ANALYSIS OF FLOW CHARACTERISTICS IN SEWERAGE SYSTEMS

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ANALYSIS OF FLOW CHARACTERISTICS IN SEWERAGE SYSTEMS

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
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Specially dedicated to

my beloved father and mother

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ABSTRACT

The resolution of flow characteristics is imperative to all sewerage systems. Design of sewerage system is related to the analysis of flow characteristics. Sewerage system should be designed based on the most critical flow rate. Sewerage system design may become inappropriate if the analysis of flow characteristics is not done. The purpose of this research is to verify the suitable design criterion and by extension parameters for sewerage system as recommended in MS 1228:1991. This research also aims to study the effect of rainfall on sewerage flow pattern and analyze the flow characteristics in sewerage system. In the present study, two parameters, the per capita flow and the design criterion, were investigated. The investigation was performed on a manhole located between the library and sports complex within Universiti Malaysia Pahang, Gambang campus (UMP Gambang) where field monitoring of sewage flows was conducted. ISCO 2150 Area-Velocity Flowmeter was used to collect the flow data and Flowlink 5.1 software was used for data retrieval as well as display. Calibration of the flowmeter was done in the Hydraulics and Hydrology Laboratory of UMP Gambang. The study duration was from 17 November 2014, 4.00 pm to 9 February 2015, 4.00pm. Each set of data consists of sewage flow readings every five minutes for duration of two weeks by using Area-Velocity method. The same data measurement interval was applied to the rainfall data, collected through an ISCO 675 Rain Gauge located at Residential College 2, UMP Gambang. From the results obtained, both the parameters investigated were found to be lower than their respective values stated in the Malaysia Standard MS 1228:1991. The value of average actual per capital flow in this research was 0.076 m^3/day/person which is 66.2% smaller than per capita flow in MS 1228:1991 with amount of 0.225 m^3/day/person. On the other hand, the value of average actual design criterion in this study was 2.49 also smaller than design criterion of 4.7 mentioned in MS 1228:1991. After analysis of the results, it can be concluded that the flow characteristics in the sewerage system studied is sufficient to cater to the population equivalent in the study.

ABSTRAK

Resolusi ciri-ciri aliran adalah penting untuk semua sistem pembetungan. Reka bentuk sistem pembetungan berkaitan dengan ciri-ciri aliran analisis. Sistem pembetungan perlu direka berdasarkan kadar aliran yang paling kritikal. Reka bentuk sistem pembetungan boleh menjadi tidak sesuai jika analisis ciri-ciri aliran tidak dilakukan. Tujuan kajian ini adalah untuk mengesahkan kriteria reka bentuk yang sesuai dan dengan parameter untuk sistem pembetungan seperti yang disyorkan dalam MS 1228: 1991. Kajian ini juga untuk mengkaji kesan hujan pada corak aliran pembetungan dan aliran analisis ciri-ciri dalam sistem pembetungan. Dalam kajian ini, dua parameter, aliran per kapita dan kriteria reka bentuk, telah menemui. Kajian ini telah dijalankan pada lurang yang terletak di antara perpustakaan dan komplek sukan dalam Universiti Malaysia Pahang, kampus Gambang (UMP Gambang) di mana pemantauan bidang aliran kumbahan telah dijalankan. ISCO 2150 Kawasan-Velocity Flowmeter telah digunakan untuk mengumpul data aliran dan perisian Flowlink 5.1 telah digunakan untuk mendapatkan semula data serta paparan. Penentukuran meter aliran itu dilakukan dalam Hidraulik dan Hidrologi Makmal UMP Gambang. Tempoh kajian adalah dari 17 November 2014, jam 4.00 petang hingga 9 Februari 2015, jam 4.00 petang. Setiap set data mengandungi bacaan aliran kumbahan setiap lima minit untuk tempoh dua minggu dengan menggunakan Area-Velocity Method. Perkara yang sama selang ukuran data telah digunakan untuk data hujan, dikumpul melalui ISCO 675 Rain Gauge terletak di Kolej Kediaman 2, UMP Gambang. Daripada hasil yang diperolehi, kedua-dua parameter disiasat didapati lebih rendah daripada nilai masing-masing yang dinyatakan dalam Standard Malaysia MS 1228: 1991. Nilai purata sebenar setiap aliran modal dalam kajian ini adalah 0.076 m^3/hari/orang yang merupakan 66.2% lebih kecil daripada aliran kapita dalam MS 1228 per: 1991 dengan jumlah 0.225 m^3/hari/orang. Sebaliknya, nilai purata kriteria reka bentuk sebenar dalam kajian ini adalah 2.49 juga lebih kecil daripada kriteria reka bentuk 4,7 disebut dalam MS 1228: 1991. Selepas analisis, dapat disimpulkan bahawa ciri-ciri aliran dalam sistem pembetungan yang dikaji adalah mencukupi untuk menampung kesetaraan populasi dalam kajian ini.

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LIST OF SYMBOLS

Q_{ave}	Average flow of wastewater
Q_{pcf}	Per capita flow
K	Design criterion
H_{2150}	Water depth value recorded at the ISCO 2150 Flowmeter
H_{oc}	Water depth value recorded at the open channel in lab
Q_{2150}	Flow rate value recorded at ISCO 2150 Flowmeter
Q_{oc}	Flow rate value recorded at the open channel in lab
$Q_{1,2,3,4,5,6}$	5 sets of flow rate data recorded
$Q_{\max hourly}$	Maximum hourly flow of wastewater
$Q_{\min hourly}$	Minimum hourly flow of wastewater
$Q_{\text{avg} hourly}$	Average hourly flow of wastewater
m^3/day/person	Meter cubic per day per person
mm	Millimeter
%	Percentage
l/s	liters per second

LIST OF ABBREVIATIONS

PFF	Peak flow factor
PE	Population Equivalent
UMP	Universiti Malaysia Pahang
IWK	Indah Water Konsortium Sdn. Bhd.
STP	Sewerage treatment plant
MH	Manhole
JPPH	Jabatan Pembangunan dan Pengurusan Harta
KK 2	Residential College 2
HDPE	High density polyethylene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A sewerage system is a system that contains pipes of several lengths and diameters which are very important to convey the wastewater, including domestic, residential, industrial and commercial treatment services (Ansari et al., 2013). Sewerage system plays a critical role in that it supports public health and environmental protection. Normally, the wastewater flow in the sewerage system is directly related to human usage for all kind of activities.

Sewerage system is a main consideration in any residential, commercial, and industrial development because it can enhance the environment through the disposal of wastewater (Osmi and Mokhtar, 2013). Moreover, it also can prevent floods through removal of rain water. This research is concentrated on the sewerage system for facilities, residential and commercial areas and is currently focused on the sewerage system within Universiti Malaysia Pahang (UMP).

Sewerage system is located underground, which transfers residential, commercial and industrial sewage towards a wastewater treatment plant (Rahman et al., 2007). The typical sewerage system is based on gravity. It means that the water flows under gravity force. There are two types of sewerage systems in Malaysia which are sewerage system that is connected to a public sewage treatment plant or sewerage system that consists of an individual septic tank. IWK is mainly responsible for service of the public sewage treatment plants and the corresponding network of sewerage pipelines. The treatment facilities process has four stages which are preliminary treatment, primary treatment, secondary treatment and disposal of sludge (IWK, 2013). Figure 1.1 shows the flow diagram of wastewater from residential area to wastewater treatment plant.

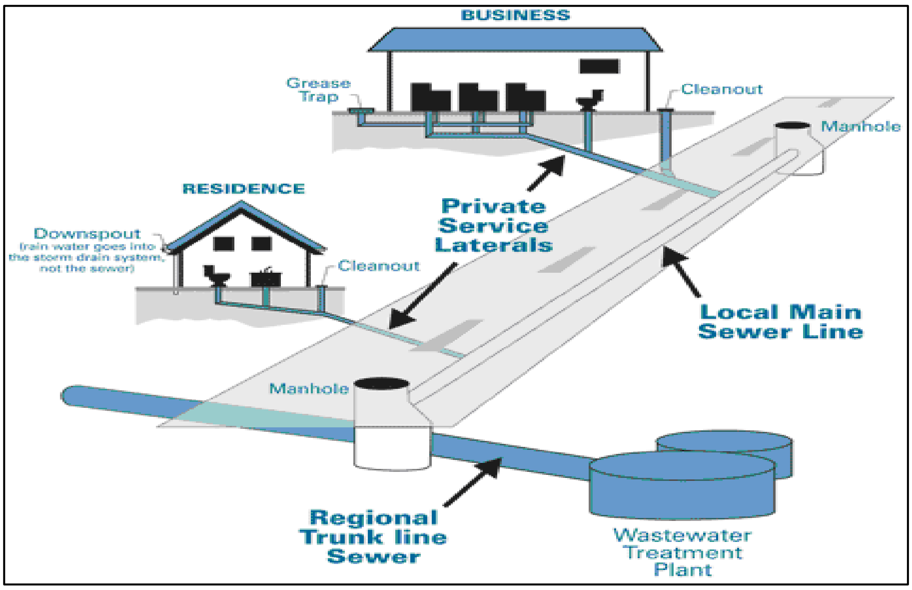

Figure 1.1: Sewer flow diagram

Source: Civil Engineers PK

The flow factors and flow characteristics are very important to design effectiveness of a sewerage system. During this research, two parameters, per capita flow and peak flow factor, will be determined in the sewerage system studied. The rainfall data is also collected during the research.

1.2 PROBLEM STATEMENT

In order to design the pipe network and sewerage system, the peak flow rate need to be estimated. There are many methods to calculate flow rate such as the Harmon method and the Babbit and Baumann method (Imam and Elnakar, 2013). In this study, the PE method was adopted to measure the flow rate in the sewerage system.

PE is used to determine the usage made of sewerage facilities and it depends on the type of premise as well as human activity. The design should include the influence of rainfall. The design criteria recommended in Malaysia Standard 1228:1991 (MS 1228:1991) Clause 3.6 and Clause 3.2 is 4.7 for the peak flow factor equation while the design per capita flow in 0.225 m^3/day/person. When the value of actual per capita flow and actual peak flow rate are higher than the design criterion stated in MS 1228:1991 it means that the sewerage system have to use bigger diameter of pipe; on the other hand, if the actual peak flow and actual per capital flow is lower than the design criteria this means the sewerage system was overdesigned, so need to use smaller pipe in the system for economical concern (Essays, 2013).

In Malaysia, sewerage systems are designed according to the Malaysian Standard Code of Practice MS 1228:1991 but in actual fact, MS 1228:1991 itself is based on British Standard. But the British Standard had been revised twice with the latest version in 2008 named BS EN 752:2008, so the design criteria and peak flow factor in the MS 1228:1991 should also be revised to see whether the design criterion is still valid or not (Ngien and Ng, 2013). Therefore, this research was implemented.

1.3 OBJECTIVES OF STUDY

The purpose of this research is to verify the suitable design criterion and by extension the parameters for sewerage system as recommended in MS 1228:1991, while the objectives are:

- To study the effect of rainfall on sewerage flow pattern in the sewerage system.
- To analyze the flow characteristics in the sewerage system in UMP area.

1.4 SCOPE OF WORK

This research is focused on fieldwork. One manhole (MH 7) was selected in this current study. The 7 sets of data will be collected from MH 7 located in between the library and sport center in UMP area. Before being used in the sewerage system, an area-velocity flowmeter model 2150 is calibrated in the Hydraulic and Hydrology Laboratory of UMP. The area-velocity flowmeter is hung on a bar attached to the wall in the manhole, while the sensor of the flowmeter is installed in the water pipeline using a mounting ring so that the sensor can record the velocity in the pipeline. The data can be downloaded through Flowlink software. One set of data will be recorded for a period of fourteen days. The next six sets of data will also be recorded in the same way, each set of data for two weeks. The reason for recording two weeks is to make sure the data is more precise and accurate. Rainfall intensity will also be recorded using an ISCO 674 Rain Gauge at the football field of Residential College 2, UMP. Each set of rainfall data will be recorded for one week.

Once the data is obtained, analysis and calculation of data can start. After calculating the actual per capital flow and peak flow factor, those data can be compared to the design criterion based on MS 1228:1991. The analysis will then show how much percentage of difference there is between the actual and recommended design criteria of the sewerage system.

1.5 RESEARCH SIGNIFICANCE

The advantage of this research is it will contribute towards any future revision and improvement of the MS 1228:1991 design criteria. Other than that, this research will verify the design characteristics of the sewerage system in UMP. If the actual design criteria are lower than the design criteria 4.7 stated in the MS 1228:1991Cl 3.6 that will mean that the sewerage system was overdesigned. But the piping system in UMP is already in place, it'll be very costly to dig up and replace with smaller pipes. Thus, in this manner, we may be able to save costs in the design of sewerage system for future development.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY

Sanskrit and Egyptian wall inscriptions had stated information about water treatment since 2000 B.C. The inscriptions described the procedure of distilling water by boiling in pottery made of copper, exposure under the sun, filtering water through charcoal, and cooling in pottery.

In 1627, Sir Francis Bacon from London, United Kingdom had published experiments about purification of water by filtration, boiling, distillation, and clarification by coagulation before his death. He had emphasized that clean water will directly affect health.

In 1685, Luc Antonio Porzio who originated from Italy had published a book about using sand filters to get clean water for soldiers in camps. He use this skill based on his experience during the Austro-Turkish war. He had carried out a lot of experiments about sewerage design in different countries such as Germany and Russia.

In 1856, Henry Darcy was the first person to apply laws of hydraulics to rapid sand filter water in France and England. The result he got was the coagulants will be more efficient.

Sir Edwin Chadwick was the person who came out with the noble idea to get clean water to solve the problem of people dying due to lack of clean drinking water

(Rahman et al., 2007). Thus, he had to improve the sanitary condition to ensure public health. The ideal which he proposed was that every residential unit is to be supplied with clean water and all the waste generated has to be discharged using pipe system at a velocity sufficient to prevent blockage within pipes. Due to the early sewerage systems had created, it is direct results of Sir Edwin Chadwick's effort to promote his ideal.

2.2 DEFINITION OF RELEVANT TERMS

Relevant terms will be discussed in this dissertation for the purpose of more understanding by readers. The definition of these terms was referred from the MS 1228:1991 and American Society of Civil Engineers (ASCE, 2007).

a) Sewerage
   - Any fluids discharged containing chemicals in it.
b) Sewer
   - Any line of pipes that is designed to discharge the wastewater.
c) Sewerage System
   - A system to transport wastewater to disposal in sewerage treatment plant.
d) Wastewater
   - Any fluids or liquids spent by the community which contains dissolved matter.
e) Per Capita Flow
   - The average daily design flow in sewer that caters to human dwelling.
f) Peak Flow Factor
   - Peak Flow Factor is a factor that is used to design sewer.
g) Sewerage Treatment Plant
   - Sewerage Treatment Plant is a plant that treats wastewater and delivers the effluent to rivers.
h) Population Equivalent
   - PE is used to estimate how many person's waste will flow into a sewerage system in that area

i) Gravity Sewer System

- A system to transport and collect sewerage to sewerage treatment plant by using its own self weight and gravity.

2.3 TYPE OF SEWERAGE SYSTEM

Sewerage system is a system to collect wastewater and deliver it to STP. There are two types of sewerage system in Malaysia, the public sewerage treatment system and the individual septic tank. Both sewerage systems are maintained by IWK. To provide fluent unimpeded service of the sewerage system underground, IWK had divided the sewerage pipelines into two sections for public sewer and private sewer (Kadir, 2006).

For the public pipe, IWK is the agency in charge of the service of this system. Meanwhile, private sewer has to be taken care of by its individual owner. If there are any problems about the sewer system, individuals need to pay for the service by IWK (IWK, 2013). Figure 2.1 shows the wastewater flow through to the sewerage system with few stages.

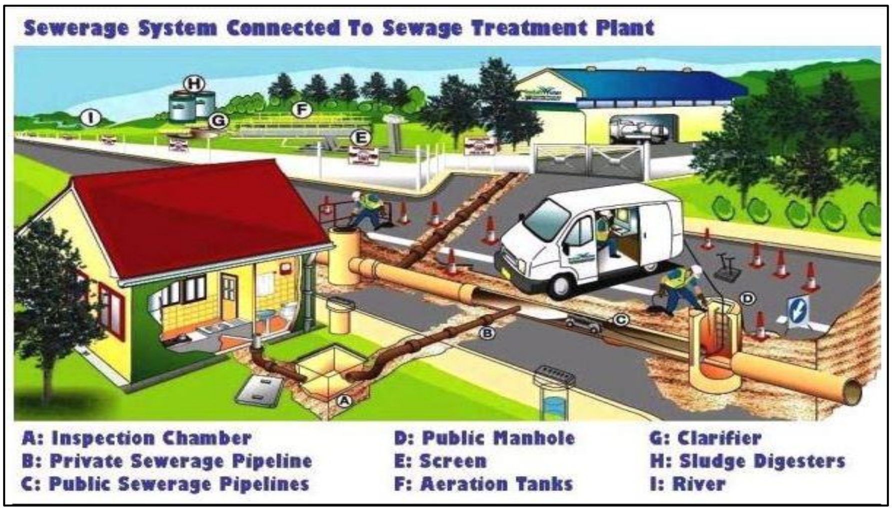

Figure 2.1: Public sewer and private sewer

Source: (IWK, 2013)

2.4 TRANSPORTATION OF WASTEWATER

There are many types of material that can be used in the sewerage system. Those materials can be vitrified clay pipe, reinforced concrete, cast iron, and high density polyethylene pipe. Before selecting the material to be used, some considerations need to be made, for example cost of installation, strength of material, and the life span of the material. Different materials have different design characters. In UMP, the most common material used in sewerage system is HDPE pipe with 225 mm diameter which shown in the Figure 2.2. In MS 1228:1991, it states the design criteria using this material. HDPE have diameter range from 110 mm to 630 mm. It also has variable lengths of 6 m. There are many advantages using HDPE pipe. It is very environment friendly due to less energy consumption. It will also never release toxic from sewerage to ground. Other than that, HDPE is a material with non-conductive polymer. It would not rust and have long life span. Due to the reason long life span, the maintenance fee is very low (LP, 2009).

