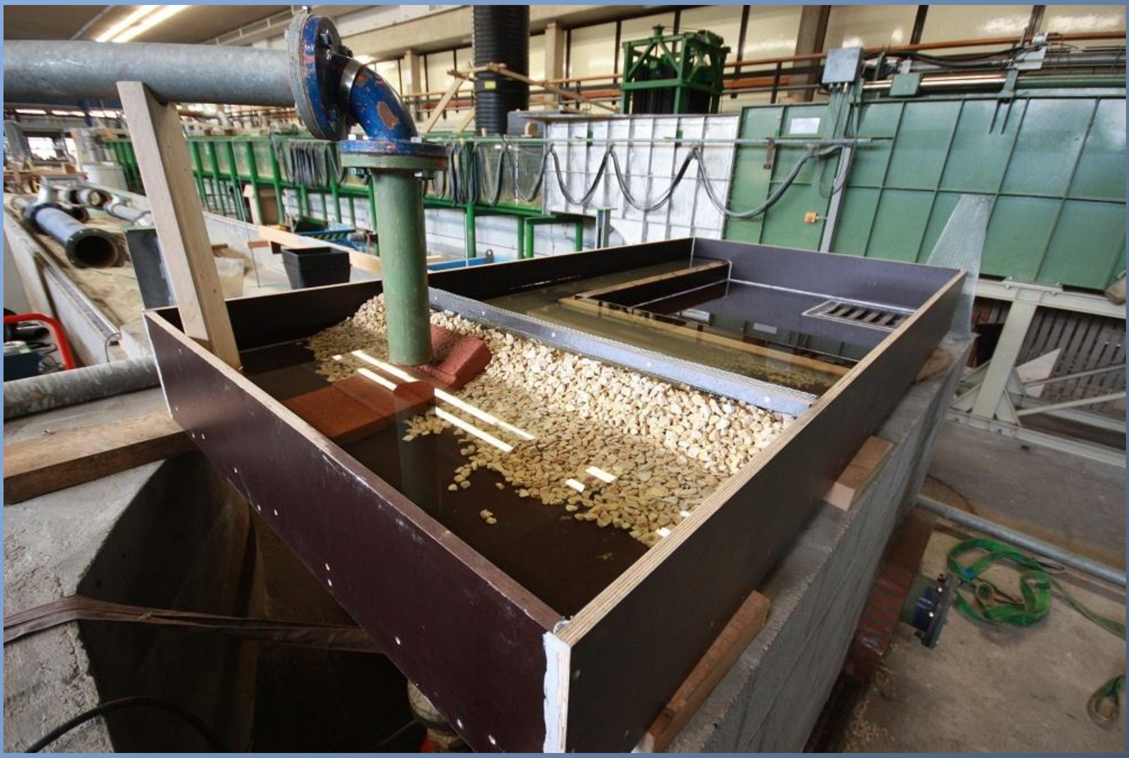
Innovative Design of Gully Pot for Preventing Big Particles Clogging Problem



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wavin

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Abstract

This thesis project aims to reduce the gully pot clogging problem by improving the design of gully pots. It will focus on the problem of clogging caused by large particles. After the literature study, it could be asserted that the construction of gully pots is found to vary all over the world. There are two parts of gully pot that can easily be clogged by large particles. In order to define the large particles, field work was done to interview the on-site workers from cleaning company. After that, the real clogging materials inside the gully pots could be concluded to be mainly leaves and branches. Based on this information, 4 kinds of new alternatives are presented. A laboratory experiment is designed to test these alternatives and also a new re-designed gully pot provided by Wavin Company is tested. At the end of the laboratory experiment, the observed results and hypothetical results are compared. The new grating alternatives show better behavior than with the original cover. Additionally, the new gully pot also has great performance because of its large dimensions.

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1. Introduction

1.1 Problem definition

Gully pots [Figure 1] or roadside catch basins are a common and important part of sewerage drainage networks. Their primary function is to retain larger solids from road runoff. They are used to minimize the problems associated with sediment in downstream drainage structures, pumps, treatment plants and receiving waters. Gully pots were essentially designed to attenuate the flow through the underground pipe system. Additionally, they act as settling tanks for road runoff solids prior to the overturning and discharge of the contents of the chamber to the sewer system.

