Assessing Feasibility of Water Accounting Toolkit for in a Poultry Processing Plant

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การประเมินความเป็นไปได้ของการใช้การบัญชีทรัพยากรน้ำ เพื่อการจัดการน้ำในโรงงานแปรรูปอาหาร

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กันตินันท์ สีลภูสิทธ์ : การประเมินความเป็นไปได้ของการใช้การบัญชีทรัพยากรน้ำเพือการจัดการน้ำในโรงงานแปรรูปอาหาร. (Assessing Feasibility of Water Accounting Toolkit for in a Poultry Processing Plant) อ.ที่ปรึกษาหลัก : ปารเมศ ชุติมา, อ.ที่ปรึกษาร่วม : ชูเวช ชาญสง่าเวช

ในโครงงานนี้เราจะมาดูหลักการบริหารน้ำที่ใช้ในโรงงานอุตสาหกรรมแปรรูปอาหาร และวัดประสิทธิภาพของมัน โดยจุดประสงค์หลักของโครงงานนี้คือ 1. แนะนำวิธีการลดการใช้น้ำโดยใช้หลักการ Water Accounting 2. ใช้หลักการในการวัดและการสื่อสารข้อมูลการบริหารน้ำ โครงงานนี้จะแนะนำวิธีที่จะลดการใช้น้ำของโรงงานนั้นด้วย เพื่อที่จะกรอกข้อมูลตามหลักการ Water Accounting เราต้องมีข้อมูลอันต่อไปนี้ 1. โรงเชือดเป็ด 2. โรงเชือดไก่ 3. โรงงานแปรรูปเป็ด 4. โรงงานแปรรูปไก่ 1 และ 2 เราจะมาดูการไหลของน้ำในแต่ละส่วนของโรงงานนี้ จากนั้นจะหาจุดที่ใช้น้ำเยอะที่สุดและลดการใช้น้ำในบริเวณนั้น จากการทำวิจัยจะเห็นว่าโรงเชือดทั้งไก่และเป็ดจะใช้น้ำเยอะที่สุด โดยการใช้น้ำสูงที่สุดจะมาจากโรงเชือดเป็ด ที่ใช้น้ำประมาณ 48,000 ลูกบาศก์เมตร ต่อวัน และมีประมาณ 11,600 ลูกบาศก์เมตร ที่ถูกพบได้ ในสินค้าปลายทาง มันมีได้หลายวิธีที่จะลดการใช้น้ำในโรงงานนี้ 1. เพิ่มจำนวนสถานที่บำบัดน้ำเสีย 2. คอยปรับปรุงและเก็บข้อมูลสำหรับ หลักการ Water Accounting 3. ลงทุนซื้อเทคโนโลยีใหม่ๆที่ลดการใช้น้ำ 4. ปรับเปลี่ยนนโยบายการทำความสะอาด 5. สอนและแนะแนวพนักงานในด้านการบริหารน้ำ การใช้หลักการ Water Accounting มีทั้งข้อดีและข้อเสีย ในเชิงของข้อดีก็คือมันสามารถใช้ สื่อสารหรืออธิบายข้อมูลที่ยากที่จะเข้าใจได้ มันเหมาะสมสำหรับการตรวจสอบดูด้วย ในส่วนของข้อเสีย หลักการนี้ยากที่จะนำมาใช้ในโรงงาน และอาจจะต้องใช้คนที่มีประสบการณ์ทางด้านการใช้หลักการนี้ แต่เมื่อติดตั้งเสร็จแล้วก็จะใช้ได้อย่างสะดวกมากขึ้น

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In this project, we will be looking into the use of a toolkit called water accounting as applied to a food processing plant and determine its effectiveness as a toolkit for monitoring water usage in a factory. The main objective of this thesis report is to 1. Recommend reducing water consumption by applying the water accounting toolkit. 2. Provide a standardized tool for the case study company to measure their sustainability progress and communicate that information clearly. This report will also discuss the extent in which the company can reduce their water consumption and their various methods in which to do so. In order to fill out the water accounting toolkit, the information regarding the flow of water into the different components of a compound factory must be considered. In this case the different components are as follows. 1. Duck Slaughter House, 2. Chicken Slaughter House, 3. Duck Processing Plant, 4. Chicken processing plant 1 and 2. We will be determining the flow of water going through each of the different components to determine which process takes up the most amount of water and potential ways in which to reduce the water consumption. It is determined that the slaughter houses take up the most amount of water; namely the duck slaughter house so in order to reduce it. It has been calculated that approximately 48,000 m^3 of water is being used in the production process each day while only approximately 11,600 m^3 of water can be found in the final product. There are many ways in which to reduce the water consumption of the factory, 1. Increase the number of water treatment facilities 2. Consistently update the water usage table 3. Purchase new

Field of Study:	Engineering Management	Student's Signature ....
Academic Year:	2019	Advisor's Signature ....
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Chapter 1 Introduction

1.1 Background Information

Water management is a growing issues in urban environments. The growing population leads to an increasing demand of water in both the household and the industrial sectors. It is expected that by 2030, water demand will exceed current supply by 40% as predicted by Water Resources Group (Schelmetic, 2012). Water is essential for a growing population and economy and is highlighted under the United Nations Sustainable Development Goals for 2030 (SDG's) under goal 6 with regards to water usage, sanitation, conservation and recycling.

The current demand in these city sectors has pushed the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) to conduct research into methods in which water can be monitored and managed on a country level. The method involves the cooperation between the different government sectors to moderate, collect, and regulate the water flow on a national scale. UNESCAP produced a toolkit called "Water Accounting" (FAO, 2018) to treat water resources as a financial asset. By using Water Accounting, countries would be able to identify key intervention points in which policies and regulations could be drafted to target the most stressed water sources/flows.

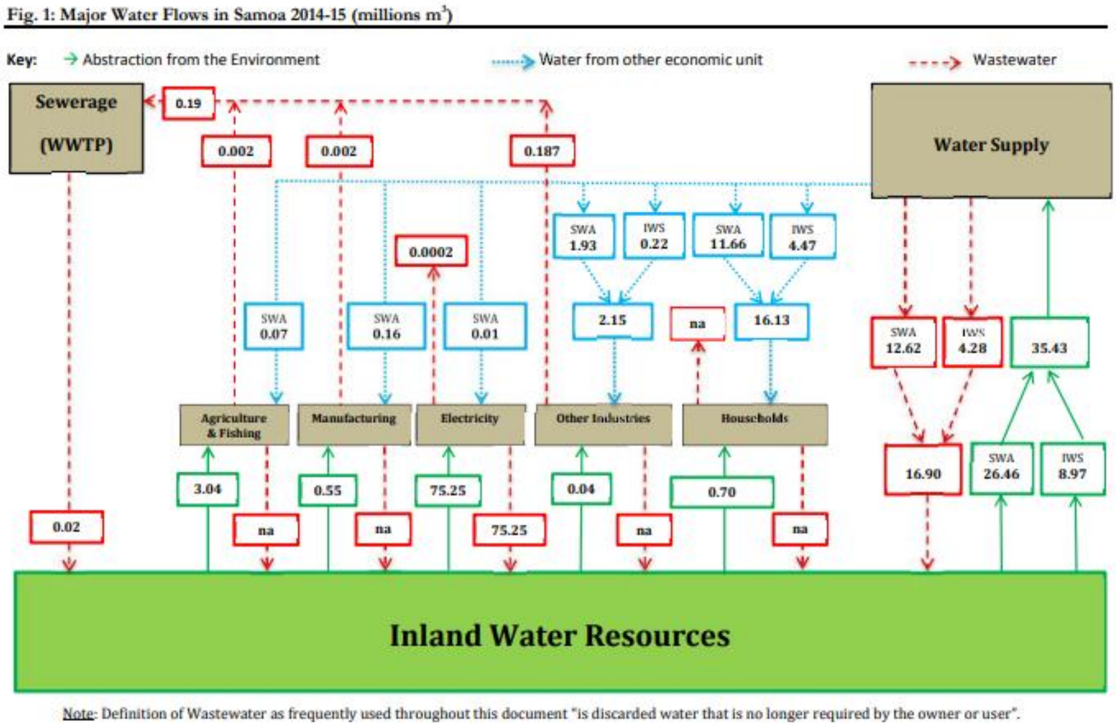


Figure 1-1: A sample diagram of a Water Accounting Flow in Samoa (Samoa Bureau of Statistics, 2015)

The figure 1-1 shows a sample of the flow of water on a country scale. In this case the country is Samoa which is an island nation. Thus the country must monitor the flow of water using the water accounting model. Water that is taken from the environment (abstracted) and water that is put back into the environment. The water flow diagram / flowchart also determines the usage of the water in the different industries on the island. This can be seen illustrated above as agriculture and farming, manufacturing, electricity, household and other industries. Water is also abstracted from the inland water supply to be distributed into the different industries which is shown above. Water from the different industries are taken out into sewage and returned to inland water resources.

The water accounting model allows for policies to target intervention points and maximize the impact that a policy may bring. This is highly similar to the mind-set used in lean production management. Lean management often focuses on reducing the raw material or the inventory space of the product, reducing time, and reducing waste. The lean approach can also be applied to water and energy to fit better with sustainable practice. This can lead to a more sustainable business model and higher stock prices while saving costs for the company. The advantage of the water accounting model is that it provides a consistent tool in monitoring water flow. The tool is easy to generate and understand which also means that it is easy to communicate. The tool is also highly flexible and may be used to adapt to different country's needs, and in our purpose to different industry plants as well.

Currently, the agricultural industry is consuming the most amount of water amongst all types of industries. Most of the water is used for irrigation in fields to grow crops, raise livestock, and process food. Thus this is the best industry to begin to look for ways in which to reduce water consumption. This also means that most agricultural countries have a lot of difficulty to develop into more economically advance industries. As the limitation of the water consumption makes it difficult for economies to grow. With high demand in water consumption, other industries can find it difficult to share industrial zones with an agriculture company.

Water-Energy-Food Nexus, shown in Figure 1-2, is the interaction and the dependencies of water energy and food. Clean water is required to grow food, food is required to fuel people, and people are required to produce energy to make clean water. Thus addressing a single issue would not be enough to solve the problem sustainably. A holistic approach would be required to address these issues. As a part of the food production industry, food production and energy consumption are often highlighted in the importance of sustainable business practice which puts stress on water as a resource.

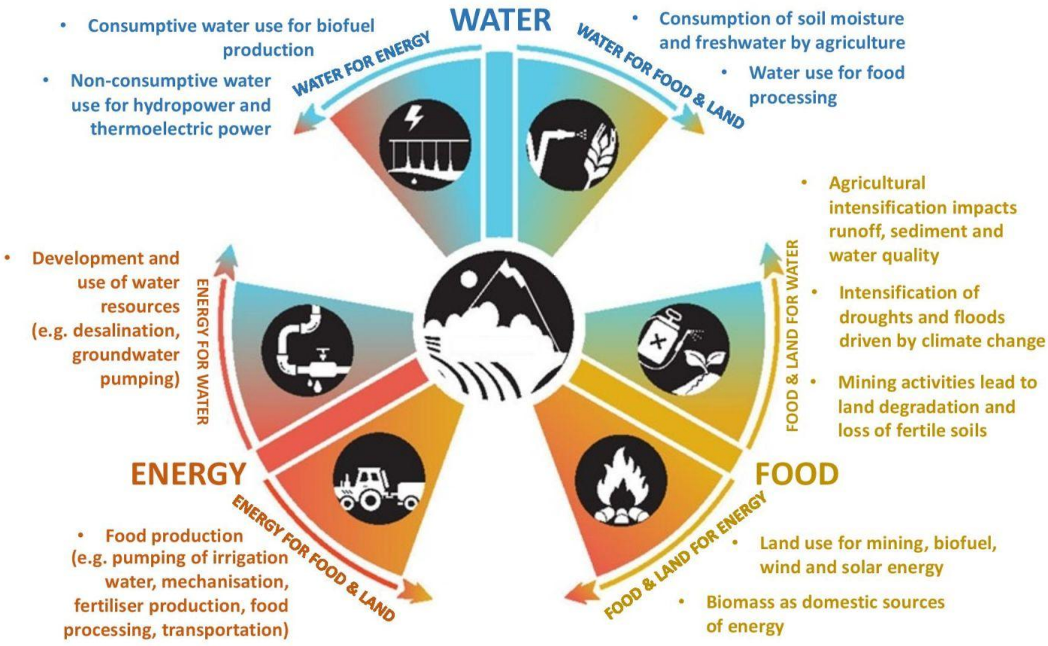


Figure 1-2: Water Energy Food Nexus Diagram (Future Earth, 2019)

1.2 Company Background

The company which will be used for the case study is Charoen Pokphand Foods (CPF). The company was founded in 1978 and now makes approximately 60% of their profits with exported ready to eat meals and the remaining 30% of their profits are made locally in Thailand. The Charoen Pokphand Group (CP) is currently one of the, if not, largest agricultural organizations in Thailand. Their main product is poultry but the organization also has infrastructure for selling swine and aquaculture. They boast a fully integrated system that allows them to sell from farm to food. They are also in the animal feed business as well as the distribution of ready-to-eat meals. The group also owns the seven-eleven franchise in Thailand which has fully penetrated the urban lifestyle of the urban Bangkok as well as the surrounding province. The company also exports many ready-to-eat cuisines to other parts of the world under the brand Authentic Asia and Kitchen-Joy. As a leading organization in agriculture, CP has also signed the UN Global Compact, which is a voluntary agreements between top global organizations, agreeing to a sustainable business practice.

Currently the board of directors of CP are as follows:

1. Mr. Dhanin Chearavanont (Chairman of Charoen Pokphand Group of Companies)
2. Mr. Adirek Sripratak (Vice Chairman, President and Chief Executive Officer, CP Foods; Director of CP All and Siam Makro)
3. Dr. Ajva Taulananda (Group Vice Chairman, Vice Chairman of True Corp.)
4. Mr. Soopakij Chearavanont (Group Executive Vice Chairman, Director of True Corp., CP All, Siam Makro and CP Pokphand)
5. Mr. Suphachai Chearavanont (Group Vice Chairman, CEO and Director of True Corp., Director, CP Pokphand)
6. Mr. Tanin Buranamanit (Director, Managing Director and Chief Executive Officer, CP All)
7. Mr. Umroong Sanphasitvong (Deputy Group CFO; Director of True Corp. CP All, and Siam Makro)

As seen in the list above, Charoen Pokphand Group does not only consist of the food industry, but also has business dealings in the tech industries as well. True Corporation is one of the leading telecommunications companies in Thailand. The company offers telecommunication as well as internet Wi-Fi as well as TV services throughout the country. As a leading organization in both the agricultural aspect as well as the technology aspect, the company is under scrutiny from the general public and their stakeholders, to perform sustainably. The duality of the business conducts means that the organization plays a major role in the development of the country as a whole. The organization also currently employs 300,000 employees for their day to day operations. Although the company is large, it is a private family owned business with the Chearavanont family taking the majority of the shares of this organization.