Figure 2.2: Installation of HDPE

Source: seekpart.com

In Malaysia, gravity sewer system is the most used which shown in Figure 2.3. This method is based on using gravity force to discharge the wastewater to STP. This method is preferred because it has the lowest cost and is suitable for most topographical locations. Gravity sewer system delivers the wastewater by utilizing the potential energy resulting from difference in elevation. The purpose of the flow from upstream to downstream is to maintain flow velocity, avoid backflow and minimize the head loss in the sewer pipe (ASCE, 2007).

The pipe must be located on a slope to allow sewer discharge by velocity between 0.8m/s to 4m/s (MS 1228:1991). If the velocity is less than required then the solid waste will block the pipe, making repairs necessary. Other than that, the minimum size of diameter in sewers is 200mm and the depth invert is 1.2m from the manhole (MS 1228:1991).

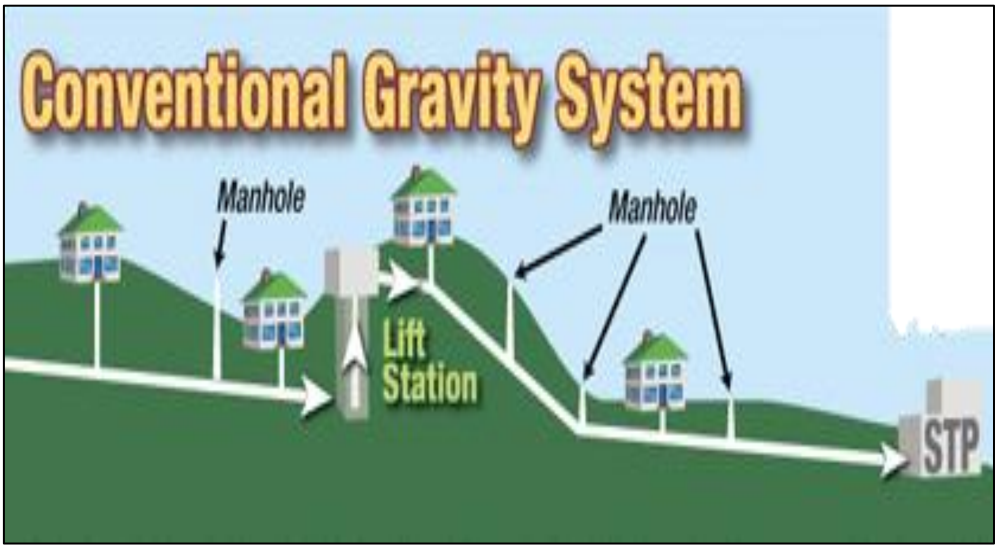

Figure 2.3: Gravity sewer system flow

Source: orenco.com

2.5 CHARACTERISTICS OF MANHOLE

The manholes are needed on the surface of the ground to provide access for sewer maintenance or repair of the sewer. They also create minimum interference to the hydraulics of the sewer. The manholes must be strong and durable.

Usually manholes are made from precast reinforced concrete and surrounded with concrete for protection and placed at roadside as well as outside of the building. Manholes have their own reference standard according to MS 1228:1991. The manhole cover is made from cast iron with minimum diameter of 600mm and the foundation of the manhole should not be less than 150mm thick. The maximum distance between a manhole to another manhole is 100m in a sewer line. Manholes are used for checking, maintaining and repairing the sewer. Manholes also signify a change of pipe size or flow direction change in the sewer system. Besides that, manholes are located where there is a change in the gradient of the sewer pipe slope. They will most likely appear intermittently along long sewerage pipelines. They will also appear at the sewer junction for easy servicing access (ASCE, 2007).

Manholes are very important because it is the only way to access sewer for maintenance and to do inspection. If the manhole cover is damaged, it needs to be repaired as soon as possible because the gases in the manhole are hazardous for human health and dangerous to human safety. There are many ways to repair the manhole cover. One of the methods is to replace and reset a new cover. Other than that, renovating and renewing the fabric of the chamber can also solve the problem (BSEN, 2009). As conclusion, manholes need to be inspected constantly. Figure 2.4 shows the detailing of the manhole cover.

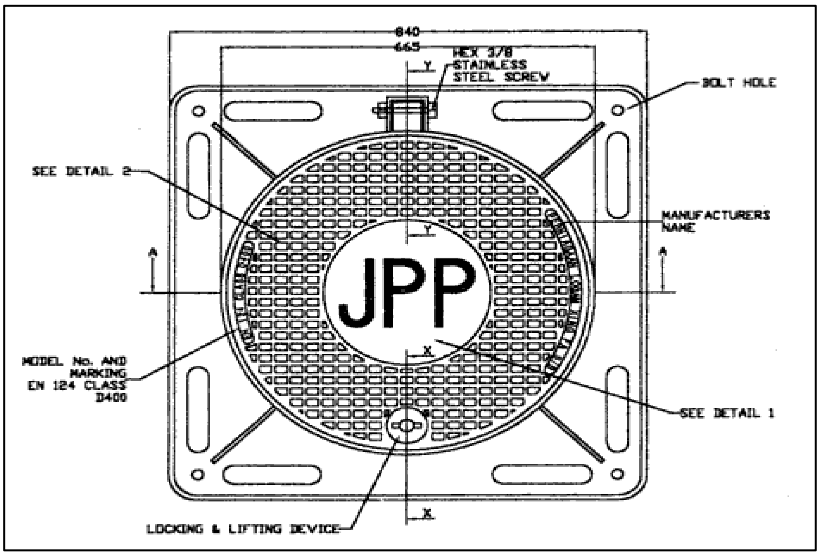

Figure 2.4: Manhole detailing

Source: plxf.com

2.6 FACTORS THAT AFFECT THE FLOW CHARACTERISTICS

Factors that will affect the flow characteristics are of concern in the study. If the factors are not taken into account, they will affect the flow characteristics and the data from this current of study will not be accurate. There are many factors that will affect the flow characteristics in the sewerage system. For example, population estimation, sewer pipe appurtenances and volume of rainfall.

2.6.1 Population Estimation

PE is one of the factors that will affect the flow characteristics. PE is used to estimate how many person's waste will flow into a sewerage system in that area as defined in MS 1228:1991. PE is not used to measure the number of people in that area. By referring to MS 1228:1991, the recommendation for PE in various places can be found in Table 3.5. For example in a hospital, four PE was recommended per bed. It means that four per dwelling in a bed. If PE is calculated incorrectly, the flow characteristics may be affected, because the STP design is based on PE.

2.6.2 Sewer Pipe Appurtenances

Size of pipe is another main factor affecting the flow characteristics. Sewerage flow will be faster in a system with smaller size of diameter pipes rather than bigger size of diameter pipes (Lin and Hanratty, 1987). Besides that, the length of pipe will also affect the flow rate. The flow rate in sewerage system will be higher when using a longer length of pipe (Ruktantichoke, 2011). Sewer pipe material used will also affect the flow characteristics. There are many type of materials, each type of material will have their own benefit and own application. For example, concrete pipe that is constructed underground for sanitary sewer purpose. Concrete pipe will be used in certain environment, it only allows direct installation for micro-tunneling. It has potential disadvantages if used as sanitary sewer. The disadvantage of this type of material is its weight and the trend to crack if there are foundation settlements. Corrosion may occur due to acid present in the wastewater. Type of materials should be used in a suitable environment (ASCE, 1982) .

2.6.3 Volume of Rainfall

Rainfall volume is also one of the factors that will affect the flow characteristic. In this research, rainfall will be counted in the analysis with the flow rate in the sewerage system. Dry season and wet season will be analyzed in this study. When there is wet season, the flow characteristics will increase due to some of the rainfall becoming runoff into the sewerage system (Ashley, 2008). This phenomenon will affect the flow characteristics in sewerage system.

2.7 PREVIOUS STUDIES

Study of previous works is very important to a researcher because the researcher can make it as reference and improve and advance the method done before. Through reading the case studies, more knowledge and understanding will be gained on the topic to be done. Thus, comparison can be made between the past case studies and the current study. In this research, there are 7 study cases referred to.

2.7.1 Case Study – Chicago, Illinois

This research was conducted in the apartment area in Chicago which was located in Illinois. The method used to analyze the flow characteristics in the research area is fixture unit (Hunter, 1940) which is the same as the case study in Los Angeles. The result from the study found that the peak flow factor and per capita flow is lower than the actual design criteria. The reason for the result is the population of the area was at an early age, had low income and lived with large groups of families (Braxton, 1965).

2.7.2 Case Study – Los Angeles, United States

This research was conducted in a residential area which single story houses in Los Angeles. This study was conducted by following the American Society of Civil Engineers (ASCE) standard. The method use in the study was fixture unit method. According to National Standard Plumbing Code -1980, fixture unit is defined as the total flow discharge divided by 7.5 which provide the flow rate of plumbing fixture as a unit of flow (Plumbing, 1980). From the study, peak flow rates were obtained using probability studies. The probability studies consist of a number of assumptions to get peak flow factor and per capita flow based on the population estimation (ASCE, 1982).

2.7.3 Case Study – Washington State

This research was conducted by the Department of Health staff researcher in Washington in 2002. The experiment was conducted to determine the residential sewerage flow rates. This research is referred to the Criteria for Sewerage Works Design from Washington State Department of Ecology. This experiment was conducted for three months. The result of peak flow was shown to be lower than the recommended peak factor which is 2.5 according to the Criteria for Sewerage Works Design (Benefield, 2002).

2.7.4 Case Study – Taman Sri Pulai, Skudai, Johor

This research was conducted by a few of students of Universiti Teknologi Malaysia (UTM) at Johor in 2000. The residential area of Taman Sri Pulai, Skudai was the place that the research was conducted in. In Taman Sri Pulai, two areas were selected for conducting the experiment. The flow rate and rainfall data was measured at hourly interval by using ISCO Area Velocity Flowmeter Model 4250 and ISCO Rain Gauge. A few manholes were selected during research in both two areas, while the last manhole was required to connect to the STP. Data was recorded continuously for 22 days including weekdays and weekends. The data of weekdays and weekends was analyzed separately. From the result, it was shown that the design parameter per capita flow and peak flow factor had a lower value than stated in MS 1228:1991 and rainfall was the main factor to affect the flow characteristic (Rahman et al., 2007).

2.7.5 Case Study – Johor Bahru, Malaysia

This research was conducted by an assistant professor of Mehran University of Engineering and Technology in 2005. This research was located in two residential areas close to UTM. The total number of manholes selected in the research was 10. Flow rate and rainfall data was measured for every five minutes of interval using ISCO Area Velocity Flowmeter Model 4250 and ISO 674 Rain Gauge. Data was recorded continuously for five days including weekdays and weekends but the data was analyzed separately for weekdays and weekends due to the need to see the difference of usage between these two periods. From the result, it was shown that the design parameter per capita flow and peak flow factor had lower values than MS 1228:1991. The main factor to affect the result was the amount of rainfall, because heavy rain will result in overburden in the sewerage system (Ansari et al., 2013).

2.7.6 Case Study – SEGI University, Selangor

This research was conducted inside the compound of SEGi University, Kota Damansara campus in 2013. One manhole close to the hostel of the university was selected for the research. Flow rate was measured for every fifteen minutes of interval by using a portable ISCO 2150 Area Velocity Flowmeter Model. Once recorded, the data will be downloaded using the Flowlink software. Data was recorded continuously for seven days including weekdays and weekends. The data recorded was separated into 168 hourly slots and the maximum flow, average flow and minimum flow was extracted from each hourly slot. Meanwhile, the rainfall data was not recorded. From the result, the per capita flow was shown to be higher than recommended in MS 1228:1991. The reason is that the students living in the hostel used excess water than designed for. The actual peak flow factor was found to be lower than the value in MS 1228:1991 (Ngien and Ng, 2013).

2.7.7 Case Study – West of Golf, New Cairo

This research was conducted by a professor of Cairo University in Egypt in 2010. This research was located in the West of Golf in New Cairo, Egypt. Flow rate and rainfall data was measured at hourly intervals by using portable ultrasonic flowmeter. Data was recorded continuously for 280 days including weekdays and weekends. The result was modeled by using Gumbell distribution and hydrograph, to get the best fit to find the maximum and minimum flow factor. From the result, it showed that the flow was higher than the factor of maximum sewer flow stated by the American Society of Civil Engineers (ASCE) because the community had development there during the early stages of occupation. Other than that, probability of non-exceedance was also one of the main considerations to estimate the design flow factor (Imam and Elnakar, 2013).

2.7.8 Research Gap

Through studying all the previous works, a summary can be made in Table 2.1. This table shows the research gap of the previous studies and current research. The reason for compiling this table is to give a clear picture and better understanding to readers of the difference between previous studies and the current study.

Table 2.1: Research gap between previous research and current research

Place Conducted	Method for Getting Data	Rainfall Data	Time Interval to Record Data (min)	Duration 1 set Data (days)	Source
Residential Area	Fixture Unit Method	No	-	-	(Braxton, 1965)
Residential Area	Fixture Unit Method	No	-	-	(ASCE, 1982)
Residential Area	Area Velocity Doppler	No	15	7	(Benefield, 2002)
Residential Area	Area Velocity Doppler	Yes	10	7	(Rahman et al., 2007)
Residential Area	Area Velocity Doppler	Yes	10	7	(Ansari et al., 2013)
Residential Area	Area Velocity Doppler	No	15	7	(Ngien and Ng, 2013)
Residential Area	Harmon Method	Yes	60	1	(Imam and Elnakar, 2013)
Mostly commercial area	Area Velocity Doppler	Yes	5	14	Current study

In this study, there are many differences compared to the previous researches. In the current study, the research area is mostly in commercial area such as Faculty Office, Curriculum Centre, Library and Sport Complex. Those areas are more to commercial and very different from previous research in residential area. The reason for choosing this research is to find the difference of flow rate between residential and commercial areas. Besides that, the time interval of record data is five minutes compared to previous researches. By using five minutes of interval time to record data it is more precise and more accurate compared to intervals of more than ten minutes. Same goes to duration of one set of data. In this research, duration of one set of data is two weeks which is fourteen days. It means that the results will contain analysis for every two weeks. The method used in this research is area velocity method. This method is the most common method for analysis of flow rate. According to the theory of Volumetric Flow Rate, it can calculate the flow rate by using area multiply by velocity. During the research, it will collect depth of wastewater and wastewater velocity also to implement the Volumetric Flow Rate theory. Other than that, rainfall data will also be collected with the same time interval as the flow rate data. Thus, both data can be compared and analyzed together to study the effect of rainfall on sewerage flow pattern in the sewerage system.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is a process to describe how the project will be done in detail. In this chapter, all the information about the research will be collected including preliminary work, information gathering, flow characteristics measurement, and equipment that were used. Through this chapter, all the information and procedure to achieve the objectives of the research will be explained clearly.

3.2 PRELIMINARY WORK

At the start of the research, self-study had to be done such as searching journals, articles and magazines which are related to the title. By studying those materials, more knowledge can be gained to form the idea and concept of what has to be done as well as what kind of methods can be applied in the research. Other than that, reading the catalogues of the equipment to be used also has to be done to understand how they work. Moreover, meetings with staff of JPPH, site visit with supervisor and JPPH’s staff as well as calibration of equipment had to be done before collecting the flow rate data.

3.2.1 Information Gathering

All the information was obtained from journals and articles related to flow characteristics. Owing to the research area being within UMP, the drawings were requested from UMP Holding Bhd and JPPH. Those drawings include UMP site plan and UMP sewer reticulation site plan which are attached in Appendix A. There are very few local studies on the topic of this research because it is still quite new in Malaysia.

3.2.2 Site Visit

Figure 3.1: Site visit at the area between library and sports complex

Site visit is a compulsory activity in this research. It is very hard to reconnaissance a suitable manhole to do research because the criteria of the manhole are directly related to the sewer pipe. Determination of manhole location is dependent on several criteria. Manholes are usually situated at sewer lines having a change in direction, gradient or size of sewer. Other criteria of the manhole to be selected in this research is that the manhole needs to be shallow, will not flood and the location is near to the STP. In this research only one manhole is required. During the site visit in UMP area, six manholes were inspected including one in Residential College, KK2. The reason KK2 manhole was not chosen is because the sewer floods frequently. The manhole located in between library and sports complex was selected and is shown in Figure 3.1.

