all water.
5. There were no indications of algae growth.
6. The tipping feature eliminated the need for additional cleaning tools, such as brushes, since the water agitation effectively dislodged grime and dirt, which was then flushed out during the tipping process.
7. Most to all of the water drained towards the designated area.

The necessary adaptations include implementing a revised bearing system in the axle hub to address friction and designing a splash guard to prevent water from entering the pen. These changes would ensure the tipping feature functions optimally.

6.1.2.2.4 Refilling system

1. The float was well-protected from cattle interactions, preventing any tampering or damage.
2. The system refilled quickly, taking less than 3 minutes to fill from empty.
3. The trough was highly responsive, filling immediately whenever cattle drank from it.
4. The smaller water volume was sufficient, as cattle did not drink simultaneously, likely due to the regular feeding schedule.
5. Some unwanted splashing occurred from the float when the trough was emptied. This can be mitigated by better enclosing the float hood.

These observations have led to specific points for design refinement, ensuring the system meets an optimal and polished operational standard.

6.1.2.2.5 Summary of design refinement topics

Several refinements were identified during operation of the first prototype as discussed in the previous sections. In summary, the following items were included/modified for the final prototype water trough.

1. Longer flexible hose;
2. Trough body 90-degree lip return;
3. Smoother axle hub option; and
4. Splash guard for the float hood.

6.1.3 Refinement and adaptations

The necessary adaptations for design refinement, identified from the observations of the first prototype, are outlined below to ensure the system achieves optimal operational functionality. This process demonstrates how iterative development and analytical problem-solving are crucial in engineering to enhance system performance:

1. Extended hose for float system: Using a longer hose for the float will provide flexibility, allowing the float pod to remain attached to the trough body even when the gate is fully swung. This adjustment simplifies the operation and reduces the need for manual disassembly.
2. Additional locking feature for stability: Adding a 90-degree return to the lip on the trough to sit over the bumper rail will provide a more secure fit. This lip would act as a secondary locking mechanism and guide.
3. Axle hub friction issue: The axle and axle hub demonstrated excessive friction even with the application of grease. To address this, a revised bearing system could be introduced. This might involve using higher-quality bearings or incorporating a more effective lubrication method to enable smoother rotation and reduce wear.
4. Float hood enclosure improvement: To minimise water splashing from the float system, the hood could be redesigned with a more comprehensive enclosure. This modification will help contain water spray and protect against spillage during trough operation.

6.1.3.1 Hose length

The length of the flexible hose could be lengthened to allow for the gate to be swung while the float hood it still attached to the trough body. The hose length can be simply increased to allow more slack at the closed position. This is a simple fix and requires no extra design.

6.1.3.2 Trough body 90-degree lip return

As discussed in section 6.1.3 this addition will aid in 'latching' the trough body to the bumper rail, to hold the trough in place more securely, and will be as a hard fixed redundant system if the locking mechanism is to fail. Figure 77 illustrates the modified trough body lip.

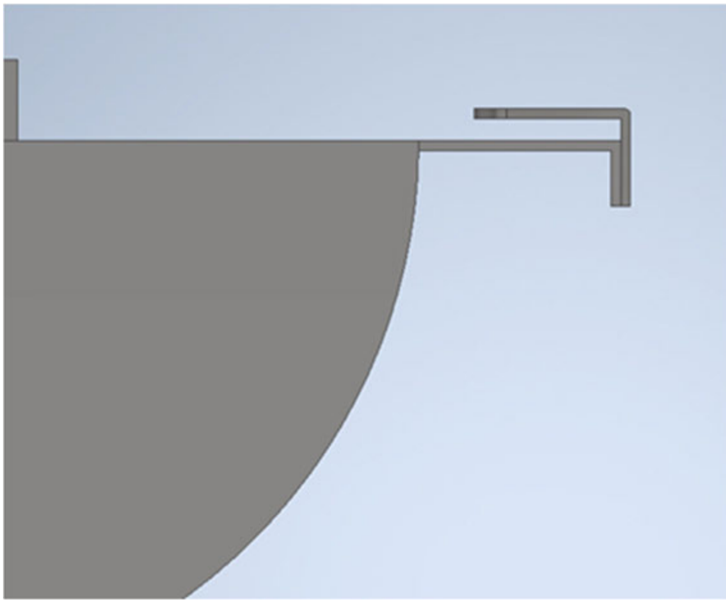


Figure 77: Prototype Design Modifications – trough body lip with 90-degree lip return

6.1.3.3 Axle hub

The primary issue identified with the previous axle hub was the friction caused by steel-on-steel contact. This friction was exacerbated by changes in temperature, leading to varying resistance during rotation. To address this concern, adjustments were made to the axle design.

The diameter of the axle was reduced to 50 mm, which is a more manageable size, while simultaneously increasing the wall thickness to 3 mm—double that of the previous axle.

This design alteration not only reduces the overall weight of the axle but also enhances its strength and durability.

Additionally, modifications were made to the model on the trough to accommodate these changes, ensuring compatibility and optimal functionality within the system. These adjustments aim to minimise friction and improve the overall performance of the tipping trough, providing a more reliable and efficient operation.

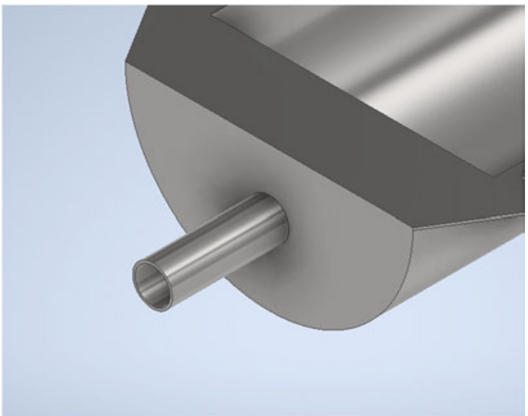


Figure 78: Prototype Design Modifications – Water trough axle, 50mm OD (metric)

The axle hub was subsequently modified to include a rubber bearing insert, effectively transforming it into a specialised bearing system. This innovative approach eliminates the friction associated with steel-on-steel contact, significantly reducing wear and tear on the components.

The incorporation of the rubber bearing insert also addresses the challenges posed by material shrinkage and expansion due to temperature fluctuations. By using a flexible material, the hub can accommodate these changes without compromising functionality. Moreover, this design enhancement minimises maintenance requirements, as the rubber bearing does not necessitate constant greasing like traditional metal bearings. Overall, these modifications aim to enhance the performance, longevity, and ease of maintenance of the tipping trough system.

Figure 79: Prototype Design Modifications – Axle hub example of acquirable inner rubber bearing (RUBBER INSERT-205 BEARING/62P HOUSING, 2024)

Figure 80 shows the new 3D model with the revised rubber bearing inserted into the axle hub.

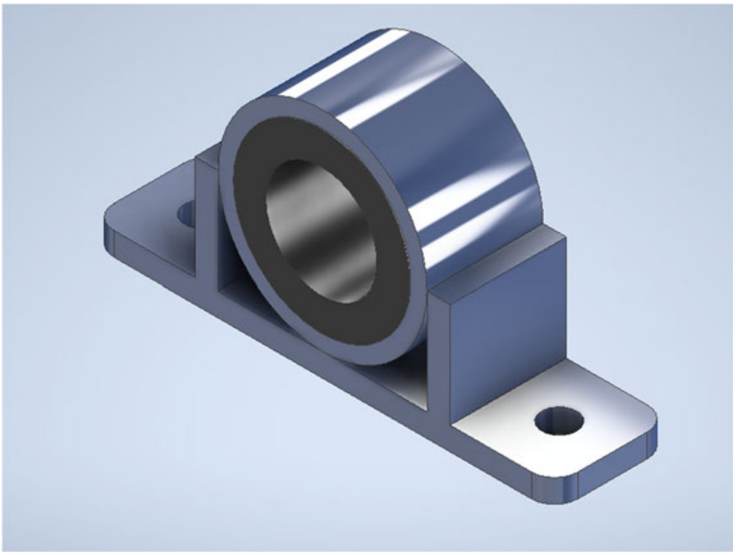


Figure 80: Prototype Design Modifications – New Axle hub with inner rubber bearing

6.1.3.4 Float hood splash guard

The identified issue with splash out occurring at the opening of the hood can be effectively addressed by incorporating a simple splash guard. This guard will extend downward into the trough's body valley, designed to redirect splashes without completely enclosing the area. The proposed shape of the splash guard will be tailored to mitigate the impact of water flow while ensuring that it does not obstruct the free movement of water within the trough. By allowing for some degree of openness, the design ensures that water can flow freely around the guard, preventing any potential blockages or pooling.

Confidence in this design stems from its straightforward approach to addressing the splash out problem while maintaining the overall functionality of the trough system. This solution has been integrated into the 3D model of the float hood, reflecting the modifications made to enhance performance and efficiency.

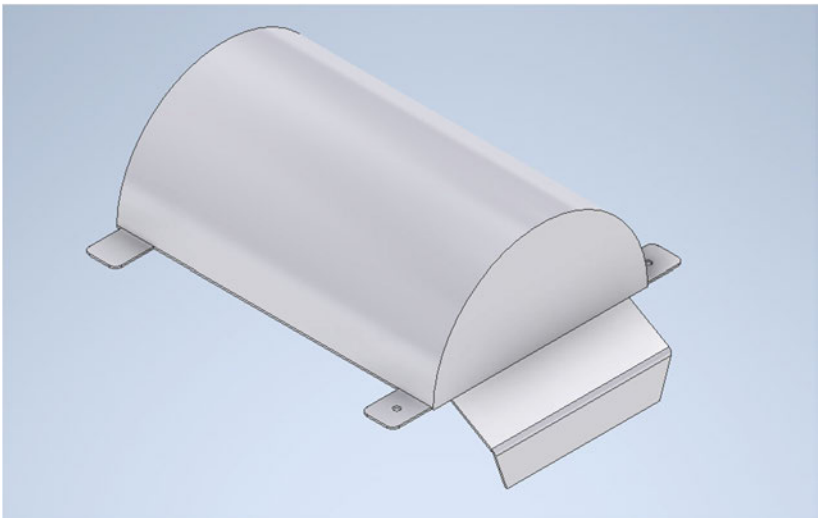


Figure 81: Prototype Design Modifications – Splash guard on float hood, isometric view

Further images of the splash guard can be found in Appendix E – Results.

With the updates to the systems implemented, the final 3D model will showcase the enhanced features of the gate-mounted tipping trough. Key improvements, such as the modified axle with a rubber bearing insert and the new splash guard, will be highlighted to demonstrate their functionality

However, the hose extension and rope components will be omitted from this model, as they are not integral to the trough's design and may vary based on individual site requirements. This decision allows the focus to remain on the specific features of the trough that contribute to its operational efficiency and effectiveness in managing water supply for cattle. The final model will provide a clear representation of these updates and their intended benefits.

6.2 Final prototype

6.2.1 Design

The final visualisation of the 3D models is presented below, showcasing many of the major components necessary for constructing this system. This visualisation will outline some final generic dimensions, thereby finalising the required technical specifications.

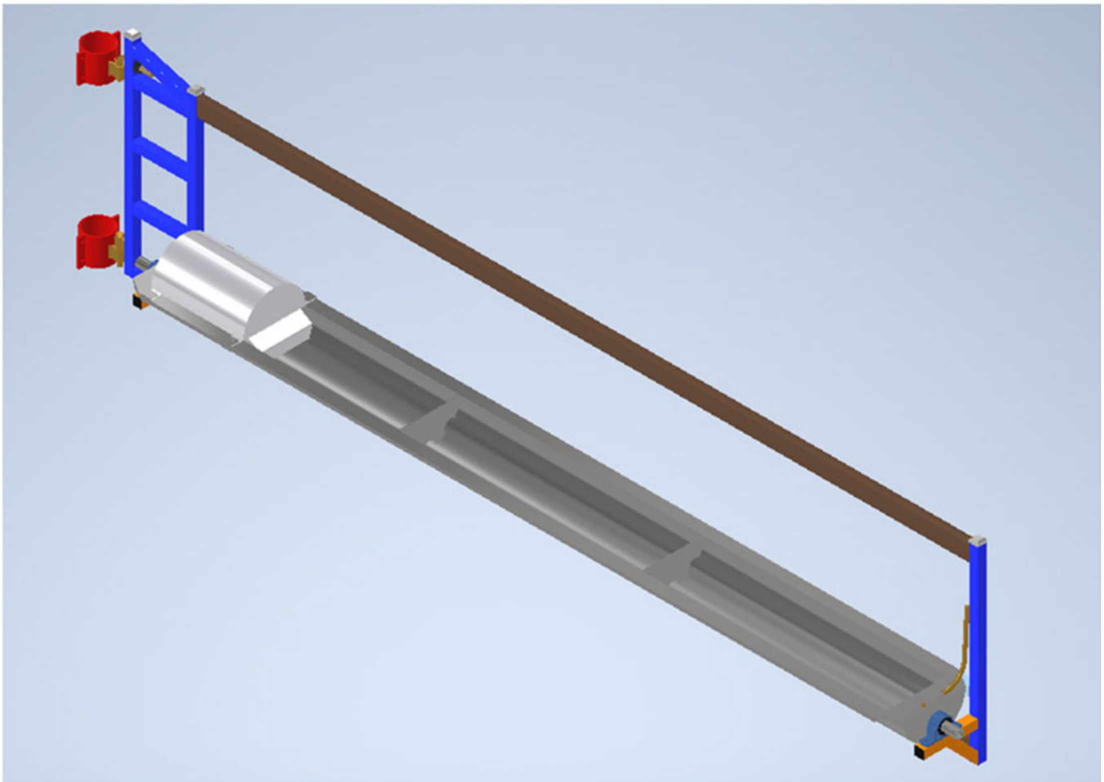


Figure 82: Final prototype water trough – Final 3D assembly, isometric view

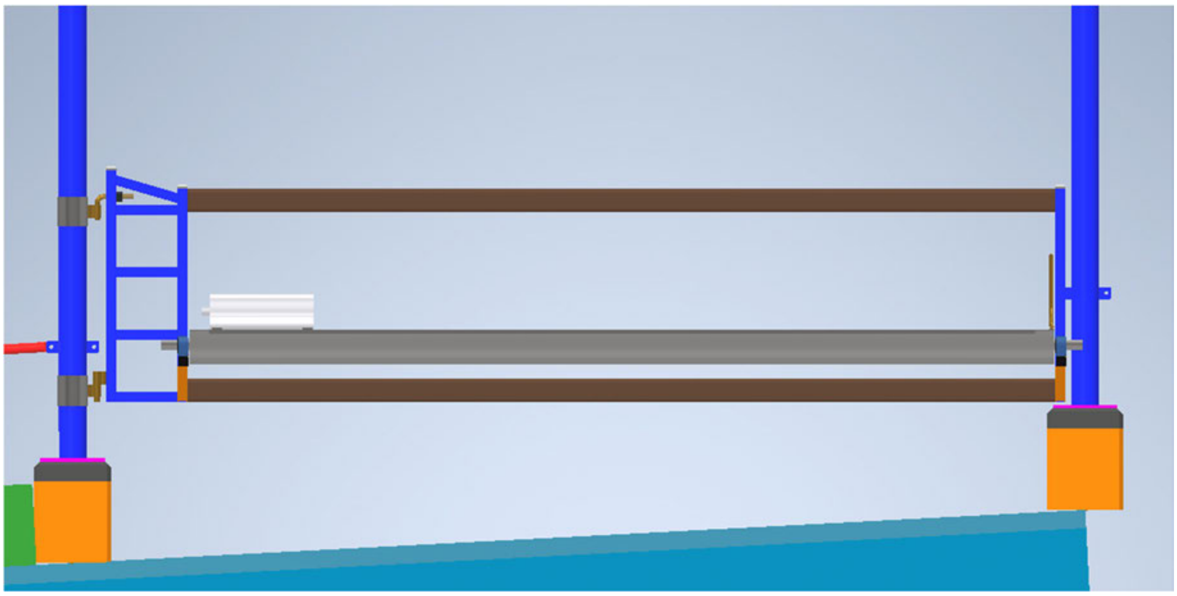


Figure 83: Final prototype water trough - front view

For more views of this final iteration of the 3D model look in Appendix E – Results.

6.2.2 Field operation

This section outlines the important and final images of the final prototype in the field. Showcasing and addressing more specific details on the final prototype dubbed the – **'Gate Mounted Tipping Trough'.**

Figure 84 illustrates the final prototype water trough installed at Struggle Downs Feedlot.

Figure 84: Final prototype water trough – Front on view

Figure 85 illustrates several of the final prototype water troughs installed at Struggle Downs Feedlot. In total there are 10 units installed.

Figure 85: Final prototype water trough – Multiple trough installations

Figure 86 illustrates the final prototype water trough installed at Struggle Downs Feedlot being full of water. The water is supplied from a newly constructed earthen dam and is turbid due to clay particles.

Figure 86: Final prototype water trough – Side view of trough

Figure 87 illustrates the Wagyu cattle drinking from the final prototype water trough installed at Struggle Downs Feedlot.

Figure 87: Final prototype water trough – Cattle drinking from trough

Figure 88 illustrates the final prototype water trough installed at Struggle Downs Feedlot when filling with water and the hand tipping mechanism.

Figure 88: Final prototype water trough – Filling with water

Figure 89 illustrates the final prototype water trough installed at Struggle Downs Feedlot with the extended hose arrangement.

Figure 89: Final prototype water trough – Hose extension

Figure 90 illustrates the float hood on the final prototype water trough installed at Struggle Downs Feedlot.

Figure 90: Final prototype water trough – Float hood

Figure 91 illustrates the axle and axle hub on the final prototype water trough installed at Struggle Downs Feedlot.

Figure 91: Final prototype water trough – Axle and axle hub

Figure 92 illustrates the underside of the trough body on the final prototype water trough installed at Struggle Downs Feedlot and shows the folding bends and welding techniques to fabricate the component.

Figure 92: Final prototype water trough – Underside of the trough

Figure 93 illustrates the final prototype water trough installed at Struggle Downs Feedlot and shows the welding techniques to fabricate the component.

Figure 93: Final prototype water trough - Construction and welds

Figure 94 illustrates the hood splash guard on the final prototype water trough installed at Struggle Downs Feedlot.

Figure 94: Final prototype water trough – Hood splash guard

Figure 95 illustrates the final prototype water trough installed at Struggle Downs Feedlot in relation to the shed columns and pen locations.

Figure 95: Final prototype water trough – Shed and trough arrangement

To further view the design in operation Australian Lot Feeders Association has a video that shows the trough in action: This can be found here:

https://www.feedlots.com.au/post/struggle-downs-stainless-tipping-trough-innovation

6.3 Final prototype results validation

For a final validation of this project some critical numbers can be compared side by side, to effectively summarise the projects attributes against conventional trough attributes. For which facts cannot be argued and removes bias.

6.3.1 Critical parameter comparison

For this section we can discuss some of the parameters that can summarise the differences between the gate mounted tipping water trough and the conventional concrete water troughs.

Parameter	Gate mounted tipping water trough	Conventional concrete water trough
Volume	190 Litres	350 – 750 Litres
Weight (empty)	~200 kg	~500 – 800 kg
Install time	1 to 2 hours	1 days
Ground footprint	0	15 m^2
Cost (including installation)	$2,400	$6,000+
Cleaning time	2 minutes	4-5 minutes
Refill time (empty to full)	2 minutes	4 minutes

Table 15: Critical parameter comparison

6.3.1.1 Chapter summary

This chapter provides a comprehensive overview of the entire design process, culminating in the presentation of the final solution to the project. It highlights the achievements made through prototype testing, design refinement, and the assessment of overall operational functionality and usability. The chapter reiterates the significance of the project, supported by tangible evidence rather than purely theoretical hypotheses. By comparing and justifying the outcomes based on critical data and finalised figures, this section effectively underscores the legitimacy of the project's findings and its contribution to the field.

7 Conclusions

The objectives and research questions set at the beginning of this dissertation shall now be discussed to assess if they were achieved and thus validate the application and implementation of this project. The owner of Struggle Downs Feedlot, Mr Darren Hamblin was extremely happy with the prototype water trough, and states that it "*works wonderfully*" (Darren Hamblin pers comms 2024). There are 10 units in operation in the covered housing system which means that the project is validated from a practical working perspective.

Addressing the objectives of the design specifically is crucial to relate back to the achievements within this project. This can be effectively summarised through discussions relating to the design questions outlined in the section 3.9.2.