The sustainable business practice that CP has put into place consist of 3 main issues. Firstly, CP considers the food safety as their primary concern. As an agricultural organization the safety of their products must be the first priority. CP has made this one of their sustainable development goals to promote good health to their customers. Not only do they promote food safety, but CP also ensures that food is accessible for all; this means expanding their reach to other parts of the country. CP's next key issue in sustainable development is the self-sufficient society. CP dedicates resources into corporate social responsibility (CSR) in the form of education and building libraries and schools to ensure that the organization is giving back to the local people, no matter where they set up their facilities. Lastly, CP's final main sustainable development issue is the balance of nature. This final issue is the devotion to maintaining the ecological quality and pursuing the ecological balance. According to the Bangkok Post (Bangkok Post, 2019), CP Foods has been listed in the Dow Jones sustainability index (DJSI) for emerging markets for the 5^{th} consecutive year. The DJSI is one of the most widely acknowledged global sustainability indices in the world. With over 3,500 companies from 61 industrial sectors across the world.

CP's Water stewardship program is a reflection of committing to the sustainable development goals of water management. CP has done a thorough examination of the water risk assessment in all water stressed areas as of 2018. The company also boasts that 11.24% of water used in the factories are recycled for reuse in the factories and also the reduced water withdrawal per unit of revenue has decreased by 41.56% as compared to the 2015 baseline. The organization also understands the impending need for water management as the International Water Management Institute (IWMI) predicts that there will be water scarcity in 48 countries by 2025. This also fits into CP's sustainable pillars of ecological balance, as water management and preventing water scarcity is extremely vital to marine biodiversity. The importance of water management also fits into the self-sufficient society which ensures that local communities are not impacted by water withdrawal from plants and factories nearby. The water management aspect finally also plays a role in the food safety as the quality of water must be strictly monitored to ensure that food is treated with the appropriately clean water. The company is also able to harvest the bio-gas as a result of the water treatment system to use as an alternative fuel for the factory while also harvesting the organic waste products to be sold back as fertilizers to the local community. The company has also considered the importance of risk management of water usage in their annual report of 2019. Even to the extent of using an updated water risk indicator called the Aqueduct 3.0 to monitor the water risk score of the country in which the processing plants are located and preparing for risks.

Our main case study will be focused onto the poultry slaughterhouse and processing plant as it is one of the oldest processing plants in the organization. With this in mind, the plant may not be as technologically updated as other factories. Steps are being taken to make repairs and modernize the facilities. Many of the factories still rely on manual labour to accomplish the task of slaughtering and separating the poultry before feeding them in batches into a cooking station. The company is now considering investing into a more autonomous procedure to ensure larger quantities of production. However the nature of the final product means that certain customizations are required for brand to brand (B-2-B) sales. The main products to come from this factory is the

Chicken Roll, sold under the brand of CP Fresh Mart and the Original Soya Duck, sold under the CP brand.

1.3 Problem Statement

One of the major water consuming industries is the food and beverage industry. Wastewater management from this industry is considered to be a normal practice in many food processing plants. The food and beverage industry withdraws up to 30% of indirect water withdrawals (Hendrikson, et al., 2010). Wastewater treatment can also play a huge role in factory planning as space must be allocated for wastewater treatment and maintenance on filters and water recycling systems must be considered. Then there are dangers in wastewater management, as often the microorganisms used to treat waste water can produce toxic by-products.

What most people did not consider is using less water or energy as these are often cheap and easy to enact. This may lead to companies having a large carbon footprint or producing large quantities of wastewater. With the ever growing concern for the environment and sustainable business practices, managing factory's wastes can be a step in the right direction to reduce the damage to the environment.

As stated previously the water accounting toolkit is used to apply on a country scale and consider water management in multiple factors. This presents an opportunity for industries to apply it to their business practices as well. By applying the water accounting and water management into their business practices, an organization will be able to monitor the water intake and output, and find areas in which water usage can be reduced. In doing so, factories should be able to reduce their waste water and reduce the cost involved in a factory. Applying the Toyota Production System (TPS), also referred to as lean production systems, to consider water as a resource similar to the raw material it could save costs in the long term. The water accounting system will also identify locations where leaks may be present and they can be narrowed down and fixed.

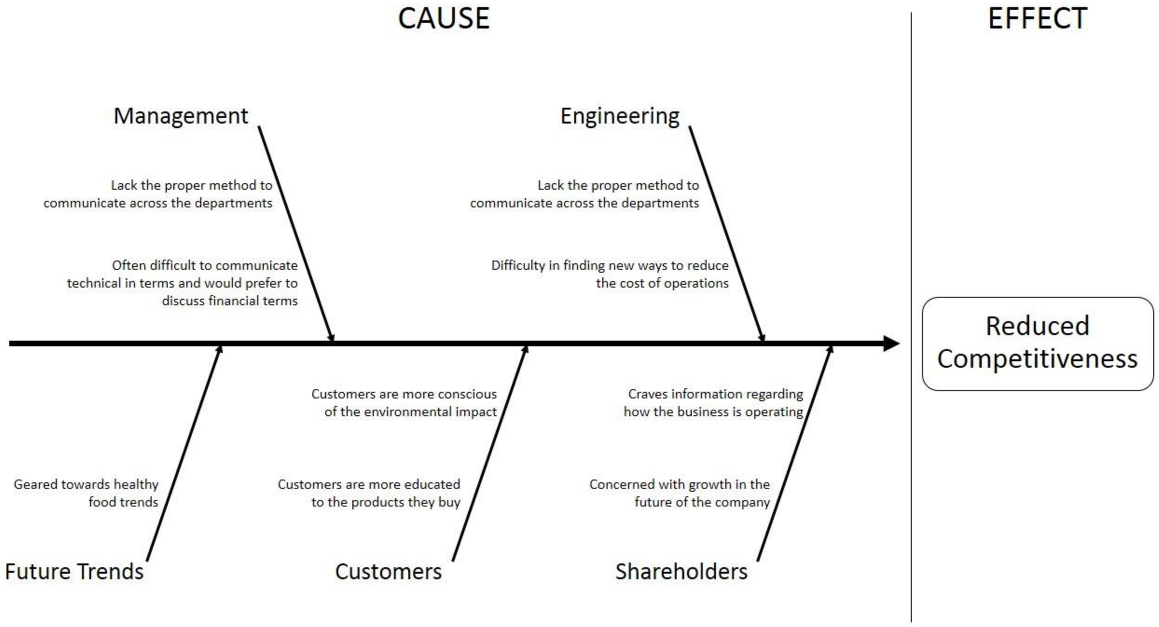


Figure 1-3: Fishbone Diagram of Cause and Effect (Derived by author)

The fishbone diagram shown in figure 1-3 highlights the cause and effect. The company must constantly improve in order to maintain their competitive advantage. These improvements can come from both internal and external factors. Water accounting can address the internal factors, as well as communicate to the external factors to the benefits that the company is providing for their stakeholders. In terms of the internal aspect of the fishbone diagram, the management and engineers are responsible for creating company competitiveness. An organization wide problem is the problems in communication across departments as this is common issue with large businesses. Also, while both teams are part of the same company, there are communication issues such as the technical focus and financial focus of both teams. Hence this miscommunication results in large amounts of bureaucracy and delays the time to action of the company. Both these factors play a role in the reduced competitiveness of the organization as a whole. In terms of the external aspects of the company, the three major factors are the food trends, customers, and shareholders. One of the company's main profits stems from the selling of shares to the public. Thus the demands of the shareholders of the organization must be met. This means that the company must be able to demonstrate sustainable growth in order to maintain the trust that they have from their shareholders. The customers are also another aspect of their profits and thus they must be able to follow the needs of the customers as well. With the increase in the number of educate customers, the company must be able to provide answers when questions are asked. Lastly food trends can change the market landscape by introducing new types of foods and demands in the market. The company must be able to be flexible in developing new products to meet these demands.

1.4 Research Objectives

The research is designed to further promote water management to become a common-practice amongst industries and encourage sustainable business practices. The objectives are as follows:

1. To recommend the reduction of water consumption by applying the water accounting toolkit to the case study factories
2. To provide a standardize tool for the case study company to measure their sustainable progress and communicate it clearly to stakeholders.

Highlighting the impending issues on the growing demand for water in economic growth shows that there are alternative methods of water management that are not only more sustainable, but also profitable for an organization to implement. The water accounting model is only one of many methods that companies may use to begin to reduce water consumption and can save costs to increase profits to align the sustainable objectives with the objective of an organization. Finding new ways to reduce cost can also be beneficial for the consumers as well. By introducing a standardize water management model, the research aims to allow standardize models to be compared across sectors and allow for stakeholders to determine sustainable business practice at a glance.

1.5 Research Questions

The research question will discuss how the water accounting can be applied to a small scale factory. It will also narrow down the research scope as to what the report will look into.

The research questions are as follows:

1. Is the water accounting toolkit applicable to a factory when scaled down? And how much water intake can be reduced as a result? How effective is this method for water management?
2. What issues and limitations does water accounting have in terms of the implementation onto a factory?
3. How much money can be saved from reducing the amount of water intake and from wastewater treatment costs?
4. Determine whether the cost saved are of such significance that an organization will profit from their application and determine the cost saved in terms of percentage?

1.6 Scope

The scope of the research is expected to encompass the factories in the food and beverage industry, the data will be collected from food processing plants. Once the data has been collected, it will be applied into the water accounting model. In this method the water flow of a plant can be mapped and key areas of waste identified. This involves water that is being treated. The areas of waste can be addressed and the intake of water reduced and thus reducing the cost. Once these changes have been identified, they will be suggested to the factory to implement and use.

1.7 Hypotheses / Expected Outcomes

The outcomes expected are as follows:

1. Water usage in the plant will be reduced to only the necessary components.
2. The amount of wastewater will be reduced as it directly relates to water inputs.
3. The reduction of water in treatment will reduce the treatment costs, saving money for the organization.
4. The validity of the toolkit can be assessed and improvements can be made to further develop the toolkit for a wider range of usage.

Chapter 2 Review of Literature

The review of literature will be used to present information regarding past researches into the topic. The review of literature will cover previous methods in which water management has been conducted in other food processing plants and the current method for water management. There will also be discussion about the laws and policies in which water quality and management must be maintained. Finally, there will be a swot and pestle analysis to determine the suitability of applying water accounting into a business as this toolkit is designed for much larger bodies of water and higher flow rate.

2.1 Water Resource Scarcity and Their importance to a growing economy

Freshwater resource scarcity is a growing concern in urban environments, with the ever growing urban population, the demand for water and their infrastructure grows along with it. According to the research article published by the 11th Global Conference of Sustainable Manufacturing by (Refalo & Zammit, 2013). Water consumption is taken in by the form of manufacturing usage, cooling/heating, domestic usage and reverse osmosis rejects. The toll of water usage is clearly seen in developing cities while lower water usages can be associated with lower economic areas as this is one of the constraints for an area to grow. (Fan, et al., 2017) Pointed out that low-consumption areas are restricted by the water sources which are available in the given area. This means that even though the infrastructure may be developed for sustainable economic development, environmental limitations play a role in influencing a city’s growth.

Water management and treatment are greatly emphasized in the SDG 6 according to the United Nations. The UN has emphasized the scarcity of clean water and availability of sanitation for developing countries. In many areas around the world, water stress has been noted which may lead to future demands for water. In 2015, 29% of the global population lack the necessary infrastructure and fresh water source for drinking (United Nations, 2018). This information highlights the key importance of water usage and with the ever growing population, this demand for fresh water is only going to increase.

Water Management strategies have been discussed in the public sector and strategies have been thought up in areas where droughts are common. Dry countries have begun implementing policies such as digging water reserves in wet seasons to draw from in dry seasons while other countries have built dams to store water for seasonal usage. Private sectors have also dug up ground water reserves although these reserves have to be highly regulated to ensure that it is done sustainably. Countries next to oceans have begun to draw water from the ocean and desalinating them for industrial and agricultural uses.

A growing concern for water management in developing urban environments would be water sanitation. Clean water may be difficult to find as the ever growing demand for water continues to rise. Some cities have begun to implement infrastructure where water can be collected and reused from waste water to promote sustainability and independence from environmental resources. This practice is called circular economy as it encapsulates water into a cycle without interference from external sources. Collecting ground water often results in the sinking of cities and damage to infrastructure above ground. In an industrial zone this often leads to cost incursion from building maintenance as well as damaged machinery.

2.2 Life Cycle Management and Water Footprint Analysis

Most corporations that rely on sustainable business practice will mainly focus on reducing carbon emission and energy consumption, however, water management should also not be overlooked. A common process that many are familiar with is the Lifecycle Management (LCA) as a common tool used to determine the environmental impact of a product. LCA details the raw materials, inventory, transportation, and wastes generated from a product. LCA is often used to consider the carbon footprint of a product. The lifecycle management could also be tailored towards water management and when done so it is referred to as Water Footprint Assessment (WFA), developed by Arjen Hoekstra. The WFA attempts to quantify the water usage localized to a product and therefore a country (Olson-Sawyer, 2018). The WFA is a great start but it can be difficult to identify the individual process in which water is being overused.

According to Ercin and Hoekstra (2014), the WFA has been applied to different scenarios to best fit the potential changes in the year 2050. These compensation changes population growth, economic growth, production/trade pattern, consumption pattern (dietary change, bioenergy use) and technological development are considered according to the 2013 article. The changes considered can be used to better illustrate the impact of water management and how a sustainable focus objective can benefit the world. The results indicate that a change from 130% (global market focus) shifts to a change in 30% (global sustainability focus) of water usage can be achieved through sustainable water usage and practice.

The water footprint classifies water into 3 main categories depending on their source and usage. Green water originates from precipitation such as rain, snow, or hail. Blue water originates from groundwater sources such as rivers, lakes, and underground sources. Grey water is classified as waste water that may be treated easily using basic filtration systems (Water Footprint Network, 2019). These categories identify the source of water used and the method in which they will be treated after usage. Since economic growth is constrained by freshwater sources, knowing which sources are being extracted from and how the wastewater is treated will lead to a more sustainable utilization of water.

In the food industry water is specifically categorized depending on the application and usage. The framework coined by the International Life Science Institute (ILSI), a global organization that conducts research into public health and safety, categorized water into potable or non-potable, microbiologically and chemically (The International Life Sciences Institute, 2008). Table 1 shows the safety classification, according to ILSI.

Table 2-1: Safety Classification of Water (The International Life Sciences Institute, 2008)

I. Potable Microbiologically Potable Chemically	II. Potable Microbiologically Non-Potable Chemically
III. Non-Potable Microbiologically Potable Chemically	IV. Non-Potable Microbiologically Non-Potable Chemically

2.3 Water Accounting

Environmental accounting is the concept in which factors in the environment are considered using the principles of accounting, the framework can also be called System of Integrated Environmental and Economic Accounting (SEEA). Environmental accounting considers the economic and environmental aspect of resource management. The information may be presented in the form of physical resources used or monetary values that the company incurs or saves from resource management (United Nations, 2003). Environmental accounting is considered from a national scale to a corporate level and for virtually any resources that the production process uses, in our case the emphasis will be on corporate water accounting.