3.3 STUDY OF THE SITE

One manhole (MH 7) had been selected in UMP area between the library and sports complex with PE of 1473. This site was used to analyze flow characteristics in sewerage system of the area studied. Once the preliminary work had been done, calibration of flowmeter, installation of software and load test can start. The purpose of the load test is to make sure the hanger can support the flowmeter, so that the flowmeter will not fall down. 4.5 kg of water simulated the weight of the ISCO 2150 Flowmeter for one week. The flowmeter including the batteries and sensor is 4.3 kg as weighted in the lab, shown in Figure 3.2. At the end, the load test achieved its objective and managed to sustain 4.5 kg of water. So there is no problem to hang the ISCO 2150 Flowmeter inside the manhole.

Figure 3.2: Weighting flowmeter (including batteries and sensor)

3.3.1 Selection Criteria of the Sewer Line

There are some considerations that need to be taken into account when selecting the sewer line:

1. There is no lateral connection in the sewer line.
2. There is no backflow and turbulence happening in the sewer line.
3. The sewer flow inside the sewer line is steady and has little head loss.
4. The manhole must be near to the STP.

3.3.2 Materials and Equipment Used

In this study, flow metering system was adopted. Flow metering system consists of 2 components which is the primary device and secondary device (MINISTÈRE DU DÉVELOPPEMENT DURABLE, 2007). Primary device is known as open channel to measure the flow rate. Meanwhile secondary device is using flowmeter as an indicator to measure the flow rate. During the present study, some materials and equipment will be used. The main equipment used was the ISCO 2150 Flowmeter which is shown in Figure 3.3.

This flowmeter was hung in the manhole and will store the flow rate data from the sewer pipeline. It works by using 2 batteries with 6 volt each. It is a new model compared to the ISCO 4100 Flowmeter. This flowmeter is adopted because it is user friendly and easy to control. On the other hand, its sensor is more sensitive compared to the ISCO 4100 Flowmeter, so the result will more precise and accurate (ISCO, 2012).

Figure 3.3: ISCO 2150 Flowmeter

Before measuring the flow rate using flowmeter, batteries of the flowmeter need to be checked. To double check the batteries whether they are fully charged or not, a digital multimeter will be used as shown in Figure 3.4. It works on the principle of electrical current detection. To be sure the batteries are fully charged, the voltage is 6.45 V.

Figure 3.4: Digital multimeter

To record the flow rate, the flowmeter has its own sensor as shown in Figure 3.5, which will be placed in the sewer pipeline to record the flow rate data. This sensor is very sensitive. If the flow rate in the sewer is too slow, it will not be able to read the data because it is beyond its limit.

Figure 3.5: Sensor of ISCO 2150 Flowmeter

To install the flowmeter, a mounting ring is needed. The equipment is shown in Figure 3.6. The reason for using mounting ring is because the manhole depth is deep, so the mounting ring is needed to place the sensor and fix it in the pipeline as well as to hang the flowmeter inside the manhole.

Figure 3.6: Mounting ring

Once the data is stored in the flowmeter, the Flowlink 5.1 software as shown in Figure 3.7 is needed to extract the data. This software is needed to convert existing site data and to transfer the data to Microsoft Excel format to analyze the characteristics of the flow rate. It can also analyze and compare the dry and wet season including rainfall data (ISCO, 2013). Before extracting the data stored inside the flowmeter, a Flowmeter Cable Adaptor is needed. It is used to connect flowmeter to computer and extract data to computer as shown in Figure 3.8.

Figure 3.7: Flowlink 5.1 software

Sources: Flowlink 5.1 User Manual

Figure 3.8: Flowmeter cable adaptor is connected to the computer

3.3.3 Calibration of Equipment

After deciding the location of the manhole, the condition of ISCO 2150 Flowmeter will be checked and calibrated at Hydrology and Hydraulic Laboratory, UMP. The purpose of checking the flowmeter is to make sure it is ready to use and its batteries are working. Moreover, calibration of the equipment is to make sure the data collected is accurate and precise.

3.3.3.1 Flowmeter

Once the batteries have been fully charged and ready to be used, the flowmeter can be installed. The sensor is set up in the open channel, and then connected to the flowmeter. The flowmeter will be calibrated with the depth of water, and flow rate in the open channel. Table 3.1 shows the result of flow rate during the calibration in lab.

Table 3.1: Comparison of calibration result between ISCO 2150 Flowmeter and open channel

	mm		Percentage of error, %	l/s		Percentage of error, %
DATA	$\boldsymbol{H_{2150}}$	$\boldsymbol{H_{oc}}$		$\boldsymbol{Q_{2150}}$	$\boldsymbol{Q_{OC}}$	
Q_1	42.967	43	0.08	5.009	5.2	3.81
Q_2	61.916	64	3.37	9.283	10.11	8.91
Q_3	80.3	80	0.37	14.451	14.83	2.62
Q_4	92.335	95	2.89	18.267	18.711	2.43
Q_5	107.41	108	0.55	22.212	23.58	6.16

Where $\boldsymbol{H_{2150}}$ = Water depth value recorded at the ISCO 2150 Flowmeter

$\boldsymbol{H_{oc}}$ = Water depth value recorded at the open channel in lab

$\boldsymbol{Q_{2150}}$ = Flow rate value recorded at ISCO 2150 Flowmeter

$\boldsymbol{Q_{OC}}$ = Flow rate value recorded at the open channel in lab

$\boldsymbol{Q_{1,2,3,4,5}}$ = 5 sets of flow rate data recorded

From Table 3.1, there are some differences between the data of the open channel and the flowmeter. Thus, the following observations were made:

I. There is waiting time of around 1 to 2 minutes from switching the open channel on to recording the results from the flowmeter. It is because the flowmeter is slow to capture the change in flow rate when the velocity of flow is changed.

II. Flowmeter is not suitable table placed in the place with high water flow rate.

III. Average percentage error of depth between ISCO 2150 Flowmeter and open channel is 1.45%.

IV. Average percentage error of flow rate between ISCO 2150 Flowmeter and open channel is 4.79%.

3.3.3.2 Batteries

Machine and equipment does not function if battery does not exist. Thus, the battery needs to be checked every day to confirm that the battery is functional and still usable. In this model of flowmeter, 2 batteries were needed to operate. In the lab, there are 2 extra batteries as spare. Those batteries are rechargeable and 0.4 kg each. First, those batteries need to be checked and tested at the site before calibration of the flowmeter. Digital multimeter will be used to check the batteries. Furthermore, to charge 90% of the batteries, the time needed is 22 hours with 6.45 volt as stated in Table 3.2. To determine how long each battery can stand, a battery calibration report as in Table 3.3 was done on-site.

Table 3.2: Battery content with charge voltage and time

No. Load Voltage	% of Full Charge	Maximum Charge Time (hours)
5.75	10	22
6.00	20	20
6.06	30	17
6.13	40	15
6.19	50	12
6.26	60	10
6.32	70	7
6.39	80	5
6.45	90	2

Sources: (ISCO, 2012)

Table 3.3: Calibration of Battery A and Battery B Report

Date		Time	Battery (Volt)			
			A	% of battery	B	% of battery
17 Nov 2014	Mon	4pm	6.410	83.3	6.410	83.3
19 Nov 2014	Wed	4pm	6.226	55.1	6.226	55.1
21 Nov 2014	Fri	10am	6.182	48.7	6.182	48.7
24 Nov 2014	Mon	4pm	5.931	17.2	5.931	17.2

Table 3.3 shows the Battery A and Battery B that was calibrated on the site. The result shows that Battery A and Battery B can only stand for one week because the voltage of Battery A and Battery B on Monday 24 November 2014 have 17.2 % remaining. Due to the batteries having 17.2 % left, Battery A and Battery B have to be switched to Battery C and Battery D on Monday 24 November 2014. Meanwhile, Battery C and Battery D will be tested on site using the same procedure as Battery A and Battery B. The calibration report of Battery C and Battery D is shown in Table 3.4. Through the testing at site, those batteries can stand only for around one week. After one week, the two batteries have to be change to prevent the flowmeter from being powerless and not functioning

Table 3.4: Calibration of Battery C and Battery D Report

Date		Time	Battery (Volt)			
			C	% of battery	D	% of battery
24 Nov 2014	Mon	4pm	6.5	90	6.5	90
26 Nov 2014	Wed	4pm	6.289	64.8	6.289	64.8
28 Nov 2014	Fri	10am	6.201	51.6	6.201	51.6
1 Dec 2014	Mon	4pm	6.058	29.7	6.058	29.7

3.4 POPULATION EQUIVALENT (PE)

PE is used to determine the population usage of the sewerage facilities. In this present study, PE is calculated based on the facilities area decided by location of the manhole. Based on the plan obtained from UMP Holding Bhd. shown in Appendix A, the sewer flow is coming from FKASA classrooms and laboratories shown in Figure 3.9. The PE is calculated to be 1473 PE based on the MS1228:1991 and IWK which is shown in Table 3.5. Moreover, Table 3.6 shows how the PE was calculated for MH 07.

Table 3.5: Population Equivalent (PE)

Type of Establishment	Population Equivalent
Residential	5 per house
Commercial :	
Includes offices, shopping complex, entertainment/ recreational centres, restaurants, cafeteria and theatres	3 per 100 m^2 gross area
School / Educational Institutions :	
- Day schools / Institutions	0.2 per student
- Fully residential	1 per student
- Partial residential	0.2 per non-residential student
	1 per residential student
Hospitals	4 per bed
Hotel with dining and laundry facilities	4 per room
Factories, excluding process water	0.3 per staff
Market (Wet Type)	3 per stall
Market (Dry Type)	1 per stall
Petrol kiosks / Service stations	15 per toilet
Bus Terminal	4 per bus bay
Mosque / Church / Temple	0.2 per person
Stadium	0.2 per person
Swimming Pool or Sports Complex	0.5 per person
Public Toilet	15 per toilet
Airport	0.2 per passenger/day 0.3 per employee
Laundry	10 per machine
Prison	1 per person
Golf Course	20 per hole

Sources: (MS, 1991), (IWK, 2014)

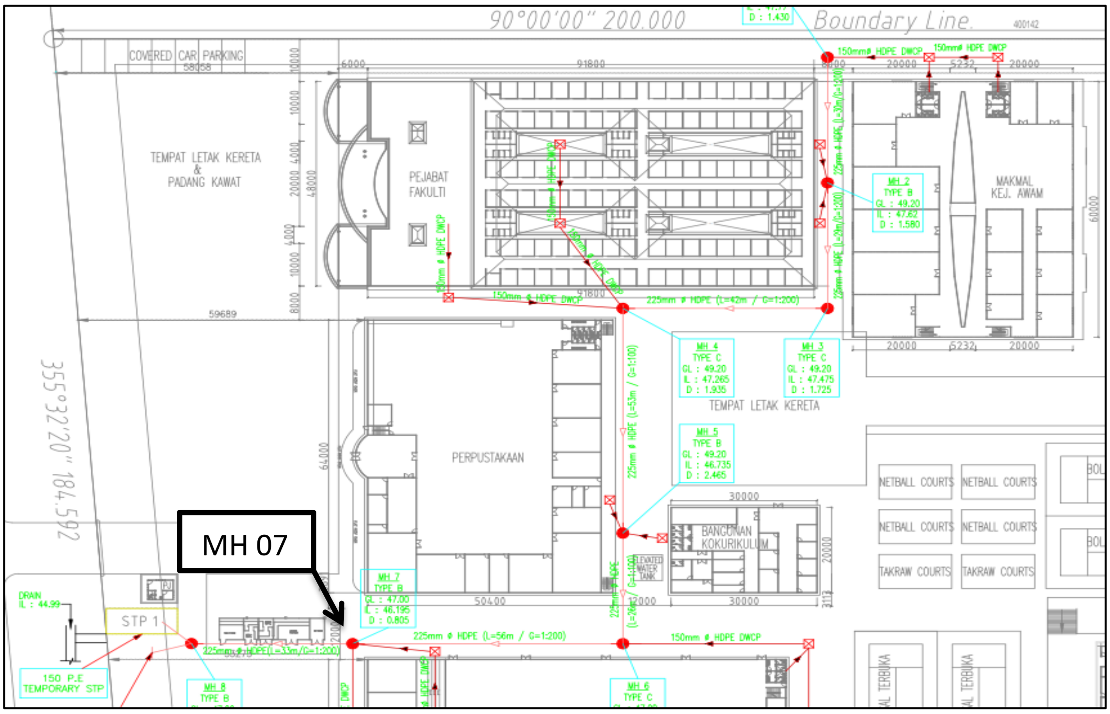

Figure 3.9: Flow direction of wastewater in the sewerage system

Source: UMP Holding Bhd.

Table 3.6: Population Equivalent (PE) calculated

AREA	UNIT/AREA	REQUIREMENT	PE
	COMMERCIAL		
Curriculum Centre	600 m^2	3/100 m^2	18
Faculty Office	4406.4 m^2	3/100 m^2	133
	FACILITIES		
FKASA Laboratory	2713.92 m^2	3/100 m^2	82
Library	1200 students	0.2/student	240
Sports Centre	2000 persons	0.5/person	1000
	TOTAL POPULATION EQUIVALENT		**1473**

Direction of the wastewater flow starts from FKASA laboratory, which than leads to the Faculty Office where MH 02 is located. After collecting wastewater from those places, the wastewater will flow to the Library represented by MH 05. Other than that, wastewater from the Curriculum Centre will also flow to MH 05. After the wastewater flows through MH 05, it will flow to MH 06. MH 06 is a T-junction pipeline collecting wastewater from Library and Sports Centre. Once wastewater is collected in MH 06, it will flow to the desired manhole which is MH 07 in a straight with no lateral pipeline. This is the reason to determine PE for the related places which that contributed the wastewater.

The reason Curriculum Centre used requirement of 3 dwelling per 100 m^2 is due to the Curriculum Centre being categorized as commercial. That is the reason why Curriculum Centre used 3 dwelling per 100 m^2 as shown in Table 3.6. Once the requirement was set, PE can be calculated. For example area of Curriculum Center is 600m^2. The requirement used is 3 dwelling per 100 m^2 gross area. So the PE of the Curriculum Centre is 18. Same goes to Faculty Office, PE is 133 when calculated according to Table 3.6.

FKASA Laboratory, Library, Sports Centre are facilities of UMP. From Table 3.5, there are no requirement for laboratory and Library. The reason FKASA Laboratory use the requirement of 3 dwelling per 100 m^2 is due to the fact that inside the laboratory there are office room for staff and classrooms for student. Library can occupy a maximum of 1200 students based on information from the official website of UMP (UMP, 2014). So the PE of the Library can be calculated as 240. The same procedure was applied to the Sports Centre, where PE was calculated as 1000.

3.5 FLOW CHARACTERISTICS MEASUREMENT

Flow characteristics measurement will be done using flowmeter with sensor. Flowmeter will record the data automatically which consists of the depth of water flow, velocity of water flow and flow rate of water at interval of 5 minutes. Once the data is recorded, the data can be downloaded from the flowmeter to computer by using Flowlink 5.1. This software is able to extract and convert those data to formats compatible with other software such as Excel file.

After analysis of the data, maximum hourly flow($Q_{\max hourly}$), minimum hourly flow ($Q_{\min hourly}$) and average hourly flow ($Q_{\text{avg} hourly}$) will be extracted. Per capita flow and peak flow factor are the parameters that are needed to analyze flow characteristics in the sewer system.

$$Q_{pcf} = \frac{Q_{ave}}{PE} \tag{3.1}$$

Where, Q_{pcf} = Per capita flow, m^3/day/person

Q_{ave} = Average daily flow obtained from data, m^3/day

PE = Population Equivalent

$$Q_{peak} = PFF\ x\ Q_{ave} \tag{3.2}$$

Where, Q_{peak} = Peak flow, m^3/day

PFF = Peak Flow Factor

$$PFF = K\ (\frac{PE}{1000})^{-0.11} \tag{3.3}$$

Where, K = Design criterion in sewerage system

To determine the value of design criterion, Equations 3.1, 3.2, and 3.3 is combined and rearranged to get Equation 3.4.

$$K = \frac{Q_{peak}}{(Q_{pcf}\ x\ PE)\ (\frac{PE}{1000})^{-0.11}} \tag{3.4}$$

According to MS 1228: 1991 Clause 3.6 and Clause 3.2, the value of design criterion, K will be taken as 4.7, while per capita flow, Q_{pcf} will be taken as 0.225 m^3/day/person. To obtain the objectives mentioned in Chapter 1, K and Q_{pcf} are needed for verification in this research.

If the values of Q_{pcf} and K are higher than the values mentioned in MS 1228:1991, it means that the sewer pipes are being overburdened. On the other hand, if the values of Q_{pcf} and K are lower than the values mentioned in the MS 1228:1991, it means that the sewer pipes are overdesigned.

3.6 FIELD MODEL

The manhole (MH 07) selected during site visit is at the place between library and sports complex within UMP area as shown in Figure 3.10. This manhole is near to the STP which located at beside the guard house. Diameter of the manhole is 62 cm which was measured during a site visit on 10th October 2014 and the type of manhole is Type B. Type B means the manhole is considered as a shallow manhole. Other information of the sewer pipe in the MH 07 is stated in Table 3.7.