1. **What types of factors can be integrated into a design solution to deliver a practical watering system within the covered housing arrangement of Struggle Downs feedlot?**

The adopted methodology played a key role in delivering a successful design project. The waterfall approach combined with the use of 3D modelling software and workshop drawings allowed a functional prototype water trough to be fabricated quickly and then installed within the covered housing system. The design used simple design techniques and standard material sections and modular components to facilitate quick and low cost fabrication, off-shelf components were used where possible to allow quick and easy installation.

2. **What types of factors can be integrated into a design solution to satisfy the Struggle Downs feedlot requirements but also allow the system to be fundamentally adaptable for integration into covered housing systems and potentially uncovered feedlots at other sites?**

The design facilitated the development of adaptive techniques in line with traditional manufacturing and attachment methods, ensuring that the system is not restricted to a specific site. The integration of post collars with off-the-shelf hinges enabled seamless attachment to the Struggle Downs infrastructure, and hence the system is easily adaptable for use at other sites, regardless of size or shape of the steel uprights.

3. **How can engineering principles be combined with industry expertise to create an innovative and practical system that provides advantages over conventional water troughs currently available on the market?**

Understanding the limitations of conventional concrete troughs informed design decisions, leading to the integration of specific materials such as stainless steel and systems such as the modular float hood aimed at outperforming current alternatives. This question was answered overall by developing a design that is more cost-effective, compliant, and water-efficient than traditional water troughs.

The knowledge of people within the industry was invaluable as it identified issues which may not have been identified until a prototype was in operation. The requirements for enhancing production performance were clearly identified, with time-saving attributes serving as a measure of productivity. This project achieved its goal by reducing the overall interaction needed to maintain the troughs in an operational and functional condition, particularly by minimising maintenance via the use of the modulation components and cleaning times due to the tipping system. Consequently, more time can be allocated to critical production operations, such as feeding and waste management. The prototype water trough demonstrated that engineering principles combined with industry knowledge can lead to an innovative design solution.

4. **Finally, how can this particular system help transform and increase adoption of covered housing systems within the intensive feeding industry, including demonstrating improvements in environmental impact and animal welfare.**

The project successfully delivered a practical working prototype of a water trough within a covered housing system. The water trough delivers environmental benefits through a significant reduction in the amount of wastewater used during trough cleaning. The water trough is simple and quick to clean which reduces labour requirements and therefore productivity improvements within the development. Additionally, the water trough enhanced animal welfare considerations by ensuring a continuous supply of fresh clean and cool water which cattle prefer to drink thereby leading to performance gains. The water trough offers a simple, practical and cost effective solution to watering cattle within a covered housing system and thereby will assist in the adoption of covered housing systems within the Australian feedlot industry.

Overall, this design project was a complete success, as it effectively delivered a working prototype water trough and addressed all the design criteria. However, to build upon this success, future work considerations can be explored to further develop and enhance the system, incorporating the principles outlined throughout this project.

7.1 Future work

Future work is imperative when concluding a design project. It is essential in addressing and emphasising the ongoing relevance and overall impact this design project has. There are multiple aspects for which justify the necessity of future work, these are summarised below.

1. **Technological Advancements** – Understanding that technology is continuously evolving, and designs will need to be adapted and preferably refined as new techniques and materials become available. Future involvement of technologies could help greatly improve this current design to be more efficient or effective in operation such as rolling the trough body instead of bending.

2. **Addressing Design Limitations** – Acknowledging any limitations in the design is crucial so that future research can overcome these. This could include further testing, enhanced modelling techniques, or exploring areas that this study couldn't cover such as an automatic tipping mechanism.

3. **Unexplored Areas or Opportunities** - Pointing out promising areas beyond the scope of the project that need further exploration. This could be new testing conditions, alternative use cases, or adaptations to other applications.

4. **Potential for Broader Impacts** – The argument can be made that future research can be expanded upon into different areas of this industry or different industries. For example, this design and its principles could influence shared fields such as other animal related fields or align with affect more operations and current industry trends.

Each one of these topics can be addressed accordingly with suggestions made based off engineering principles and future advancement predictions.

7.1.1 Technological advancements

This design was engineered to facilitate future technological advancements. The following four advancements could be fitted to the water trough.

1. Data monitoring - via sensors, which would enable data collection and analyse aspects such as water intake, for example this may be useful to adjust aspects such as salt content in cattle feed if necessary to reduce the overall need and intake for cattle drinking to create a more sustainable system in terms of water usage across intensive feeding.
2. Autonomous integration – as the tipping mechanism is simple, autonomous integration could be easy and extremely useful to the overall efficiency of the operation, mitigating the need for human interaction with monotonous tasks. The system could incorporate an electric or hydraulic motor (for which is protected) that is direct drive to the axle of the trough axle. This could allow many different features such as -
   - Adaptive tipping - the autonomous program could be designed to monitor water quality and tip according on a timer or analysis approach, which could manage water more efficiently.
   - The torque on the electric motor could help lock the gate in via gears to remove the handle and locking ring system.

The motor will have to be tailored appropriate to the forces that will be experienced by tipping, as well as rigorous testing to test viability A hydraulic motor would be more optimal due to the lower rpm and higher torque which would enable a more sturdy and reliable strength quality to the higher weight experienced in the tipping motion. A motor for which would be applicable is shown in Figure 96.

Figure 96: Future Work – Future Technology, hydraulic drive motor (Timalco Hydraulics, 2021)

Future work on this aspect would involve determining whether one or two motors should be used, which would require strength testing, as well as assessing gearing and power input requirements. Additionally, the optimal programming, code, and analytics for the system must be identified, along with considerations for protecting and industry-proofing the system to withstand the harsher conditions found in an intensive feeding arrangement.

In conclusion, there are numerous potential avenues for future technological advancements that could be applied to this design project, offering opportunities to further improve efficiency and enhance the performance of the system within the industry.

7.1.2 Addressing design limitations

The current limitation of this project lies primarily in the design constraints, as there is an expected functional limit to the weight and size of the trough, beyond which it would become difficult or impossible to operate. This challenge could be addressed through future work that incorporates limit testing to determine the maximum feasible size based on human strength constraints. Rigorous testing, such as Finite Element Analysis (FEA), along with trialling different diameters, would help identify the optimal size more efficiently while maintaining operational functionality. Another approach could involve proposing technological solutions, such as hydraulic drive motors, jack systems, or actuator-assisted tipping, which could alleviate tipping difficulties related to size using mechanical advantage principles.

Another limitation is that this system is designed to suit a covered housing arrangement. To adapt it for use in an uncovered system, certain areas would need to be redesigned and modified accordingly. As mentioned, while covered housing arrangements are uncommon in the industry, they hold potential for the future. In the interim, to fully utilise the benefits of this system, a cover-type arrangement could be implemented for use in open environments, as the conductive properties of stainless steel could become undesirable with prolonged exposure to the sun. A solution for this would be to attach the trough to a fixed structure featuring a shade system, which would mitigate most sun exposure, keeping the water cool and maintaining the required cattle welfare standards. This structure would resemble the one shown in Figure 97, enabling the system's smooth integration into any type of intensive feeding operation.

Figure 97: Future work – Proposed shade structure (Pope, 2021)

7.1.3 Other applications

There are many areas where the tipping trough principle could be adopted and utilised. Incorporating technology or adapting the frame to the system could prove beneficial for other applications within the industry. After all, this design project was also focused on adaptability to different sites. The broader perspective was always considered, and as a result, a theory and design have already been developed in alignment with future work and applications of the "tipping trough" concept. Although this area was not fully explored during the design phase, a suggestion for a “fence-mounted tipping trough” was proposed. This concept briefly entered the design phase and is currently undergoing refinements. Preliminary 3D models are available to demonstrate how the principles from the “gate-mounted tipping trough” have been applied to this new design. As seen in

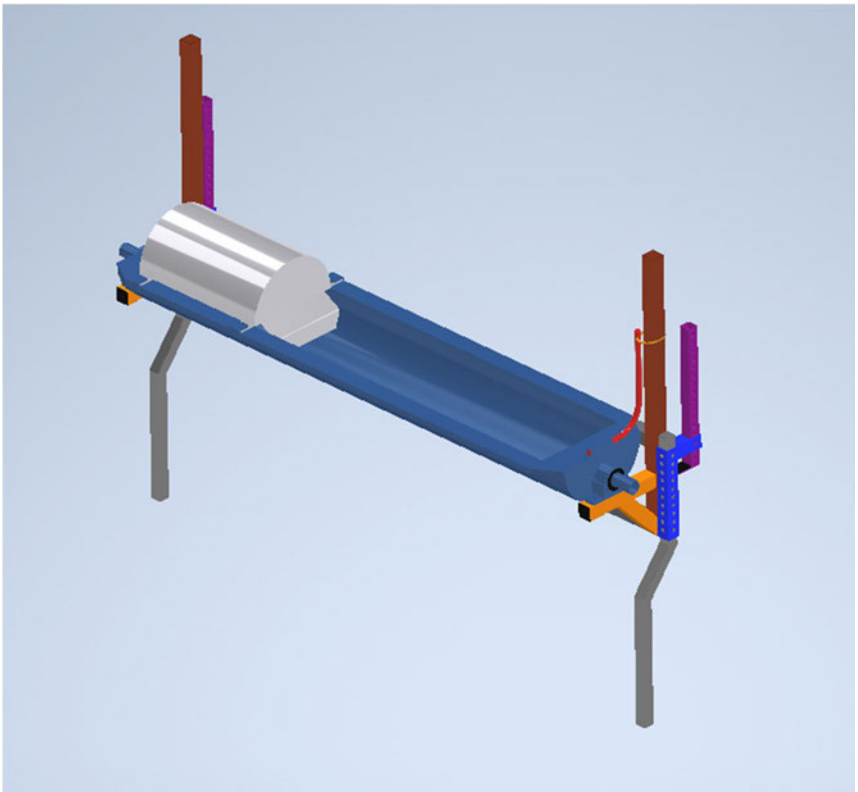


Figure 98: Future work - Fence mounted tipping trough – Isometric view

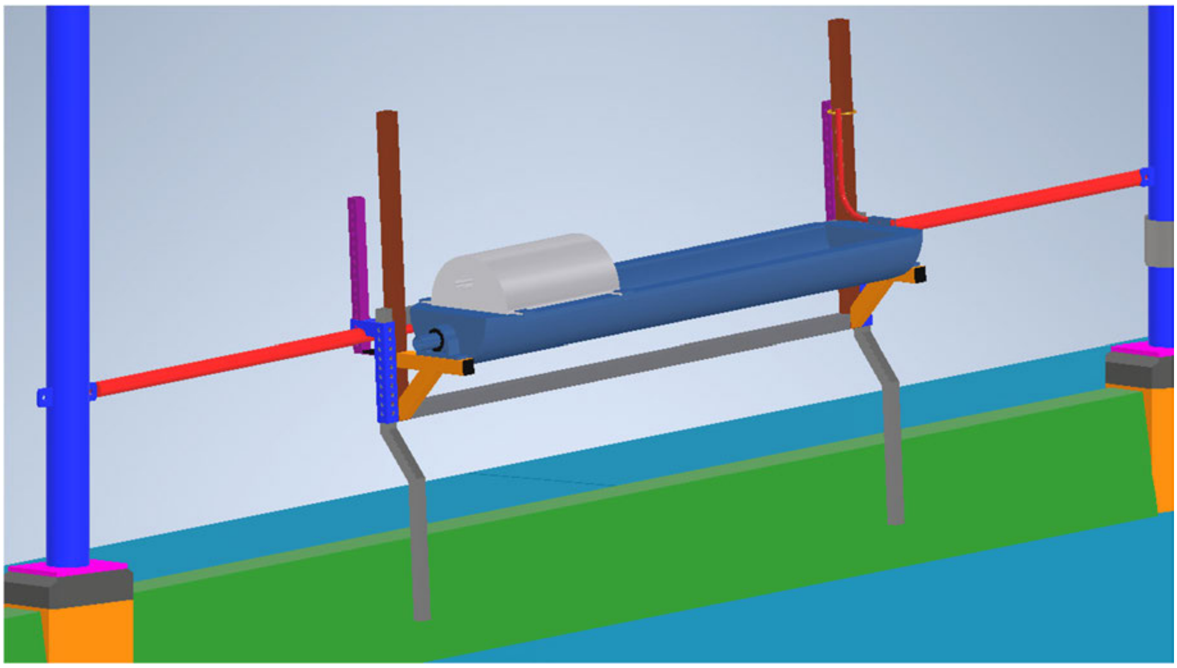


Figure 99: Future work - Fence mounted tipping Trough - 3D models

As can be seen in Figure 97 and Figure 98 the original gate frame has been changed to suit a fence application. The features are -

- This design retains some of the same components used in the gate-mounted tipping trough, aiming to minimise fabrication and maintain consistency in drawings and spare parts for easier maintenance.
- The fence-mounted tipping trough had to incorporate a more adaptable system to accommodate the varying shapes, positions, heights, number of rails, and overall geometries of fences. As a result, more thought and analysis were needed to address these diverse conditions. This is evident in the inclusion of adjustable rail and leg options, which can be modified to suit most fence variations as shown in Figure 100. The tipping principle is maintained, allowing cleaning to be easily performed, just as it was with the gate-mounted tipping troughs

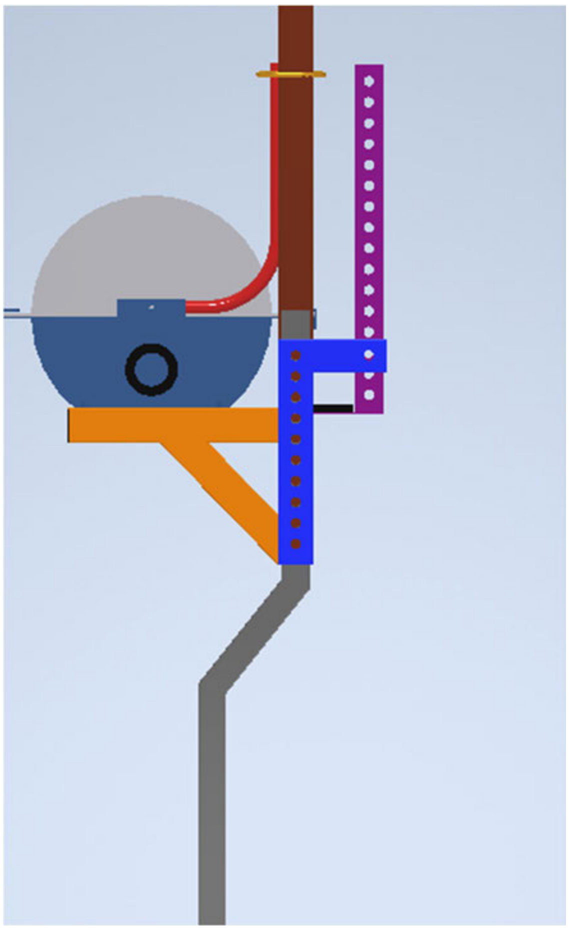


Figure 100: Future Work - Fence Mounted Trough

This flexibility allows the system to be placed in various locations around the operation, intended for use in small pens, temporary pens, or where additional water is needed in regular pens to increase stocking density. It can also serve as a general-purpose, small, and removable trough. This future work holds great promise for the industry, as small, adaptable, and functional trough systems are relatively uncommon but could be valuable in a variety of applications within a single operation and across the industry as a whole.

7.1.4 Other industries

As discussed in the above section that motions are already in place to broaden the horizons on this design and the accompanying principles. However, it is worth noting what other industries or applications this system could be used in. As seen, it can interact with cattle quite well, especially in an intensive feeding operation, however the "gate mounted tipping trough" and the attached principles could be used in any industry that encloses animals in pens or fences. This includes a variety of industries and areas, below is a list of areas and applications where this design could be used.

- Dairy farms - milking sheds – pens etc
- All stockyards
- Piggeries
- Sheep pens
- Horse sheds/stables

All these areas suggested above will have some type of trough arrangement, it could be easily replaced with a gate or fence mounted tipping trough.

Other Animal Sectors

- Zoo animals

7.1.5 Future work summary

Overall, there are numerous areas of future work where this design project and its underlying principles could be applied to adapt, improve, or even transform the way intensive feeding operations are conducted globally.

8 References

Agriculture and Agri-foods Canada (n.d.). Peak Flow Requirement for Livestock Watering Total Daily Water Requirement (Litres) Peak Flow Requirement (Litres per minute) TROUGHS FOR WATERING RANGE LIVESTOCK. [online] Available at: https://www.beefresearch.ca/content/uploads/2022/05/Troughs-for-Watering-Range-Livestock.pdf. [Accessed 10 Sep. 2024]

Admin (2014). Australian manufacturing cost among highest in the world, says report. [online] Hornet. Available at: https://hornetgroup.com.au/australian-manufacturing-cost-2014-report/... [Accessed 30 Jun. 2024]

Animals Australia. (n.d.). This controversial farming practice surprises many. [online] Available at: https://animalsaustralia.org/our-work/factory-farming/feedlots/. [Accessed 1 Apr. 2024].

Animal Health Australia (AHA) (2014). Australian Animal Welfare Standards and Guidelines for Cattle. Australian Animal Welfare. [online] https://animalwelfarestandards.net.au/wp-content/uploads/2023/08/Cattle-Standards-and-Guidelines-Endorsed-Jan-2016-061017_.pdf. Available at: https://animalwelfarestandards.net.au/wp-content/uploads/2023/08/Cattle-Standards-and-Guidelines-Endorsed-Jan-2016-061017_.pdf. [Accessed 3 Nov. 2024]

Atlas Steels. (n.d.). Stainless Steel Sheet. [online] Available at: https://atlassteels.com.au/stainless-steel-sheet-coil-and-plate/stainless-steel-sheet/... [Accessed 30 Jun. 2024]

Austgen.vn. (2017). Australian General Engineering. [online] Available at: http://austgen.vn/blogs/how-to-weld-aluminum [Accessed 3 Nov. 2024].

Autodesk (2019). Autodesk Viewer | Free Online File Viewer. [online] Autodesk.com. Available at: https://viewer.autodesk.com/. [Accessed 10 Sep. 2024]

Autodesk (2019). *Autodesk Viewer | Free Online File Viewer*. [online] Autodesk.com. Available at: https://viewer.autodesk.com/. [Accessed 3 Nov. 2024].

Bagshaw, C.S., Thorrold, B., Davison, M., Duncan, I.J. and Matthews, L.R., 2008. The influence of season and of providing a water trough on stream use by beef cattle grazing hill-country in New Zealand. Applied Animal Behaviour Science, 109(2-4), pp.155-166. [Accessed 3 Nov. 2024]

Barker, E. (2023). Top 25 Lotfeeders: could shed structures move feedlots into new areas? [online] Beef Central. Available at: https://www.beefcentral.com/features/top-25-lot-feeders-2023/top-25-lotfeeders-could-shed-structures-move-feedlots-into-new-areas/ [Accessed 1 Apr. 2024].

Bechtel, W. (2018). Cattle on Feed Numbers: A Look Around the World. Drovers. [online] 7 Dec. Available at: https://www.drovers.com/markets/cattle-feed-numbers-look-around-world.

Beef (2023). Feeding Frequency Of Cattle In The Feedlot. [online] Beefmagazine.com. Available at: https://www.beefmagazine.com/cattle-nutrition/feeding-frequency-of-cattle-in-the-feedlot [Accessed 3 Nov. 2024].

Beef Central (2019). Southern Qld feedlot invasion slammed by Minister. [online] Beef Central. Available at: https://www.beefcentral.com/news/latest-farm-invasion-inspired-by-aussie-farms-website-slammed-by-minister/ [Accessed 5 Apr. 2024].