Environmental accounting is also extremely important to determine the next strategies which will be implemented. Understanding the impact of the resources available is a key importance in the determination of the future strategies. With the use of environmental accounting, the managers and those in charge of the business will be able to determine the most effective way in which to allocate their resources. Without the correct understanding of the internal factors of the organization, key strategic decisions made might be impractical or costly to accomplish. With regards to environmental accounting, it could be a viable method in which companies and organizations are able to gather data regarding their environmental impact.

Without a clear consensus on the format in which water resources used are portrayed, it can be difficult for such information to be communicated effectively with a larger audience, thus water accounting was developed to solve this issue. Water Accounting is the toolkit in which records the flow of water and all the available water resource in an area. Water accounting was developed by a multi-institutional team from international knowledge centres to catalogue, identify, and communicate information regarding water resources (Water Accounting Plus, 2016). The water accounting often records information from cross government ministries to better direct policy drafting and implementation, these information would often take months if not years for data collection and can be used to predict droughts and floods. A company can use water accounting to apply to their plants and factories to monitor water consumption and areas in which water may be consumed unsustainably. Once the information has been collected, the process may also be audited to ensure sustainable transparency in the organization, leading to higher consumer trust and potentially share prices.

2.4 Water Management in Production Factories

Water management comes in two basic criteria; efficient water usage in the production process and waste water treatment for recycling (Ölmez, et al., 2014). While most factories have already implemented waste water treatment into their plants, only a few leading factories have begun to implement efficient water management in the production process.

A case example is Siam Cement Group (SCG) which have begun to implement water management since the year 2014 (Siam Cement Group, 2018). SCG is one of the leading business conglomerates in the ASEAN region, with the original intention to produce cement, now the organization has diversify to packaging and chemicals as well. With the information obtained from drafting water scenarios, SCG has been able to predict water balances and shortages in their industrial zones. They are able to clearly hypothesize worst case scenarios of water shortages and develop contingency plans to deal with crises as they arrive such as stocking up for water shortages or prepare for floods to minimize any damage. SCG also enlisted help from water management consulting firms to discuss methods in reducing water usage.

Another organization that has begun to implement the sustainable water management is Unilever, the company achieved their 2020 goal in 2018 to reduce their water usage by 44% per tonne of production since 2008 (Unilever, 2019). By implementing water management, the company has saved 22 billion tonnes of water each year since 2008. The company has also been able to avoid costs up to €105 Million since 2008 due to water management. Their main strategy for reducing water usages in general is to develop new product specifically designed to reduce the impact it has on the environment and technology that relies on reduced water usage. Unilever has also begun to conduct water scarcity assessments to evaluate potential risks to the local environment.

A final key example of efficient water management is Nestlé which has begun reducing water since 1997. Nestlé has shown that by reducing water consumption, they have been able to reduce waste water generation down by almost 35% in the year 2006 while also maintaining a consistently higher production volume (Nestlé, 2007). Nestlé achieves this by both increasing water efficiency and also promote water recycling through waste water treatment. This enables Nestlé to operate in areas where freshwater resources are considered to be limited. Nestlé's investment into water treatment technologies has reduced the cost of operations in the organization significantly as well as benefitting the local communities.

2.5 Water Usage in Food Industry

Most water usage comes from agriculture and food processing. The water required for food processing must be pure to a certain grade to ensure safety when consumed. Often the water process needs to be treated in accordance with their usage. Water used in cleaning / sanitation, consumption, or heating / cooling are all treated differently before being used in a factory (EuFic, 2015). Thus water management plays a role in ensuring food safety, with government regulations specifically designed to prevent harm from coming to the consumers.

Currently water usage in factories are high and expected to grow exponentially within the near future. In 2015, processing meat (beef, swine, and poultry) produces a water footprint of 25,728 litres/kg (Wechsler, 2015). With the current water usage trends, it is predicted that developing countries will be increasing their water usage by 50% as a result of feeding the growing population. With this ever growing demand for water, the price of water is expected to rise (Kirby, et al., 2003), resulting in food costs rising as well. The food industry is known for requiring water of varying degrees of quality, as such water from different sources will demand specific treatment to adjust their quality to prevent contamination in food. Up to two-thirds of freshwater abstraction worldwide foes towards food production. In the year 2000, the water requirement to produce 1 kg of chicken is 3500 – 5700 kg of water (Kirby, et al., 2003). In this case the research will be conducted in a poultry processing factory to reduce the water requirements.

2.6 Wastewater treatment and purification

Water treatment and purification is the process in which organizations treat their wastewater. Often companies are required to treat their water before the end use.

This is also true for public water usage and water needs to be treated before it can be distributed into homes. The water treatment steps start with the screening process in which large debris are first removed from the wastewater. Then coagulants are added to adhere to dissolved particles and allow the substances to build up into larger particles. The waste water is then slowly mixed to build-up the larger particles and are left to flow slowly allowing the sediments to slowly fall to the bottom of a tank. This process is called flocculation and sedimentation. The result is two layers, one of clean water and the other is organic sludge which can be used as fertilizer or dumped into landfills. The water must then pass through several filtration mediums. Common filtration mediums include, carbon, sand, and gravel. The next step is to correct the pH level using acid or base to neutralize the water, disinfectant can also be added to remove any organisms that could be harmful to the environment or end usage. Currently there are projects in development regarding the Lower-Cost water treatment to encourage factories and companies to begin improving their water treatment processes. (Gijzen, 2001)

Many factories that use processed water or that water needs to be contaminated will often have their own water treatment systems. Although, some factories outsource the water treatment process to organizations which are specialized in doing so. Currently there is emphasis in the process of reusing water as it is a regulation put on by the government. The cost for the materials used to clean the water before reuse or discharge is very high. These materials are often single chemical uses and must be restocked making them a huge variable cost to the company. The nature of the water used is also quite fickle and difficult to forecast, meaning that it could be a factor when an organization calculates the finances and budgets for the next term. The costs for water recycling include:

1. Maintenance

2. Electricity
3. Chemical Component
4. Labour
5. Cleaning
6. Analysis and Consultation

Environmental regulations is the regulations that determine the water quality that water being discharged from a factory or processing plant is required to have. In the USA the government agency responsible for the drafting of laws regarding the safety requirements for water discharge is the Environmental Protection Agency (EPA). The case study will be analysed using the UK laws and regulations as a standard for proper water management. The current regulations in the United Kingdom is determined by the European Parliament under the order of the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (The European Parliament and The Council of The European Union, 2017). This is the current version being used after the repeal of Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (The European Parliament and the Council of the European Union, 2006). The latter determined the quality of water which is required before the water may be returned to natural sources. Firstly, in article 5 of the Directive states that all members must conduct an analysis of the body of water in their respective territories', a review in to the environmental impact that is caused by human activities, and the economic usage that is being abstracted from the water source. Secondly, article 8 highlights the volume and rate of flow of the extent of the ecological and chemical status along with their potential of ground water and protected areas. Each of the community legislations must also accommodate the monitoring of ground water and protected areas. Article 9 also regards the water pricing policies with incentives for efficient use of water resources and note their contribution to the overall objectives. Water usage may also be recorded in terms of their estimates of the volume, prices and costs or forecasts of such costs. The record must also include the biological components of the number of microorganisms in the water as well as the flow dynamics of water and any connection it may have to ground water sources, thermal regulations, salinity and acidification. According to the Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC) (The European Parliament and The Council of The European Union, 2017), Industrial waste water must be pre-treated before given to waste-water treatment plants or dumped into natural sources due to the following reasons.

- protect the health of staff working in collecting systems and treatment plants,
- ensure that collecting systems, waste water treatment plants and associated equipment are not damaged,
- ensure that the operation of the waste water treatment plant and the treatment of sludge are not impeded,
- ensure that discharges from the treatment plants do not adversely affect the environment, or prevent receiving water from complying with other Community Directives,
- Ensure that sludge can be disposed of safety in an environmentally acceptable manner.

In article 12 of the same legislation, Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC), details the fact that treated wastewater must be reused whenever appropriate. It also documents that all wastewater treated must be within 10 000 p.e or less of agglomerations and fall within the details of regulations stated in the following table.

Table 2-2: Requirements for discharge of urban waste water treatment (The Council of the European Communities, 1991)

a Reduction in relation to the load of the influent.			
b The parameter can be replaced by another parameter: total organic carbon (TOC) or total oxygen demand (TOD) if a relationship can be established between BOD5 and the substitute parameter.			
c This requirement is optional.			
Parameters	**Concentration**	**Minimum percentage of reduction**[a]	**Reference method of measurement**
Biochemical oxygen demand (BOD5 at 20 °C) without nitrification[b]	25 mg/l O_2	70-90 40 under Article 4 (2)	Homogenized, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20 °C ± 1 °C, in complete darkness. Addition of a nitrification inhibitor
Chemical oxygen demand (COD)	125 mg/l O_2	75	Homogenized, unfiltered, undecanted sample Potassium dichromate
Total suspended solids	35 mg/l[c] 35 under Article 4 (2) (more than 10 000 p.e.) 60 under Article 4 (2) (2	90[c] 90 under Article 4 (2) (more than 10 000 p.e.) 70 under Article 4 (2) (2	• Filtering of a representative sample through a 0.45 μm filter membrane. Drying at 105 °C and weighing • Centrifuging of a representative sample (for at least five mins with mean acceleration of 2 800 to 3

	000-10 000 p.e.)	000-10 000 p.e.)	200 g), drying at 105 °C and weighing

2.7 Water Metering

Water management starts with measuring the amount of water that an establishment takes in. This is done by using water meters to monitor the flow of water from a public source into an establishment. The standard water meter is able to measure the flow of water in the units of m3 or litres. However with the emerging new technology and the Internet of things, there are steps being taken to ensure that water is being used effectively from the measurements in the meter. A technology that we may look into is the Drago water meter model from Thai Sunwa Engineering Co., Ltd. The meter is a one stop service which links information directly into a cloud system. This gives access of information and control to anyone that may wish to access it on phone or tablet device. The battery life of a water meter like this is 8 – 10 years and the overall lifespan of the water meter is 10 – 12 years. The Sunwa Company has begun to discuss the application of these water meters in homes and land development programs across the country. Not only can the water meter be used to measure the amount of water that is being used but also it can be used to control the flow of water. This allows the water to shut off if there is more water being used than expected, indicating a leak or an unclosed tap. The expected cost for a full set-up of water meter in a household will be approximately 30,000 THB or £800

Another company in Singapore has begun to use a different method to monitor water on a national scale. The method is to compare the flow of the water with the water pressure that is coming out at the source. Key strategic markers are placed throughout the city to measure the flow and pressure. At points where there are discrepancies, a team can be dispatched to determine the location of any leakages through the use of ultrasound technology. The method in which this is done causes the leaks to be identifiable in a way that is non-destructive and non-invasive to the surrounding. Currently, there have been tests for 4 years and there is potential for this system of water measuring in the future to come.

2.8 SWOT and Pestel analysis of Implementing Water Accounting

The Swot analysis is an analysis of the potential benefits and limitations that must be considered before making a decision that involves changing the business. No decision made will only result in the positive benefits for an organization, water management and water accounting is the same. Before determining the Swot analysis, we must also first determine the Pestel analysis which is judging the external forces and the impact that it may have on the implementation of water accounting and management. Pestel is an acronym for Political, Economic, Social, Technology, Environmental and Legal aspects. The Pestel analysis will be using the information with regards to August 2019.

1. Political
    - Currently Thailand is a constitutional monarchy. This means that the country is governed by a King who is designated as the Head of State, Head of the Armed Forces, Upholder of Buddhism, and Defender of faiths. Thailand also has a democratically elected leader who acts as the head of the government. The military takeover in May 2014 was only recently lifted in 2019.
    - Under the influence of the shifting political climate, foreigners are hesitant to make investments into organizations which are located in Thailand. This could make foreign investments be more attracted to the surrounding countries.
    - China's One Belt One Road initiatives have begun to draw interest from investors making South-East Asia a highly interesting place for potentially new players in the global market.
2. Economic

- The GDP of Thailand is 455.2 Billion USD as of 2017 (The World Bank, 2019)
- One of the main exported products of Thailand is Meat and Seafood which corresponds to 2.6% of the total exports. This brings in 6.6 Billion USD in 2018 (Workman, 2019) with major trading partners being China, The USA, and Japan.
- The strengthening of the local currency (Thai Baht) has put off foreign investors in buying products in Thailand. Many industries that thrive on foreigners or tourists have taken a toll.
- With the strengthening of the local currency, investors and financial institutes are highly interested in retaining the savings rather than looking for risky investments to sink their funds.

3. Social
    - As of 2019 the population of Thailand is 69,692,800 (WorldOMeters, 2019)
    - The majority of the country's citizen are Buddhist with the racial ethnicity of Thai, Chinese, Mon, Khmer, Lao, and Indian Decent.
    - Transparency and sustainability is a trend in which many countries are highly interested in. More consumers are being educated and thus they are more aware of the types of foods that they are eating.
4. Technology
    - Technology is being developed each day with clear focus in combating the damage that people are having on the environment. This includes new building infrastructure and sharing policies and technological innovations to other companies to gain better practices in running a business.
5. Environmental
    - The environmental impact that many companies has done to the natural resources could be seen as severe. Many companies (specifically social

enterprises) are trying to reduce the impact that they are having on the environment.

- South East Asia is one of the most vulnerable and also has one of the highest greenhouse gas emissions in the world. Mainly this has caused severe weather changes and flooding in many parts of Thailand. (Raitzer, et al., 2015)

6. Legal

- There are legal regulations in which are vital in meeting the food and health organization’s standards. These regulations involve the adequate use of cleaning and preparing procedures deemed necessary for an industrial operations of food and beverage processing.

	Internal Factors	External Factors
Advantage	**Strength** - Easy to communicate the information with shareholders and potential investors. - Global standard set for water management. - Information can be organized and readily available when asked to audit. - Information can be taken to form potential strategic road-maps for future planning.	**Opportunities** - Can be used as an effective tools to form partnerships with other companies - Water Accounting can show the impact that each factory has on the environment and also be used to compare the sustainability progress internally.
Limitations	**Weakness** - The data collection process takes a duration of time to collect and change will be witnessed slowly. - Implementation may require the help and support from many different departments to put together and monitor. - Initial investments may be required to install data gathering infrastructures into factories	**Threats** - Risk of water usage information taken through corporate espionage.

Table 2-1: SWOT analysis of potential benefits and limitations of water accounting implementation (Derived by Author)

From table 2-1 of the swot analysis, it can be seen that there is more emphasis on the strength and weakness then the opportunity and threats. This means that the use of water accounting model has a much higher emphasis on the internal factors rather than the external factors. As you can see the main strength of the internal Factor stems from the fact that the information can be easily organized and ready to be presented in the event that is asked. However the weakness of the water accounting toolkit can also be seen in the internal aspect as well. As stated above the main issue is that this endeavour is a joint effort between the different departments of the organization. In order to complete the water accounting model extensive communication is needed to ensure that the benefit of the water accounting mode is highlighted in the final product. The external benefits highlighted is the communication between organizations as this will ensure that other organizations in the area can also benefit from using water accounting to manage their own businesses. Finally the external threats of the water accounting model is the fact that the information regarding water usage could be used in the form of corporate espionage and the data could be considered sensitive enough to not share with others.