Table 3.7: Characteristics of sewer pipe in the manhole (MH 07)

Characteristics of Sewer Pipe	
Length of pipe	5.6m from MH06
Diameter of the pipe	0.225m
Type of pipe material	High Density Polyethylene (HDPE)
Ground Level	47.00m
Induce Level	46.03m
Depth of manhole	0.805m
Gradient of pipe	1 to 200

Sources: Sewer Reticulation Site Plan from UMP Holding Bhd.

Figure 3.10: Selected manhole (MH 07)

The flowmeter's sensor will be put on the right side of the sewer pipeline. It is because in this study the selected manhole should not have lateral connections. Unfortunately, MH 07 has a lateral connection which is shown in Figure 3.11, so the sensor should be put at the right hand side of the sewer pipeline which means the sensor is put at the sewer pipeline before the lateral connection, as shown in Figure 3.12.

Figure 3.11: Sewer pipeline located under the manhole

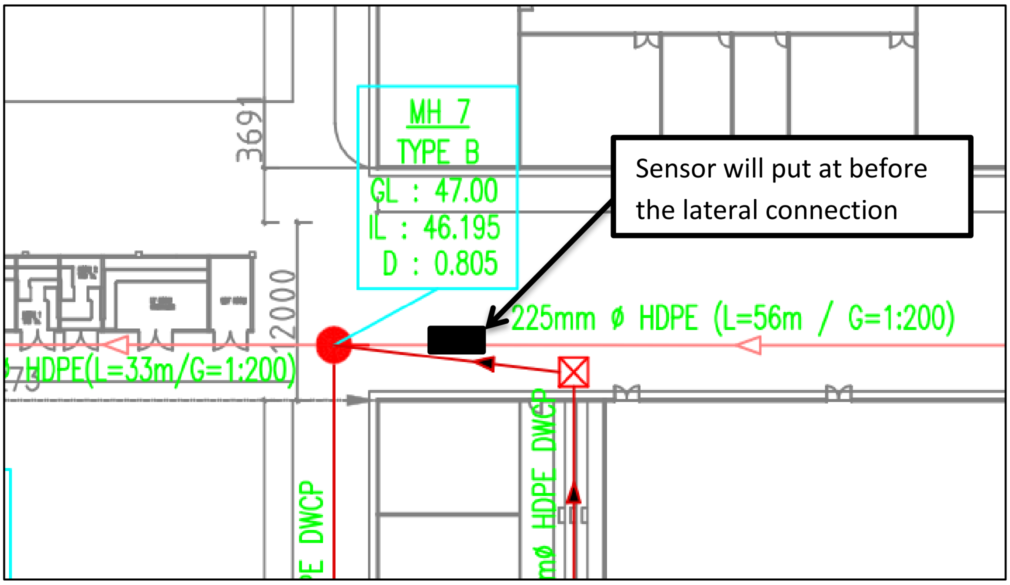

Figure 3.12: Location of sensor

Sources: Sewer Reticulation Site Plan from UMP Holding Bhd.

3.7 RAINFALL MEASUREMENT

Rainfall data will be collected during the research. There are two types of devices to measure rainfall which are the tipping bucket and the electronic weight. The equipment used in this present study is the tipping bucket by the model ISCO 674 Rain Gauge shown in Figure 3.13. Tipping bucket was chosen to record the rainfall data because it has a long history of success in sewer management. It is also durable and not affected by temperature change. The rain gauge is used to record the amount of rainfall in the area during wet season and dry season, which will affect the flow rate in the sewer line (Thomas, 2000). This rain gauge is made from steel, aluminum and plastic. All the steel had been coated to assure it will never rust. The cover of the screen is used to block objects except for fluids (ISCO, 2011). This rain gauge was set up at KK2 within UMP area with the purpose of collecting the rainfall data. Rainfall data will be collected by interval of 5 minutes, and then this data will be analyzed together with the flow rate data.

Figure 3.13: ISCO 674 Rain Gauge

3.8 PROJECT SCHEDULE

Project scheduling is very important to a research. It will help in planning and finishing work on time. The purpose of doing project scheduling is to prevent work delay in this research. It also helps to promote deeper understanding about what is needed to be done during the research. The flow chart of work, project planning to obtain data and Gantt chart of the research are shown in Figure 3.14, Table 3.8 and Table 3.9, respectively.

Table 3.8: Project planning

OCT'14

MON	TUE	WED	THU	FRI	SAT	SUN
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
MIDTERM BREAK					25	26
27	28	29	30	31		

NOV'14

MON	TUE	WED	THU	FRI	SAT	SUN
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

DEC'14

MON	TUE	WED	THU	FRI	SAT	SUN
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

JAN'15

MON	TUE	WED	THU	FRI	SAT	SUN
			1	2	3	4
5	EXAM	7	EXAM	9	10	11
12	EXAM	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

FEB'15

MON	TUE	WED	THU	FRI	SAT	SUN
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	NEW YEAR		21	22
23	24	25	26	27	28	

Where

	Get information from JPPH about the manhole
	Demo installation
	Installation the equipment/ download data [MON - 4pm]
	Check battery [WED - 10am]
	Check battery [FRI - 10am]

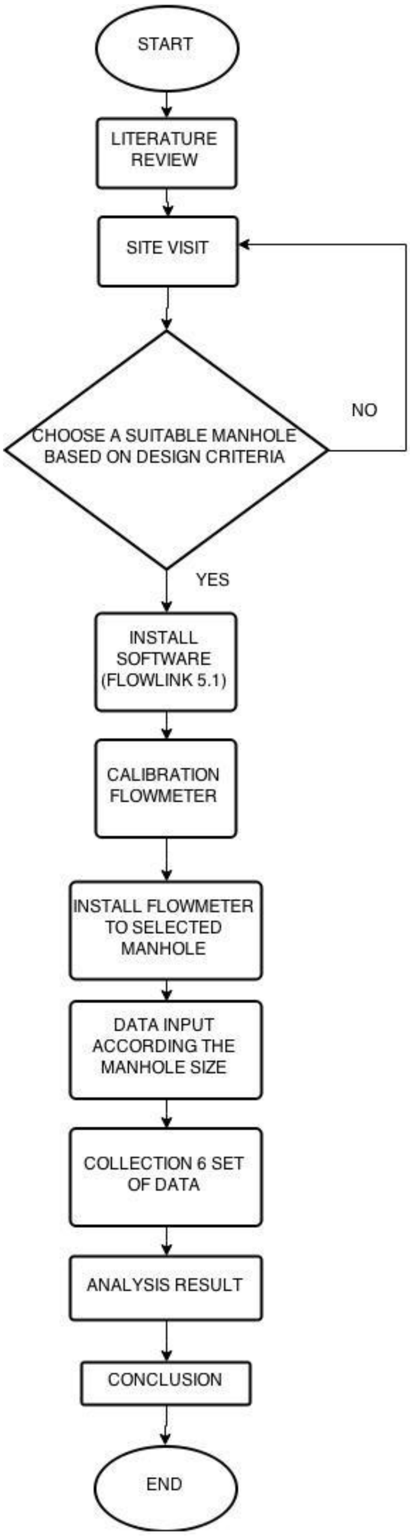

Figure 3.14: Project flow

Table 3.9: Gantt Chart

Task delegation	September 2014				October 2014			November 2014				December 2014				January 2015		Febrary 2015			March 2015				April 2015				May 2015			
Timeline	8/9 - 12/9	15/9 - 19/9	22/9 - 26/9	29/9 - 3/10	6/10 - 10/10	13/10 - 17/10	27/10 - 31/10	3/11 - 7/11	10/11 - 14/11	17/11 - 21/11	24/11 - 28/11	1/12 - 5/12	8/12 - 12/12	15/12 - 19/12	22/12 - 26/12	19/1 - 23/1	29/1 - 30/1	2/2 - 6/2	9/2 - 13/2	23/2 - 27/2	2/3 - 6/3	9/3 - 13/3	16/3 - 20/3	23/3 - 27/3	30/3 - 3/4	13/4 - 17/4	20/4 - 24/4	27/4 - 1/5	4/5 - 8/5	11/5 - 15/5	18/5 - 22/5	25/5 - 29/5
Week	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Brainstorming																																
Meeting with Supervisor (SV)																																
Choosing a research topic																																
Understand the topic																																
Read journal which related to the topic																																
Planning																																
Writing Report																																
Introduction Chapter 1																																
Meeting with JPPH																																
Literature Review Chapter 2																																
Get softcopy of drawing																																
Decide manhole location																																
Confirnation of equipment																																
Site Visit with JPPH staff and SV																																
Prepare work schedule for JPPH																																
Population Equivalent of research area																																
Confirmation with JPPH about the manhole is ready to use																																
Demo and calibrate equipment																																
Methodology Chapter 3																																
Data Collection or Result																																
Installation Flowmeter																																
Flowrate data collect 1																																
Rainfall Intensity data collection 1																																
Flowrate data Collect 2																																
Rainfall Intensity data collection 2																																
Flowrate data Collect 3																																
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Rainfall Intensity data collection 4																																
Prepare multimedia for oral presentation																																
Powerpoint presentation in class																																
Flowrate data Collect 5																																
Rainfall Intensity data collection 5																																
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Rainfall Intensity data collection 6																																
Flowrate data Collect 7																																
Rainfall Intensity data collection 7																																
Data Collection and result (Chapter 4)																																
Result Discussion and Analysis																																
Tabulate data and drawing graph																																
Analysing data and discussion																																
Result discussion and analysis (Chapter 5)																																
Conclusion and Recommendation																																
Draw conclusion and recommendation																																
Conclusion and Recommendation (Chapter 6)																																
Finishing and submitting report																																
checking grammar mistake																																
Print report																																
submit report																																
Prepare multimedia for oral presentation																																
Powerpoint presentation in class																																

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 INTRODUCTION

In this chapter, analysis of the data retrieved from MH 07 with a PE of 1473 and discussion of the results will be done. PE plays an imperative role in determining the parameters mentioned earlier. Thus, PE needed to be verified correctly. Other than that, Q_{peak} and Q_{ave} also need to be calculated correctly from the data by using those equations mentioned in Section 3.5. However, the parameters such as Q_{pcf} and K will be obtained. Thus, the objective was achieved in this research.

4.2 DATA COLLECTION IN THE STUDY

The flowmeter was installed in the selected manhole (MH 07) located in between the Library and Sport Complex in UMP Gambang. In the current study, 6 sets of data were collected continuously from 17 November 2014, 4pm to 9 February 2015, 4pm. Furthermore, every set of data was collected for 2 weeks with the interval of 5 minutes between each measurement reading. The continuous data was recorded in the form of level, velocity, and flow rate of wastewater. Same goes to rainfall data measured by the ISCO 674 Rain Gauge which was installed in the field of Residential College 2 within UMP Gambang compound. The total time recorded in this whole research is 2016 hours of flow rate data and rainfall data. The data were recorded on both weekdays and weekends. The detail of each set of data will be shown as hydrographs. Other than that, the maximum flow, minimum flow and the average flow for each set of data in the study will also be discussed. Table 4.1 shows the characteristic of each set of data such as time interval of data and duration of the data.

Table 4.1: Data collected from MH 07

Data Set	Time interval of data [minute]	Duration of 1 set of data [days]	Duration of data collection [hours]	Rainfall during the time
MH07-01	5	14	336	Yes
MH07-02	5	14	336	Yes
MH07-03	5	14	336	Yes
MH07-04	5	14	336	Yes
MH07-05	5	14	336	Yes
MH07-06	5	14	336	Yes

4.2.1 1st Set of Data Collection

This set of data was the early phase in this whole research. It was collected from the period of 17 November 2014, 4pm to 1 December 2014, 4pm. Flow rate and rainfall data were collected simultaneously within the period. In Figure 4.1, flow rate and rainfall data is shown in the form of hydrograph within the period.

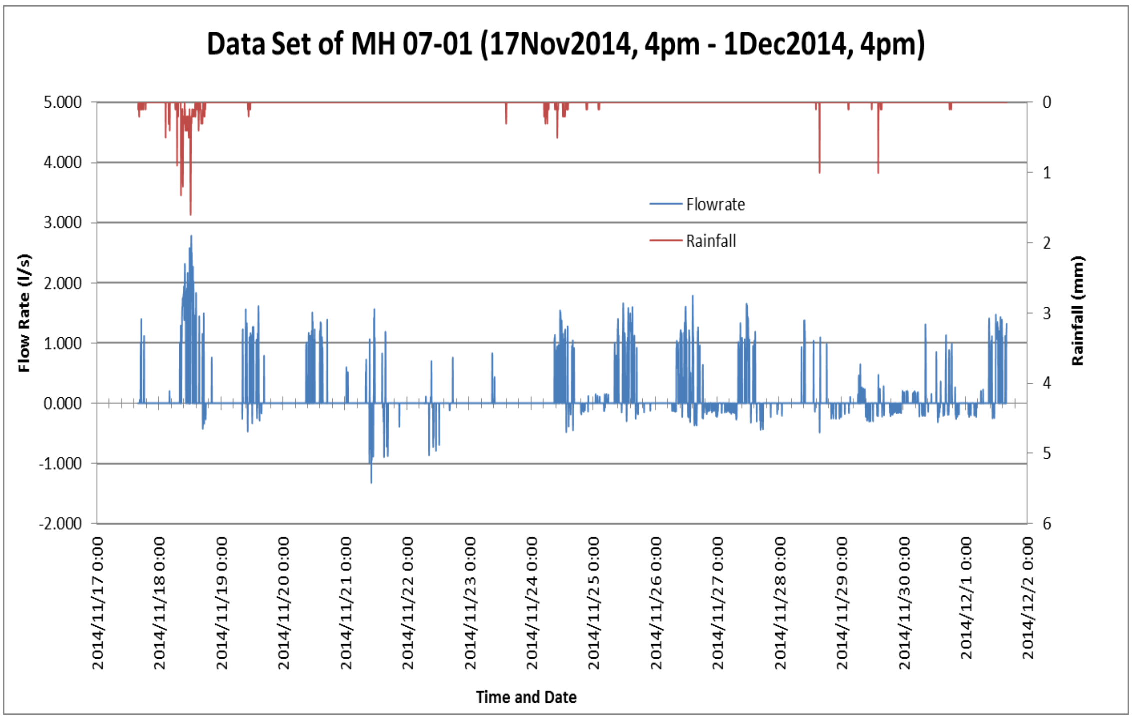

Figure 4.1: Flow pattern of first set data in MH 07

Within this period, it was shown that weekdays have the same trend with the average flow of 1.65 l/s when there is no rainfall distributed. Meanwhile, weekends have little flow compared to weekdays. The Q_{peak} and Q_{ave} can be calculated after data was collected including weekdays and weekends. Within this period, the result showed that Q_{peak} occurred on weekday 18 November 2014, 12.35pm with a result of 2.783 l/s which is equal to 240.45 m^3/day. It was likely due to high volume of rainfall during that time. The peak volume of rainfall during that period was 1.6mm. On the other hand, Q_{ave} was calculated when 2 weeks' worth of data with interval of 5 minutes was collected. The total flow of this set of data was calculated to be 370.93 l/s which is equivalent to 32048.4 m^3/day. Q_{ave} can be figured out after the total flow was determined. The value of Q_{ave} was calculated in this set of data to be 1.085 l/s which amounts to 93.71 m^3/day. Once flow rate data by interval of 5 minutes was determined Q_{peak}, Q_{ave}, and then Q_{pcf}, PFF, and K can be calculated using Equations (3.1) to (3.4).