Beef Central (2023). Top 25 Lotfeeders: No 1 JBS Australia. [online] Beef Central. Available at: https://www.beefcentral.com/features/top-25-lot-feeders-2023/top-25-lotfeeders-no-1-jbs-australia/. [Accessed 10 Sep. 2024]

Behrendt , K. and Weeks, P. (2009). How are global and Australian beef feedlots performing? [online] Available at: https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/agri-benchmark/mla-agribenchmark-feedlot-results-report-jan-2019.pdf. [Accessed 1 Apr. 2024].

bendbrothers Guarantee (2024). 3" (76mm) 304 Stainless Steel Tube - 1 Meter Length - 1.6mm Wall. [online] Available at: https://bendbrothers.com.au/products/3-304ss-tube-1-meter-length-1-6mm-wall-1?variant=12164712300638¤cy=AUD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&utm_campaign=gs-2018-10-14&utm_source=google&utm_medium=smart_campaign&gad_source=1&gclid=CjwKCAjwyfe4BhAWEiwAkIL8sDoS11DP_o5kk3iq66yAPYeDO3mMUa80DVAc3ii3iX5uWGS8LK2HBxoC_jwQAvD_BwE [Accessed 3 Nov. 2024].\

Bennet, R., Deyzel, G. and Davidson, S. (2022). De-Dagging Project. [online] Available at: 26. https://www.ampc.com.au/getmedia/b728c405-2977-47a7-9eb2-23d29ee47b57/De-Dagging-FINAL-REPORT-2021-1119.pdf?ext=.pdf [Accessed 5 Apr. 2024].

Broom, D.M. (2019). Land and Water Usage in Beef Production Systems. Animals, [online] 9(6), p.286. doi:https://doi.org/10.3390/ani9060286. [Accessed 1 Apr. 2024].

Brisko (2024). CHS 139.7 X 3.2 mm. [online] Brisko.co.uk. Available at: https://www.brisko.co.uk/Product/1000213/Lightning-Column-Tubes/CHS-139.7-X-3.2-mm [Accessed 3 Nov. 2024].

Burkhardt, Franziska & Hayer, Jason & Heinemann, Celine & Steinhoff-Wagner, Julia. (2022). Drinking behavior of dairy cows under commercial farm conditions differs depending on water trough design and cleanliness. Applied Animal Behaviour Science. 256. 105752. 10.1016/j.applanim.2022.105752. [Accessed 3 Nov. 2024]

Cabot Creamery. (n.d.). Farmer Friday: The Senses of a Cow. [online] Available at: https://cabotcreamery.com/blogs/community/farmer-friday-senses-cow. [Accessed 10 Sep. 2024]

Canadian Fabricating and Welding (2023). Maximizing laser cutting performance. [online] Canadianmetalworking.com. Available at: https://www.canadianmetalworking.com/canadianfabricatingandwelding/article/fabricating/maximizing-laser-cutting-performance. [Accessed 10 Sep. 2024]

CanDooRural. (2022). Weld On Hinge Sets - Standard Pin. [online] Available at: https://candoorural.com.au/products/weld-on-hinge-sets-standard-pin?variant=42497614643425 [Accessed 3 Nov. 2024].

Cocky Valve (2024a). How To Stop Water Troughs Going Green - Cocky Valve. [online] Cocky Valve. Available at: https://cockyvalve.com.au/how-to-stop-water-troughs-going-green/. [Accessed 10 Sep. 2024]

Cocky Valve (2024b). "Ulti Flo Water Float Valve | Cocky Valve." *Cocky Valve*, 5 Nov. 2024, cockyvalve.com.au/product/ulti-flo-float-valve/. Accessed 6 Nov. 2024.

Coimbra, P.A.D., Machado Filho, L.C.P., Nunes, P.A., Hötzel, M.J., De Oliveira, A.G.L. and Cecato, U., 2010. Effect of water trough type on the drinking behaviour of pasture-based beef heifers. animal, 4(1), pp.116-121. [Accessed 3 Nov. 2024]

Coimbra, P.A.D., Machado Filho, L.C.P. and Hötzel, M.J., 2012. Effects of social dominance, water trough location and shade availability on drinking behaviour of cows on pasture. Applied Animal Behaviour Science, 139(3-4), pp.175-182. [Accessed 3 Nov. 2024]

Condon, J. (2021). ACC gains approval for 65,000 head feedlot – but has no immediate plans for construction. [online] Beef Central. Available at: https://www.beefcentral.com/lotfeeding/acc-gains-approval-for-65000-head-feedlot-but-has-no-immediate-plans-for-construction/ [Accessed 5 Apr. 2024].

Conron Stockcrete (2024a). BEEF BUNKS CATTLE OPEN FEED BUNK. [online] Conron Stockcrete. Available at: https://conronstockcrete.com.au/products/the-ultimate-in-open-feed-bunks [Accessed 3 Nov. 2024].

Davis, R., McGahan, E. and Lawrence, R. (n.d.). Feedlot covered housing systems Best practice design and management manual. [online] Available at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/documents/mla-feedlot-covered-housing-systems_v03.pdf. [Accessed 1 Apr. 2024].

Davis, R. and Watts, P. (2016). Occupancy Drinking Water Feed Processing Cattle Washing Administration Sundry FEEDLOT DESIGN AND CONSTRUCTION 4. Water requirements. [online] Available at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/feedlot-design-manual/04-water-requirements-2016_04_01.pdf. [Accessed 1 Apr. 2024].

Department of Primary Industries and Regional Development (2017). Calculating livestock water requirements for small landholders. [online] www.agric.wa.gov.au. Available at: https://www.agric.wa.gov.au/small-landholders-western-australia/calculating-livestock-water-requirements-small-landholders?nopaging=1.. [Accessed 30 Jun. 2024]

Department of Agriculture, Fisheries and Forestry (2023). Cattle feedlot industry - DAFF. [online] Agriculture.gov.au. Available at: https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/cattle-feedlot#australias-feedlot-industry-becoming-increasingly-important. [Accessed 10 Sep. 2024]

E.A Systems Pty Ltd (2024). Cooling Water for lot-fed Cattle. [online] Cooling Water for lot-fed Cattle. Available at: https://www.mla.com.au/contentassets/4517a8f3dd64489da503f1b0ee3b0a3b/flot.322_final_report.pdf [Accessed 3 Nov. 2024].

Eichinger, M. (2018). Pop Rivets vs. Blind Rivets: What You Need to Know. [online] blog.baysupply.com. Available at: https://blog.baysupply.com/pop-rivets-vs-blind-rivets. . [Accessed 30 Jun. 2024]

Elbow Valley. (n.d.). Our story. [online] Available at: https://elbowvalleybeef.com.au/canning/ [Accessed 1 Apr. 2024].
farmstyle.com.au. (n.d.). Wagyu cattle for the experienced small farmer | Farmstyle Australia. [online] Available at: https://farmstyle.com.au/news/wagyu-cattle-experienced-small-farmer#:~:text=There%20is%20currently%20strong%20demand [Accessed 5 Apr. 2024].

Elders (2024). Leyburn Weather | Elders Weather. [online] Eldersweather.com.au. Available at: https://www.eldersweather.com.au/climate-history/qld/leyburn [Accessed 3 Nov. 2024].

Emprende Jalisco (2015). Five Tips for Reducing Evaporation in Your Livestock Water Tanks - Green Themes in Agricultural Equipment and Supplies. [online] Emprendejalisco.com. Available at: https://emprendejalisco.com/2015/08/17/five-tips-for-reducing-evaporation-in-your-livestock-water-tanks/ [Accessed 3 Nov. 2024].

Engineering Design. (n.d.). Design Methods. [online] Available at: https://www.mcgill.ca/engineeringdesign/step-step-design-process/design-methods. .[Accessed 30 Jun. 2024]

Facebook.com. (2014). Facebook. [online] Available at: https://www.facebook.com/photo.php?fbid=147225760453595&id=106996654476506&set=a.147225140453657&locale=de_DE [Accessed 3 Nov. 2024].

Grieger, C. (2020). *Cattle Feedlot, Clare*. [online] CROC Trough Pumping Systems. Available at: https://croctroughpumps.com.au/blogs/news/hale-river-feedlot-cattle [Accessed 4 Nov. 2024].

Feedlot-covered housing systems Best practice design and management manual. (n.d.). Available at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/documents/mla-feedlot-covered-housing-systems_v03.pdf. [Accessed 5 Apr. 2024].

Fisheries, A. and (2011). Cattle code of practice. [online] www.business.qld.gov.au. Available at: https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/animal/health/welfare/codes/cattle#:~:text=Ensure%20cattle%20in%20a%20feedlot [Accessed 5 Apr. 2024].

FEEDLOT DESIGN AND CONSTRUCTION 2 FEEDLOT DESIGN AND CONSTRUCTION 16. Shade. (2016.). Available at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/feedlot-design-manual/016-shade-2016_04_01.pdf. [Accessed 5 Apr. 2024].

Four Daughters. (n.d.). NEWSLETTER #16 - Have you been in bed with a mosquito? 50 000 screws? [online] Available at: https://fourdaughters.com.au/blogs/news/newsletter-16-have-you-been-in-bed-with-a-mosquito-50-000-screws [Accessed 1 Apr. 2024]

Fleming, E., Fleming, P., Griffith, G. and Johnston, D. (2010). Measuring Beef Cattle Efficiency in Australian Feedlots: Applying Technical Efficiency and Productivity Analysis Methods. Australasian Agribusiness Review, [online] Available at: https://bpb-ap-se2.wpmucdn.com/blog.une.edu.au/dist/d/1339/files/2019/04/AAR-2010-Paper-4-Fleming_el_al-1hpbzkq.pdf [Accessed 5 Apr. 2024].

FutureBeef. (n.d.). Diet formulations. [online] Available at: https://futurebeef.com.au/resources/beef-cattle-feedlots-diet-formulations/#:~:text=on%20available%20commodities.-. [Accessed 5 Apr. 2024].

FutureBeef. (n.d.). Feedlots. [online] Available at: https://futurebeef.com.au/resources/beef-cattle-feedlot/#:~:text=The%20beef%20cattle%20feedlot%20industry [Accessed 2 Apr. 2024].

Gaughan, J.B., Bonner, S., Loxton, I., Mader, T.L., Lisle, A. and Lawrence, R. (2010). Effect of shade on body temperature and performance of feedlot steers1. Journal of Animal Science, 88(12), pp.4056–4067. doi:https://doi.org/10.2527/jas.2010-2987.

Gill, D., Barnes, K., Lusby, K. and Derrel, P. (n.d.). Beef Cattle Handbook. [online] Available at: https://www.iowabeefcenter.org/bch/RanchCustomFeeding.pdf [Accessed 5 Apr. 2024].

Gomes, R.C., Sainz, R.D., Silva, S.L., César, M.C., Bonin, M.N. and Leme, P.R. (2012). Feedlot performance, feed efficiency reranking, carcass traits, body composition, energy requirements, meat quality and calpain system activity in Nellore steers with low and high residual feed intake. Livestock Science, 150(1-3), pp.265–273. doi:https://doi.org/10.1016/j.livsci.2012.09.012. [Accessed 5 Apr. 2024].

Greenwood, P. (2021). Review: An overview of beef production from pasture and feedlot globally, as demand for beef and the need for sustainable practices increase. Animal, [online] 15(1), p.100295. doi:https://doi.org/10.1016/j.animal.2021.100295. [Accessed 5 Apr. 2024].

Greenwood, P.L., Gardner, G.E. and Ferguson, D.M. (2018). Current situation and prospects for the Australian beef industry — A review. Asian-Australasian Journal of Animal Sciences, [online] 31(7), pp.992–1006. doi:https://doi.org/10.5713/ajas.18.0090. [Accessed 1 Apr. 2024].

Hartech (n.d.). Top 5 Metal Bending Techniques & Machines| HARtech. [online] https://www.har-tech.com/en/. Available at: https://www.har-tech.com/en/metal-bending-techniques/. [Accessed 30 Jun. 2024].

House, J. (2019). It pays to have shade | Meat & Livestock Australia. [online] MLA Corporate. Available at: https://www.mla.com.au/news-and-events/industry-news/it-pays-to-have-shade/. [Accessed 1 Apr. 2024].

humans.txt (n.d.). Feeding robot - automatic feeding - Vector - Lely. [online] www.lely.com. Available at: https://www.lely.com/solutions/feeding/vector/. [Accessed 1 Apr. 2024].

humans.txt (2018). The new Lely Juno takes automatic feed pushing to the next level - Lely. [online] Lely.com. Available at: https://www.lely.com/au/press/2018/04/10/new-lely-juno/ [Accessed 3 Nov. 2024].

Isabirye, M.G. (2019). Water trough management system. *Busitema.ac.ug*. [online] doi:http://hdl.handle.net/20.500.12283/1691. [Accessed 3 Nov. 2024]

Lean, I. and Moate, P. (2021). Cattle, climate and complexity: food security, quality and sustainability of the Australian cattle industries. Australian Veterinary Journal, 99(7), pp.293–308. doi: https://doi.org/10.1111/avj.13072. [Accessed 1 Apr. 2024].

Lely, T. (n.d.). Lely Automatic Feeding Improves Results for Trehane Holsteins. [online] www.lelylife.com. Available at: https://www.lelylife.com/trehane-holsteins [Accessed 5 Apr. 2024].

Lemos Teixeira, D., Hötzel, M.J., Pinheiro Machado Filho, L.C., Cazale, J.D. and Enríquez-Hidalgo, D., 2017. Designing Better Water Troughs: Does Trough Color Influence Dairy Cows' Preference?. Journal of applied animal welfare science, 20(2), pp.192-197. [Accessed 3 Nov. 2024]

McAllister, T.A., Stanford, K., Chaves, A.V., Evans, P.R., Eustaquio de Souza Figueiredo, E. and Ribeiro, G. (2020). *Chapter 5 - Nutrition, feeding and management of beef cattle in intensive and extensive production systems*. [online] ScienceDirect. Available at: https://www.sciencedirect.com/science/article/abs/pii/B9780128170526000057..
[Accessed 3 Nov. 2024]

Media, W.A. (2022). Assignment: Inside Canada's Cattle Feedlots. [online] We Animals Media. Available at: https://weanimalsmedia.org/2022/07/19/new-assignment-inside-canadas-cattle-feedlots/ [Accessed 5 Apr. 2024].

MLA Corporate. (2019). Feed truck auto-delivery system fit for purpose. [online] Available at: https://www.mla.com.au/news-and-events/industry-news/feed-truck-auto-delivery-system-fit-for-purpose/ [Accessed 3 Nov. 2024].

MLA Corporate. (2024). *AUS-MEAT marbling | Solutions to feedback*. [online] Available at: https://solutionstofeedback.mla.com.au/cattle/chiller-assessment/aus-meat-marbling/ [Accessed 3 Nov. 2024].

MLA Corporate. (n.d.). What we do | Meat & Livestock Australia. [online] Available at: https://www.mla.com.au/about-mla/what-we-do/.[Accessed 1 Apr. 2024].
Mwangi, F.W., Charmley, E., Gardiner, C.P., Malau-Aduli, B.S., Kinobe, R.T. and Malau-Aduli, A.E.O. (2019). Diet and Genetics Influence Beef Cattle Performance and Meat Quality Characteristics. Foods, [online] 8(12). doi:https://doi.org/10.3390/foods8120648. [Accessed 1 Apr. 2024].

nutrition/feedlot-design-manual/04-water-requirements-2016_04_01.pdf. .[Accessed 30 Jun. 2024]

NSW Department of Primary Industries (2014). Water requirements for sheep and cattle Primefact 326 third edition Agriculture NSW Water Unit WARNING: Chemical residues and pollutants. [online] Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/96273/Water-requirements-for-sheep-and-cattle.pdf. [Accessed 10 Sep. 2024]

Ocen, G., Grace, I., Ali, M., Davis, M. and Flex, B., 2022. WATER BORNE DISEASES CONTROL IN LIVESTOCK THROUGH WATER TROUGHS MANAGEMENT SYSTEM. American Journal of Livestock Policy, 1(1), pp.1-7. [Accessed 3 Nov. 2024]

Okine, E.K., McCartney, D.H. and Basarab, J.B. (2003). Evaluation of the National Research Council (NRC) nutrient requirements for beef cattle: Predicting feedlot performance. Canadian Journal of Animal Science, 83(4), pp.787–792. doi:https://doi.org/10.4141/a03-009.

Pinheiro Machado Filho, L.C., Teixeira, D.L., Weary, D.M., Keyserlingk, M.A.G. von and Hötzel, M.J. (2004). Designing better water troughs: dairy cows prefer and drink more from larger troughs. *Applied Animal Behaviour Science*, [online] 89(3), pp.185–193. doi:https://doi.org/10.1016/j.applanim.2004.07.002. [Accessed 3 Nov. 2024].

Pope, E. (2021). *Hot tips for hot days: drinking water and cattle performance | Select Carbon*. [online] Selectcarbon.com. Available at: https://www.selectcarbon.com/news-insights/hot-tips-for-hot-days-drinking-water-and-cattle-performance/ [Accessed 6 Nov. 2024].

RDC Engineers (2024). RDC Engineers. [online] RDC Engineers. Available at: https://www.rdcengineers.com.au/ [Accessed 5 Apr. 2024].

RUBBER INSERT-205 BEARING/62P HOUSING (2024). *RUBBER INSERT-205 BEARING/62P HOUSING*. [online] The Boss Shop Online. Available at: https://www.thebossshop.com.au/rubber-insert-205-bearing62p-housing [Accessed 4 Nov. 2024].

Salvin, H.E., Lees, A.M., Cafe, L.M., Colditz, I.G. and Lee, C. (2020). Welfare of beef cattle in Australian feedlots: a review of the risks and measures. Animal Production Science, 60(13), p.1569. doi:https://doi.org/10.1071/an19621.

Sarah (2022). What Is The ALFA Shade Policy Initiative? [online] Action Steel. Available at: https://www.actionsteel.com.au/what-is-the-alfa-shade-policy-initiative/#:~:text=%E2%80%9CALFA%20supports%20that%20all%20cattle [Accessed 5 Apr. 2024].

Sarah (2024). Partial Shade Versus Feedlot Sheds. [online] Action Steel. Available at: https://www.actionsteel.com.au/partial-shade-versus-feedlot-sheds/ [Accessed 5 Apr. 2024].

Stockcrete, C. (n.d.). 8FT BEEF BAR CATTLE TROUGH. [online] Conron Stockcrete. Available at: https://conronstockcrete.com.au/products/8ft-cattle-trough [Accessed 5 Apr. 2024].

Study.com (2022). Centroid & Center of Mass of a Semicircle | Overview & Examples. [online] Study.com. Available at: https://study.com/learn/lesson/centroid-semicircle-formula-examples.html. [Accessed 10 Sep. 2024]

Sullivan, M.L., Cawdell-Smith, A.J., Mader, T.L. and Gaughan, J.B. (2011). Effect of shade area on performance and welfare of short-fed feedlot cattle1. Journal of Animal Science, 89(9), pp.2911–2925. doi:https://doi.org/10.2527/jas.2010-3152. [Accessed 5 Apr. 2024].

Team Lely (2017). Precision Feeding with Lely tools. [online] Lelylife.com. Available at: https://www.lelylife.com/2017/02/precision-feeding-with-lely-tools [Accessed 3 Nov. 2024].

Teixeira, Day & Hötzel, Maria José & Pinheiro Machado Filho, L. (2006). Designing better water troughs: 2. Surface area and height, but not depth, influence dairy cows' preference. Applied Animal Behaviour Science - APPL ANIM BEHAV SCI. 96. 169-175. 10.1016/j.applanim.2005.06.003. [Accessed 3 Nov. 2024]

Timalco Hydraulics (2021). *Low Speed High Torque Motors | Timalco Hydraulics*. [online] Timalco.com.au. Available at: https://timalco.com.au/product-category/hydraulic-motors/low-speed-high-torque-motors/ [Accessed 6 Nov. 2024].

The Cattle Site. (n.d.). Breeds - Wagyu. [online] Available at: https://www.thecattlesite.com/breeds/beef/49/wagyu/.[Accessed 5 Apr. 2024].
The Metal Warehouse (2022). CATTLE RAIL 115 x 42 x 2MM- 6.1M. [online] Themetalwarehouse.com.au. Available at: https://www.themetalwarehouse.com.au/shop-online/clearance/cattle-rail-115-x-42-x-2mm-6-1m.html [Accessed 3 Nov. 2024].

The Metal Warehouse (n.d.). Square Tube: 50 x 50 x 3.0 SQUARE TUBE. [online] www.themetalwarehouse.com.au. Available at: https://www.themetalwarehouse.com.au/shop-online/steel/square-tube/50-x-50-x-3-0-square-tube.html.

Tobias, M. (2019). Structural Engineering: Comparing Welded and Bolted Unions. [online] Ny-engineers.com. Available at: https://www.ny-engineers.com/blog/structural-engineering-comparing-welded-and-bolted-unions. [Accessed 10 Sep. 2024]

Warner, R.D., Dunshea, F.R., Gutzke, D., Lau, J. and Kearney, G. (2014). Factors influencing the incidence of high rigour temperature in beef carcasses in Australia. Animal Production Science, 54(4), p.363. doi:https://doi.org/10.1071/an13455. [Accessed 5 Apr. 2024].