Chapter 3 Research Methodology

The research methodology will cover the steps in which this report will explore the concept of applying water accounting to a case study business. It will determine the inputs necessary and the information required to design a water accounting model.

3.1 Initial Data Collection

The first step would be to acquire permission from a factory to facilitate the research, highlight the potential benefits that the organization may gain from participating. Then conduct the initial interviews with engineers and production operators of the intended factory to gain an understanding of the processes involved in a production. The interview will emphasize the water usage in the production as well as overall water usage on site. Interviews will also be conducted with accounting for a record of water costs and usages.

3.2 Flow-Chart Design

A general flow chart will be designed to better understand the production process. This will allow for a general view of the production plant and to monitor the flow of water in the different processes of the factory. The flow chart of the factory may also be provided by the engineering department as they should have a copy. The flow chart will be designed as follows on a monthly timeframe to fully demonstrate water usage in the factory. The result of the flow chart may change depending on factory layout. The Flow-Chart design will allow the researcher to map out the process of production and the different factories involved to get a clear understanding water consuming processes. With the correct information, the flow chart can also be used to identify leaks in areas and the cost that these leaks incur on the factory can also be calculated.

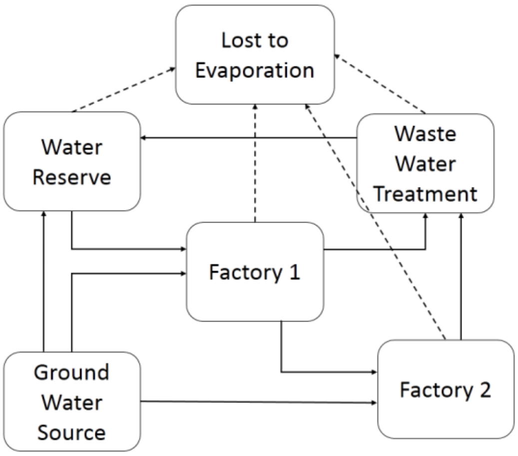


Figure 3-1: Proposed Format for Flow Chart of Process with reference to Water (Derived by Author)

3.3 Water Accounting Implementation

Implement the concepts of water accounting to find key areas for improvements. Determine where the process is consuming water unsustainably and find alternative methods to decrease the water consumption. The water accounting model can be used to identify the key intervention points in which improvements can be considered. The model will answer the questions of:

1. Which sources are the water coming from?
2. Which process demands the most water in the compound factory?
3. What is the overall costs that are incurred by water consumption?

In Table 3, a brief water accounting table has been drafted to demonstrate the information which will be collected in this research. The sources of water will be identified. The table can also be configured for waste water treatment and the total for both intake and abstracted. The final difference will be the amount of water in the product and a water footprint can be identified. The tool will also be able to highlight which process in the production chain is consuming the most water and improvements can be identified to reduce the flow of water into the overall system.

Intake	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total
Plant 1		0	0	0	0	0.00
Plant 2	0		0	0	0	0.00
Plant 3	0	0		0	0	0.00
Plant 4	0	0	0		0	0.00
Plant 5	0	0	0	0		0.00
Total	0.00	0.00	0.00	0.00	0.00	

Abstracted Water	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total
Plant 1		0	0	0	0	0.00
Plant 2	0		0	0	0	0.00
Plant 3	0	0		0	0	0.00
Plant 4	0	0	0		0	0.00
Plant 5	0	0	0	0		0.00
Evaporation	0	0	0	0	0	0.00
Reuse Water	0	0	0	0	0	0.00
Total	0.00	0.00	0.00	0.00	0.00	

Table 3-1: Proposed Format for Water Accounting Table Volume (Derived by Author)

The water accounting values will look into the flow of water from each part of the compound factory. It will be determined by focusing on the flow of water to determine which part of the compound factory is consuming the most water and determine where the water is being supplied from. The table will allow us to determine which part of the compound factory is using water most effectively and which parts are losing water in the form of wastewater or evaporation.

3.4 Improvements to Existing System

Consider the changes and further discuss with engineering department of the compound factory regarding the feasibility of implementing the change. Discuss about possible changes in water consumption levels and consider the cost for implementing new water efficient technology in the factory. Improvements can be considering water intake from a different source to save time or to invest in an onsite water treatment system to reduce the cost of water from a source. Consider practice to reduce water consumption which will result in lower amounts of waste water and water evaporated. Once a consensus has been determined, a cost saved can be calculated.

3.5 Cost Calculation

The change in water use can incur a change in water cost as the cost for different water sources are different along with the quality. Determine the cost reduction that will result from this improvement and discuss the accuracy with accounting to determine the feasibility of implementing these changes. The reduction in cost could be considered and a turnover period could be established if new technology was needed to be implemented such as a water treatment unit to change from one water quality to another.

Cost calculations can be conducted by observing the cost of using the different water sources and determine potential areas in which water sources can be changed to. For example shifting water usage from public water suppliers to local water sources might be an alternative for saving cost. A table with the costs for water can be calculated using the formula:

$$Water\ Cost\ \times Water\ used\ (Liters) = Water\ Cost\ per\ Liter$$

The result will produce a table similar to Table 2 but the values will be in the unit of currency (using THB) instead of volume. This will be a clear indication of the process that is currently consuming the most operating cost for water processing and the improved method will produce a value which is less than the current cost. That value will be the amount of money saved through water management. The value saved can be calculated by:

$$Water\ Cost\ per\ Liter\ Total\ (initial) - Water\ Cost\ per\ Liter\ Total\ (Final) = Cost\ Saved$$

Intake	Plant 1	Plant 1	Plant 1	Plant 1	Plant 1	Total
Private Sector (50 THB/L)	0	0	0	0	0	0.00
Previous plant (0 THB/L)	0	0	0	0	0	0.00
Aquifers (0 THB/L)	0	0	0	0	0	0.00
Public Sector (5 THB/L)	0	0	0	0	0	0.00
Recycled (0 THB/L)	0	0	0	0	0	0.00
Total	0.00	0.00	0.00	0.00	0.00	

Table 3-2: Proposed Format for Water Accounting Table Currency (Derived by Author)

3.6 Result Interpretation

Brainstorm further improvements that can be suggested or alternative solutions from the data. Doing so could also highlight the benefits of water accounting for the business for the management level to consider.

The process in the methodology will consist of the original findings from the research as well as a proposed method in which the factory can adopt to further reduce the cost of water consumption in the factory as well as the benefits of reduced water.

3.7 Water Accounting Evaluation

Consider the use of the water accounting toolkit up to this point and discuss the advantages and disadvantages of implementing the water accounting toolkit for a factory. This can also determine if the practice should be considered in other industries as well. The questions which will be asked would be as follows:

1. How effective is the Corporate Water Accounting Toolkit?
2. Should the organization continue to use the Corporate Water Accounting Toolkit?
3. Will the organization be able to benefit from the changes recommended by the toolkit?
4. How practical are the changes suggested by the interpretation of the toolkit?

Chapter 4 Results and Discussion

Results and discussion will discuss about the raw results and the processed results obtained from the investigation. It will detail the values obtained from the investigation and determine what these values mean.

4.1 Step 1: Initial Data Collection

With permission from the management of the factory, we have surveyed the site of the factory. The components inside the grounds that are related to water usage are as follows

1. **Duck Slaughter House**

   The main slaughter house used for dismembering ducks into their key parts. The whole duck is used and very little is discarded.

2. **Chicken Slaughter House**

   The main slaughter house used for dismembering chicken into their key parts. The chicken is then taken to the processing plant to shape into the product to be sold. The demand of the different products of chicken varies and thus the product forms varies.

3. **Duck Processing plant**

   The processing plant is connected to the slaughter house. The main product is Chinese stewed duck menu. Blood is also extracted from the fowl to make blood stew.

4. **Chicken Processing plant**

   The chicken processing plant is used to make chicken rolls. This is one of the main product that the factory produces and requires a long assembly line of manual labour to complete it.

5. Chicken Processing plant 2

The chicken processing plant 2 is used as a back-up processing plant in the event that there is an increase in demand and the main processing plant is unable to keep up with the production. This is used to maintain consistency in meeting demands or developing new products.

6. Boiler

The boiler is used to heat water before distribution to the other parts of the compound factory. The heated water is used for cooking the ducks and chicken before preparing them into the final product.

7. Aquifer Withdrawal

The compound factory also draws water from aquifers which are underground water sources. The water from the aquifers are free to draw from, however, there is a limit to 1200 m^3 per day on average for the duration of a month.

8. Reused Water

Waste water from the production line is treated and reused to other parts of the factory. This means that the water reused for cleaning and maintenance of the equipment daily.

Initial Observations regarding the plants

- According to engineers in charge of the factory. The legally required amount of water for each individual duck and chicken is 1.5L and 2.5L respectively for each animal.
- The machine which is known to consume large amounts of water is the chiller which cools down the temperature of the animal in a pool of water. The water is being constantly fed into and drained out from the machine. This machine

then slowly turns to ensure that the temperature whole animal is fully cooled to a certain temperature.

- There are also some areas in which water usage could be improved as the air inside can be described as humid. This indicates evaporation and therefore water loss.
- The number of ducks slaughtered is approximately 50,000 – 70,000 ducks each day.
- The number of chicken slaughtered is approximately 140,000 chickens each day.

Water Usage during May and June of 2019

The following tables are the initial collected and processed data the data will late be used to determine the intake and outflow of water in each part of the compound factory. The initial data obtained is the amount of water used in m^3 used per day. The data obtained covers a duration of May and June and details the amount of water read off the water meter for the components in the compound factory as stated above. The data collected regarding the amount of water used isn't separated into the usage since it would be almost impossible to determine. Hence, the value shown is the combined usage for maintenance, heat exchange, processing, and cleaning of the equipment and personnel in the factories. The factories all contain a highly strict cleaning policy regarding their employees and thus tubs and washbasins occupy all entrances and exits. This ensures that all employees and visitors are decontaminated before entering or exiting the premises. In a water management perspective, this also presents an issue in that these waters need to be drained and replaced daily as well as cleaning agents used. There are some assumptions in which must be considered for the raw data:

1. The usage of water is consistent throughout the year and little to no fluctuation is found in each month.
2. The value obtained in the raw data is value from the water meter which is connected to the municipal water source. This is with the exception of the aquifer water meter which is connected to the aquifer.
3. The values obtained are from a water meter which means that they all have an uncertainty value of ±0.00005 m^3

Flow Chart of the plant

The water flow chart of the compound factory can be shown below in figure 4-1. Firstly, water is taken from the municipal water supply and is kept in water storage. Water taken from aquifers and the treated recycled water are also stored there. Water from storage can then be distributed to the boiler for heating and cooking or taken directly to the processing plants to assist in either the cleaning or cooking. Some of the water which is taken to these locations will be loss through evaporate and water from these sources will be loss as discharged water. Some of the water from these sources will be recycled back into the system. In this water flow diagram, we will be looking into the water from the initial raw material input into the system as well as how much of that water is taken to the final product. The flow chart has been confirmed to be accurate with the chief of engineering at the plant. The following figures will be composed of the raw data obtained from the compound factory as well as the flowchart detailing the flow of water from the different points in the estate. Figure 6-1 will display the flow of water throughout the compound factory.

Table 4-1: The Total, Total Municipal, Duck Slaughterhouse and Chicken Slaughterhouse water usage in May 2019 (Case Study Company)

<table>
<tr><th colspan="2">May</th><th>Total Used (m^3/ day)</th><th>Municipal Water (m^3/ day)</th><th>Duck Slaughter (m^3/day)</th><th>Chicken Slaughter (m^3/day)</th></tr>
<tr><td>Monday</td><td>1st</td><td colspan="4"></td></tr>
<tr><td>Tuesday</td><td>2nd</td><td>35884</td><td>31517</td><td>11912</td><td>10193</td></tr>
<tr><td>Wednesday</td><td>3rd</td><td>49233</td><td>44789</td><td>12857</td><td>11135</td></tr>
<tr><td>Thursday</td><td>4th</td><td rowspan="3">68248</td><td rowspan="3">63791</td><td rowspan="3">18313</td><td rowspan="3">14446</td></tr>
<tr><td>Friday</td><td>5th</td></tr>
<tr><td>Saturday</td><td>6th</td></tr>
<tr><td>Sunday</td><td>7th</td><td>48952</td><td>44506</td><td>17090</td><td>10198</td></tr>
<tr><td>Monday</td><td>8th</td><td>52607</td><td>48155</td><td>17474</td><td>10444</td></tr>
<tr><td>Tuesday</td><td>9th</td><td>56201</td><td>51757</td><td>15715</td><td>11569</td></tr>
<tr><td>Wednesday</td><td>10th</td><td>53678</td><td>49222</td><td>15547</td><td>11185</td></tr>
<tr><td>Thursday</td><td>11th</td><td rowspan="2">90282</td><td rowspan="2">85835</td><td rowspan="2">18528</td><td rowspan="2">17236</td></tr>
<tr><td>Friday</td><td>12th</td></tr>
<tr><td>Saturday</td><td>13th</td><td>54246</td><td>49796</td><td>15312</td><td>11237</td></tr>
<tr><td>Sunday</td><td>14th</td><td>49854</td><td>43452</td><td>17304</td><td>9634</td></tr>
<tr><td>Monday</td><td>15th</td><td>48329</td><td>43731</td><td>15395</td><td>9893</td></tr>
<tr><td>Tuesday</td><td>16th</td><td>54881</td><td>49619</td><td>15987</td><td>11561</td></tr>
<tr><td>Wednesday</td><td>17th</td><td rowspan="3">91820</td><td rowspan="3">83900</td><td rowspan="3">22293</td><td rowspan="3">13128</td></tr>
<tr><td>Thursday</td><td>18th</td></tr>
<tr><td>Friday</td><td>19th</td></tr>
<tr><td>Saturday</td><td>20th</td><td>57196</td><td>54056</td><td>14405</td><td>9524</td></tr>
<tr><td>Sunday</td><td>21st</td><td>57852</td><td>54713</td><td>16338</td><td>12477</td></tr>
<tr><td>Monday</td><td>22nd</td><td>57530</td><td>54035</td><td>15907</td><td>11179</td></tr>
<tr><td>Tuesday</td><td>23rd</td><td>56105</td><td>52597</td><td>16274</td><td>11556</td></tr>
<tr><td>Wednesday</td><td>24th</td><td>56947</td><td>53944</td><td>11312</td><td>10968</td></tr>
<tr><td>Thursday</td><td>25th</td><td rowspan="2">75442</td><td rowspan="2">70002</td><td rowspan="2">22637</td><td rowspan="2">13437</td></tr>
<tr><td>Friday</td><td>26th</td></tr>
<tr><td>Saturday</td><td>27th</td><td>55666</td><td>52567</td><td>16357</td><td>10364</td></tr>
<tr><td>Sunday</td><td>28th</td><td>52188</td><td>46683</td><td>16149</td><td>11141</td></tr>
<tr><td>Monday</td><td>29th</td><td>42532</td><td>37841</td><td>15862</td><td>13039</td></tr>
<tr><td>Tuesday</td><td>30th</td><td>55427</td><td>48839</td><td>16628</td><td>12674</td></tr>
<tr><td>Wednesday</td><td>31st</td><td>59971</td><td>52287</td><td>15809</td><td>9706</td></tr>
</table>