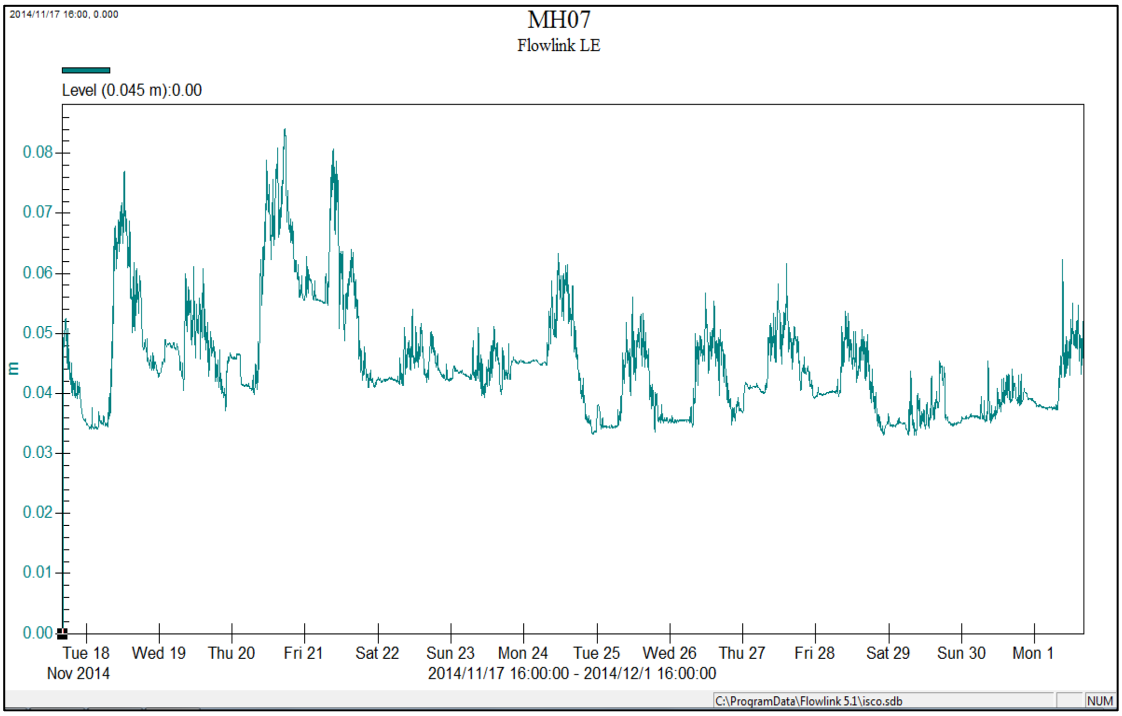

Figure 4.2: Wastewater level in MH 07 from period of 17 November 2014, 4pm to 1 December 2014, 4pm

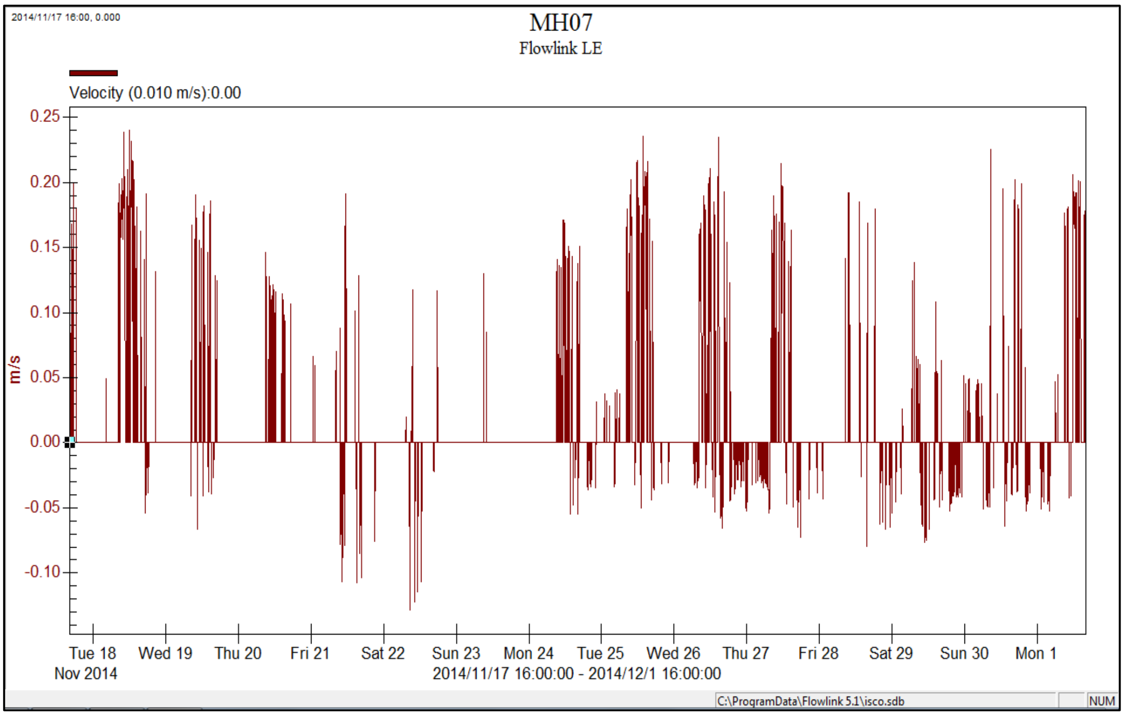

Figure 4.3: Velocity of wastewater flow in MH 07 from period of 17 November 2014, 4pm to 1 December 2014, 4pm

Figure 4.2 and Figure 4.3 shows the wastewater level and velocity in MH 07 from period of 17 November 2014, 4pm to 1 December 2014, 4pm. During the research, level and velocity of wastewater have to be extracted from the flowmeter. The purpose of extracting wastewater level data is to verify the flow pattern of the study. The flow pattern of velocity and flow rate are similar. The reason flow pattern of velocity and flow rate are similar is because of volumetric flow rate theory. Volumetric flow rate theory is defined as volume of fluid which passes per unit time. The formula of this theory is $Q = Av$ where Q is flow rate of the wastewater, A is cross section area of sewer pipeline, and v is velocity of the flow. Once the velocity of wastewater is detected from sensor, the flowmeter will automatically convert the velocity data to flow rate data by multiplying the cross section area of sewer pipeline.

4.2.2 2nd Set of Data Collection

The second set of data was collected within the period of 1 December 2014, 4pm to 15 December 2014, 4pm. The analysis method is the same as used for the first set of data. Flow rate and the rainfall data were collected together within the period. In Figure 4.4, flow rate and rainfall data are shown in the form of hydrograph within the period.

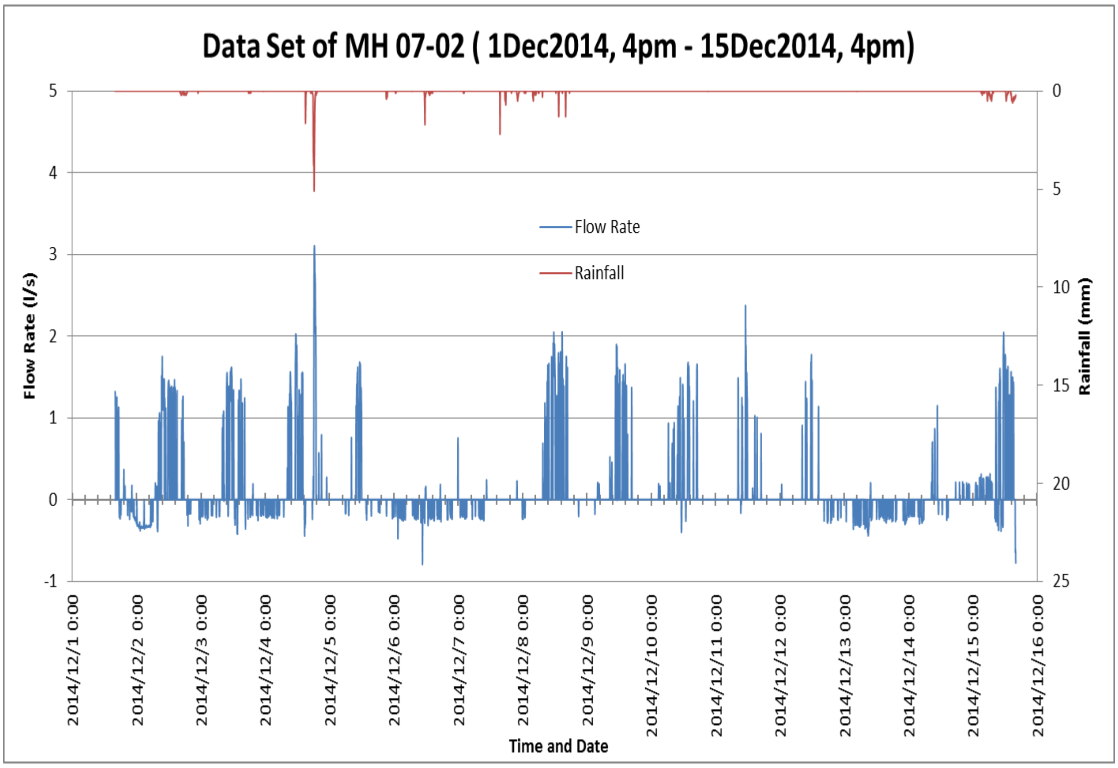

Figure 4.4: Flow pattern of second set data in MH 07

The hydrograph in Figure 4.4 shows the period of 1th to 15th December, 4pm. It shows that weekdays have the same pattern with average flow of 1.88 l/s when there is no precipitation. On the other hand, weekends have little flow compared to weekdays which falls on 6th to 8th December 2014 and 13th to 15th December 2014. The Q_{peak} and Q_{ave} can be calculated after data was collected including weekdays and weekends. Within this period, the result showed that Q_{peak} occurred on weekday 4 December 2014, 6.20pm and the value was 3.106 l/s which is equal to 268.36 m^3/day. It happened because there was rainwater distributed during that time. The volume of rainfall was lower compared to the first set of data. The peak volume of rainfall during that period was 5.1 mm. On the other hand, Q_{ave} was calculated based on total flow rate. The total flow of this data set was calculated as 434.42 l/s which comes to 37533.9 m^3/day. The value of Q_{ave} was calculated in this set of data to be 1.18 l/s which is equivalent to 101.72 m^3/day. After calculating Q_{ave} and Q_{peak}, the K, PFF, and Q_{pcf} can be obtained. Figure 4.5 shows the wastewater level in MH 07 for the second data set. The highest level in this set of data is 0.078m on 4 December 2014, 6.20pm due to rainfall. Meanwhile, Figure 4.6 shows the velocity of the wastewater in MH 07 from 1st to 15th December 2014, 4pm. The highest velocity of wastewater happened on 4 December 2014, 6.35pm at a value of 0.26 m/s. The average velocity of wastewater in this second set of data was 0.17 m/s. Generally by comparing first set and second set of data, it was found that the average velocity of 0.15 m/s in the first data set was unexpectedly lower than the average velocity from the second data set although more rainfall occurred during data collection in the second data set. Other than that, second data set showed a peak negative value on 6 December 2014, 10.40am with the value of 0.14 m/s. The reason for this negative value is because either the wastewater flow is too slow or too little beyond the sensor limit.

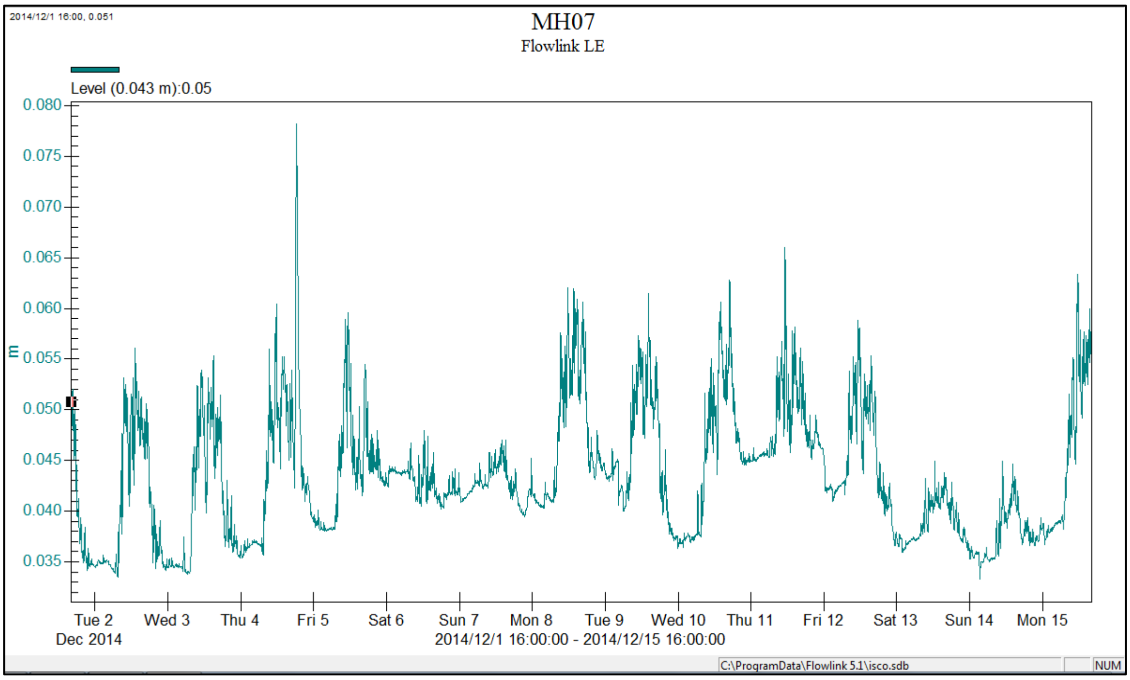

Figure 4.5: Wastewater level in MH 07 from 1December 2014, 4pm to 15 December 2014, 4pm

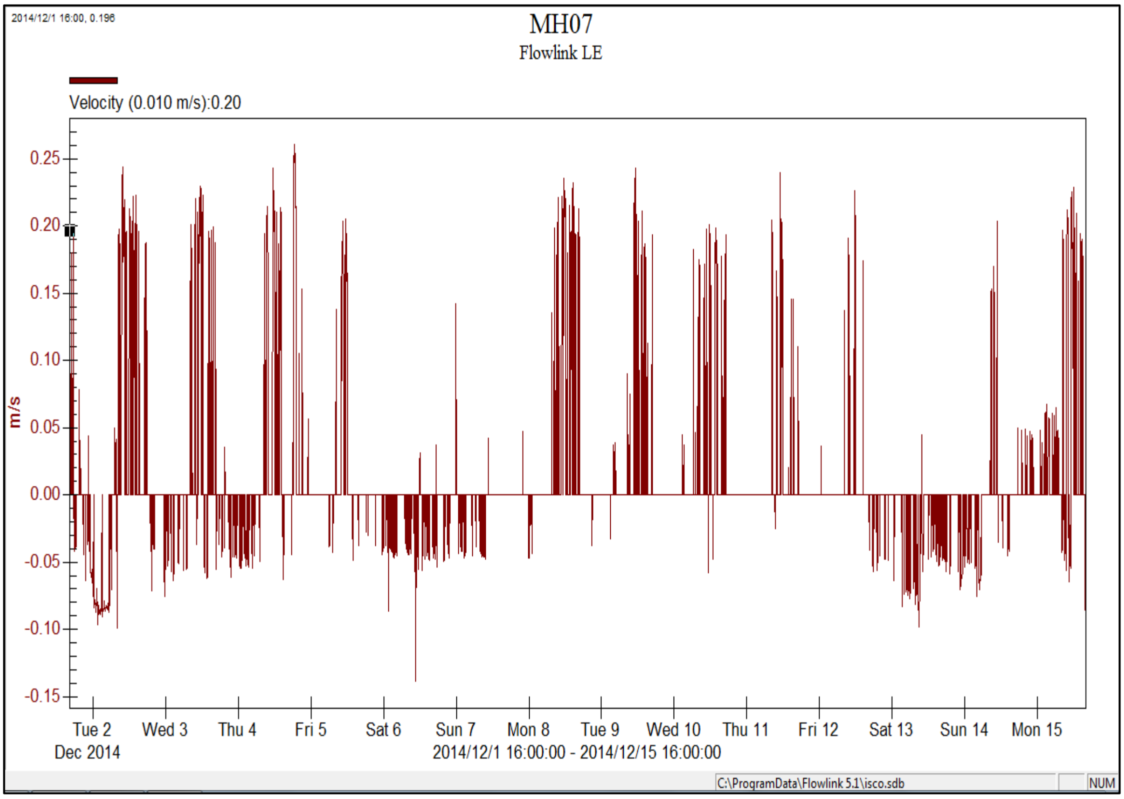

Figure 4.6: Velocity of wastewater in MH 07 from 1December 2014, 4pm to 15 December 2014, 4pm

4.2.3 3rd Set of Data Collection

This set of data was collected within the period of 15 December 2014, 4pm to 29 December 2014, 4pm. This data set was the middle set of data in this whole research. Flow rate and the rainfall data were collected simultaneously in this period. Figure 4.7 shows the flow rate and rainfall data in the form of hydrograph in this period.

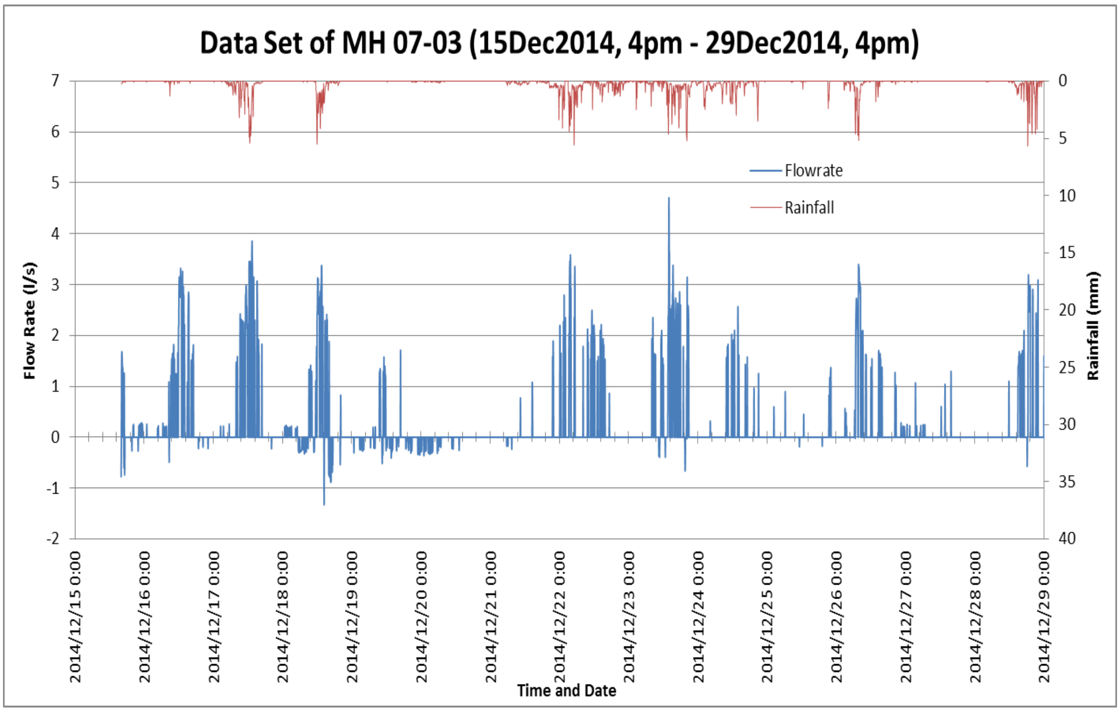

Figure 4.7: Flow pattern of third set data

This period can be considered rainy season. The precipitation was distributed continuously for a week in the middle of the period. Thus, the total volume of rainfall is the highest among the 6 sets of data. The total rainfall in this phase was 827.7mm. The peak volume of rainfall happened on 22 December 2014, 5.05pm with a value of 5.5 mm. At the same time, Q_{peak} occurred on Tuesday 23 December 2014, 2pm with the amount of 4.69 l/s which is similar to 405.48 m^3/day. It happened due to high volume of rainfall during that period. On the other hand, Q_{ave} was calculated in this data set to be 1.89 l/s which is equal to 163.41 m^3/day. Q_{ave} can be determined after the total flow rate was figured out. The total flow rate in this stage was measured and amounted to 826.49 l/s.