Water use in the paddock. (n.d.). Available at: https://www.mla.com.au/globalassets/mla-corporate/extensions-training-and-tools/creative-commons/unit-of-work---water-use-in-the-paddock---cc.pdf [Accessed 5 Apr. 2024].

Watts, P., Davis, R., Luttrell, M. and Keane, O. (n.d.). 5. Fences, gates and lanes FEEDLOT DESIGN AND CONSTRUCTION 2 FEEDLOT DESIGN AND CONSTRUCTION. [online] Available at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/feedlot-design-manual/015-fences-gates-and-lanes-2016_04_01.pdf. [Accessed 30 Jun. 2024]

Wikipedia Contributors (2019). Feedlot. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Feedlot. [Accessed 15 Mar. 2024].
Wikipedia. (2023). Leyburn. [online] Available at: https://en.wikipedia.org/wiki/Leyburn [Accessed 15 Mar. 2024].

Wong, J. (2022). *Beef and veal - DAFF*. [online] Agriculture.gov.au. Available at: https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/beef-and-veal. [Accessed 15 Mar. 2024]

World Animal Protection Australia. (2023). Beef cattle feedlots in Australia: everything you need to know. [online] Available at: https://www.worldanimalprotection.org.au/news/beef-cattle-feedlots-australia-everything-you-need-know/#:~:text=Did%20you%20know%20Australia%20has [Accessed 15 Mar. 2024].
www.farmersjournal.ie. (n.d.). Spanish feedlot margins squeezed. [online] Available at: https://www.farmersjournal.ie/beef/news/spanish-feedlot-margins-squeezed-150309 [Accessed 5 Apr. 2024].

www.google.com. (n.d.). Darren Hamblin - Google Search. [online] Available at: https://www.google.com/search?sca_esv=6cb148437a7a9a38&sxsrf=ACQVn0-LZx46PfBBEK18ZY53E44dQQvGWA:1711433721560&q=darren+hamblin&tbm=vid&source=lnms&prmd=ivnsmbtz&sa=X&ved=2ahUKEwiFr564o5GFAxWu1zQHHY5RBFsQ0pQJegQIDBAB&biw=1920&bih=911&dpr=1#fpstate=ive&vld=cid:924c4124 [Accessed 1 Apr. 2024].

www.google.com. (n.d.). Darren Hamblin - Google Search. [online] Available at: https://www.google.com/search?sca_esv=ba9cb985dba3a779&sca_upv=1&sxsrf=ACQVn086yzRfmuMhR [Accessed 5 Apr. 2024]

www.hamblin.com.au. (n.d.). SDL Strathdale Wagyu. [online] Available at: http://www.hamblin.com.au/Strathdale-Wagyu.php [Accessed 5 Apr. 2024].
www.ibisworld.com. (n.d.). IBISWorld - Industry Market Research, Reports, and Statistics. [online] Available at: https://www.ibisworld.com/au/industry/beef-cattle-farming/17/.https://www.mla.com.au/globalassets/mla-corporate/researchand- [Accessed 5 Apr. 2024]

u9ZnKtrj80es2xdQ:1712214878859&q=darren+hamblin&tbm=vid&source=lnms&prmd=ivsnmbtz&sa=X&sqi=2&ved=2ahUKEwj2uIi9gaiFAxXvSGcHHYcKB8EQ0pQJegQICxAB&biw=1920&bih=911&dpr=1#fpstate=ive&vld=cid:655f7186 [Accessed 5 Apr. 2024].

www.merriam-webster.com. (2024). Definition of FEEDLOT. [online] Available at: https://www.merriam-webster.com/dictionary/feedlot#:~:text=%3A%20a%20plot%20of%20land%20on%20which%20livestock%20are%20fattened%20for%20market [Accessed 15 Mar. 2024].

www.youtube.com. (n.d.). Darren Hamblin, Strathdale Wagyus, Qld. [online] Available at: https://www.youtube.com/watch?v=wzElm9ArWeo [Accessed 8 Feb. 2024]

Ye, R. (2023). What is a Milling Machine? [online] Rapid Prototyping & Low Volume Production. Available at: https://www.3erp.com/blog/milling-machine/... [Accessed 30 Jun. 2024]

9 Bibliography

Britannica Kids. (n.d.). Australian cattle industry. [online] Available at: https://kids.britannica.com/students/article/Australian-cattle-industry/629917. [Accessed 10 Sep. 2024]

Condon Engineering. (2024). Centralised Drinker Gate - Condon Engineering. [online] Available at: https://condonengineering.ie/product/centralised-drinker-gate/ [Accessed 3 Nov. 2024].

National Guidelines for Beef Cattle Feedlots in Australia. (n.d.). Available at: https://futurebeef.com.au/wp-content/uploads/National-guidelines-for-beef-cattle-feedlots-in-Australia-third-edition.pdf. .[Accessed 30 Jun. 2024]

Peel, Derrel.S. (2023). Feedlot trends in management and productivity. [online] www.farmprogress.com. Available at: https://www.farmprogress.com/cattle-news/feedlot-trends-in-management-and-productivity. .[Accessed 30 Jun. 2024]

Precision Brush (2024). Cylinder Brushes | Precision Brush. [online] Precisionbrush.com. Available at: https://precisionbrush.com/cylinder-brushes [Accessed 3 Nov. 2024].

Science Buddies (2012). The Engineering Design Process. [online] Science Buddies. Available at: https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps. .[Accessed 30 Jun. 2024]

Science Direct (n.d.). Feedlot - an overview | ScienceDirect Topics. [online] www.sciencedirect.com. Available at: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/feedlot. [Accessed 10 Sep. 2024]

Teemore Engineering - Livestock Housing Specialists. (2024). Hang on Trough - Teemore Engineering - Livestock Housing Specialists. [online] Available at: https://www.teemoreengineering.com/products/hang-on-trough/ [Accessed 3 Nov. 2024].

Tjcagriculturalengineering.co.uk. (2024). Tipping Water Trough – TJC Agricultural Engineering. [online] Available at: https://tjcagriculturalengineering.co.uk/portfolio/tipping-water-trough/ [Accessed 3 Nov. 2024

9.1 Appendix A – Project specifications

ENP4111 Research Project

For	Lachlan Davis
Topic:	A Capable and Effective Watering System for an Intensive Beef Cattle Covered Housing Arrangement
Supervisors:	Steven Goh (University of Southern Queensland) Darren Hamblin (Strathdale Wagyu)
Enrolment:	ENP4111 – Year long, 2024
Project Aim:	To design a functional and innovative water trough that can be used in an intensive feeding covered housing arrangement that suits specific requirements for the site and industry.
Sponsorship:	Strathdale Wagyu
Programme:	1. Research background information 2. Understand trends in the industry 3. Establish all requirements and constraints 4. Begin design processing 5. generate fabrication drawings to be sent to fabricator 6. analyse prototype in field make necessary refinements 7. analyse final prototype and discuss finding 8. compile and submit in report style

Agreed: [redacted]

____________________(student)

______________________________________(supervisor)

Examiner/Co-Examiner: ____

9.2 Appendix B – Risk assessment

5722	RISK DESCRIPTION	STATUS	TREND	CURRENT	RESIDUAL
	A Capable and Effective Watering System for an Intensive Beef Cattle Covered Housing Arrangement.	Awaiting Approval		Very Low	Very Low

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Lachlan Davis	12/09/2024	12/09/2024	12/09/2025

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Due to the fact of writing this report will be a lengthy process. Proper Ergonomics need to be considered for furniture and equipment such as keyboards, office chair and desks.	Control: No control was needed initially, all these furniture items have already been acquired and implemented.	Very Low	The risks will be eliminated by purchasing an ergonomic keyboard to avoid carpal tunnel. An ergonomic desk and chair will also be used to prevent aches, soreness or injuries sustained by a static posture for long periods. These factors are recognised and will eliminate all possible threats associated with my project writing.		12/09/2024	Very Low

This was the only risks that were involved with the creation of this report. The project was undertaken privately and there was a risk management plan in place from RDC Engineers Pty Ltd and Strathdale Wagyu and was conformed to during the site visit.

9.3 Appendix C – Methodology

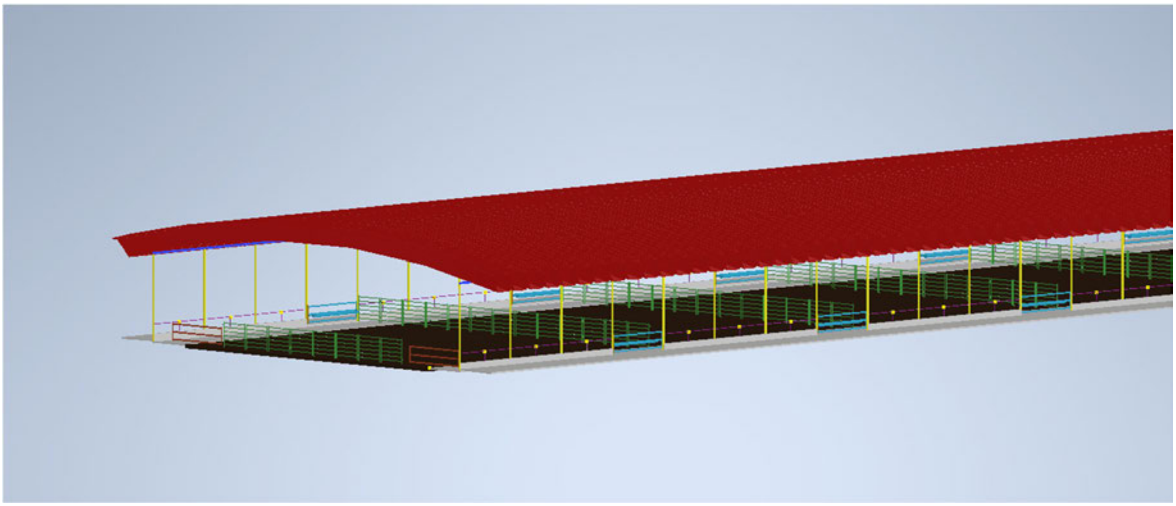


Figure 101: Struggle Downs Feedlot – Shed 3D model – Isometric view

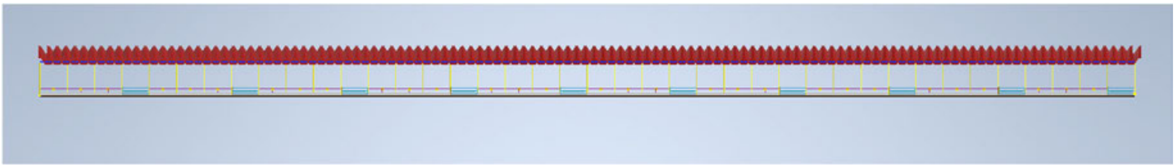


Figure 102: Struggle Downs Feedlot – Shed 3D model – Side view

9.4 Appendix D – Design

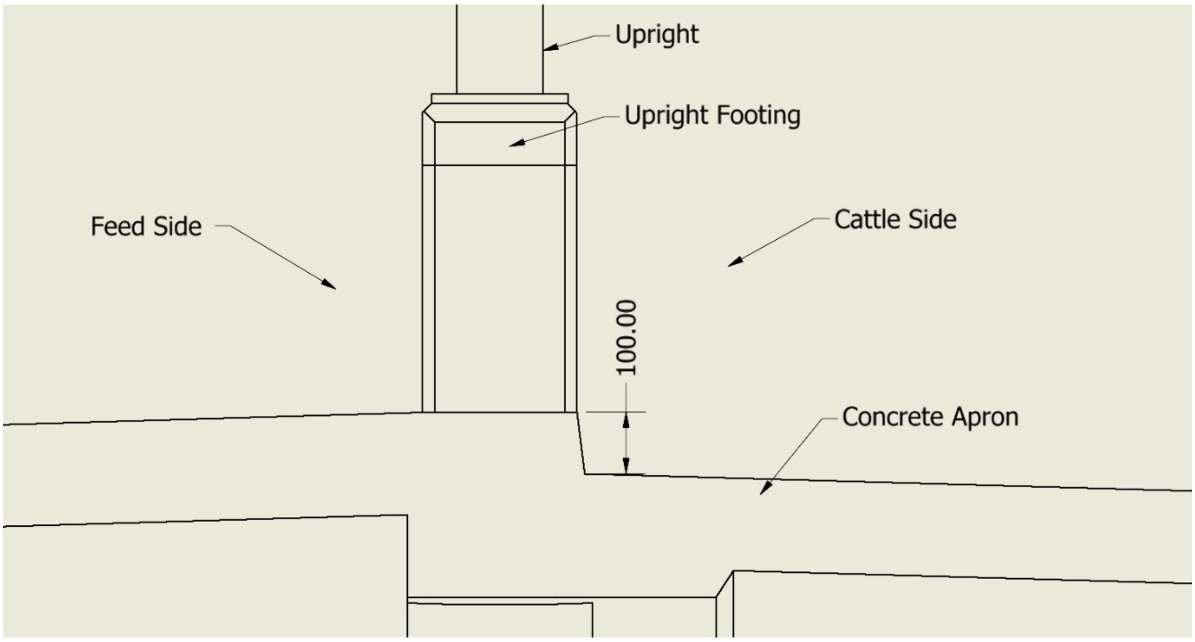


Figure 103: Struggle Downs feedlot Shed – Shed upright - Cross section

Figure 103 shows the 100mm step down between the feed side concrete apron and the cattle side concrete apron.

Figure 104: Materials - SHS 50x50mm at 3mm and 1.5 thickness (The Metal Warehouse, n.d.)

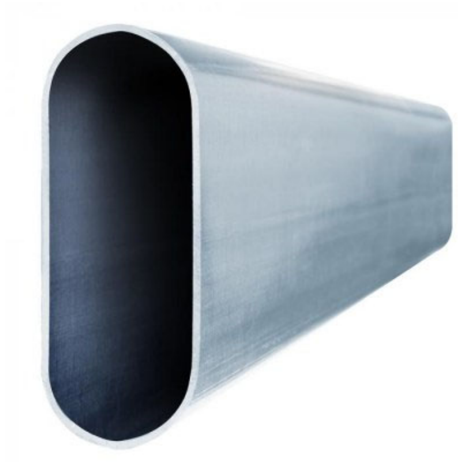


Figure 105: Materials - Oval Cattle Rail 115x42x2mm, galvanised (The Metal Warehouse, 2022)

Figure 106: Materials - Weld on Hinge – W27mm weld on hinges (CanDooRural, 2022)

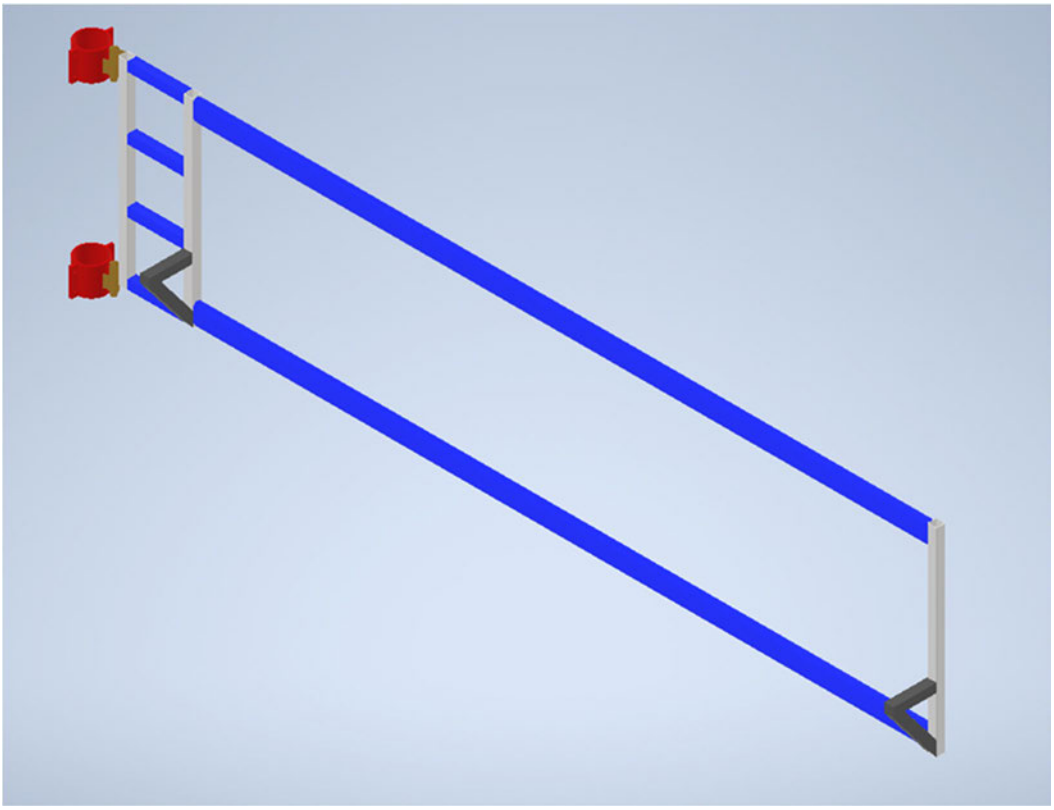


Figure 107: Struggle Downs Feedlot – Pen gate – Iteration 2 – Isometric view

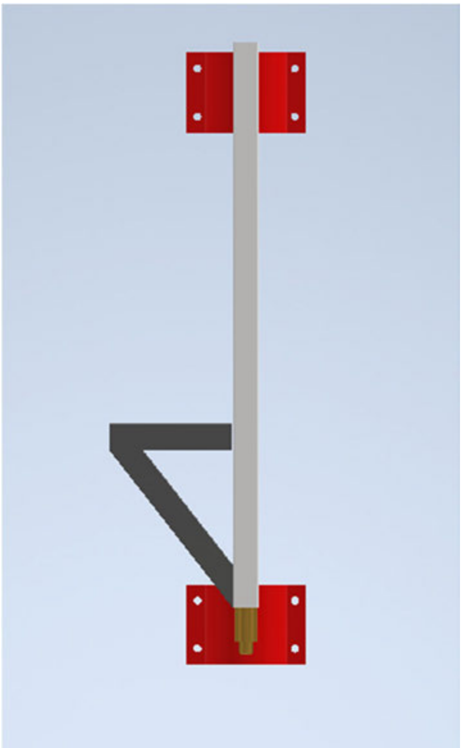


Figure 108: Struggle Downs Feedlot – Pen gate – Iteration 2 - Side view

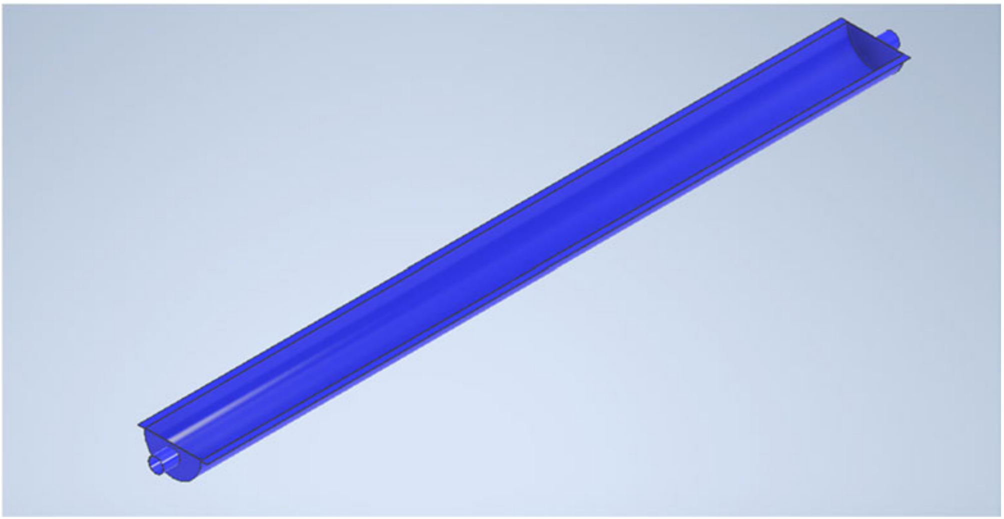


Figure 109: Struggle Downs Feedlot – Trough body iteration 2

Stainless Steel Sheet	
Grade	304, 304/304L, 316, 316/316L, 2205, 4003/3CR12 & 4003Ti/3CRTi.
Thickness (mm)	0.45 to <3.0.
Width (mm)	914, 1219, 1500, 2000 & customer specific width.
Length (mm)	1829, 2438 & customer specific length.
Finish	2B, No.4, BA & customer specific polish.
Standard coating	Paper interleaf & PE.
Optional coating	Laser & Deep drawing PVC.
Plasma profiles	To customer drawings.