Table 4-2: Table of Processing Plants and Aquifers and Boilers water meters in May 2019 (Case Study Company)

May		Chicken Processing 2 (m^3/day)	Aquifers (m^3/day)	Chicken Processing (m^3/day)	Boiler (m^3/day)	Duck Processing (m^3/day)
Monday	1st					
Tuesday	2nd	3104	1386	2767	994	875
Wednesday	3rd	4957	1192	2915	1075	20
Thursday	4th	9329	2178	8629	2593	334
Friday	5th					
Saturday	6th					
Sunday	7th	6044	1690	3312	1005	457
Monday	8th	3987	1177	2933	1137	635
Tuesday	9th	4215	0	3074	998	383
Wednesday	10th	4474	1317	2997	996	378
Thursday	11th	11386	1150	5568	1929	531
Friday	12th					
Saturday	13th	3496	663	3069	1057	579
Sunday	14th	6088	1228	2824	985	474
Monday	15th	5481	1162	3025	947	425
Tuesday	16th	5074	1181	2826	1062	420
Wednesday	17th	10890	680	7628	2111	467
Thursday	18th					
Friday	19th					
Saturday	20th	5347	150	2827	973	463
Sunday	21st	2522	152	2818	964	676
Monday	22nd	4734	227	2856	926	485
Tuesday	23rd	4405	405	2439	977	434
Wednesday	24th	4406	0	2291	976	608
Thursday	25th	6117	373	5995	1604	150
Friday	26th					
Saturday	27th	5087	490	3284	988	422
Sunday	28th	4972	508	2927	1100	624
Monday	29th	3071	1208	2916	1010	307
Tuesday	30th	2983	1185	3145	1019	670
Wednesday	31st	6036	1123	2999	1025	428

Table 4-3: The Total, Total Municipal, Duck Slaughterhouse and Chicken Slaughterhouse water usage in June 2019 (Case Study Company)

June		Total Used (m^3/ day)	Municipal Water (m^3/ day)	Duck Slaughter (m^3/day)	Chicken Slaughter (m^3/day)
Saturday	**1st**	35124	29804	9598	6379
Sunday	**2nd**	35124	29804	9598	6379
Monday	**3rd**	35124	29804	9598	6379
Tuesday	**4th**	35124	29804	9598	6379
Wednesday	**5th**	35124	29804	9598	6379
Thursday	**6th**	61344	50215	16456	11797
Friday	**7th**				
Saturday	**8th**	81318	70331	19017	13434
Sunday	**9th**				
Monday	**10th**	47483	39932	15389	9495
Tuesday	**11th**	40156	33483	16948	12669
Wednesday	**12th**	52375	45409	16023	11682
Thursday	**13th**	53045	45620	15672	10673
Friday	**14th**	54036	46847	16771	11150
Saturday	**15th**	61189	50905	17710	13517
Sunday	**16th**				
Monday	**17th**	50230	42606	14744	11330
Tuesday	**18th**	53634	45314	16687	10776
Wednesday	**19th**	106798	91148	31503	22099
Thursday	**20th**				
Friday	**21st**	53964	46949	17705	10744
Saturday	**22nd**	75309	64180	19186	13237
Sunday	**23rd**				
Monday	**24th**	53844	46497	12859	11289
Tuesday	**25th**	103467	87208	25614	22111
Wednesday	**26th**				
Thursday	**27th**	53536	43646	12665	10890
Friday	**28th**	51428	42954	12260	10456
Saturday	**29th**	73875	55408	13227	14397
Sunday	**30th**				

Table 4-4: Table of Processing Plants and Aquifers and Boilers water meters in May 2019 (Case Study Company)

June		Chicken Processing 2 (m^3/day)	Aquifers (m^3/day)	Chicken Processing (m^3/day)	Boiler (m^3/day)	Duck Processing (m^3/day)
Saturday	**1st**	3258	579	2496	821	305
Sunday	**2nd**	3258	579	2496	821	305
Monday	**3rd**	3258	579	2496	821	305
Tuesday	**4th**	3258	579	2496	821	305
Wednesday	**5th**	3258	579	2496	821	305
Thursday	**6th**	2327	693	2926	1035	481
Friday	**7th**					
Saturday	**8th**	4488	323	6501	1644	678
Sunday	**9th**					
Monday	**10th**	4239	711	2737	1227	1499
Tuesday	**11th**	2137	1203	3149	1049	546
Wednesday	**12th**	3472	1155	3118	1045	934
Thursday	**13th**	5070	1169	3015	1001	864
Friday	**14th**	4261	1145	2936	986	526
Saturday	**15th**	5606	2370	3860	1134	1068
Sunday	**16th**					
Monday	**17th**	3794	1159	2911	1007	451
Tuesday	**18th**	4465	1171	2962	1033	1247
Wednesday	**19th**	8969	2348	5824	1995	1666
Thursday	**20th**					
Friday	**21st**	4490	1217	3215	1018	839
Saturday	**22nd**	7947	2318	5069	1641	761
Sunday	**23rd**					
Monday	**24th**	4121	1090	2807	1055	894
Tuesday	**25th**	6843	2363	6155	1994	1316
Wednesday	**26th**					
Thursday	**27th**	4024	1563	3236	1022	617
Friday	**28th**	4097	1197	3087	973	630
Saturday	**29th**	3646	1987	4761	1579	1013
Sunday	**30th**					

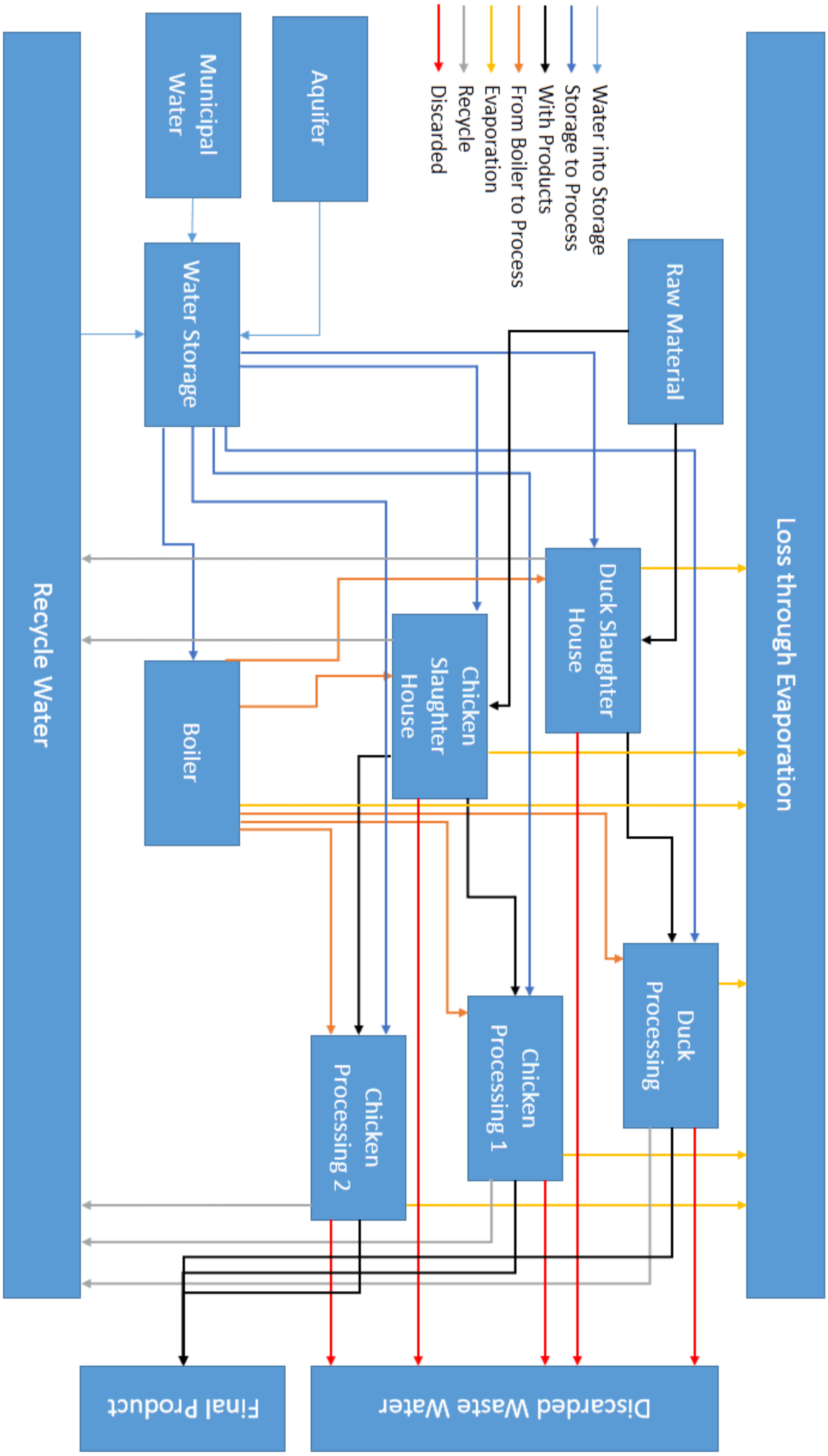

Water into Storage
Storage to Process
With Products
From Boiler to Process
Evaporation
Recycle
Discarded
Aquifer
Municipal Water
Water Storage
Raw Material
Loss through Evaporation
Recycle Water
Duck Slaughter House
Chicken Slaughter House
Boiler
Duck Processing
Chicken Processing 1
Chicken Processing 2
Discarded Waste Water
Final Product

Figure 4-1: Flow Diagram of water in the compound factory (Derived by Author)

4.2 Water Cost Raw Data

According to the information provided by the chief engineer of the plant, the cost for water treatment of the plant has been collected. The values for the month of May and June are as follows. This information includes the amount of water treated in the units of m^3 as well as the following costs:

1. Cost of electricity

The cost of electricity is the cost to run the process of water cleaning and treatment. This involves the cost of running the machinery that is specifically designed to help with the process of treating water. Machines include stirrer, coagulator and water pumps that facilitate the flow of wastewater throughout the system.

2. Cost of Maintenance

Maintenance is the cost involved with ensuring that the system flows smoothly. This is done by replacing worn machine parts and replacing the filters when needed. This also includes paying for the services that are involved with replacing the damaged components of the water treatment system.

3. Cost of used Chemicals for water treatment

This is the cost of single used chemicals which are required for water treatment. Chemicals such as chlorine to disinfect water and kill any microbes that may be inside to ensure that the water is safe for reuse or disposal. Lime and Alum is also added to facilitate the coagulation process in which the small particles adhere to these chemicals allowing them to fall into a sediment at the bottom of a basin.

4. Labour cost

This cost is connected to the cleaning cost as it is the cost for people to clean the water treatment system. This cost also includes the cost for the engineer directly related to the overseeing of the water treatment process.

5. Cleaning cost

The cleaning cost involves the cost for chemical reagents that are used for cleaning the water treatment system. This is required as the waste treatment plant requires the sludge to be emptied out regularly.

6. Analysis and consulting costs

The final cost is the consultation cost for advice in dealing with problems when they arise along with the analysis cost of the water quality before it can be safety discharged into the environment.

	May	June
Water Treated / m^3	155778.0	151883.0
Cost of Electricity / ฿	556658.4	528910.5
Cost of Maintenance / ฿	621650.0	380937.3
Cost of Chemicals / ฿	427971.1	485375.0
Labour Cost / ฿	149863.0	140403.0
Degradation Cost / ฿	107657.3	102274.4
Cleaning Cost / ฿	857313.0	980424.0
Analysis and Consulting Cost / ฿	58250.0	46600.0
Total Cost of Water Treatment / ฿	2779362.8	2664924.2

Table 4-5: Cost of Water Treatment each month (Case Study Company)

Chapter 5 Analysis

This chapter will determine the different calculations involved that are necessary for determining the different values that are involved in creating the water accounting model with the lack of data collected. The analysis will also discuss the interpretation of the water accounting model as well as potential improvements that can be deducted from the information obtained from the investigation.

5.1 Process Data

Firstly, the amount of water that is being taken back into the system from recycling can be calculated using the stated formula shown below.

$$Total\ Water\ Use - Municipal\ Water\ Used = Recycled\ Water$$

These values are calculated and shown in the table 6-6 and 6-7

Table 5-1: Amount of Reused water re-entering into the system during May 2019 (Derived by Author)

Day		Reuse (m^3/day)
Monday	1st	
Tuesday	2nd	4367
Wednesday	3rd	4444
Thursday	4th	4457
Friday	5th	
Saturday	6th	
Sunday	7th	4446
Monday	8th	4452
Tuesday	9th	4444
Wednesday	10th	4456
Thursday	11th	4447
Friday	12th	
Saturday	13th	4450
Sunday	14th	6402
Monday	15th	4598

Tuesday	16th	5262
Wednesday	17th	7920
Thursday	18th	
Friday	19th	
Saturday	20th	3140
Sunday	21st	3139
Monday	22nd	3495
Tuesday	23rd	3508
Wednesday	24th	3003
Thursday	25th	5440
Friday	26th	
Saturday	27th	3099
Sunday	28th	5505
Monday	29th	4691
Tuesday	30th	6588
Wednesday	31st	7684

Table 5-2: Amount of Reused water re-entering into the system during June 2019 (Derived by Author)

June		Reuse (m^3/day)
Saturday	1st	5320
Sunday	2nd	5320
Monday	3rd	5320
Tuesday	4th	5320
Wednesday	5th	5320
Thursday	6th	11129
Friday	7th	
Saturday	8th	10987
Sunday	9th	
Monday	10th	7551
Tuesday	11th	6673
Wednesday	12th	6966
Thursday	13th	7425
Friday	14th	7189
Saturday	15th	10284
Sunday	16th	
Monday	17th	7624
Tuesday	18th	8320
Wednesday	19th	15650
Thursday	20th	

Friday	21st	7015
Saturday	22nd	11129
Sunday	23rd	
Monday	24th	7347
Tuesday	25th	16259
Wednesday	26th	
Thursday	27th	9890
Friday	28th	8474
Saturday	29th	18467
Sunday	30th	

Secondly, the average of the total amount of water will be calculated for each of the following months in each part of the industrial plant. The total value can then be used to find the average amount of water used per day of that month. If we assume that the water usage is evenly distributed throughout the month we can calculate the average volume of water used for each day. The value of the average and total for all the different parts of the processing plant is shown in figure 4-8 below.