The occurrence of negative flow rate values were reduced due to the high level and high velocity of wasterwater occurring in this period. In between the period of 20th December 2014 and 22nd December 2014, Figure 4.7 shows zero flow and negative flow. This occurred because that period was a weekend which means there are no working days, so the wastewater flow was limited. Figure 4.8 shows the wastewater level of the third set of data in MH 07. The highest level in this set of data was obviously 1.19m on 17 December 2014, 2.40pm. Meanwhile, Figure 4.9 shows the velocity of the wastewater in MH 07 from 15th to 29th December 2014. The average velocity of the wastewater was 0.17 m/s, whereas the highest velocity of wastewater was 0.3 m/s located on 23 December 2014, 2pm.

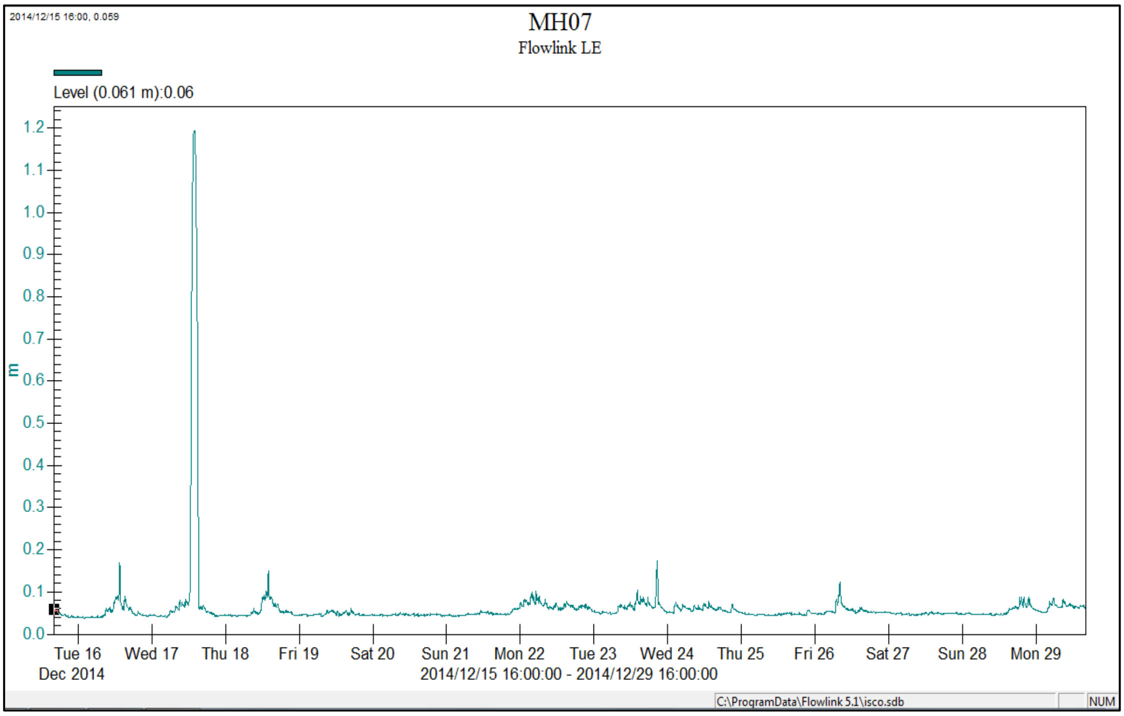

Figure 4.8: Wastewater level in MH 07 from 15 December 2014, 4pm to 29 December 2014, 4pm

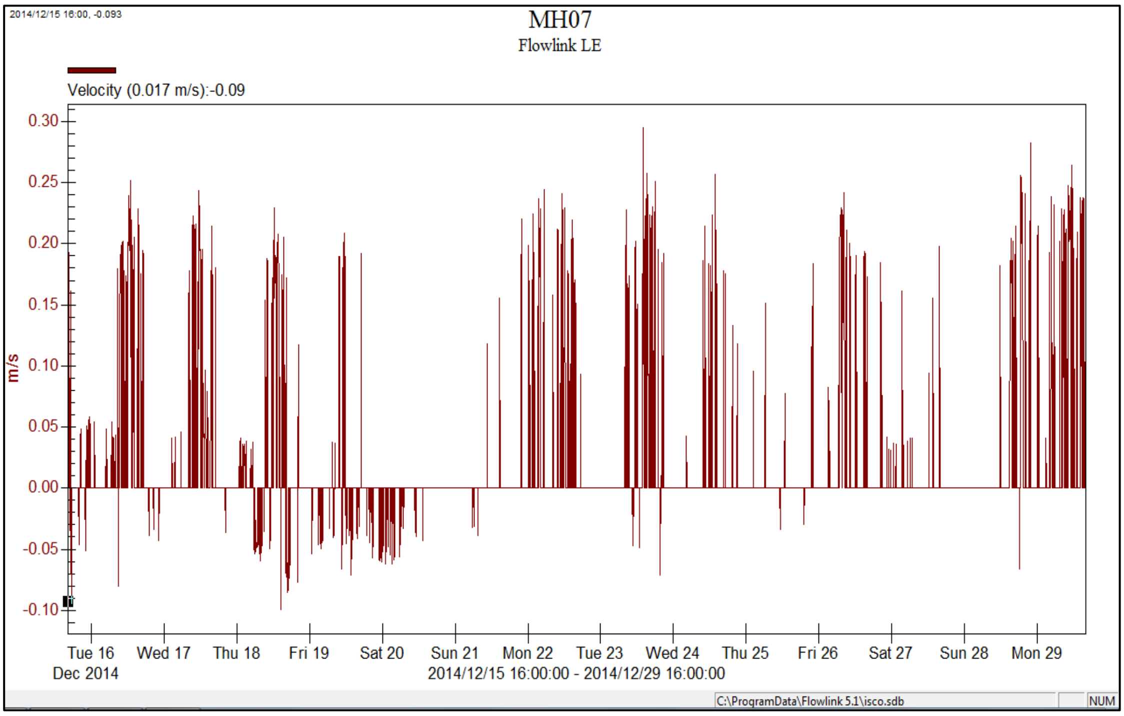

Figure 4.9: Velocity of wastewater in MH 07 from 15 December 2014, 4pm to 29 December 2014, 4pm

4.2.4 4th Set of Data Collection

The fourth set of data assembled the flow rate and the rainfall data between the periods of 29 December 2014, 4pm to 12 January 2015, 4pm. Figure 4.10 shows the flow rate and rainfall data in the form of hydrograph for readers to understand easily. The red colour represented rainfall data in unit millimeters, while blue colour represented flow rate data in unit liters per second.

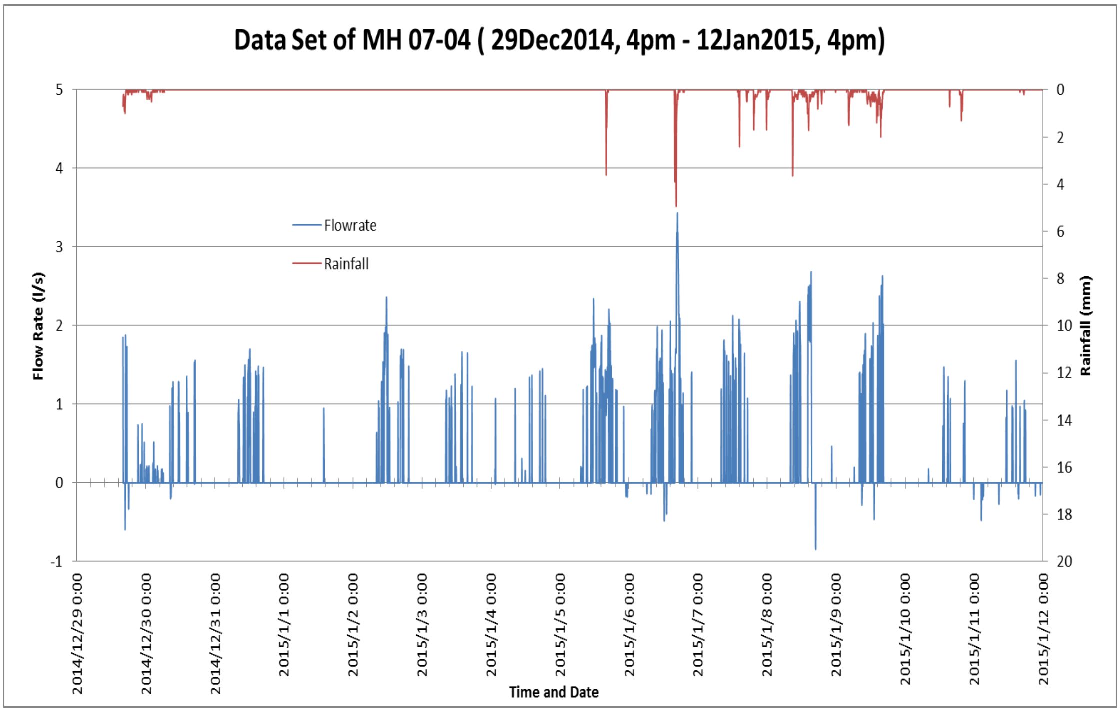

Figure 4.10: Flow pattern of fourth set data

In this phase, it was shown that the volume of rainfall started to decrease compared to previous sets of data. There was no rainfall dispersed in between the period of 30th December 2014 to 4th January 2015. However, on 6th January 2015, 4.25pm a light rainfall with value of 4.9 mm happened which is the peak rainfall in this phase. The total volume of rainfall was 784.88 mm which is one point zero five times lesser than previous data. At the same time, it directly affected the flow rate. The peak flow rate was also located at the same time with amount of 3.44 l/s equivalent to 296.87 m^3/day.

The total flow rate in this phase was 540.19 l/s. It was one and a half times smaller than previous sets of data. Q_{ave} can be determined after total flow rate was discovered. Q_{ave} was calculated with the value of 1.42 l/s which equals 122.50 m^3/day. It is one point three times lesser than previous data. Figure 4.11 shows the wastewater level in the middle phase of the complete set of data in MH 07. The highest wastewater level in this set of data was shown to be 0.11m on 2 January 2015, 11.25am. Figure 4.12 shows the velocity of the wastewater in MH 07. The highest velocity occurred at the same time when there was precipitation distributed with value of 0.27 m/s on 6^{th} January 2015, 5.00pm.

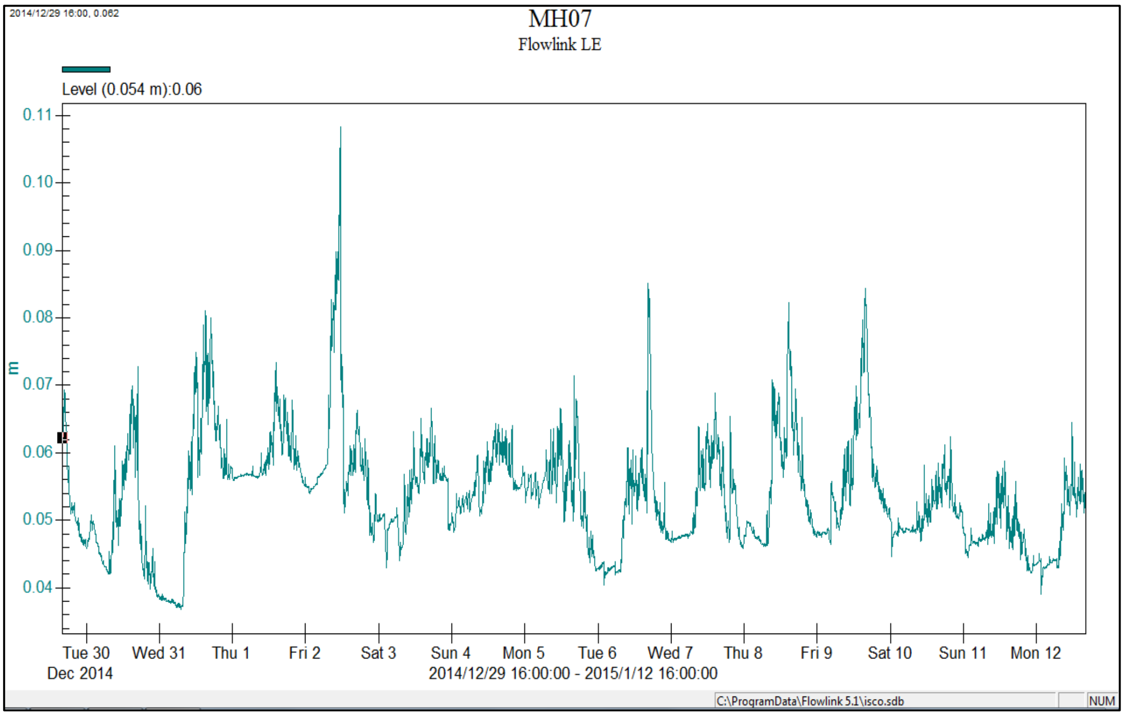

Figure 4.11: Wastewater level of in MH 07 from 29 December 2014, 4pm to 12 January 2014, 4pm

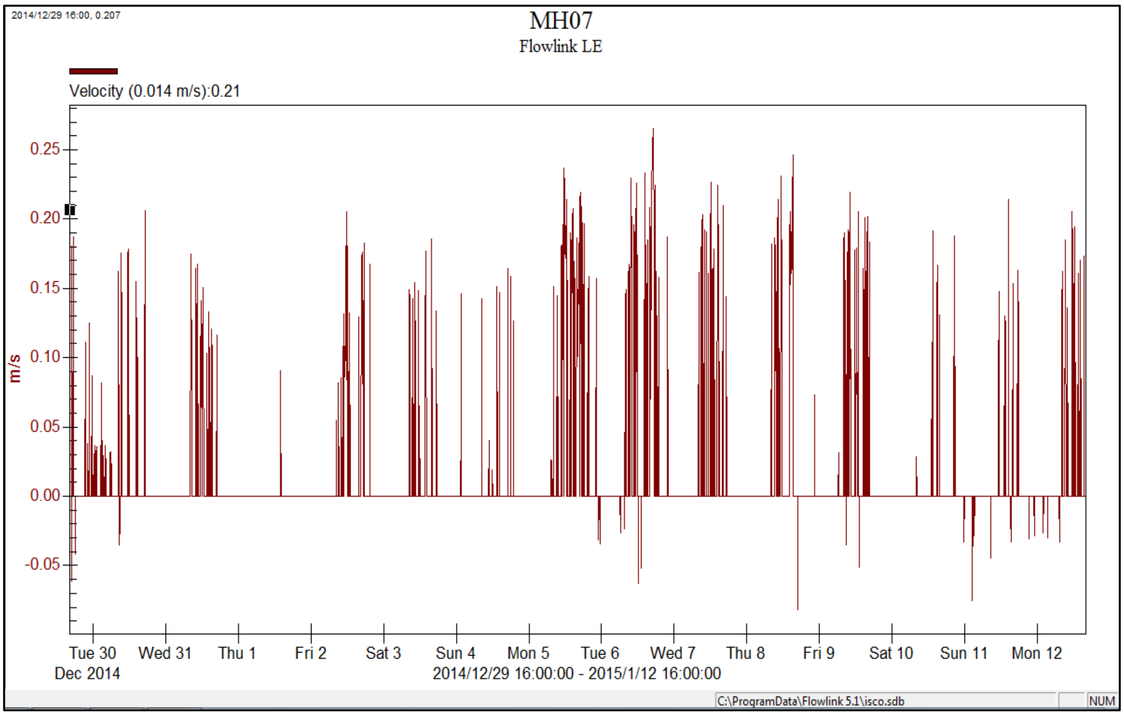

Figure 4.12: Velocity of wastewater in MH 07 from 29 December 2014, 4pm to 12 January 2014, 4pm

4.2.5 5th Set of Data Collection

The collection of this data set was continued from the 4th data set. The flow rate and rainfall data were extracted from the flowmeter and rain gauge between 12 January 2015, 4pm and 26 January 2015, 4pm. Figure 4.13 shows the flow rate and rainfall data in the form of hydrograph for the period mentioned.