Figure 110: Stainless steel - Available profiles for manufacturing (Atlas Steels, n.d.)

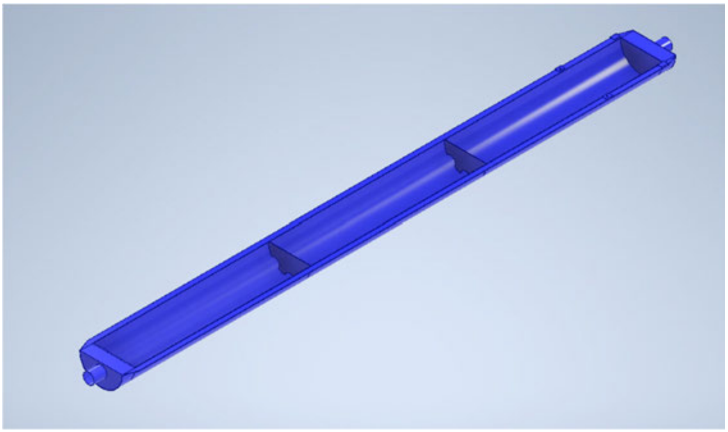


Figure 111: Struggle Downs Feedlot - Trough body – Lateral strengthening plates

Figure 112: Bend Brothers 76mm Stainless CHS (bendbrothers Guarantee, 2024)