Table 5-3: Table of Processed Data of each component of the compound factory for May and June 2019 (Case Study Company)

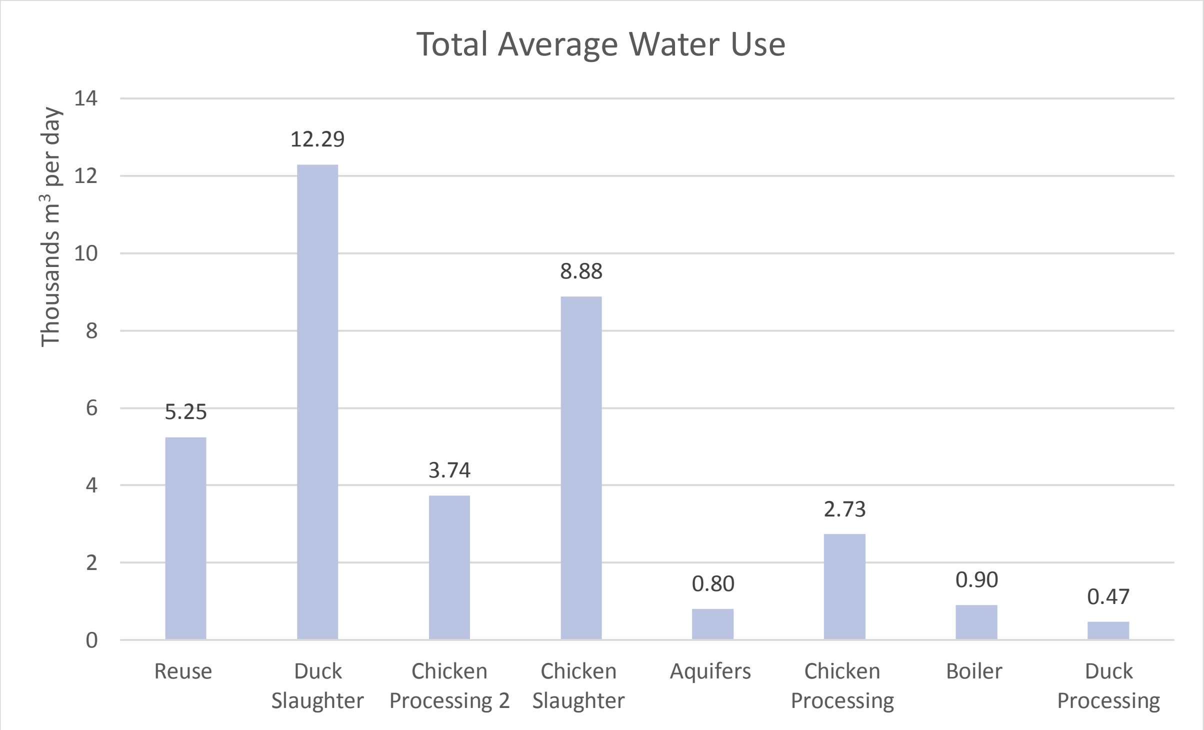
	May	
	Total (m^3)	**Avg. Per Day (m^3 / day)**
Duck Processing (m^3/day)	11,245	362.74
Boiler (m^3/day)	28,451	917.77
Chicken Processing (m^3/day)	86,064	2,776.26
Aquifers (m^3/day)	20,825	671.77
Chicken Slaughter (m^3/day)	277,924	8,965.29
Chicken Processing 2 (m^3/day)	128,205	4,135.65
Duck Slaughter (m^3/day)	391,405	12,625.97
Taken from Reuse (m^3/day)	113,437	3,659.26
Municipal Water (Total - Reuse) (m^3/ day)	1,267,634	40,891.42
Total Used (m^3/ day)	1,381,071	44,550.68

June		Total
Total (m³)	Avg. Per Day (m³ / day)	Avg. Per Day(m³ / day)
17,555	585.17	473.95
26,543	884.77	901.27
80,749	2,691.63	2,733.95
28,077	935.90	803.84
263,641	8,788.03	8,876.66
100,286	3,342.87	3,739.26
358,426	11,947.53	12,286.75
204,979	6,832.63	5,245.95
1,097,672	36,589.07	38,740.24
1,302,651	43,421.70	43,986.19

From this a basic water accounting table can be formed. Using information from the flow diagram figure 4-1 and the information on the table 4-8, the flow of water from the different parts of the compound factory can be identified.

The total water used of each of the facilities can also be seen in the follow graph figure 4-2:

Figure 5-1: Total Average Water use per day (Derived by Author)



Final Product information

The final product that is being produced from this factory as stated previously is the Chicken Roll and the Original Soya Duck. The figure 4-3 to 4-6 shows the packaging of the product, both front and the ingredients sections. Both the ingredients sections will be used to calculate the water content of the final product. The Ingredients listing in figures 4-4 and 4-6 are written in Thai. An English translation of the ingredients are shown in Table 4-9

Figure 5-2: Packaging of Chicken Roll (Front) (Case Study Company)

Figure 5-3: Packaging of Chicken Roll (Ingredients) (Case Study Company)

Figure 5-4: Packaging of Original Soya Duck (Front) (Case Study Company)

Figure 5-5: Packaging of Original Soya Duck (Ingredients) (Case Study Company)

Original Soya Duck		Chicken Roll	
Ingredients	Quantity in percentages	Ingredients	Quantity in percentages
Duck	75%	Chicken	70%
Marinating Soup	17%	Spice	15%
Internal Organs (Liver, Spleen, Heart)	4%	Vegetables	9%
Sauce	4%	Vermicelli	4%
		Tofu	2%

Table 5-4: Ingredients List (English) (Derived by Author)

According to the literature (Clayton, et al., 1973), the amount of water (W) which can be found in living ducks correlate to the amount of fat (F) with the following equation to yield a r value of -0.98.

$$F = 96.40 - (1.24 \times W)$$

We can interpret the equation to find the percentage of water in the Duck's body by rearranging the equation as follows:

$$W = \frac{(96.40 - F)}{1.24}$$

The Duck which is being processed currently has a 39% fat content which means that the percentage of water in the raw material must be 80%. Since we are also aware of the net-weight of the final product and the percentage that the duck makes up the final product. We can estimate that the ducks weigh 1.35 Kg which 1.08 Kg comes from the water. According to the production engineer, 60,000 Ducks are slaughtered and processed each day. This brings the value of water which is contributed by the raw product of ducks into the compound factory to be 64.8 m^3.

The weight of the chicken raw product is determined to be 0.85 kg according to the average weight of the chickens as stated by the production engineer. According to the literature from (United States Department of Agriculture Food Safety and Inspection Service, 2011) the composition of water makes up 66% of the weight of chicken. We can then calculate to find that 0.561 kg of water makes up the raw material. The factory is known to slaughter on average 137,500 per day. This means that the input of water from chicken raw material could be calculated to obtain the value of 77.14m^3.

The remaining calculations will be determined using the assumption values of the water intake from municipal sources to determine the water usage from the recycled source and from aquifers. Since the water from those sources will be combined in the indirect water withdrawal method into a holding storage unit for distribution throughout the compound factory. Water evaporation will be calculation under the assumption that 10% of all water inputs into the compound factory will evaporate. This is due to the fact that the literature method for calculating water evaporation rate involves the wind rate, surface area, and the ambient vapour pressure and this applies to a stationary pool of water. Assumptions avoids the calculations which is considered to be impossible as it would be highly difficult to determine the water surface area of all water usage in an industrial plant. The value taken of water flowing from the boiler to the other components in the compound factory is provided by the engineering department of the factories. According to the engineering department, it is also determined that 11.24% of the water used in the entire compound factory is recycled to be reused again and thus it could be calculated from the total water input from for each component of the compound factory. With this we are able to calculate the amount of water discarded from the process using the basic mass balancing equation. The value of water evaporated from the boiler will be replaced with the value of water discarded since water from the boiler will not be directly discarded but evaporated instead.

From the aforementioned calculations, the water accounting table for the compound factory can be calculated and shown below.

5.2 Table for water accounting

Table 5-5: Intake Water Accounting (Derived by Author)

Intake	Duck Slaughter House	Chicken Slaughter House	Duck Processing 1	Chicken Processing 1	Chicken Processing 2	Boiler	Total
Input From Raw Material	64.80	77.14	0.00	0.00	0.00	0.00	141.94
Duck Slaughter House		0.00	4320.00	0.00	0.00	0.00	4320.00
Chicken Slaughter House	0.00		0.00	3072.06	4201.69	0.00	7273.75
Boiler	321.16	324.70	112.80	114.87	117.78		1008.98
Reuse Water	1669.78	1688.18	586.50	597.22	612.39	91.88	5245.95
Aquifers	255.86	258.68	89.87	91.51	93.84	14.08	803.84
Municipal Water Source	12286.75	8876.66	473.95	2733.95	3739.26	901.27	29011.84
Total	14598.35	11225.36	5583.13	6609.60	8764.96	1007.23	

Table 5-6: Abstracted Water Accounting (Derived by Author)

Abstracted Water	Duck Slaughter House	Chicken Slaughter House	Duck Processing 1	Chicken Processing 1	Chicken Processing 2	Boiler	Total
Duck Slaughter House		0.00	0.00	0.00	0.00	321.16	321.16
Chicken Slaughter House	0.00		0.00	0.00	0.00	324.70	324.70
Ducking Processing 1	4320.00	0.00		0.00	0.00	112.80	4432.80
Chicken Processing 1	0.00	3257.91	0.00		0.00	114.87	3372.78
Chicken Processing 2	0.00	4455.89	0.00	0.00		117.78	4573.67
Output to Final Product	0.00	0.00	4320.00	3072.06	4201.69	0.00	11593.75
Evaporation	1459.84	1886.20	558.31	679.55	901.92	0.00	5485.81
Reuse Water	1640.85	2120.09	627.54	763.81	1013.75	0.00	6166.05
Discarded Water	7177.66	7141.93	77.27	2280.04	2901.79	15.92	19594.62
Total	14598.35	18862.02	5583.13	6795.46	9019.15	1007.23	

The table 4-10 and 4-11 can be read by matching the top row of the facility in which water is taken from and into the first column on the left. For example, in table 4-10 it can be seen that water taken from the municipal water source into the Duck slaughter house is 12286.75 m^3 according to table 4-10 while the water taken from the slaughter house and into the duck processing plant 1 is 4320.0 m^3. The two tables combined can pinpoint how much water is being taken into the different facilities in the factory while also showing how much water has been taken out from those facilities. Importantly both tables must have a balanced equation as the total amount of water taken into the system must be equal to the amount of water taken out.

5.3 Graph for water Accounting

Figure 5-6: Total Water Input from the Different Sources (Derived by Author)

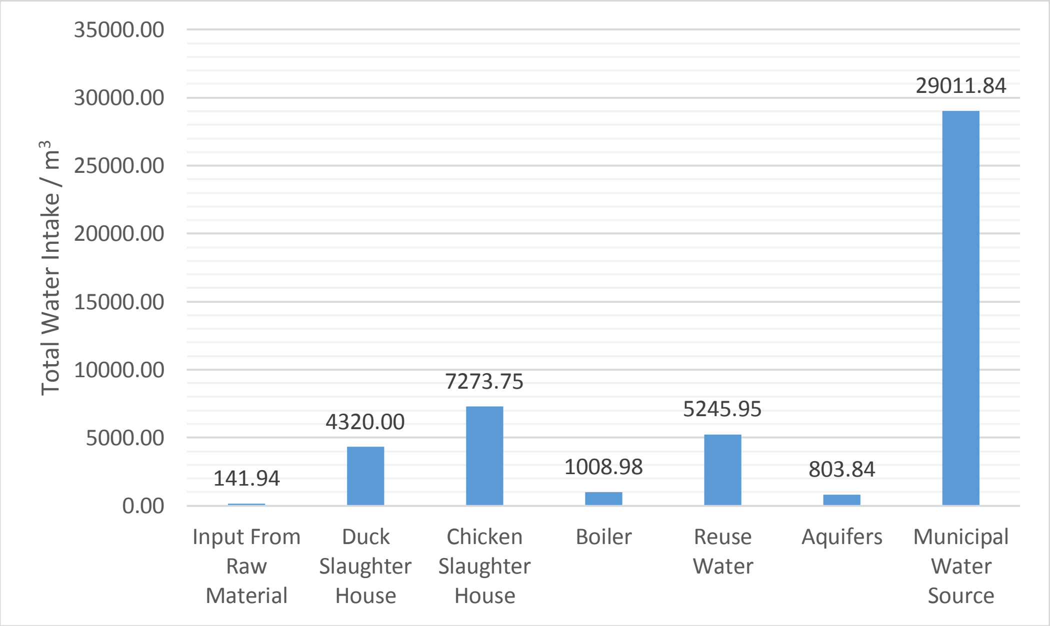
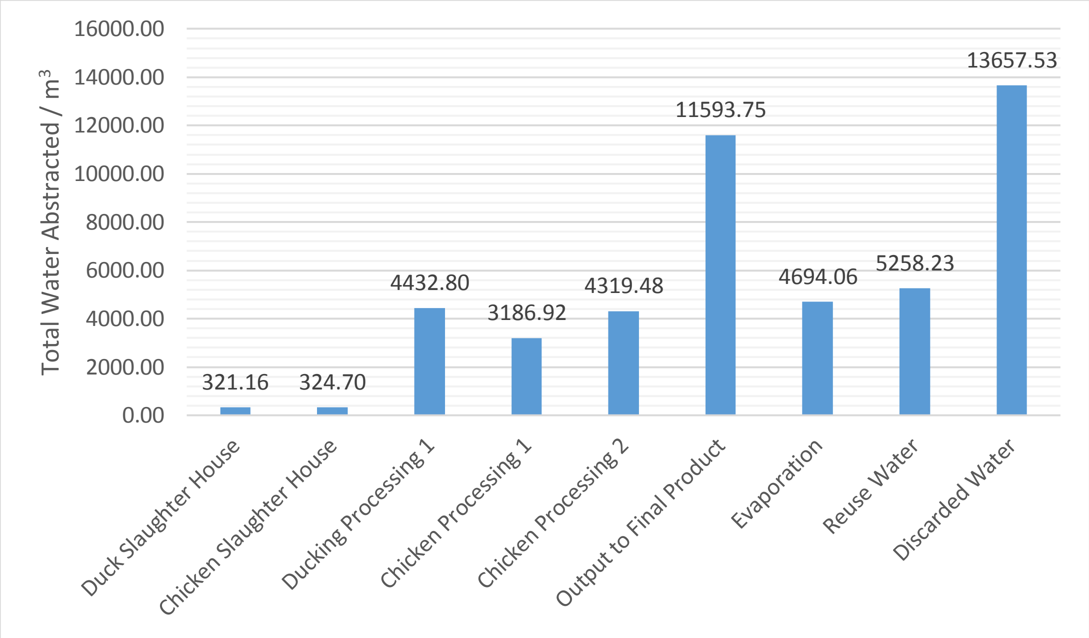


Figure 5-7: Total Water Abstracted from the Different Sources (Derived by Author)



Total Water Abstracted / m^3
16000.00
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
321.16
324.70
4432.80
3186.92
4319.48
11593.75
4694.06
5258.23
13657.53
Duck Slaughter House
Chicken Slaughter House
Ducking Processing 1
Chicken Processing 1
Chicken Processing 2
Output to Final Product
Evaporation
Reuse Water
Discarded Water

If the information in the table shown above has been inputted into the initial flowchart of the factory, the values would appear in the following diagram. Overall the table summarizes the flow diagram of the factory.