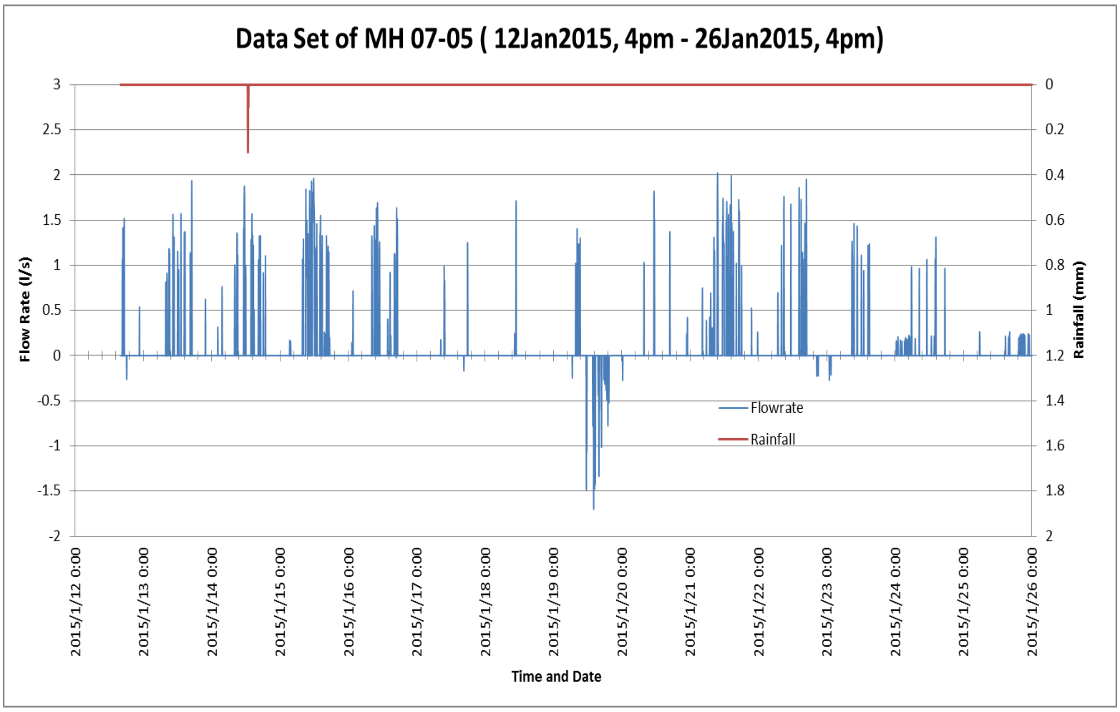

Figure 4.13: Flow pattern of fifth set data in MH 07

Based on the hyetograph shown in Figure 4.13, rainfall only happened once within fourteen days. It can be said that this constitutes hot season. The precipitation was distributed very little on Wednesday, 14 January 2015, 12.45pm with amount of 0.3 mm. Thus, it is the peak rainfall among this set of data. The total volume of rainfall distributed in this phase of data is only 0.3 mm.

The total flow rate in this phase was 309.14 l/s which is 1.25% less than the fourth set of data. The total flow rate in this phase was the lowest among all the data sets. There were almost no flow rates in between the period of 16 January 2015 to 20 January 2015. The reason for this is because of the two weeks of exam and semester break, where there were no lecture time and no students going to classrooms. Hence, the sensor failed to detect the velocity and flow rate of wastewater in the sewer pipeline because the flow rate was too slow or was below the limit of detection. This was also the reason for the peak negative flow rate on 19 January 2015, 2.10pm having a value of 1.7 l/s. During this phase, the flow rate was constant and had the same trend each day during the weekdays compared to the previous sets of data. This occurred due to the absence of rainfall. The Q_{peak} was 2.02 l/s on 21 January 2015, 9.40am which is not much different from the average flow rate on weekdays. The Q_{ave} was 1.0 l/s similar to 86.16 m^3/day. The difference between Q_{ave} and Q_{peak} was only 1 l/s.

Figure 4.14 shows the wastewater level in the fifth set of data in MH 07. The highest wastewater level in this phase was 0.07m on 19 January 2015, 2.30 am. In the meantime, Figure 4.15 shows the velocity of the wastewater in MH 07 from 12th to 26th January 2015. The velocity pattern was similar to the flow rate pattern due to the volumetric flow rate theory.

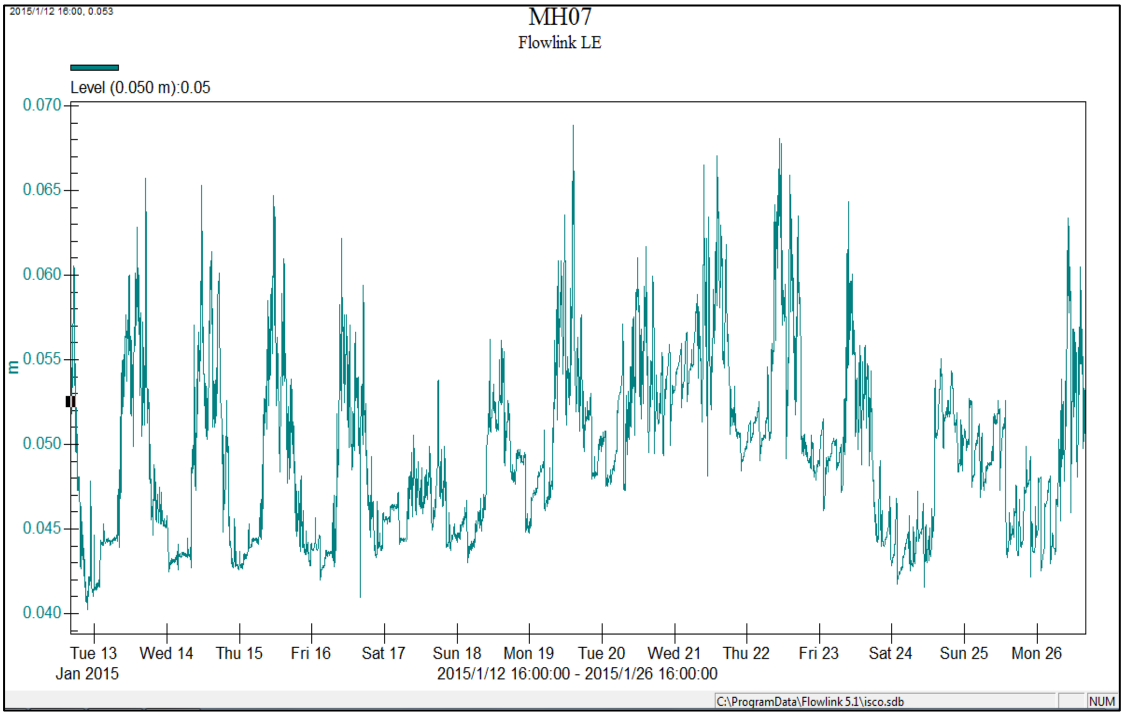

Figure 4.14: Wastewater level in MH 07 from 12 January 2015, 4pm to 26 January 2015, 4pm

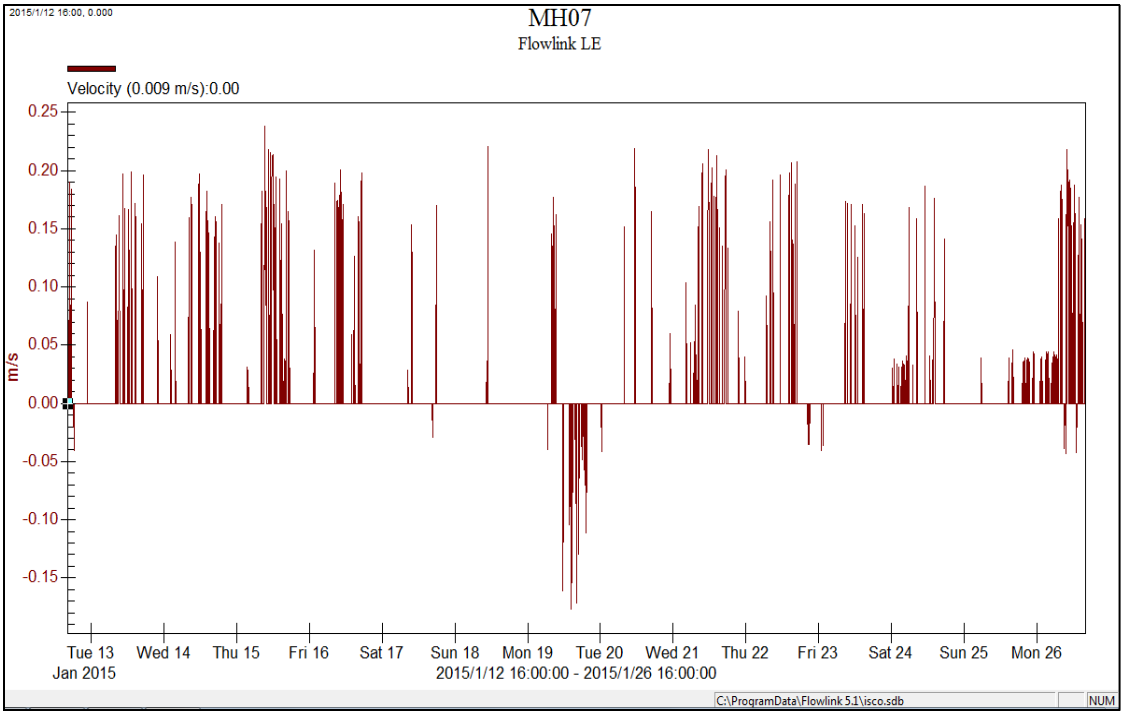

Figure 4.15: Velocity of wastewater in MH 07 from 12 January 2015, 4pm to 26 January 2015, 4pm

4.2.6 6th Set of Data Collection

This set of data was the last phase in this research. It covered a two-week block including weekdays and weekends from 26 January 2015, 4pm to 2 February 2015, 4pm. Figure 4.16 shows the last phase results of flow rate in the form of hydrograph and rainfall in the form of hyetograph.

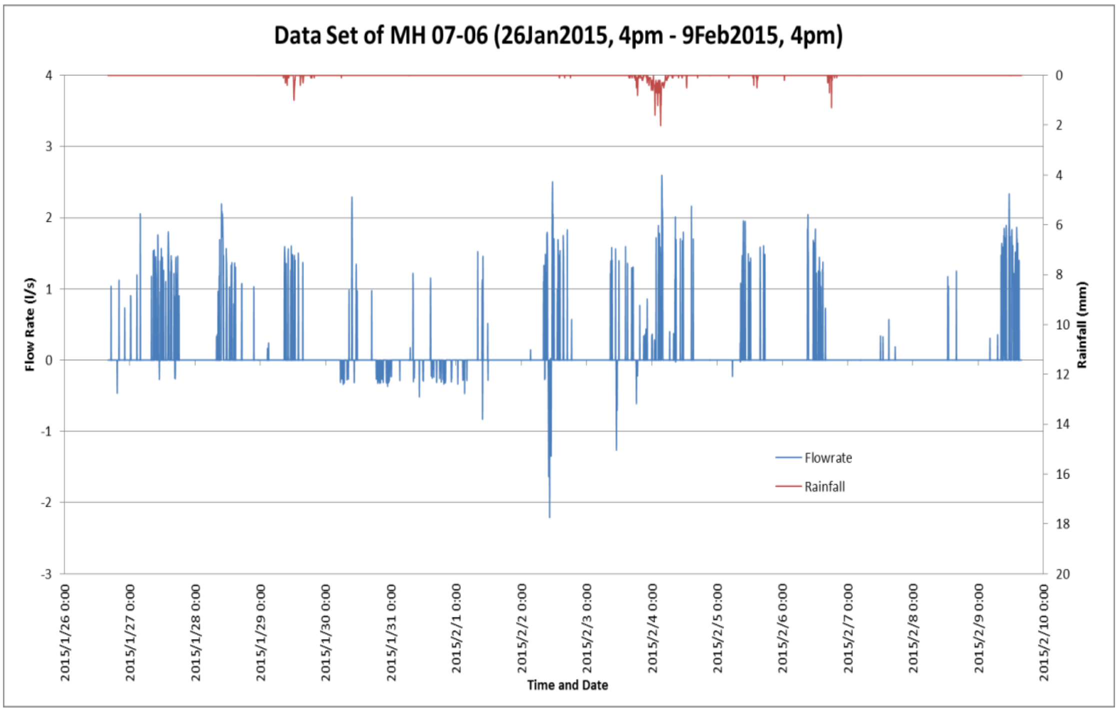

Figure 4.16: Flow pattern of sixth set data in MH 07

During this phase, the total rainfall volume increased from 0.3mm to 57.4mm. The peak rainfall occurred on midnight 4 February 2015, 3.15am with a value of 2 l/s. The precipitation was distributed continuously from 3 February 2015, 6.45pm with amount of 0.8mm to 4 February 2015, 12.45pm with value of 0.4mm.

The total flow rate was 368.57 m3/day the second lowest among the whole research. During the period of 7 February 2015, 3.55am to 9 February 2015, 11.50pm there was nearly no flow in the sewer pipeline. The reason is because it was a weekend and there are no working days. Other than that, this period was during the semester break, where there were no students going to classrooms. Q_{peak} and Q_{ave} was determined during this period. Q_{peak} happened at the same time as the peak rainfall on 4 Februray 2015, 3.15am with amount of 2.59 l/s which is equivalent to 223.78m^3/day. From this result, it was proven that rainfall is one of the factors that will affect the flow rate in this research. Thus, one of the objectives had been achieved. Besides that, Q_{ave} was calculated in this phase to be 1.19 l/s which is similar to 102.72 m^3/day.

One of the characteristics in this phase was the negative flow rate that was the highest among the full set of data. The peak negative flow rate took place on Monday, 2 February 2015, 10.25am with a quantity of 2.2 l/s. The negative flow rate occurred due to the same reason which was because the flow was too little and beyond the sensor limit. Figure 4.17 shows the wastewater level in the MH 07. The highest wastewater level was 0.232m on 29 January 2015, 3.30am. However, Figure 4.18 shows the velocity of the wastewater passing through in MH 07. The velocity of wastewater also showed negative speed due to either very low flow or there was rubbish trapped around the sensor.

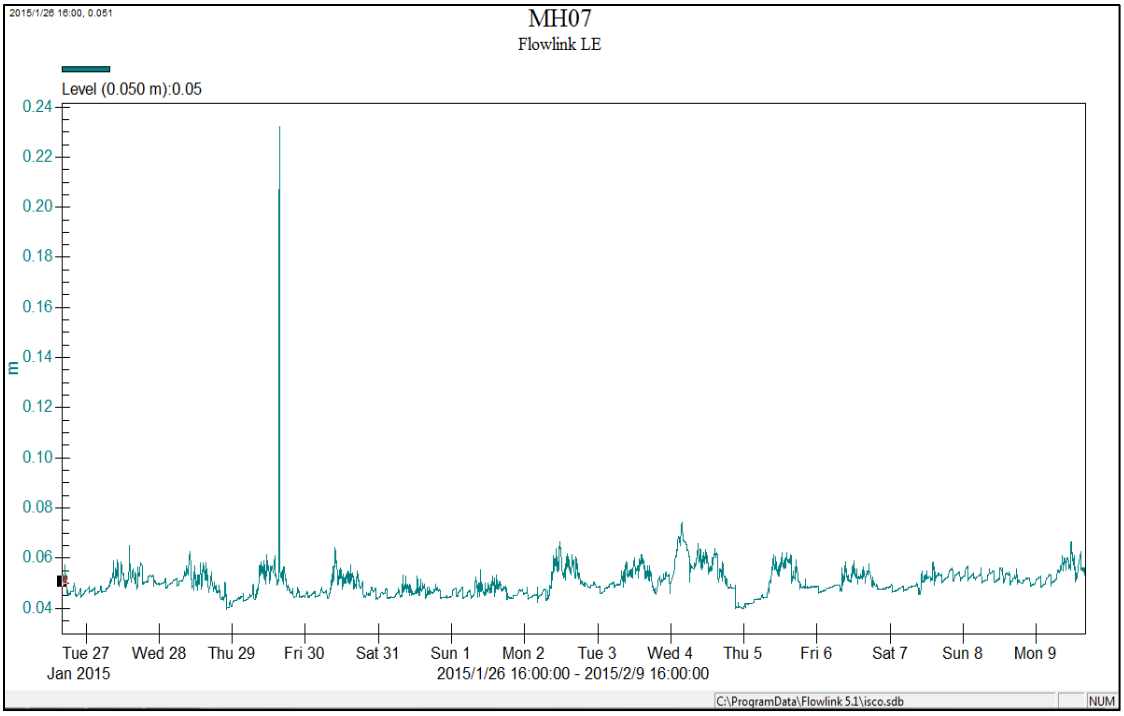

Figure 4.17: Wastewater level in MH 07 from period of 26 January 2015, 4pm to 2 February 2015, 4pm