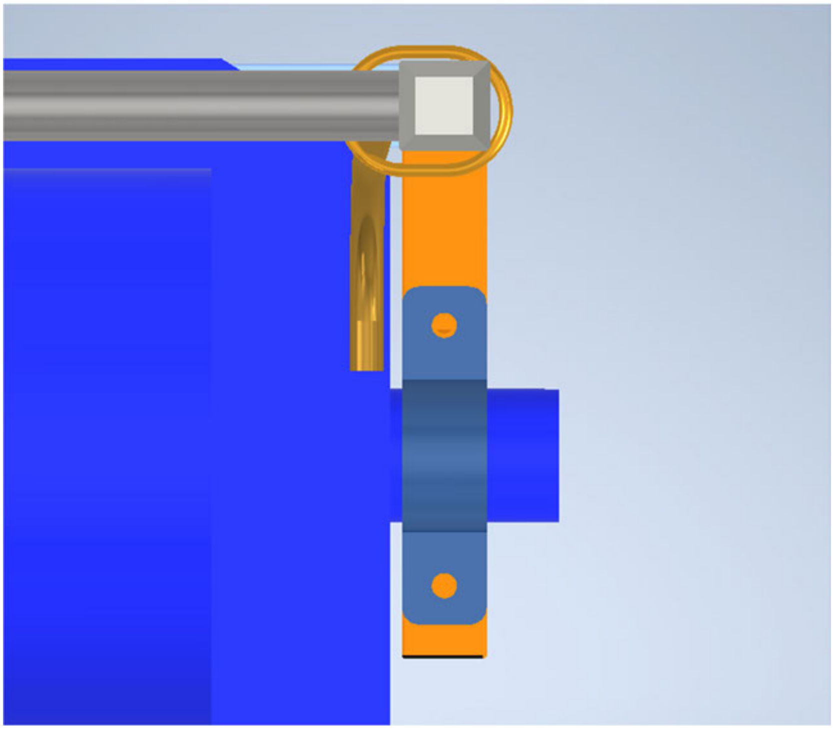


Figure 113: Struggle Downs Feedlot – Water trough locking system – Top view

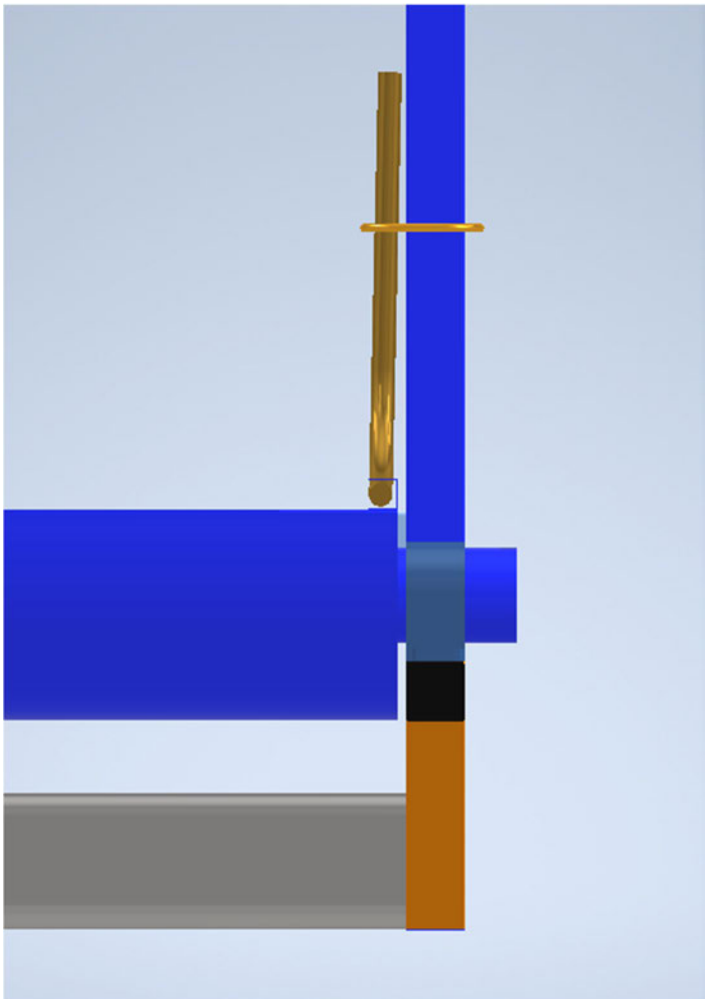


Figure 114: Struggle Downs Feedlot – Water trough locking system – Front view

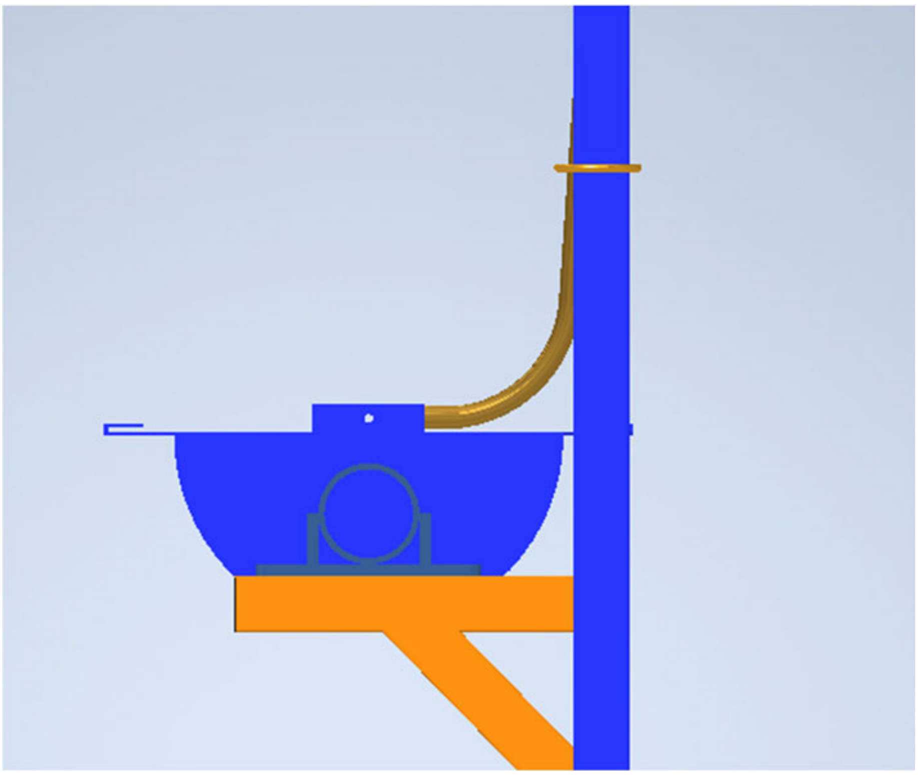


Figure 115: Struggle Downs Feedlot – First protoype - Locking System Side View

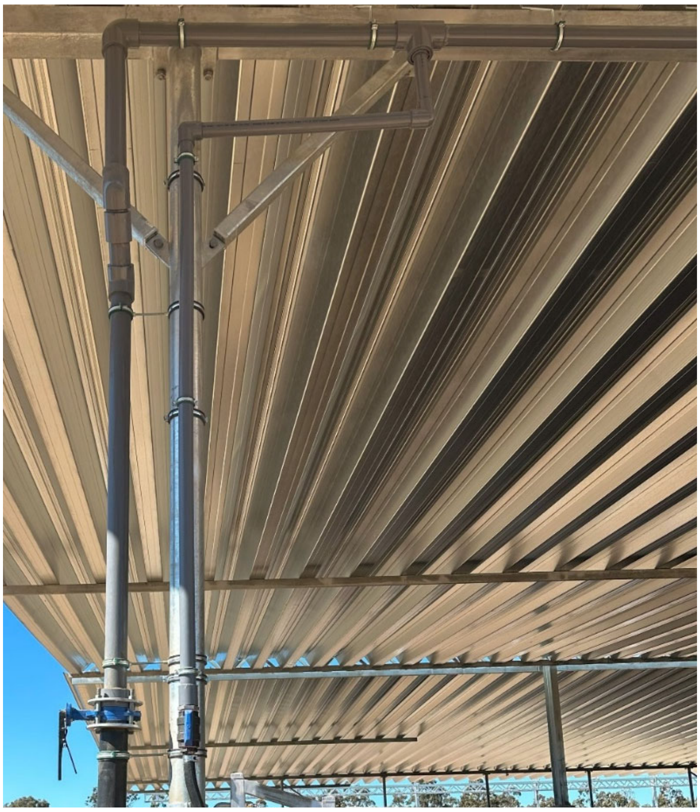


Figure 116: Piping system - roof

Figure 117: Piping system from ground

Figure 118: Piping System valve

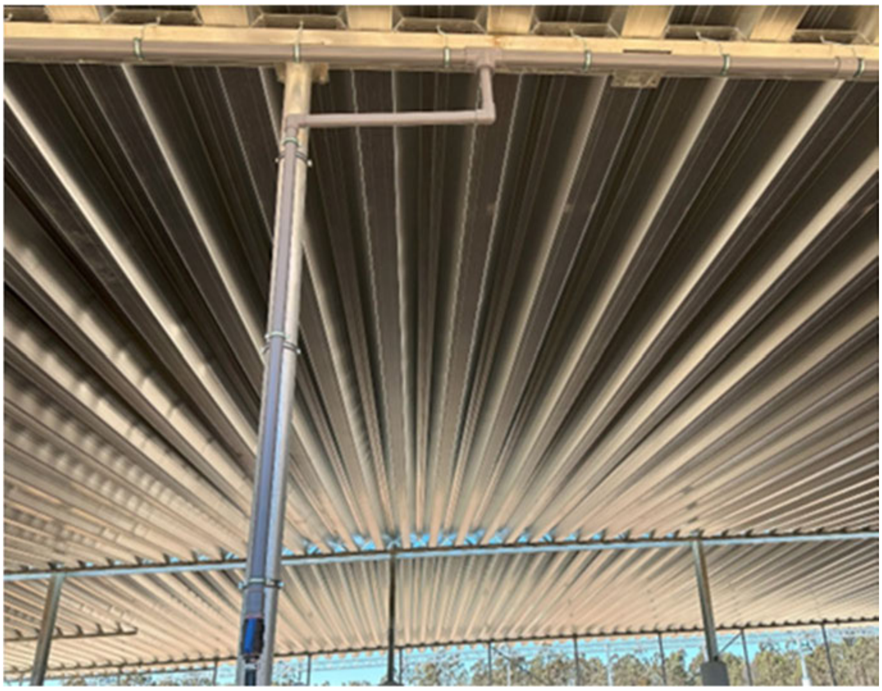


Figure 119: Piping System strategic elbow

Figure 120: Float Hood 3D model - front view

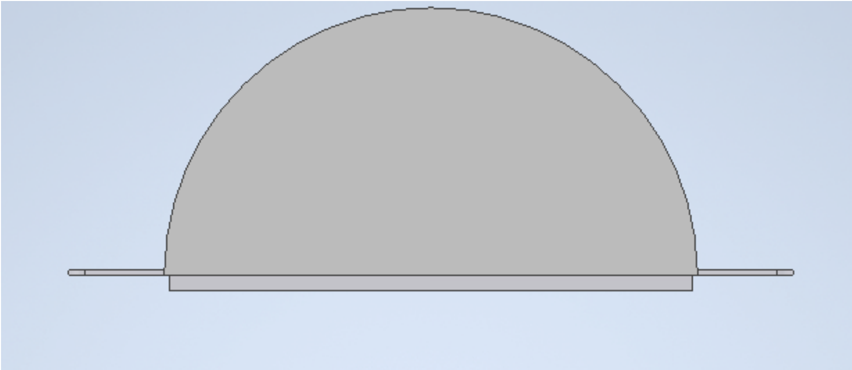


Figure 121: Float Hood 3D model - side view

Figure 122: Float hood attached to trough body - front view

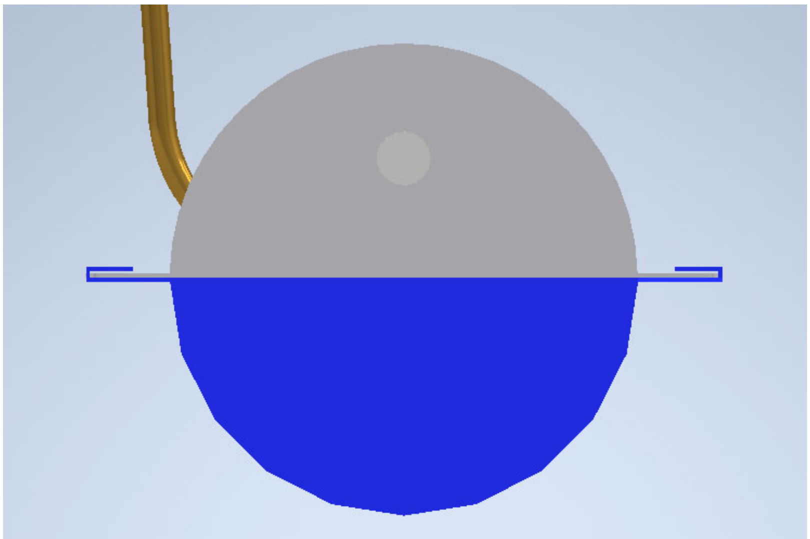


Figure 123: Float hood attached to trough body - side view

Figure 124: First prototype - Front view

Figure 125: Prototype 1 - Top View

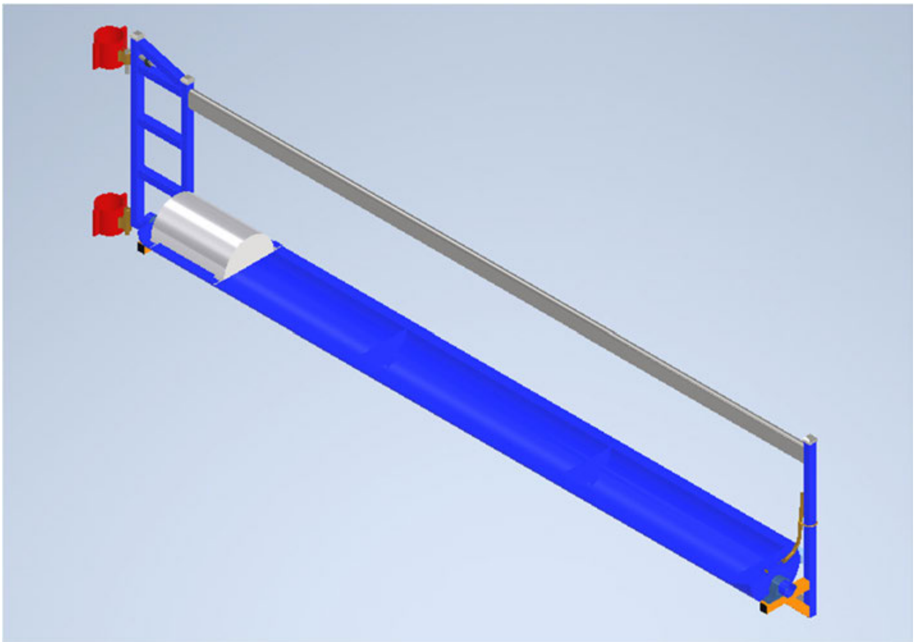


Figure 126: Prototype 1 - Isometric View 2

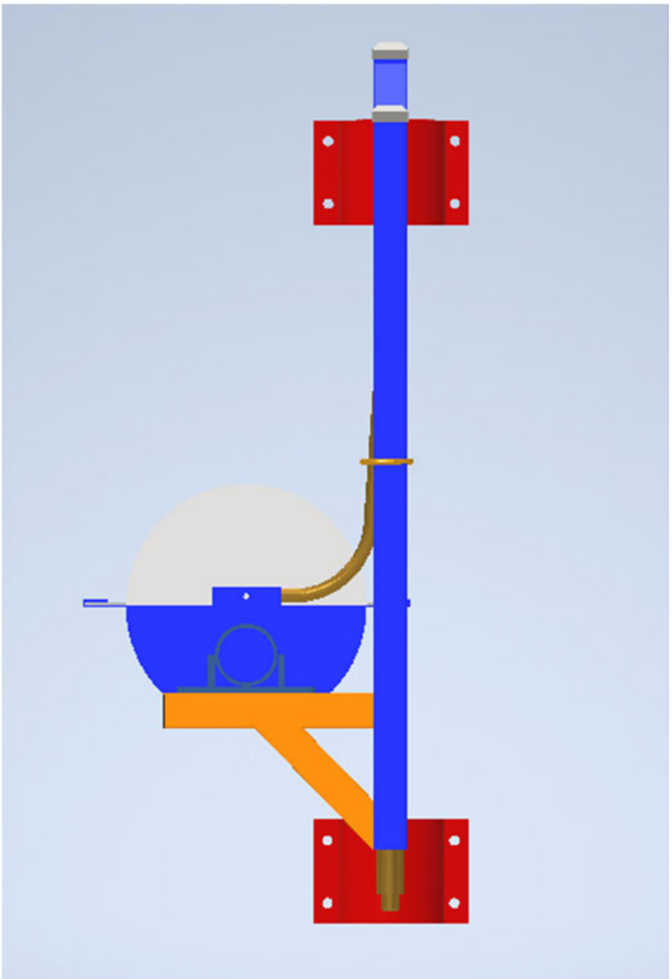


Figure 127: Prototype 1 - Side View

Figure 128: Prototype 1 in field - View 1

Figure 129: Prototype 1 in Field - View 2

Figure 130: Prototype 1 in field - View 3

Figure 131: Prototype 1 in field - View 3

Figure 132: Prototype 1 in field - View 5

Figure 133: Prototype 1 in field - View 6

Figure 134: Prototype 1 in field - View 7

Figure 135: Prototype 1 in field - View 8

9.5 Appendix E – Results

Figure 136: Splash Guard on Revised float Hood

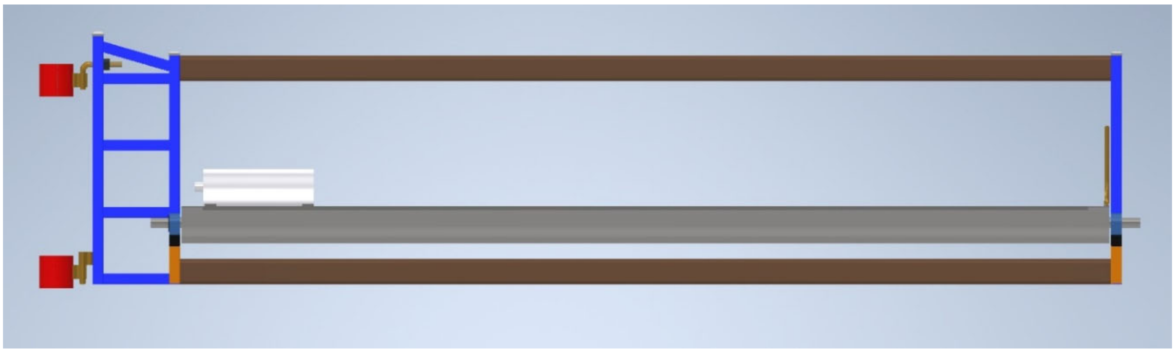


Figure 137: Final 3D model – front view

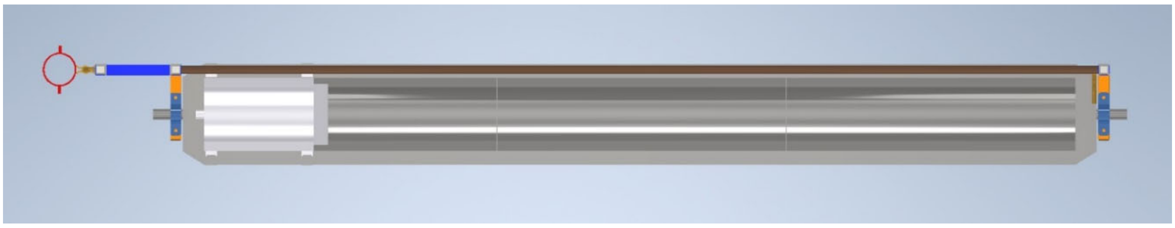


Figure 138: Final 3D model – top view

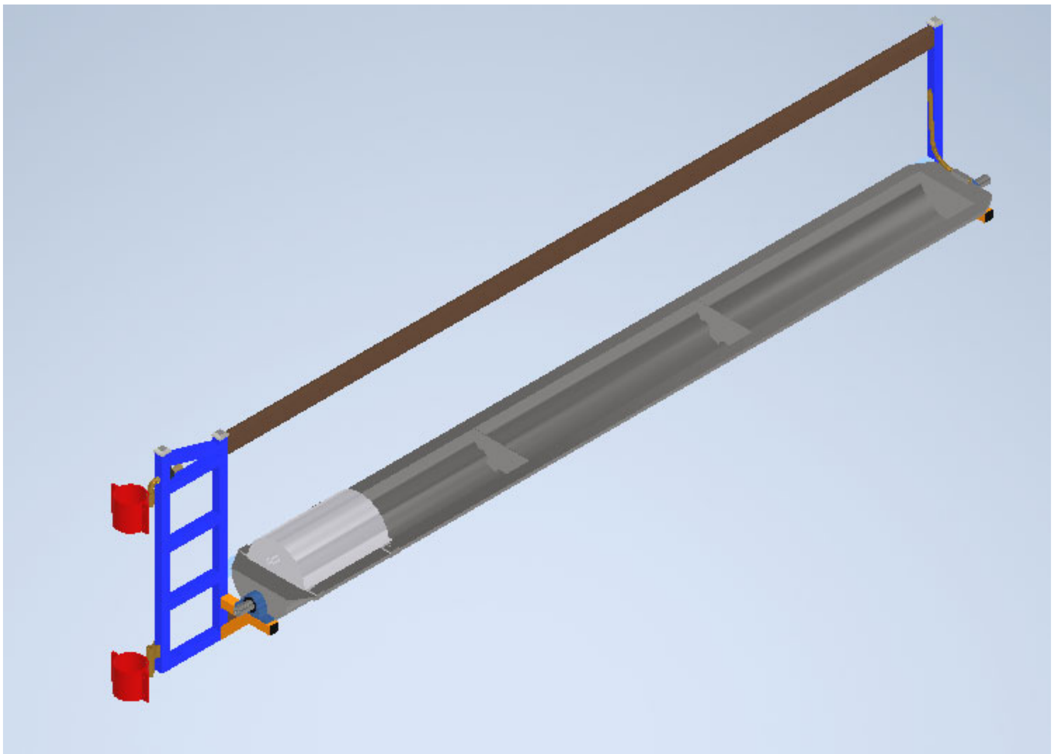


Figure 139: Final 3D model – Isometric view 2

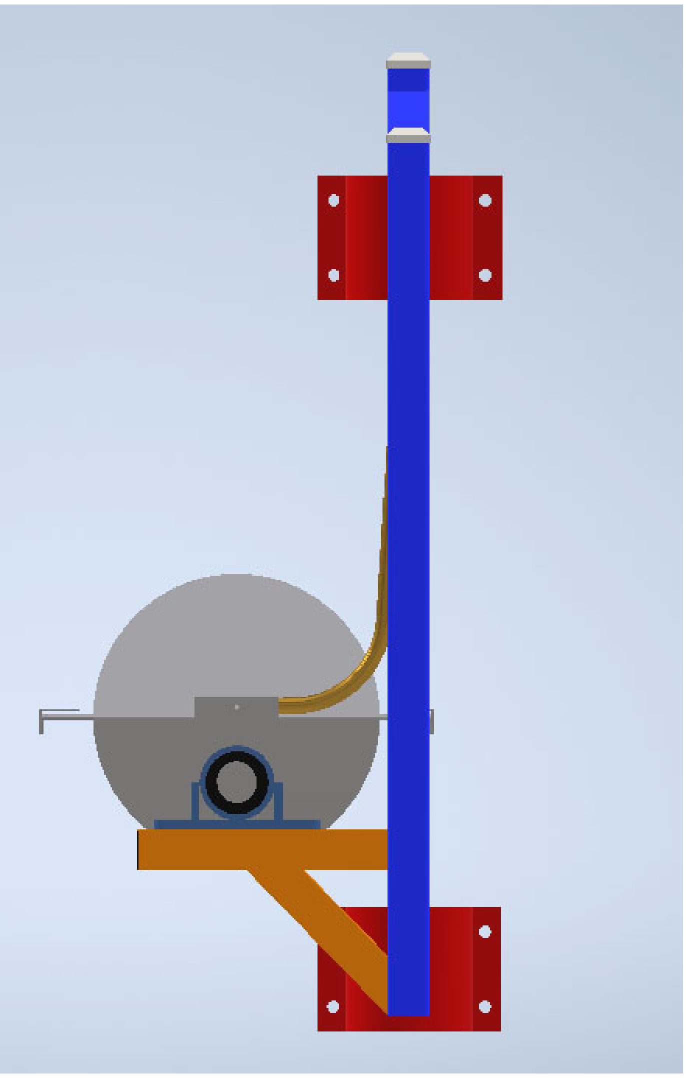


Figure 140: Final 3D model – side view

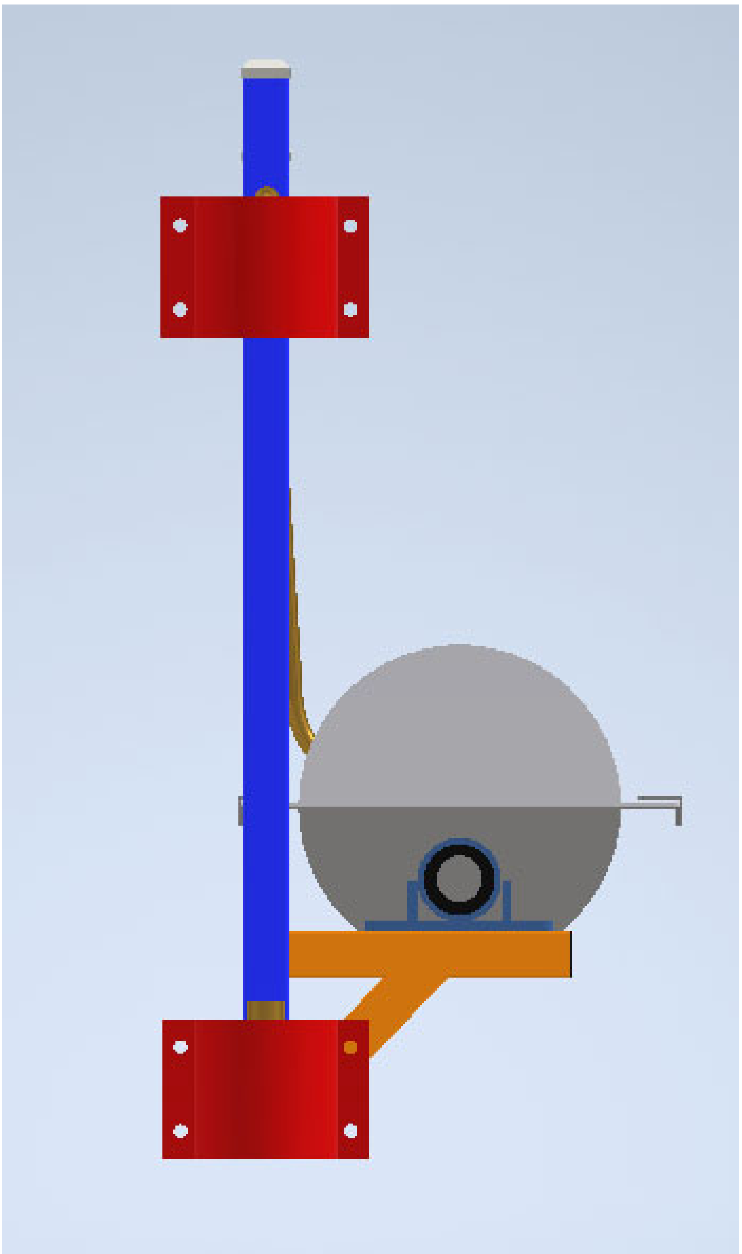


Figure 141:Final 3D model – side view 2

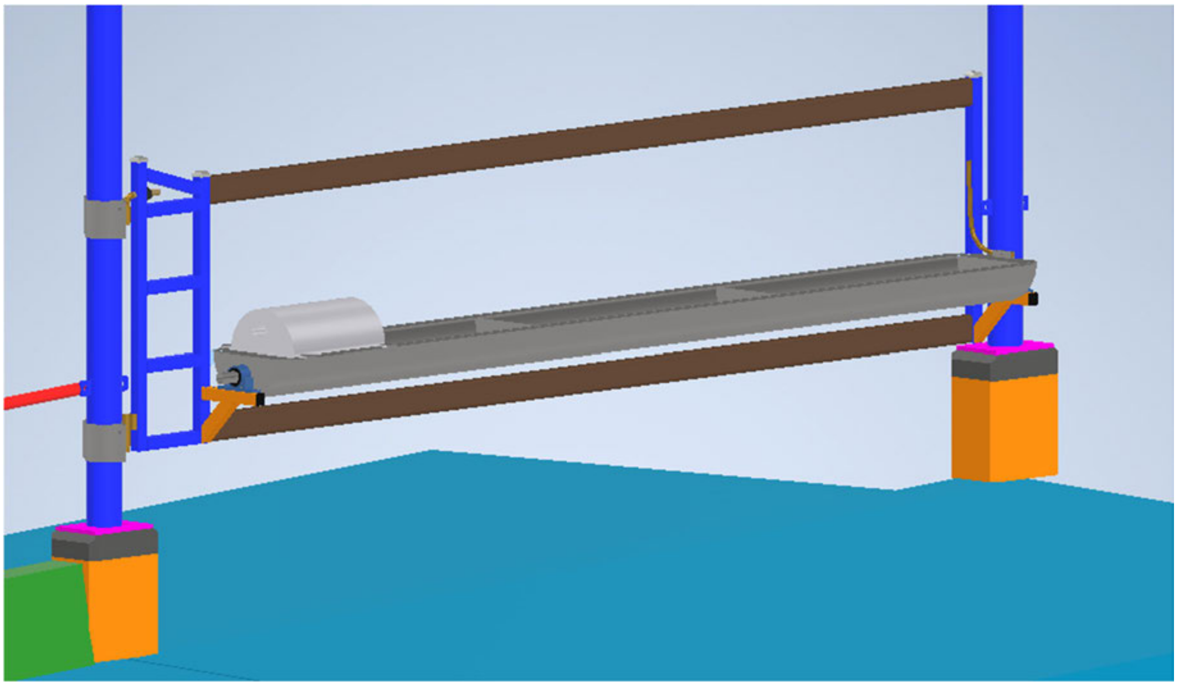
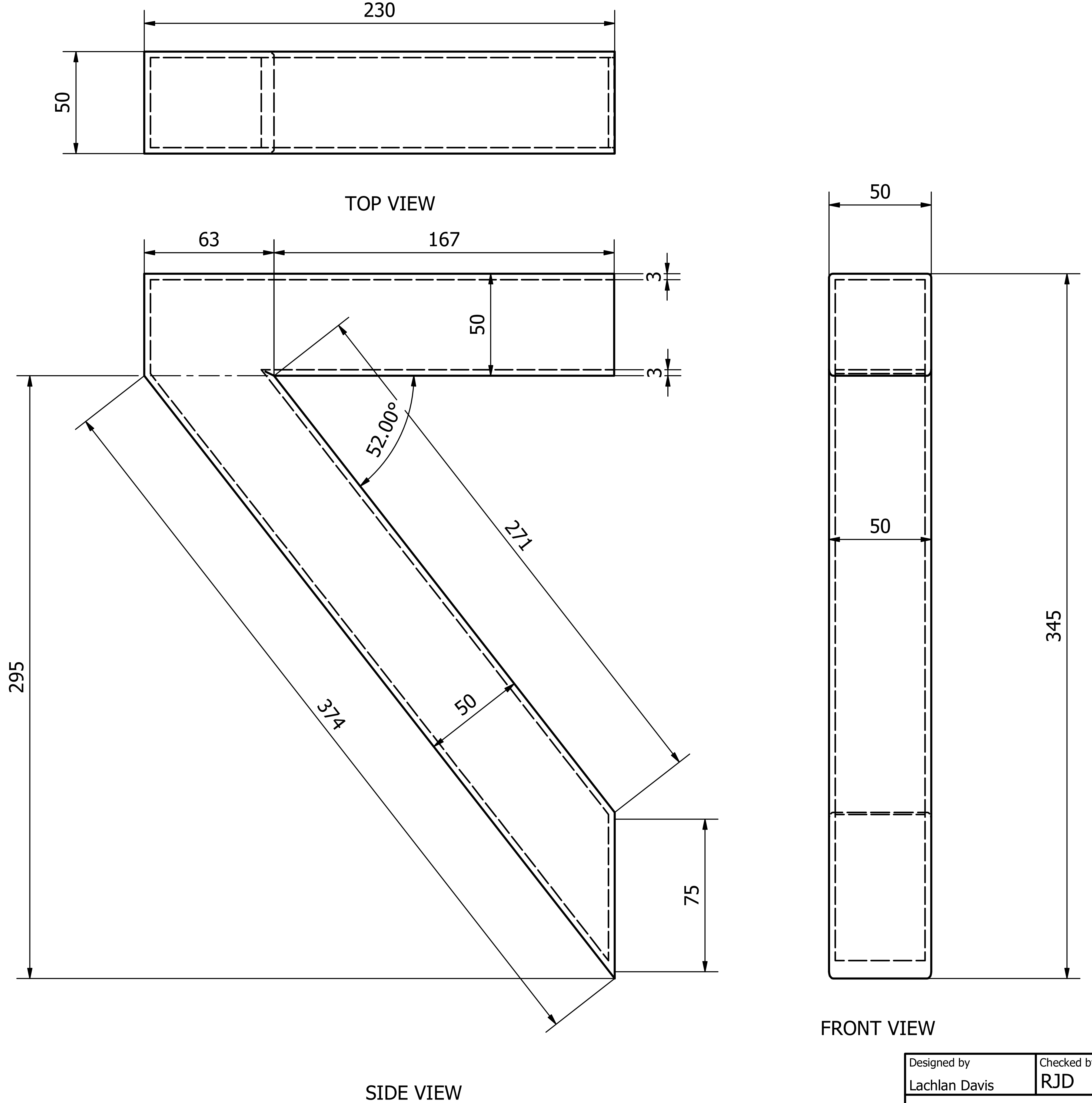


Figure 142:Final 3D model – Isometric view 3

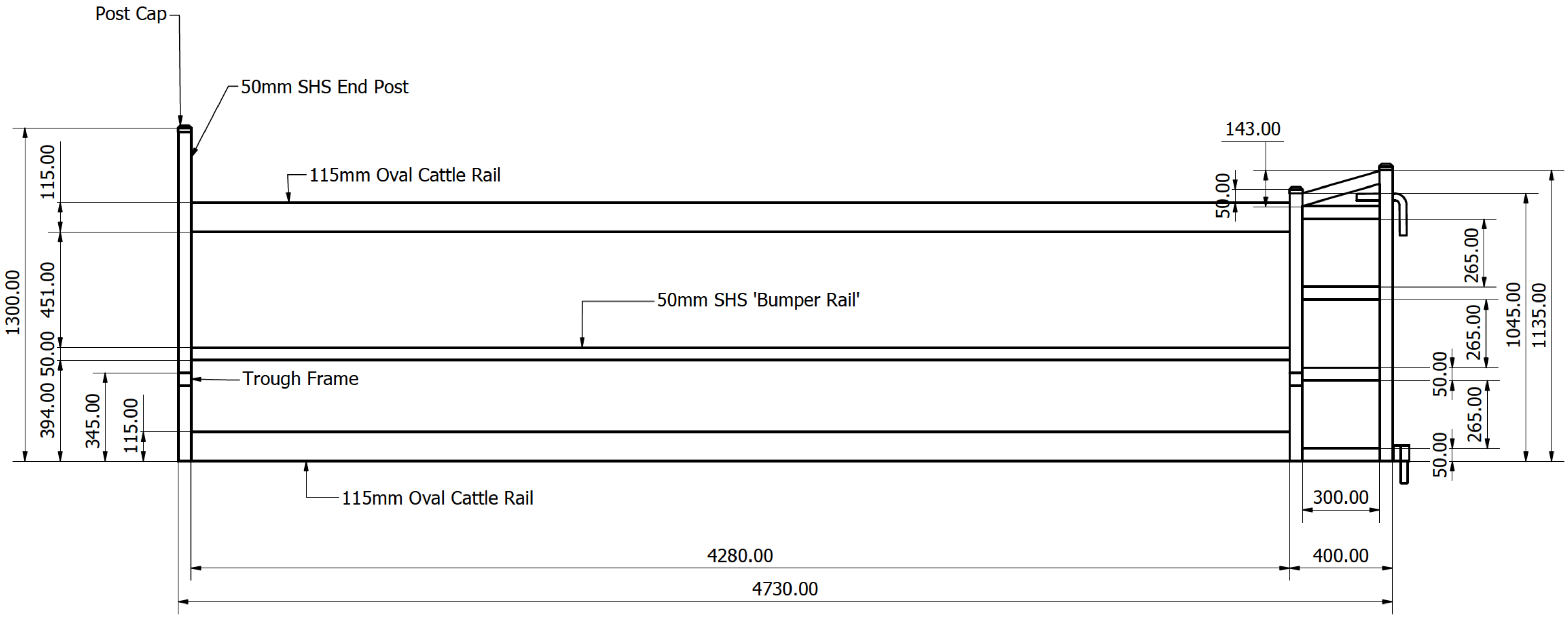
Figure 143:Final 3D model – Rear view 1

9.6 Appendix F – Fabrication drawings



Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	22/04/2024	22/04/2024

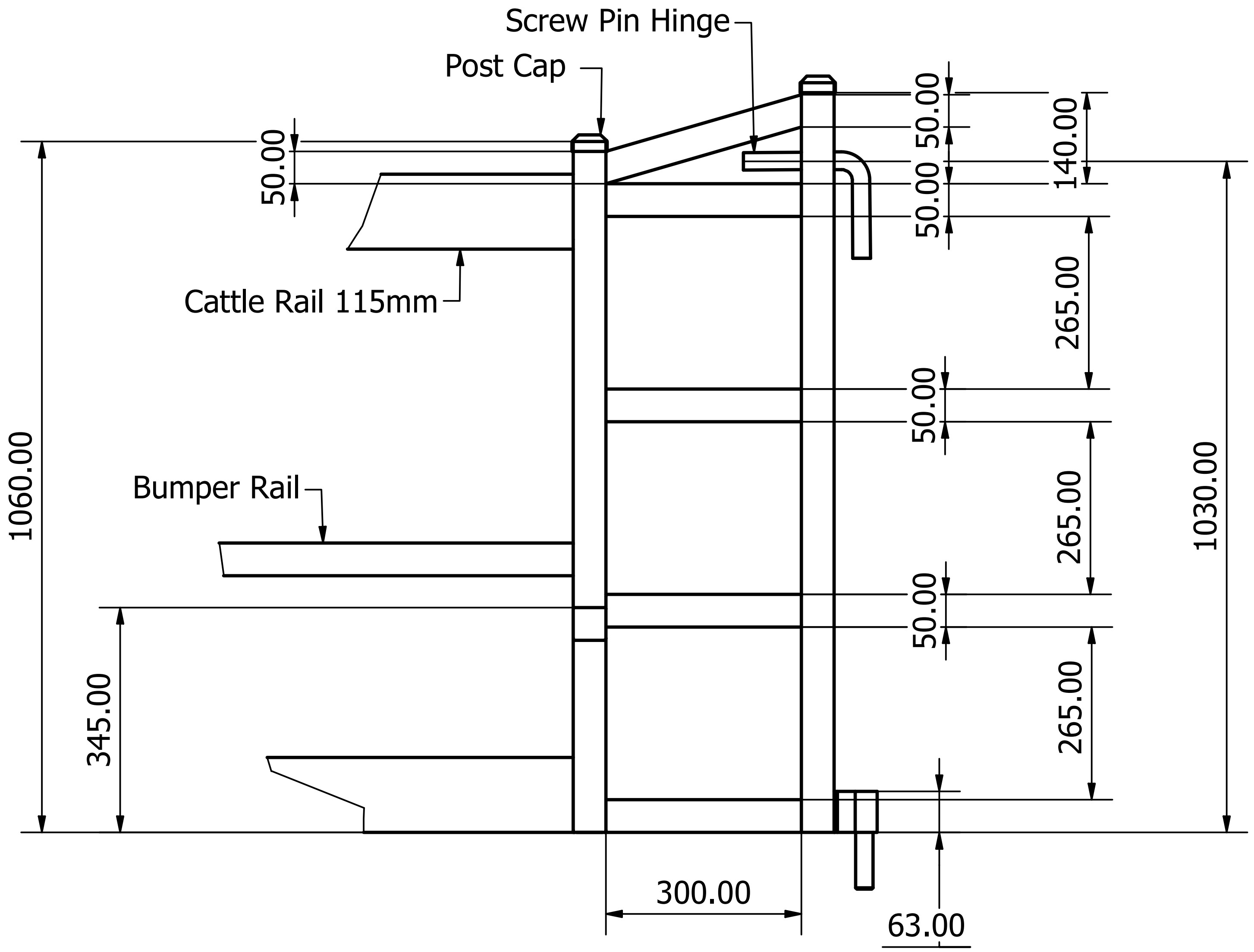
Hamblin Pty Ltd	Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd	End Frame Detailed Drawing	Edition: Revision	Sheet: 1 / 1