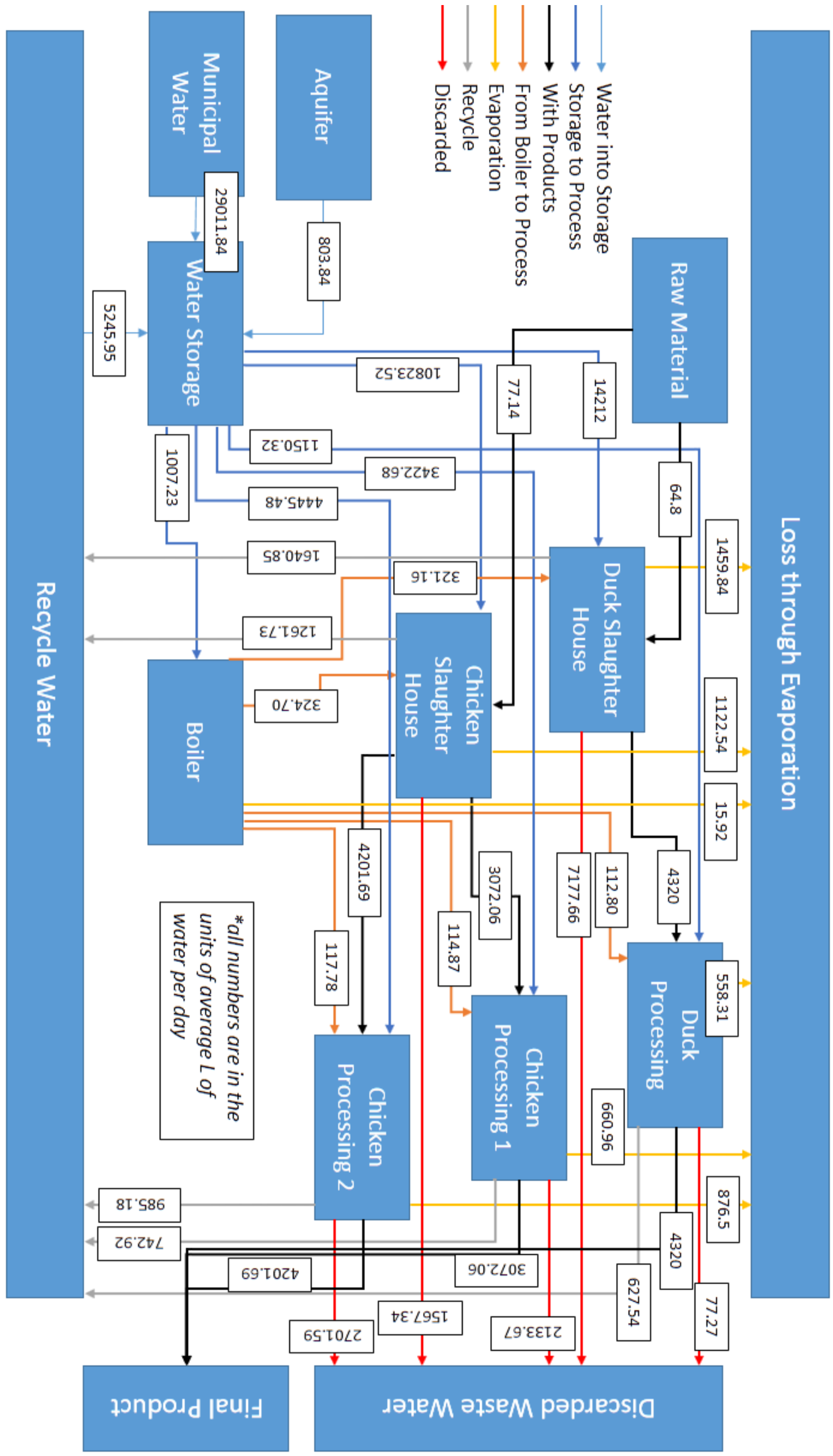


Figure 5-8: Labeled Flow Diagram of water in the compound factory (Derived by Author)

Image for Water Accounting flow in the different parts of the compound factory

According to the Thailand Board of Investments, (Thailand Board of Investment, 2017), the cost of water usage per m^3 is 15.81 for water usage of over 200 m^3. The cost of taking water from municipal sources comes to 458,677.2 THB per day to run the compound factory. This means that the water cost for municipal water comes up to almost 14 million per month for the cost of water.

The cost of water treatment per m^3 can also be calculated by using the equation shown below:

$$\frac{Cost\ of\ Water\ Treatment}{Volume\ of\ water\ treated} = Cost\ of\ Water\ Treatment\ per\ m^3$$

The cost of water treatment can be seen in the table below, table 4-12.

Table 5-7: Water Treatment Cost per m^3 (Derived by Author)

	May	June	Average
Total Cost of Water Treatment / ฿ per m^3 of water	17.84	17.55	17.69
Analysis and Consulting Cost / ฿ per m^3 of water	0.37	0.31	0.34
Cleaning Cost / ฿ per m^3 of water	5.50	6.46	5.98
Degradation Cost / ฿ per m^3 of water	0.69	0.67	0.68
Labour Cost / ฿ per m^3 of water	0.96	0.92	0.94
Cost of Chemicals / ฿ per m^3 of water	2.75	3.20	2.97
Cost of Maintenance / ฿ per m^3 of water	3.99	2.51	3.25
Cost of Electricity / per m^3 of water	3.57	3.48	3.53

5.4 Water Accounting Data Interpretation

The water accounting data provided information to better understand the water consumption of each of the different facilities in the industrial plant. Firstly, we can see that the majority of water inflow comes from municipal sources. This inflow of water bears the high cost of water usage in terms of the operation cost. We can also see that the outflow of water from the compound factory is also considered to be high, as 19,600 m^3 is discarded from the facility each day. We can also see that the slaughter houses use up the majority of the water in the compound factory. The second highest usage of water in the factories is to add water to the product which is a value adding process. It can also be noticed that the slaughter houses has a relatively high intake of water and a low output of water. This means that most of the water in the slaughterhouses are either evaporated or discarded as part of the process.

It is also worth taking note that the water abstracted to be reused back into the system isn't fully returned. This is due to the fact that the water treatment method will produce waste water and evaporation as the water treatment is conducted in an open air pool that is expose to the environment. This also means that precipitation from the environment can also add to the amount of water that is being treated and thus mitigate the loss of water through evaporation. The cost of water treatment can also be compared. It is shown that the highest costing activity involved in water treatment is the cleaning process which is outsourced to another company.

The total amount of water that is being used per day is 47,788.63 m^3 which is the sum of the total water input into the system which the amount of water that is used is in the final product is 11,588.74 m^3. The factory is currently using approximately 4,700 kg of water per 1 kg of poultry to process or approximately 4 m^3 to thoroughly wash the products and process it. This is currently within the industrial standards for poultry processing practice. As stated above that the current industrial standard for poultry processing is between 3,500 – 5,700 kg of water per 1 kg of poultry. This means that 24.25% of the water ends up in the final product while the remaining 75.75% is used for the maintenance and daily cleaning of the different facilities in the compound factory. This gives us a clear idea of the areas in which we can approach to reduce the water usage in the factory and thus reducing the cost.

From the water accounting table, it can also be determined that approximately 800 m^3 of water is be taken from aquifers. As stated previously the maximum legal allowance for water abstracting from local ground aquifers is set to be 1,200 m^3. This means that there is some room to extract water without damaging the local ecology and environment.

5.5 Areas of Improvements

There are many issues that could be addressed to improve the efficiency of water usage in the factory. Firstly, more water could be recycled to reduce the discarded water and instead move them into reused. The water systems in the factories could also be explored to determine if there would be any leaks in the piping which may be draining the water from the different parts of the factory. Key processing parts of the factories could be identified to determine which machinery is currently consuming the most water and if there are ways to reduce the usage. Finally engineers could also be asked to constantly collect water usage data daily to compile an updated water accounting table to determine the changes in the factory's water consumption and reuse. There are also currently machines in the facilities that is consuming more water than others to process the raw materials. This is the chiller which is used to kill bacteria and thoroughly wash the poultry prior to processing. The machine is a tub of water with a counter-clockwise turning blade that pushes the poultry along a corridor. An image taken from (Willems, 2018) of the machine can be seen below in figure 5-1.

Figure 5-9: Poultry Chiller

Chapter 6 Discussion and Conclusion

This chapter will discuss the recommendations for the case study company as a result of the analysis that has been conducted with regards to the water accounting model. It will also be highlighting the effectiveness of the water accounting toolkit for its use in small scale business operations.

6.1 Recommendation

In terms of recommendations we will be observing and discussing the potential improvements that could be made to the overall water management of the compound factory. There will be 5 possible strategies for the upcoming years to improve the water efficiency and the potential benefits and limitations will be discussed.

Increase the number of reuse facilities within the compound

Reusing water would be greatly beneficial to reducing the water consumption of the compound factory. Although the factory is already reusing water, more water is being discarded rather than reused. It would be greatly beneficial to add an additional water processing plant to the compound factory to allow more water to be reused. The addition of a water treatment plant would be an initial investment. Due to the nature of the factory and industry, the wastewater will need biologically dissolved oxygen (BDO) and will contain a large amount of oils and grease which needs to be removed. The cost for such a system would be approximately 18 Million Baht. This water processing set-up would allow water to be processed at 100 Gallons per Minute (GPM) or 0.378 m^3 per minute (SAMCO, 2016). This should process 544.32 m^3 per day or 15,329.6 m^3 per month. By install one of these treatment plants, the company can save up to 8,605.7 THB per day or approximately 258,171 THB per month. This means that the cost saved will return in value within 6 years of purchase.

The limitations to this would also be that there would be the cost of maintenance of the water treatment system. Table 4-5 is the current water treatment monthly cost. With the implementation of the new water treatment system, it is expected to double all except the degradation, cleaning cost (cleaning to an outsourced process), the analysis and consultation (both outsourced) cost. This means that the monthly cost for maintenance of the new water treatment system would be an additional 160,000 THB per month. This brings the total of cost saved for each month to approximately 90,000 THB per month (Thailand Board of Investment, 2017) after installing the new water treatment system. Finally the cost of a water treatment plant will be returned in 20 years. This strategy is considered to be a long term investment, but implementing this policy is an interpretation that the company is moving in a sustainable direction and thus would increase the stock price along with the non-current assets.

Consistently update the water accounting toolkit to determine trends and future prediction

The water accounting table must consistently be updated and maintained. This can be done be setting up water meters throughout the facility to monitor the flow of water to the different parts of the compound factory. As recommended in section 2.7 water metering. There are some modern technology that is useful in monitoring the water flow of the facilities. A water meter cost approximately 5,000 THB whereas the control system is 25,000 THB. One control system can monitor multiple water meters. The water meters can also be controlled to a certain extent to minimize leakage or stop when not in use. Doing so would provide engineers with newer and more accurate water flow values.

By adding additional water meters the data can be better obtained and water usage can be plotted onto a graph. This information can be used to plot a trend for the water consumption throughout the year. From this water can be taken and stored during the times where water usage isn't high such as during the monsoon seasons to be used during the drought periods. This would also ensure that water underground aquifers are not disrupted during the drought seasons which may impact the local area. Doing this can also mitigate the damage that would be caused in the rising of water prices during those drought periods. The water accounting will also play a role in tackling the food-water-energy nexus. The smart use of water throughout the production process can help manage the amount of water used per Kg of food and energy consumed. This information would also be greatly useful for potential investors, with the trend of water conservation potentially on the horizon, stock holders would greatly be interested in the water usage of the organization.

The current water usage per kg of chicken is 4700kg which from reusing water, this value could be reduced. Water returned from recycling is not included in this calculation and thus the amount of water used can remain the same while the calculations for water abstracted from municipal sources can be reduced significantly.

As stated by the company that sustainability is one of the key business practices. Following up on this recommendation would be a way to inspire confidence in the shareholders about the potential risks that might impact the company. This would show that the management has considered possible and likely risks of the future. There is also potential for profit to sell the water back to the public sector, during times of drought.

Purchasing new technology that uses less water consumption

The machine that is consuming a large amount of water in the compound factory is the chiller. This machine cleans the poultry by using a bath of cold water to reduce the temperature of the meat to kill bacteria prior to processing. The water from this machine can be reused. Currently the slaughter houses that we are investigating has 6 chillers in total which takes up a large amount of water.

A method in which to reduce the use of water is to replace older machines with more modern and efficient ones. This will allow for better air bubbles to flow through the system to kill bacteria, change the pH or the components of water before treating the poultry, or adjusting the water temperature. An alternative would be to change to a combination air and water chiller. The combined air and water chiller not only reduces the water consumption of the factory but there have also been reports that the product quality has improved. (Uitgeverij, 2010)

The air chillers are a system of tubs in which the poultry can be dunked in for a period of time as the line moves forward and taken out from the tub to allow the water to drip and chill in the cold air. This system can be custom made to change for the different size and type of the poultry bird being processed. Multiple baths can be set up to vary the chemical composition of the water to more efficiently remove bacteria. Changing the pH of the different water baths can greatly reduce the growth of bacteria and varying water temperatures will also improve the de-feathering process along the line.

This move to change the water chillers is not only an environmental and economic decision but it is also beginning to be a legal requirement in some countries. Water chillers take up water and there is a risk for contamination of salmonella. The air chiller would allow for the poultry to maintain being hanged on the line without being taken off their hooks as they would be in a water chiller. This saves time and money as a staff member would not be needed to remove the poultry off the hooks for chilling. The removing of a single water bath in the line can also reduce the amount of bloody water that often accompanies the product in the final stages, often resulting in bloody water when the final product is thawed.

The poultry could also be tracked easier in the process as thee poultry will not have to be mixed together into a tub during the chilling process. With the growing trend of sourcing food and knowing where each of the food products come from. This is a new way to ensure that food processed is taken from a sustainable source, raised organically, and raised without antibodies and chemicals.

Change the policy regarding cleaning and maintenance

Currently the cleaning and maintenance is to be conducted daily. There are adequate amounts of sinks and restrooms to allow for the employees to keep sanitation levels. According to the Thai regulations of sanitation in a food processing plant, the water used to process food must be up to the standards set by the Thai Ministry of Health. However this leaves gaps which can be exploited in terms of cleaning and maintenance. The policy for cleaning and maintenance could be changed to further reduce the water consumption in the factory. From the standard 24 hours, the cleaning of the factory line should be conducted every 48 hours instead. If we establish the assumption that water being transferred between the different slaughter houses and processing plants, we can then assume that the remaining water usage is directly used for maintenance. Under this assumption we can determine the water usage for maintenance purposes using the formula stated below:

$$Total\ Input\ into\ Facility - Water\ Abstracted\ to\ processing\ plant$$
$$= Water\ used\ for\ Maintenence\ purposes$$

With this calculation we could determine the water used to maintain the duck slaughter house to be 10,278.38 m3. The following table will list the details of the amount of water used to maintain their respective facilities that do not add to the final contribution of the product. Using the formula shown above, the following table can be used to identify the values of water used for maintenance of the facilities.