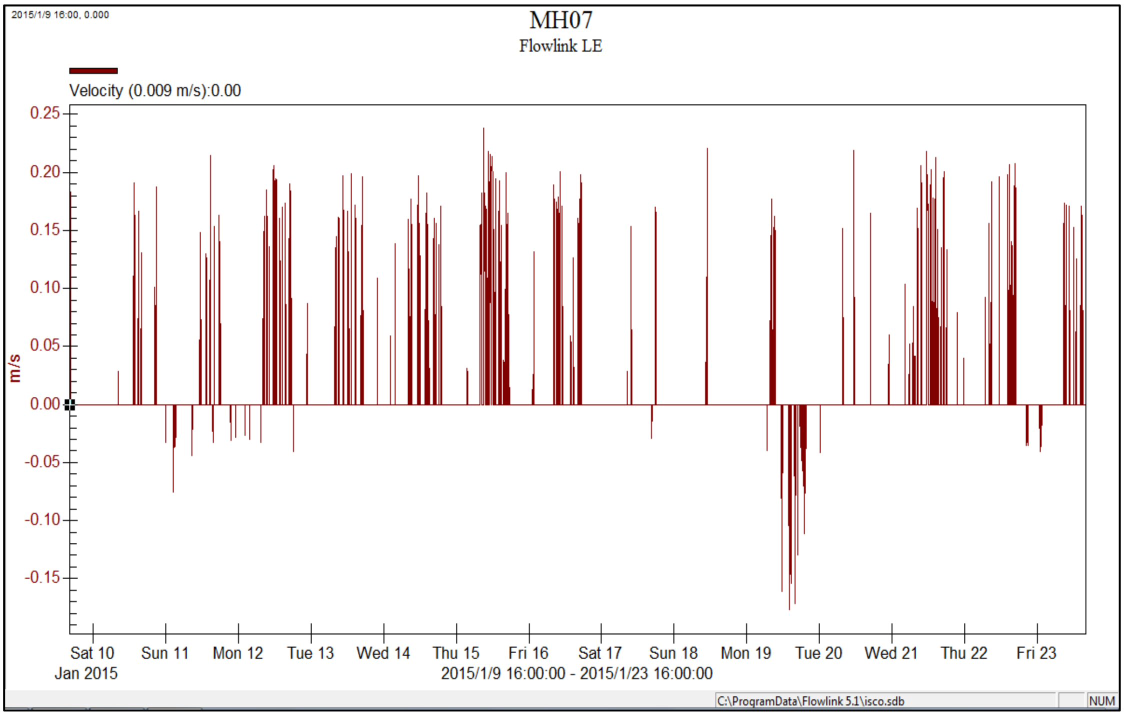

Figure 4.18: Velocity of wastewater in MH 07 from period of 26 January 2015, 4pm to 2 February 2015, 4pm

4.3 PER CAPITA FLOW CONTRIBUTION (Q_{pcf})

The average flow and peak flow using unit of m^3/day were calculated for all the data sets. The data will be analyzed in two-week blocks. The PE of the sewer line was calculated as 1473, so per capita flow can be calculated using Equation (3.1). From Equation (3.4), design criterion can be calculated after the per capita flow and peak flow were determined. Moreover, after design criterion was calculated from Equation (3.4), peak flow factor can be determined from Equation (3.3). Table 4.2 shows the detail of data collection for each set of data from MH 07.

Table 4.2: Flow characteristics for each data set from the study

Data Set	Peak Flow Q_{peak} [m^3/day]	Average Flow Q_{ave} [m^3/day]	Population Equivalent [PE]
MH07-01	240.45	93.71	1473
MH07-02	268.36	101.72	1473
MH07-03	405.48	163.41	1473
MH07-04	296.87	122.50	1473
MH07-05	174.70	86.16	1473
MH07-06	223.43	102.72	1473

From Table 4.2, these values were compared with MS 1228:1991. From the comparison of peak flow and average flow obtained in this research with MS 1228:1991, the MS 1228:1991 will result in higher values of 1492.73 m^3/day for peak flow and 331.43 m^3/day for average flow compared to the values obtained from the current study. Those values were calculated using existing per capita flow and design criteria from MS 1228:1991 which are 0.225m^3/day/person and 4.7. The calculation is shown below.

From MS 1228:1991, Q_{pcf} = 0.225m^3/day/person and K = 4.7
By using Equation (3.1),

$$Q_{pcf} = \frac{Q_{ave\ (MS)}}{PE}$$

$$0.225 = \frac{Q_{ave\ (MS)}}{1473}$$

$$Q_{ave\ (MS)} = 0.225\ x\ 1473$$

$$Q_{ave\ (MS)} = 331.425\ m^3/\text{day}$$

By using Equation (3.3),

$$PFF_{(MS)} = K\ (\frac{PE}{1000})^{-0.11}$$

$$PFF_{(MS)} = 4.7\ (\frac{1473}{1000})^{-0.11}$$

$$PFF_{(MS)} = 4.504$$

By using Equation (3.2),

$$Q_{peak\ (MS)} = PFF\ x\ Q_{ave\ (MS)}$$

$$Q_{peak\ (MS)} = 4.504\ x\ 331.425$$

$$Q_{peak\ (MS)} = 1492.73\ \text{m}^3/\text{day}$$

$Q_{peak\ (MS)}$is 1492.73 m^3/day and $Q_{ave\ (MS)}$ is 331.425 m^3/day. Both values of MS are higher than the values obtained from the current study.

A similar comparison was made for the per capita flow in Table 4.3. The actual per capita flow was found to be between 0.0585 m^3/day/person and 0.1109 m^3/day/person. Actual per capita flow values were compared to MS 1228:1991 and the result shows that the MS 1228:1991 has a higher value of 0.225 m^3/day/person compared to the values found in the current study.

Table 4.3: Per capita flow for the study

Data Set	**Average flow Q_{ave} [m^3/day]**	**Population Equivalent [PE]**	**Per Capita Flow Q_{pcf} [m^3/day/person]**
MH07-01	93.71	1473	0.0636
MH07-02	101.72	1473	0.0691
MH07-03	163.41	1473	0.1109
MH07-04	122.50	1473	0.0832
MH07-05	86.16	1473	0.0585
MH07-06	102.72	1473	0.0697

4.4 DESIGN CRITERION, K

A similar activity was performed to calculate the design criterion using Equation (3.4) and the results are shown in Table 4.4 where detailed calculation is shown below. The values for the actual design criterion vary between 2.12 and 2.75. The results were compared to that recommended in MS 1228:1991. The actual design criterions that were calculated were lower than the design criterion value of 4.7 given in MS 1228:1991.

Example of calculation K in data set of MH 07-01

Q_{peak} = 240.45 m^3/day from Table 4.2

Q_{pcf} = 0.0636 m^3/day/person from Table 4.3

PE = 1473

By using Equation (3.4),

$$K = \frac{Q_{peak}}{(Q_{pcf}\ x\ PE)\ (\frac{PE}{1000})^{-0.11}}$$

$$K = \frac{240.45}{(0.0636\ x\ 1473)\ (\frac{1473}{1000})^{-0.11}}$$

$$K = 2.68$$

Table 4.4: Design criterion for the study

Data Set	Peak Flow Q_{peak} [m^3/day]	Per Capita Flow Q_{pcf} [m^3/day/person]	Population Equivalent [PE]	Design Criterion [K]
MH07-01	240.45	0.0636	1473	2.68
MH07-02	268.36	0.0691	1473	2.75
MH07-03	405.48	0.1109	1473	2.59
MH07-04	296.87	0.0832	1473	2.53
MH07-05	174.70	0.0585	1473	2.12
MH07-06	223.43	0.0697	1473	2.27

$K_{(MS)}$ is 4.7. This MS value is higher than the values obtained from the current study.

4.5 PEAK FLOW FACTOR, PFF

Peak flow factor can be calculated using Equation (3.3) mentioned previously. Table 4.5 shows the result of each set of data from Equation (3.3). After the calculations, the values of actual peak flow factor vary between 2.03 and 2.64 in this study. The design peak flow factor calculated based on MS 1228:1991 is 4.5 where the calculation step was shown in Section 4.3, which is higher compared to the actual peak flow factors calculated in Table 4.5.

Example of calculation PFF in data set of MH 07-01 by using Equation (3.3)

K = 2.68 from Table 4.4

PE = 1473

$$PFF = K\left(\frac{PE}{1000}\right)^{-0.11}$$

$$PFF = 4.4\left(\frac{1473}{1000}\right)^{-0.11}$$

$$PFF = 2.57$$

Table 4.5: Peak flow factor for the study

Data Set	Population Equivalent [PE]	Design Criterion [K]	Peak Flow Factor [PFF]
MH07-01	1473	2.68	2.57
MH07-02	1473	2.75	2.64
MH07-03	1473	2.59	2.48
MH07-04	1473	2.53	2.42
MH07-05	1473	2.12	2.03
MH07-06	1473	2.27	2.18

4.6 FLOW PATTERN

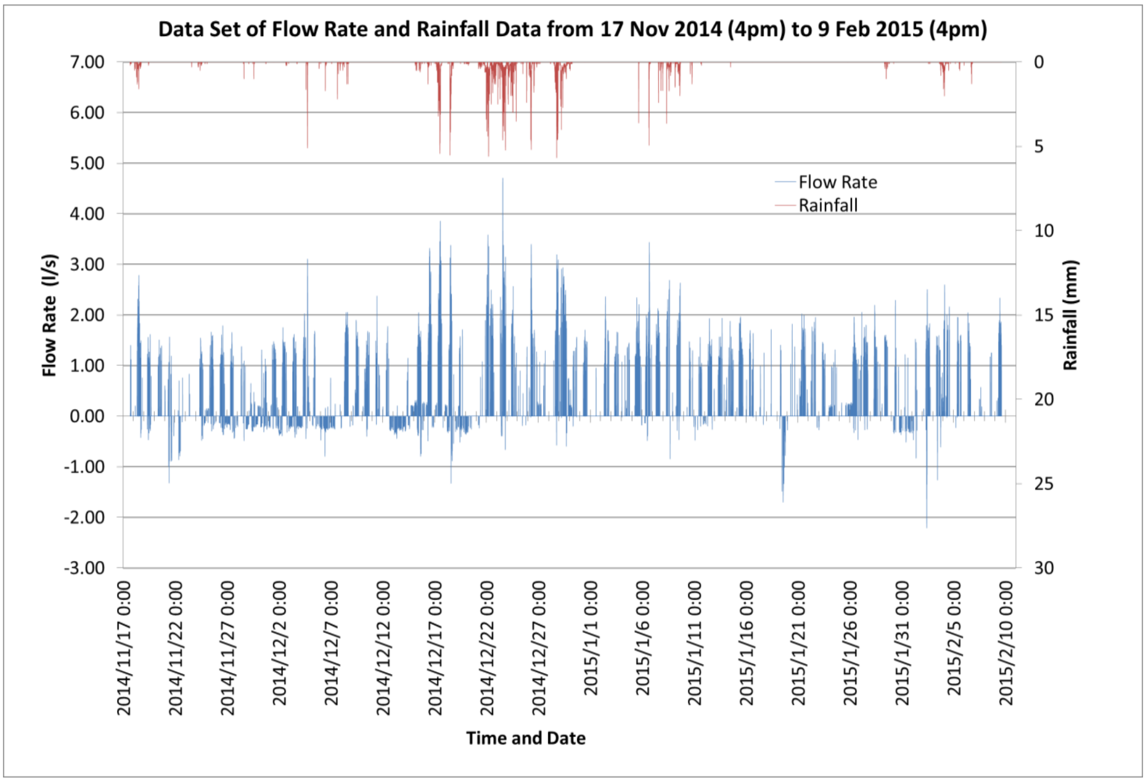

Figure 4.19: Full set of flow rate and rainfall data from 17 November 2014, 4pm to 9 February 2015, 4pm

In this study, the flow hydrograph is shown to provide more information about the result. The hydrographs will be plotted in unit liters per day together with rainfall hyetograph in millimeter. Figure 4.19 shows the period of 17 November 2014 4pm to 9 February 2015 4pm. On 23 December 2014 2pm, the hydrograph has shown the highest peak flow and highest rainfall volume in the study. The hydrograph shows the same characteristic, which is that the average flow will happen around 11.45am on weekdays if there is no rainfall distribution. This may occur because of people going to toilet before lunch or students going to toilet after class. On weekends, the hydrographs show very little flow, due to the reason weekends are not working hours and not lecturing time, so there are no people working in the office and no students going to classrooms.

The effect of rainfall on sewerage flow pattern in the sewerage system was also be analyzed in this study, so the objective is achieved. A high volume of rainfall occurred continuously from 21 December 2014 to 24 December 2014, hence the hydrograph showing the flow rate on 23 December 2014, Tuesday, 2pm has the highest peak among the period. The possible reason for this happened because of the rain infiltrating into the soil and then infiltrating into the sewer line.

Other than that, there are some negative values for the flow rates measured. The peak negative flow happened on 2 February 2015, 10.25am with a quantity of 2.2 l/s. This may have happened due to the flow being below the sensor detection limit, probably because the flow was too small. Besides that, this will also happen when rubbish blocked the sewer line as shown in Figure 4.20, so the wastewater flow is too slow when it reached MH 07.

Figure 4.20: Obstacle is blocking the sensor to detect the flow rate

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

At the end of the research, several conclusions and recommendations can be made. Other than that, a summary of the parameters as well as comparisons between the results of the research with the MS 1228:1991 is presented.

5.2 CONCLUSION

The Q_{peak} and Q_{ave} can be calculated after data was collected including weekdays and weekends. The parameters are summarized in Table 5.1 for all 6 sets of data from the study. Each parameter will be discussed in this study.

Table 5.1: Summary of the results

Data Set	Peak Flow Q_{peak} [m^3/day]	Average flow Q_{ave} [m^3/day]	Per Capita Flow Q_{pcf} [m^3/day/person]	Population Equivalent [PE]	Design Criterion [K]	Peak Flow Factor [PFF]
MH07-01	240.45	93.71	0.0636	1473	2.68	2.57
MH07-02	268.36	101.72	0.0691	1473	2.75	2.64
MH07-03	405.48	163.41	0.1109	1473	2.59	2.48
MH07-04	296.87	122.5	0.0832	1473	2.53	2.42
MH07-05	174.70	86.16	0.0585	1473	2.12	2.03
MH07-06	223.43	102.72	0.0697	1473	2.27	2.18

Average of data	268.22	111.70	0.0758	1473	2.49	2.39
MS 1228:1991	1492.73	331.43	0.2250	1473	4.70	4.50

From the Table 5.1 shows the lowest Q_{peak} as 174.70 m^3/day from MH 07-05, while the highest Q_{peak} was 405.48 m^3/day from MH 07-03. Meanwhile, the lowest Q_{ave} in this research is from data set MH 07-05 at 86.16 m^3/day whereas the highest value is from data set MH 07-03 which is 163.41 m^3/day. However, value of average PFF in this research were also shown lower than the 4.5 from MS 1228:1991 as calculated in Section 4.3 with amount of 2.39.The highest PFF located at second set of data with amount of 2.64. Alternatively, the lowest PFF was located at fifth set of data with value of 2.03.

From the analysis and comparison between the current study and MS 1228:1991, it was shown that all parameters were lower than specified in the MS 1228:1991 especially the two main parameters, Q_{pcf} and K. As shown by the results, the maximum and minimum value of actual per capita flow was 0.111 m^3/day/person and 0.0585 m^3/day/person. By comparison of average actual per capita flow to MS 1228:1991, average actual per capita flow with amount of 0.076 m^3/day/person, which lower than the design per capita flow of 0.225 m^3/day/person stated in MS 1228:1991. Meanwhile, the maximum value of actual design criterion was 2.75. The minimum actual design criterion was 2.12. To comparing the actual design criterion to design criterion in MS 1228:1991, the average actual design criterion be determined. The average actual design criterion was calculated as 2.49, which is lower than the design criterion of 4.7 mentioned in MS 1228:1991.

After analyzing the results, it can be concluded that the flow characteristics in the sewerage system is sufficient to fit the PE in this study. The sewer pipeline in UMP area was designed for high flow capacity. Thus, more cost can be saved for future development by using the new parameters. Other than that, rainfall is also one of the factors to be considered during design due to the fact that rainfall will influence flow rate of wastewater in the sewer line based on the result.

5.3 RECOMMENDATIONS

In this research, the aim is focused on verifying the suitable design criterion and by extension the parameters for sewerage system as recommended in MS 1228:1991. Other than that, the objectives of this research are to study the effect of rainfall on sewerage flow pattern in the sewerage system and to analyze the flow characteristics in the sewerage system in UMP area which had been achieved. A more detailed research about the suitable design criterion and by extension the parameters for sewerage system to analyze flow characteristic in sewerage system can be done in future.

The few recommendations that can be made for the purpose of improvement in the future are:

I. It is necessary to make sure there is no rubbish or obstacle around the sensor of the flowmeter. The reason for this is because the obstacle will affect the flow of wastewater.

II. For future study, it necessary to wait around 5 to 10 minutes after opening the manhole to release the harmful gas from the manhole. Other than that, personal protection equipment such as gloves and masks must be worn during the fieldwork.

III. When going to analysis phase, make sure the total flow rate and average flow rate has been calculate correctly because they will affect the analysis of the important parameters.

IV. Population equivalent plays an important role in the research. It is pertinent to make sure the drawing is the latest, so that PE can be estimated correctly.

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APPENDIX A Sewer Reticulation Site Plan