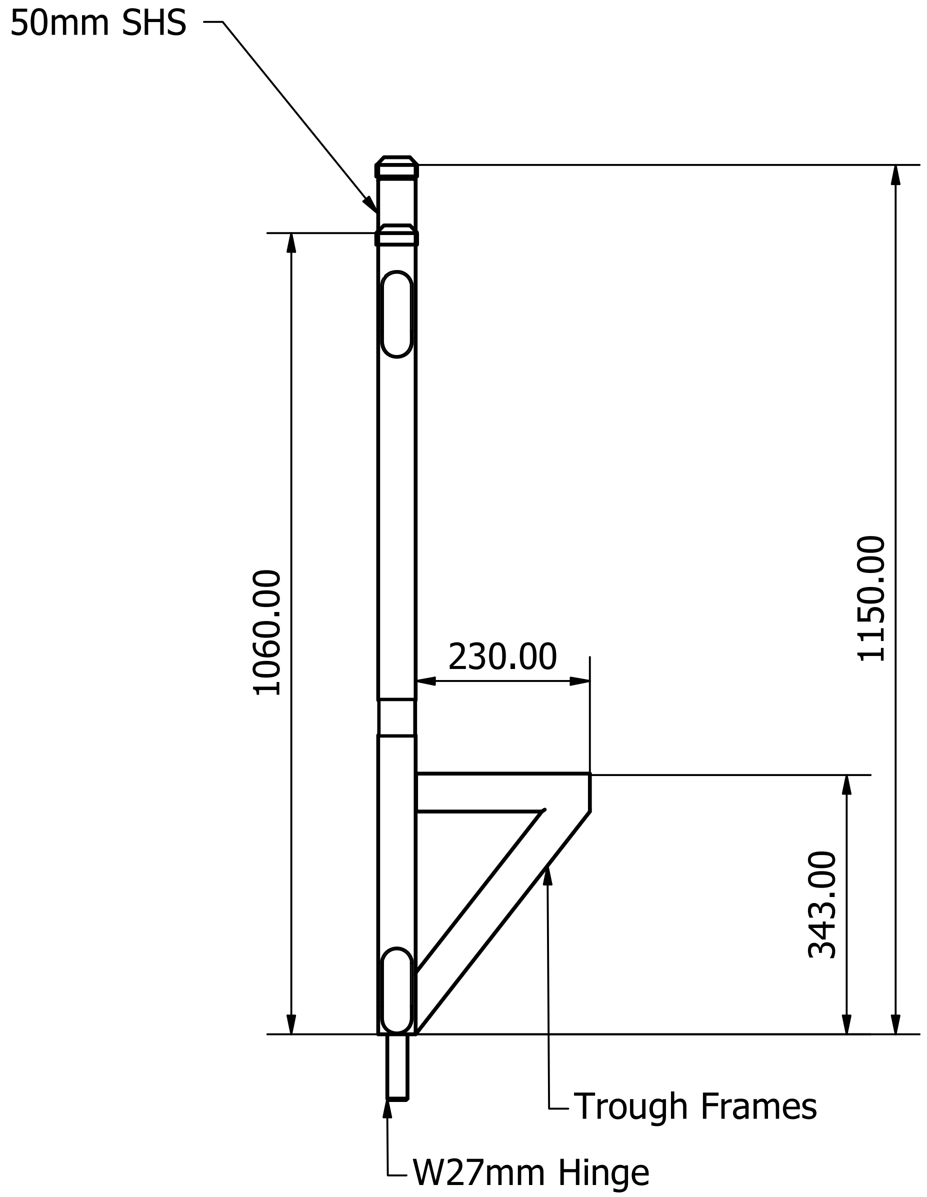
Gate Assembly Front

Designed by	Checked by	Approved by	Date Checked	Date of Creation	
Lachlan Davis	RJD	RJD	1/05/2024	1/05/2024	
Hamblin Pty Ltd		Struggle Downs Feedlot - Shed			
RDC Engineers Pty Ltd		Fence Assembly Detailed Drawing 1		Edition Revision	Sheet 1 / 1

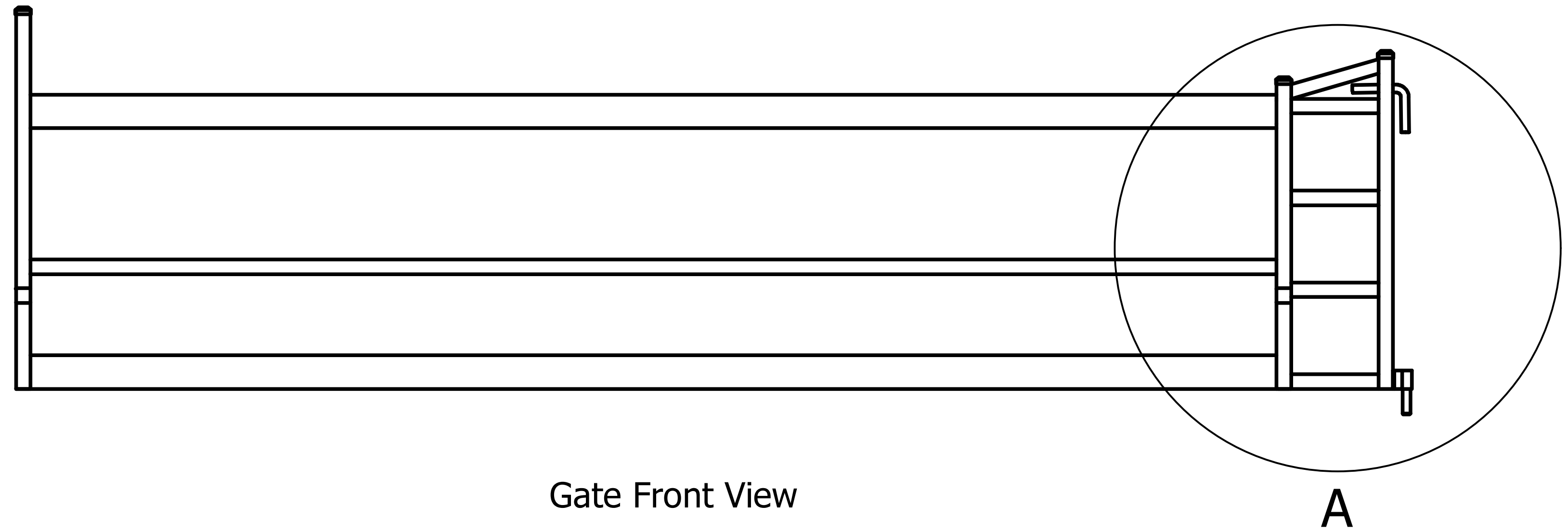
A (1:10)



Exploded Front View



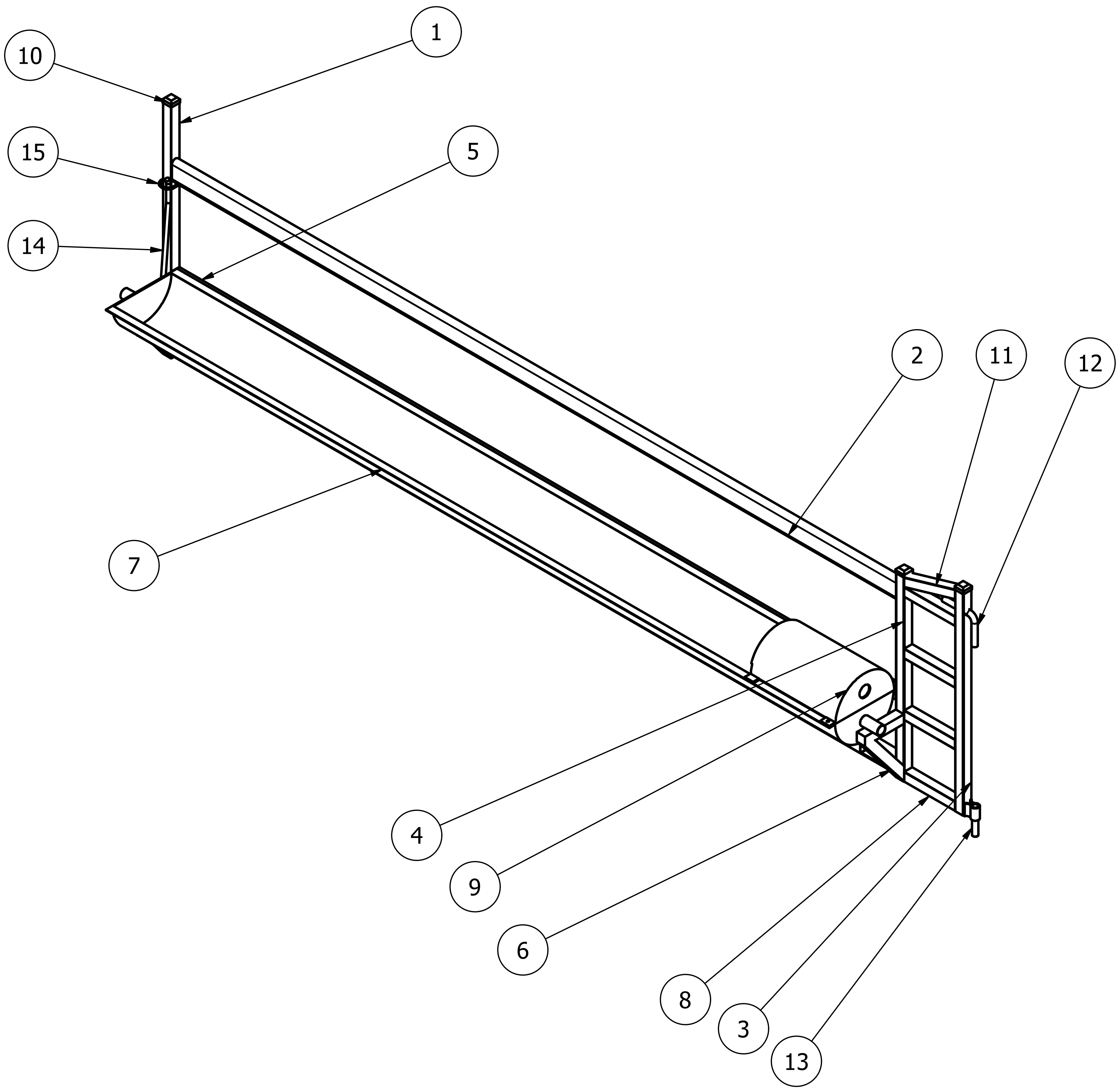
Exploded Side View



Gate Front View

Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	01/05/2024	1/05/2024

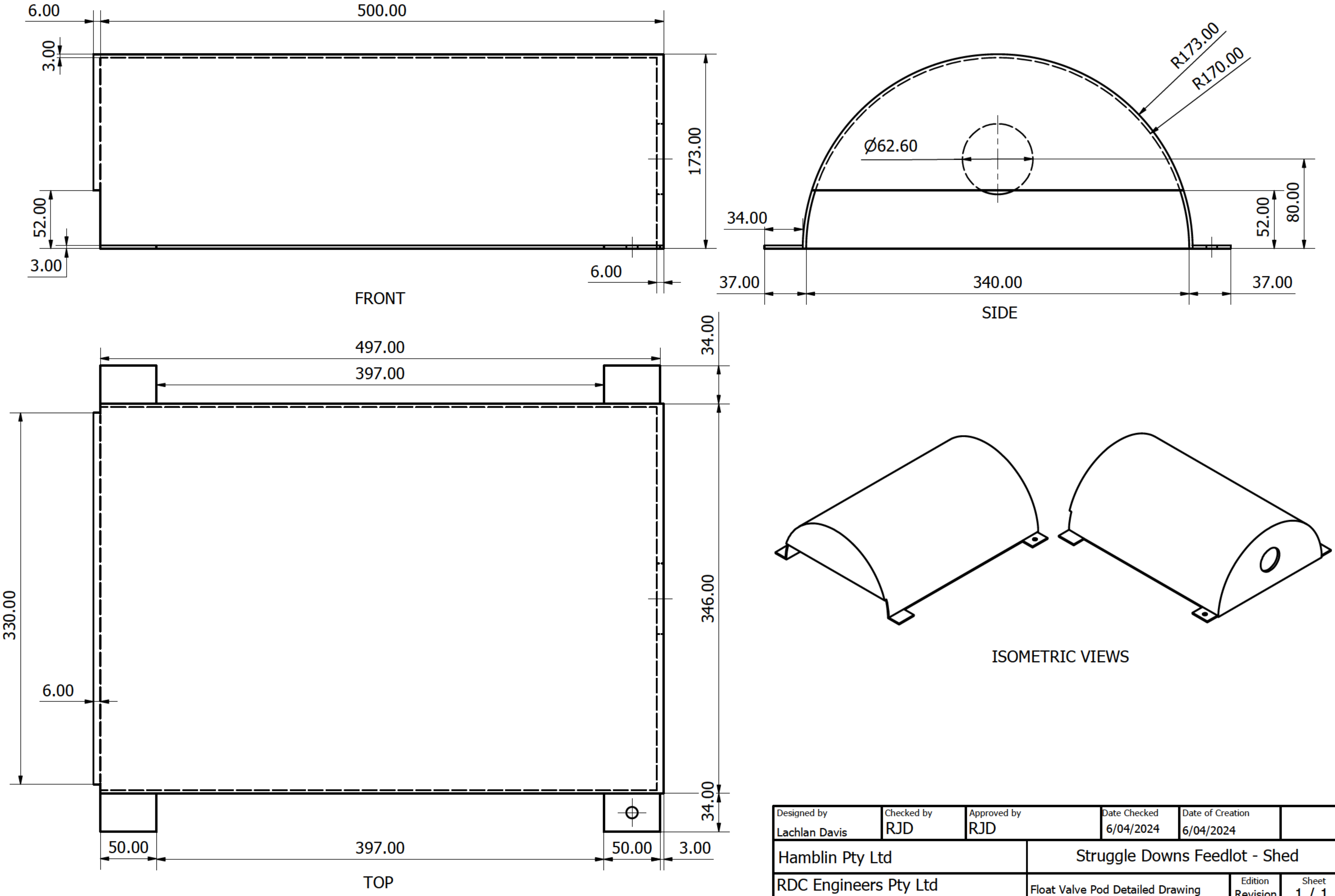
Hamblin Pty Ltd	Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd	Fence Assembly Detailed Drawing 2	Edition Revision	Sheet 1 / 1



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	latch side gate head 1300mm	50x50 SHS
2	2	Oval cattle rail 4280mmm	115mm Oval Rail
3	1	Gate Head Outside Hinge 1150mm	50x50 SHS
4	1	Gate Head Dummy inside 1050mm	50x50 SHS
5	1	bumper rail trough 4280mm	50x50 SHS
6	2	End Frames v2	50x50 SHS
7	1	Water Bucket	Stainless Steel Pipe
8	4	Spacer Brace 300mm	50x50 SHS
9	1	float valve pod v2	Stainless Steel Pipe
10	3	post caps 50x50 SHS	Gal/SS Plate
11	1	gusset piece 50x50	50x50 SHS
12	1	fastening bolt pin	Threaded Steel Bar
13	1	w27mm hinge male	Off Shelf
14	1	handle v5	20mm Steel Pipe
15	1	locking link	Folded Rebar eg

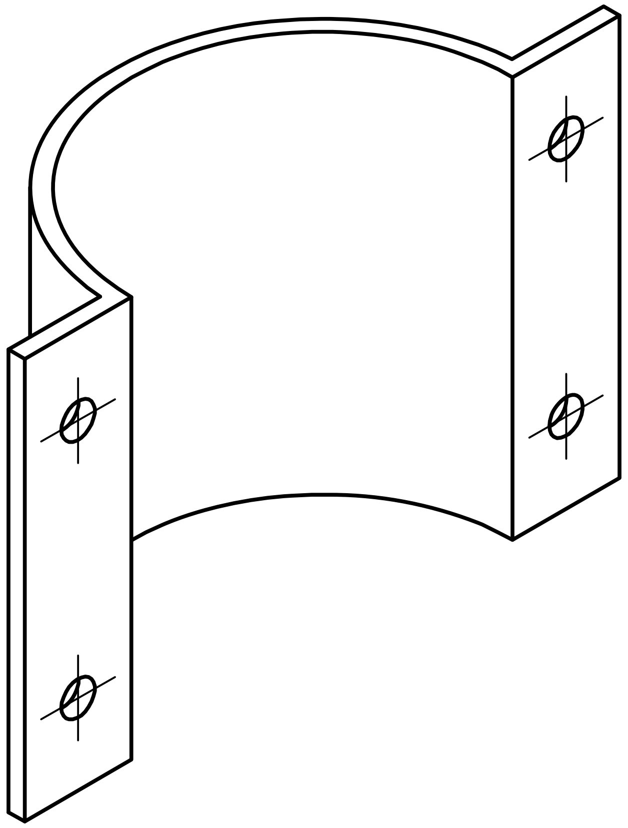
Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	02/05/2024	2/05/2024

Hamblin Pty Ltd	Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd	Fence Assembly Detailed Drawing 3	Edition Revision	Sheet 1 / 1