	Duck Slaughter House	Chicken Slaughter House	Duck Processing Plant	Chicken Processing Plant 1	Chicken Processing Plant 2	Total
Water consumed for Maintenance Purposes / m^3	10,278.38	3,951.61	1,263.13	3,723.40	4,817.46	24,033.98

Table 6-1: Water Consumed for Maintenance purposes (Derived by Author)

From the information stated above, we can determine that a majority over 10m3 of water is being used to clean the Duck Slaughter house daily. Under the assumption that all the values stated above are a result of daily cleaning. We can halve the values as a result to the shift in policy for changing the factory cleaning to two days instead of one. The results are shown below:

	Duck Slaughter House	Chicken Slaughter House	Duck Processing Plant	Chicken Processing Plant 1	Chicken Processing Plant 2	Total
Water consumed for Maintenance Purposes (After Policy Change) / m^3	5,139.19	1,975.805	631.565	1,861.7	2,408.73	12,016.99

Table 6-2: Water Consumed for Maintenance purposes (After Policy Change) (Derived by Author)

From this information, we can determine the amount of money saved by multiplying the total amount of water saved with the cost for municipal water which is 15.81 THB per m3 to result in 189,988.61 THB daily.

There are however disadvantages to implementing this shift in the policy, firstly there may result in legal ramifications as the conditions for cleanliness of the facilities are not explicitly determined. The policy should also take into consideration of the fact that there are legal requirements for cleanliness and those should be adhered to rather than focusing on cost saving. Health inspection ratings may also be damaged as a result of changing this policy. Also the sanitation levels of the processing plants changed throughout different stages of the production line. This will result in some areas being of high sanitation levels and such change in policy can not be applied to those areas. At the same time, there are areas in which sanitation is not explicitly required, such as loading the live animals to the slaughter house, as such there is little to no cleaning necessary for those specific areas. There is also potential damage to the quality of the final product as there is a higher risk of contaminants. Line workers must be vigilant in detecting any potential hazards for their own safety and the safety of their products. It will become good practice to discuss potential dangers in the work environment as these could also potentially reduce the maintenance cost and water consumption as well.

The water usage of the facilities can be centralized to the production process to reduce the water consumption of the overall factory. Water use for maintenance of the surrounding areas will be greatly reduced. The factory and the welcome centre contains many plants in the area. These plants produce pollen which may contaminate the area. Changing the outward appearance might require a small investment but it would reduce the need to hire a groundskeeper to maintain the surrounding area. Cleaning the outside facility could also be minimized as this is not a process in which is essential for the production of the product and thus does not add value to the business. The cleaning process can be managed on a seasonal level, cleaning during the spring and summer seasons, and reduce cleaning during the raining seasons to reduce water consumption.

Educating employees about the importance of water management

As with many problems, one key method of solving them is through education. In order to combat the over-use of water in the compound factory, the employees working there could be told to keep a close eye on the piping and the water works of the facility in which they are working in. These include leakages, breaks in valves, and general water accumulation in the facility. Employees should also be discourage to leaving the production area during their shifts to minimize the amount of water used for washing their hands. This is done by organizing the shifts in a more streamline manner. Doing so would ensure that employee movements to a minimal, and thus also become more productive during their shifts. This also fits with the principle of lean production as lean it would reduce the movement of the workers throughout the facility. Currently the shift times for the employees are organized into two shifts of day and night shifts. The employees should also coordinate assigned lunch breaks so that the washing could be done in a single session. Pairing that with the aforementioned changed in cleaning policy, the change in shifts could be done in tandem with the cleaning to reduce the water usage.

Engineers will also be trained to monitor the water usage in the factory. This would save the cost of hiring a new water engineer. As stated before, the water usage should be monitored to find changes that could have an impact on the collected data. This method could be used to find leaks in the systems by looking for anomalies. The water usage should be monitored for a long duration and any over-use could be easily detected in the change in data. This method is also a viable method to monitor the rate of production as the water usage fluctuates in accordance with the volume of products produced.

Training employees would also increase the loyalty of the employees to the organization. The company has been faced with a high turn-over rate during the past years. A method to combat this would be to train employees, as this would allow them employees to feel a sense of belonging to the organization. Although employees could demand for more pay, the benefits of training employees would save more cost in the long term.

6.2 How effective is the Accounting Model

Although the water accounting model has many advantages, it requires a lot of investment in terms of collecting data and time. The model is highly effective in compiling a large amount of information in a single format and portraying it in a way that could be understood and analysed. However, there are resources required to invest in the training to compile and process the information. Thus in order to communicate with this tool effectively. It must be shared amongst people with the same understanding of reading and compiling this information. Now that I have had experience compiling information I could document the first-hand advantages and disadvantages of the water accounting model. As well as provide recommendations as to how the water accounting model could be improved for commercial use.

6.3 Advantages of using Water Accounting

The advantages of water accounting can be separated into benefits for 3 groups involved in a business. The customers/ general public, stakeholders, and management.

Benefits for the customers / general public

Customers could benefit greatly from the use of water accounting especially in the area surrounding the compound factory. The local people can benefit by also looking at the information regarding the water trends in the facility near them and expect water withdrawals at certain periods from the shared aquifers. The local community can then adjust their water usage in accordance with the potential trends. They would also be better prepared for future droughts as the water accounting toolkit can be used to predict potential water scarcity.

Customers who are interested in sustainability could also look into the water accounting model to ensure that all the water used in the production process is treated or reused. Doing so would ensure full transparency in the eyes of the customers buying the product. While also at the same time promote sustainable use of raw materials. This ensures that all aspects of the production process is accounted for.

As stated before that water usage is an issue that needs to be addressed as a community and addressed holistically. The water accounting model could account for not only the water that is being used in the factory but also used to monitor the water usage in comparison to the demand of the local community. As mentioned in the literature review, water is a factor in the development of an economic zone. Thus to allow for economic growth in an area, the company can manage their water usage as this would allow the nearby areas to be able to develop further. The reduction of water consumption from the factory can ensure that water is being used in other areas and thus support economic growths.

Benefits for Stakeholders

Stakeholders could see that aspects of obtaining raw material is accounted. Water accounting could be seen as a first step to implementing environmental accounting for other aspects of the organization. By implementing environmental accounting, stakeholders can be sure that the raw materials are obtained from credible and legal sources. This will ensure that the business is operating sustainably and continue to do so as time goes by. Environmental accounting is also a step in ensuring that all the raw materials and resources being used for the production process isn't being wasted in leaks. The toolkit will detail specific use of raw materials and ensure that waste is minimized, in accordance with good production management and lean principle.

Stakeholders can see that there is long term investment into company growth. From the investment of gathering more data and transparency, stakeholders are assured that steps are being taken to encourage long term growth. Environmental accounting also demonstrates good will from the public as the information can be shared to encourage local communities near the facilities to take care of the environment. Stakeholders can also be assured that their investment will be returning in value as more information regarding sustainability is currently a growing trend in the global market. Coupled with investigations by the Dow Jones Sustainability Index, sustainability factors will play a more prominent role in the future of investments.

Benefits for Management

Management gains the most benefits from the usage of water accounting. Management can expect to see a reduction in operation costs, as the use of materials can be more properly managed. Processes that take up resources but isn't required may be reduced or eliminated altogether and thus saves costs for producing the final product. The management of the organization would also be able to identify many misuse of company resources as environmental accounting can be audited to find discrepancies. This could easily be spotted when the accounting toolkit isn't balanced in terms of intake and output as these variables could be treated as a finite resource. Management could also determine strains on resources throughout the production process in order to make the most effective investments in terms of remedying errors. They can be used to form strategies and goals in each quarter in which could reduce the amount of resources used in the production process.

Another major advantage for the management of a business to implement water accounting could be from the cost it saves for operations. Like accounting, environmental accounting could be used to determine areas in which cost could be saved. As mentioned previously, there are many ways in which excess in cost could be reduced that would not have a direct impact in the way in which the business operates. This would provide the business with a strategic advantage over competitors when it comes to cost. Since environmental accounting is highly specific to an organization, it would be extremely difficult to replicate. Along with the fact that it requires a large amount of time invested to form trends, it would also take an extremely long time for a competitor to catch up with the same level of data.

The management team could also gain more information regarding the operations behind the factory as the water accounting toolkit can be used to monitor the flow of water. This information can be used to identify ways in which other parts of the factory can reduce cost. As mentioned in the literature review of the food-energy-water nexus. Saving water could also allow for more resources of energy and food to be conserved. Meaning that less raw material and energy would be required for the production process.

6.4 Disadvantages of using Water Accounting

Although there are many benefits to implementing the water accounting toolkit, there are also meant challenges that need to be looked into before considering the practical uses of environmental accounting. A large amount of time and investment needs to be put into consideration before deciding to use the water accounting toolkit to monitor the water consumption in a compound factory. For the benefit of simplicity and understanding, the limitations have been separated into three main categories; setting up and priming for the implementation of the toolkit, processing the information obtained from the toolkit, and interpreting the information obtained and what can be done with it.

Setting up water accounting toolkit

Priming for the water accounting toolkit requires investment into data collecting infrastructure to ensure that the information collected is accurate and the model can successfully label the information. In order to do this it would be greatly beneficial to set up more data gathering points throughout the facility. This could be done by organizing separate water meters at different locations throughout the facility in order to collect more detailed data. The water sources could also be monitored for the water intake to reduce the assumptions required as to the source of water intake. Finally the water disposal and outflow from the facility back into the environment could also be monitored to accurately determine the output of waste water that is not being reused after treatment. Having more primary data and raw information can drastically reduce the time needed to invest into the processing of the toolkit along with produce more accurate interpretation of information without having to assume some values that may hinder the overall interpretation.

Processing data for obtained from the water accounting toolkit

Processing data obtained can often be difficult as the calculations involve varies depending on the final product being produced. In this report the compound factory that is being focused on is the slaughter house and the food processing plant. If the water accounting toolkit is to be used in other industries, details about the product needs to be fully realized before it can be processed correctly. The water accounting toolkit also has emphasis on the amount of water in the final product and thus determining that value can be difficult. Experiments can also be conducted on the final product in order to determine the water content, but these experiments will take time and investments into them. The calculations shown above are rudimentary and are gained from assumptions. More accurate testing procedures should be required as a standardized method for measuring water content of the final product.

Interpreting data obtained

There are obvious difficulties in interpreting the information obtained from this method of data processing. Firstly, there is a large amount of information that needs to be interpreted and an approach would be to have a team which has specific roles set in determining ways to improve. As stated, this toolkit can only allow the data to be collected and organized in a way which is suitable for distribution and processing. The toolkit cannot determine, by itself, what values are considered high or low. This gives the toolkit the advantage of being flexible in terms of the data that it can process, while at the same time, be too broad as to not cover any specific data points. Being too broad can also mean that interpreting data and information in this method must be considered as a case-by-case situation rather than a fit-for-all purpose. Ways in which to circumvent this problem would be to set industry-wide standards as to the minimal requirements for the water accounting toolkit to be applied. This would reduce the difficulty in varieties in the data, but this would also be a difficult task in itself.

Secondly, once the data has been processed, making recommendations as to ways in which the factory or the compound factory can improves can also prove to be a challenge as the scale of the project may vary depending on the organization using this toolkit. The scope of the improvements could be easily understood by the management and customer level of an organization. But implementing the changes in order to reduce the water consumption of a factory can be more difficult to tackle. Multiple water accounting models could be set-up tackle the different scopes in a compound factory to the factory level, to the machine or workstation level. Although this also means communication between the different levels of management in a factory.

Lastly, interpreting the data could be difficult in that processing the information can lead to inaccuracies to the realistic usage and all water isn't used equally. Thus it would be difficult to determine which aspects of the water management could be tackled first. Solving the problem with the highest impact to saving water could be the key, but then as the information is gathered smaller changes can be made to lower the water usage. This would finally result in a situation where water used has been lowest but that point will be difficult to make across. The only way in which to do this would be to show minimal water usage over a long duration of time which would be difficult due to the fluctuation demand and supply in the market.

6.5 Summary and Conclusion

To summarize, the water accounting model was originally used to collect data regarding the flow of water in a large scale. This includes the flow of water that is being used in a country. It is used to monitor the flow of water in land and how the economy has been using this resource. In this report we have adapted the water accounting model to fit with a business as the potential to save this resource could be discovered there. The water accounting model was adapted for a food processing plant as the agricultural industry is one of the largest water consuming industry. The water accounting toolkit should be used in tandem with other tools to reduce the water consumption. From the information we can determine the areas that could be improved in terms of water usage as well as save costs. Finally to answer the research questions, the water accounting toolkit is applicable when scaled down to be used in a factory. However, there are limitations as to the recommendations as this would require a large team to implement. Secondly the issues and limitations are the time constraint as the water accounting toolkit should be used over a long duration of time. There is also the issue of a large workforce required to maintain and check the information constantly. Thirdly, as stated in the recommendation, there are several ways in which the cost could be saved, judging by the information in the water accounting table. The costs saved are financially significant that the return on investment could happen in 10-20 years and also continue to save cost even further.

In conclusion, environmental accounting is still in its infancy stages and the water accounting model has been used to collect information regarding water usage in a compound factory. The data is collected from the engineers that are working for the company in that compound factory and the logs of water withdrawal have been taken directly from the primary source. As shown there is a large amount of information that needs to be processed and the water accounting model assist in organizing the information into a coherent manner.

Secondly, regarding the water management of the plant, firstly there could be multiple methods in which water management could be conducted in a way that would minimize the water loss. Water accounting has been used to identify the ways in which this could be done by highlighting key areas of water stress that could be improved. The ways in which the compound factory could improve their water management could be to increase the number of reuse facilities in the compound factory to better handle the volume of waste water that is being produced. This would help with reducing the amount of new un-used water from outside the facility. Then consistently monitor water usage and rainfall from the water accounting model as precipitation water could be treated to be safe for usage in the compound factory. Monitoring rainfall could also greatly benefit the company as it would show trends of floods and droughts and the company could prepare for them in advance. The company can also make changes to the cleaning policy as to reduce water consumption from overly frequent cleaning of the facility. The organization can also reduce the water consumption by removing non-production related water usages to ensure that it is not used wastefully. Finally, educating employees about the proper use of water and procedure as well as interviewing and receiving feedback regarding the ways to save resources from employees.

Thirdly, the water accounting toolkit has many advantages and disadvantages that needs to be considered when being used. The information can be spread and shared internally and externally in a company to convey areas in which could be improved. The water accounting toolkit is also a sigh of sustainable development in which customers can see and trust that they are getting food that is processed in a sustainable way. Although it must be said that there are difficulties in setting up the water accounting toolkit and interpreting the results due to the flexible nature of the toolkit. The flexibility of the toolkit makes the interpretation quite subjective and results may vary depending on the industry in which this is applied to.

There is currently a large potential for companies to begin adopting this model for use as this would greatly reduce the cost of production. The benefits can be reflected socially although the investment to make this change can be quite taxing on the finances. To further develop this study it should also be implemented in other industries as well. The usage of water to generate electricity should also be looked into as the water is generally used in heating and cooling of machines. This means that the water is generally untreated and could potentially be recycled multiple times before discharged. The water accounting model also opens up potential in other toolkits that have been developed in the public sectors to be applied in the private sectors to communicate between them more effectively.

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