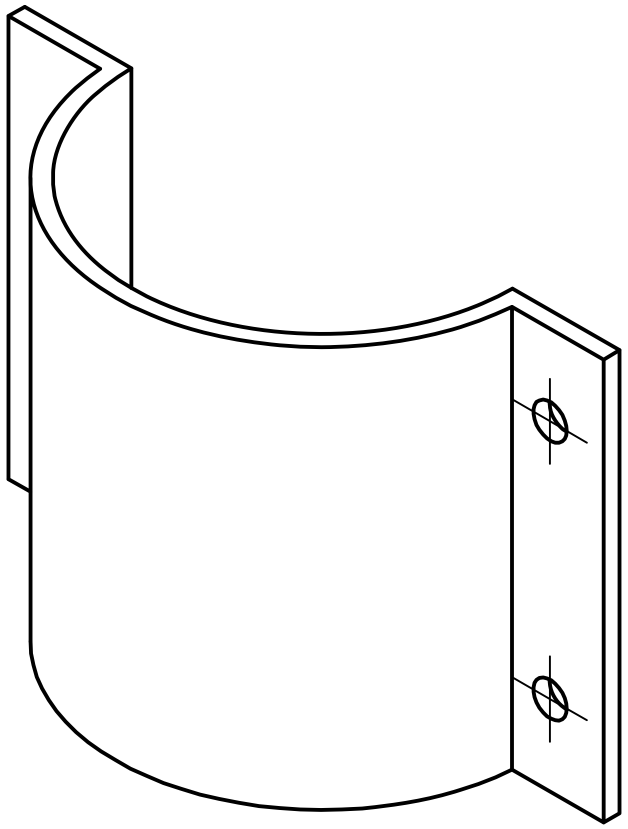


Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	6/04/2024	6/04/2024

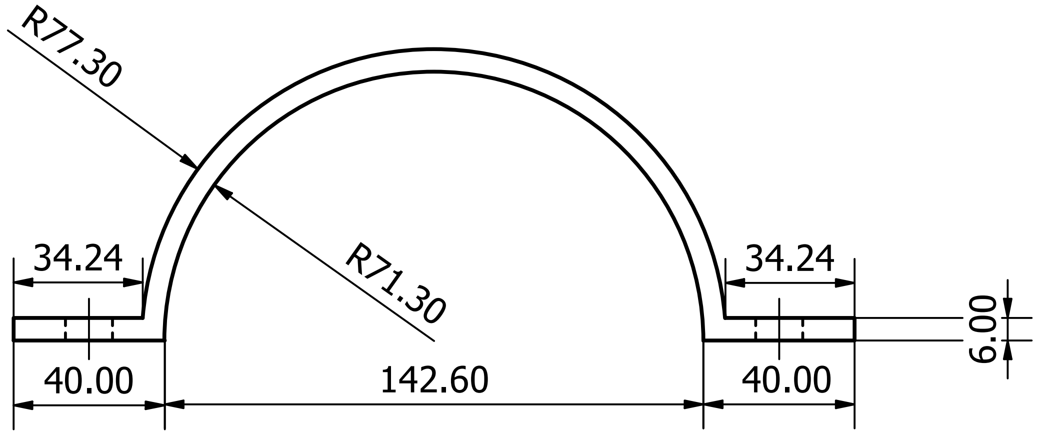
Hamblin Pty Ltd	Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd	Float Valve Pod Detailed Drawing	Edition Revision	Sheet 1 / 1



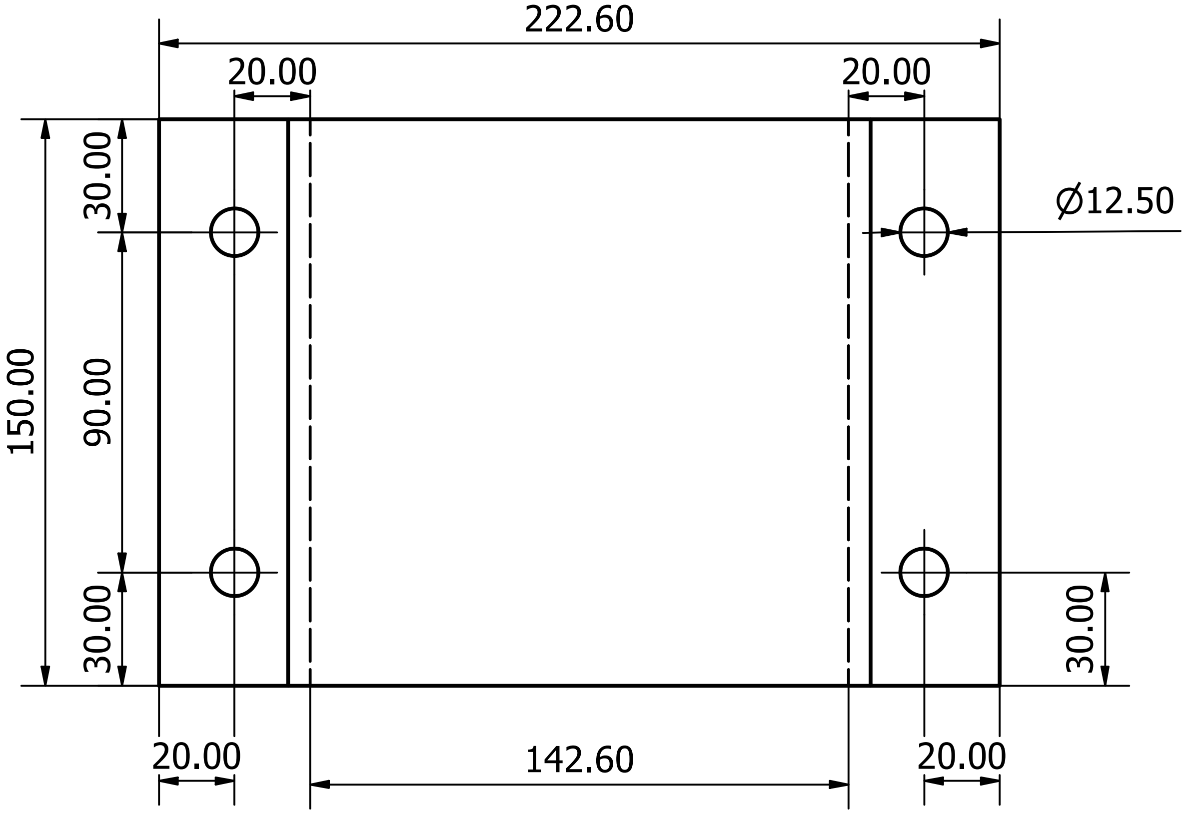
ISO 1



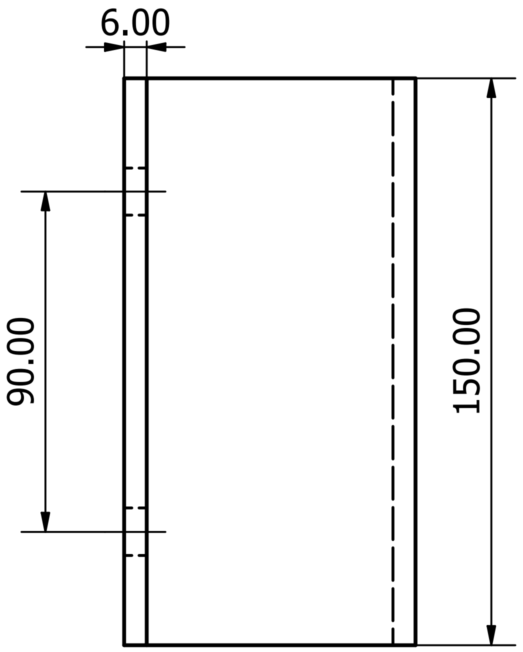
ISO 2



TOP

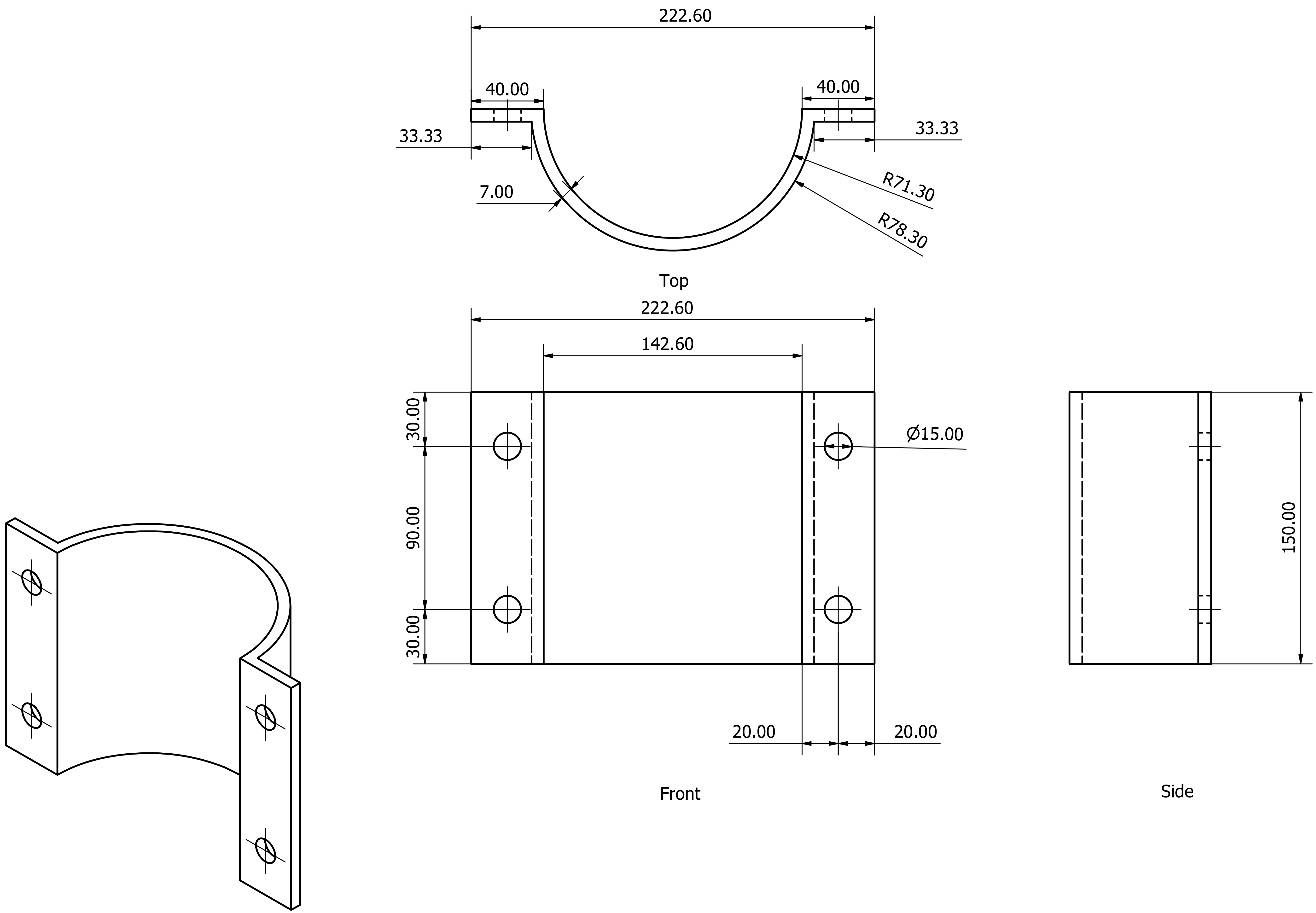


FRONT



SIDE

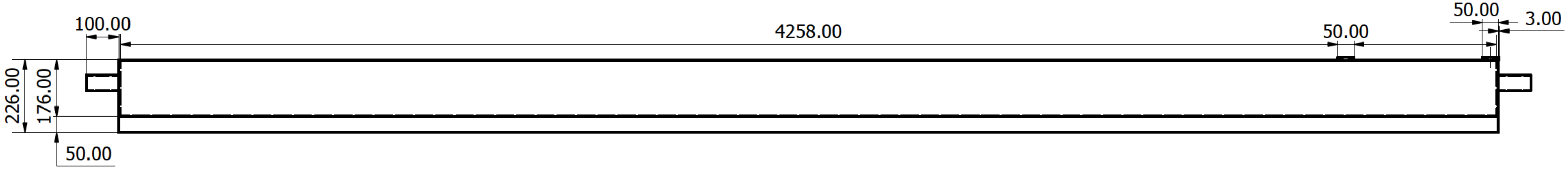
Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	26/03/2024	26/03/2024
Hamblin Pty Ltd		Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd		Post Collar D142.6	Edition Revision	Sheet 1 / 1

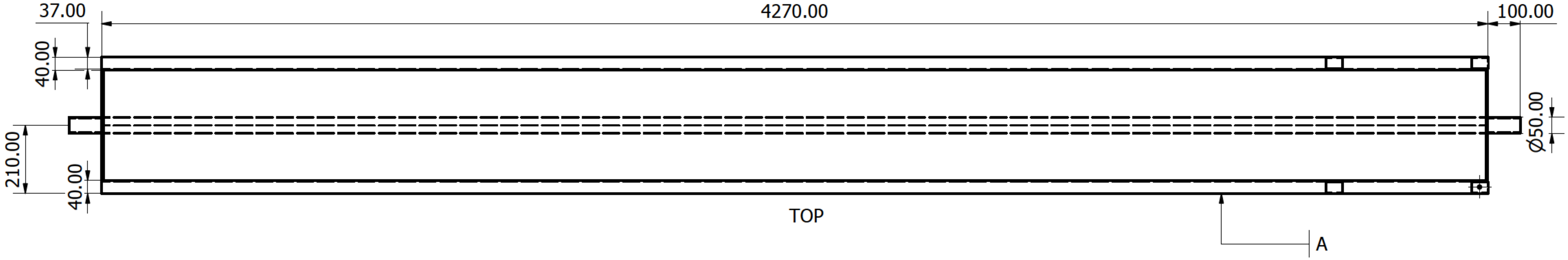


Designed by	Checked by	Approved by	Date Checked	Date of Creation
Lachlan Davis	RJD	RJD	25/03/2024	25/03/2024

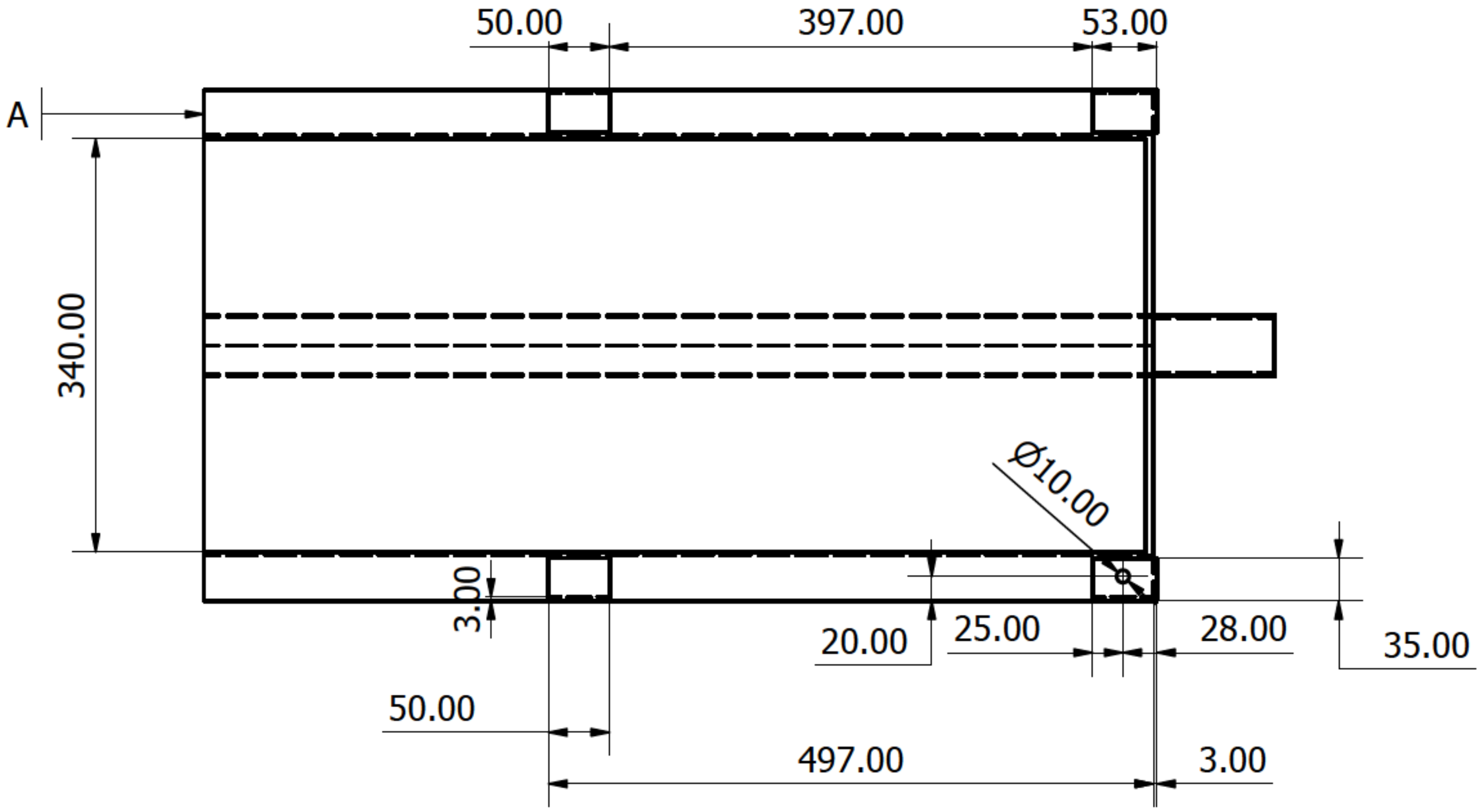
Hamblin Pty Ltd	Struggle Downs Feedlot - Shed		
RDC Engineers Pty Ltd	Post Collar Detailed Drawing	Edition Revision	Sheet 1 / 1

FRONT

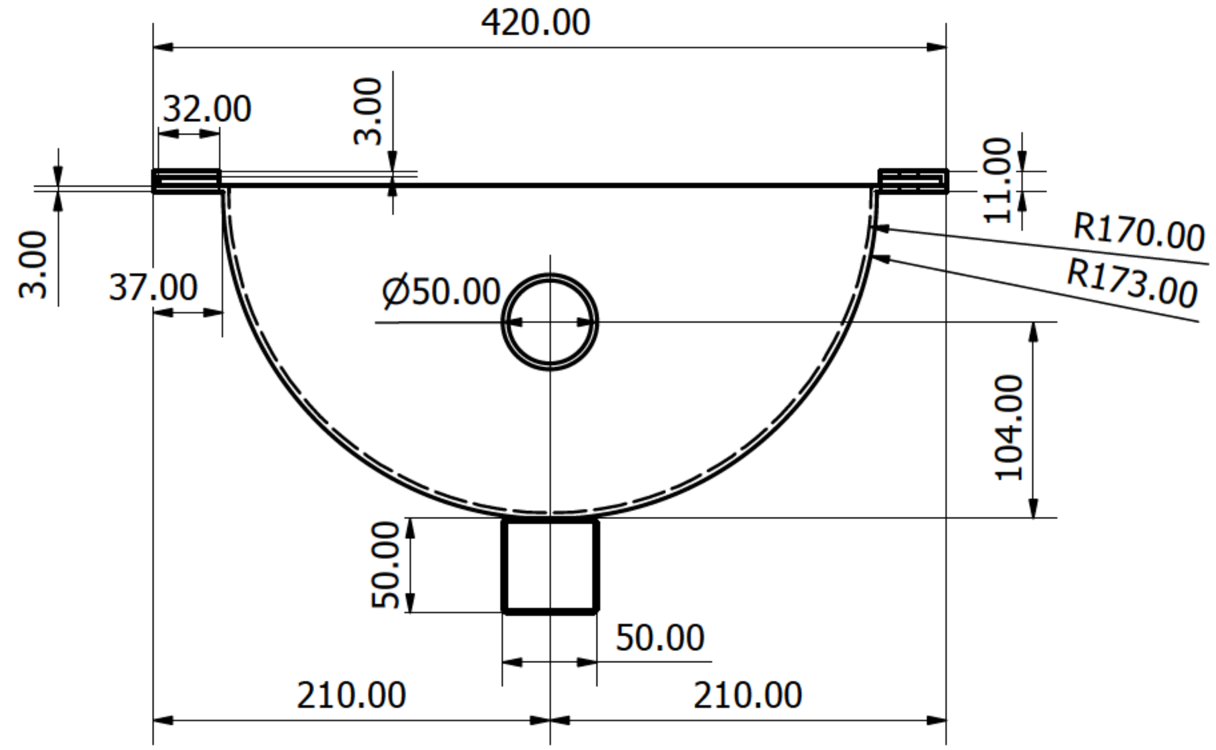




TOP



TOP - SECTION A



SIDE

Designed by	Checked by	Approved by	Date Checked	Date of Creation	
Lachlan Davis	RJD	RJD	6/04/2024	6/04/2024	
Hamblin Pty Ltd		Struggle Downs Feedlot - Shed			
RDC Engineers Pty Ltd		Water Trough Detailed Drawing		Edition Revision	Sheet 1 / 1