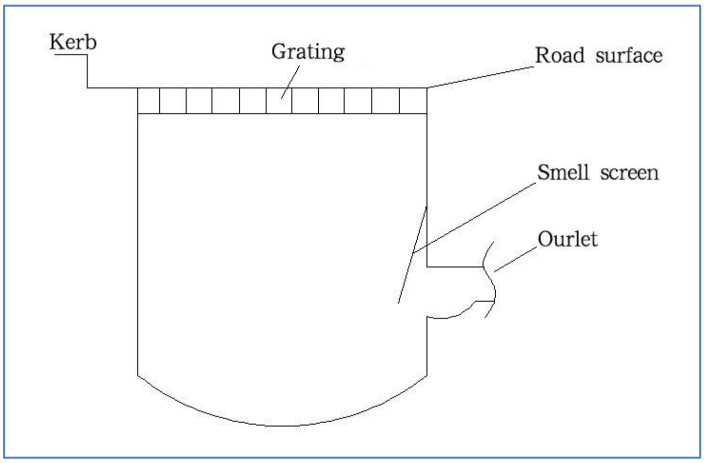

Figure 1 - Typical gully pot

For combined sewers, it is often the case that sufficiently high flow rates induce self-cleansing conditions occurring at or near the time of peak discharge during a storm event. This then entrains the sediment (and associated pollutants) into the flow at a time when the overflows are in operation (Mance et al., 1978).

In most storm water, sewers drag forces are strong enough to transport small sediments. Solids supply to the gully pot takes place primarily by the liberation of surface deposited solids by rainfall, with surface runoff entering the system during storm events. Other possible mechanisms include the action of wind and vehicle-generated turbulence and vibration.

Gully pot systems have to fulfill two functions which are the efficient discharge of surface water and the removal of pollutants. Since the removal efficiency is limited by the hydraulic loading, these are contrary tasks.

Gully pots clogging problems have gradually been recognized over recent years. Blockage of inflow devices (especially gully pots) is the most frequent cause of flooding, for flooding of buildings and of roads. Gully pot blockages cause the highest numbers of flood incidents and are subject to larger uncertainty than other basic events (Ten Veldhuis, 2010). Gully pots are known to exert a considerable influence on surface runoff quality in their own right.

There are two main types of problems caused by gully pot clogging (Deletic et al., 2000):

① Reduction of sewer system efficiency:
This problem is usually caused by large particles. During storm events, large particles such as leaves, branches, papers, tins, sticks and cigarette-stubs will be flushed into the gully pot from the street. There are two parts [Figure 2] in gully pot are easy to be clogged by large particles. One part (Part A) is the grating, which is easy to be clogged directly by the big particles like leaves, branches, stones, etc. The other part (Part B) is the outlet to the sewer system. During storm event, part of the sediment in the settling pit will be flushed into pipes, and cause the pipe clogged.

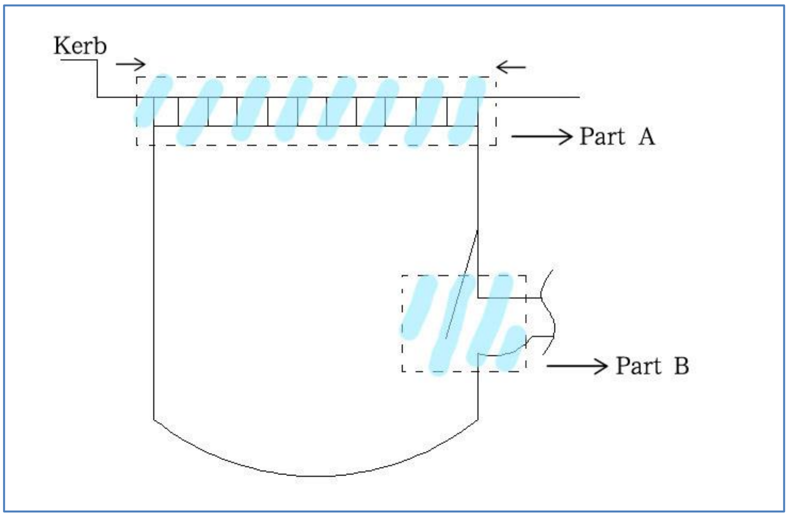

Figure 2 – The construction of gully pot

② Direct pollution of receiving waters:
The gully pot clogging may cause street flooding, and the overflowed polluted water from sewage will cause direct pollution to the aquatic environment.

1.2 Object

About 90% of the sewerage systems in the Netherlands are combined systems [Figure 3] (Kaltenbrunner, 1984). During a storm event, the rain water flows into combined sewerage systems through gully pots. The clogged gully pot causes serious street flooding and in the meantime, the big particles are the main reason to cause gully pot clogging problems. After the first stage of the literature study, it shows that the research on large particles causing gully pot clogging problem is quite few. Therefore, this research focuses on large particle clogging problem, and providing the optimal solution for redesign gully pot. The research question is whether we could reduce the gully pot clogging problems by improving the design of the grating and outlet of gully pot.

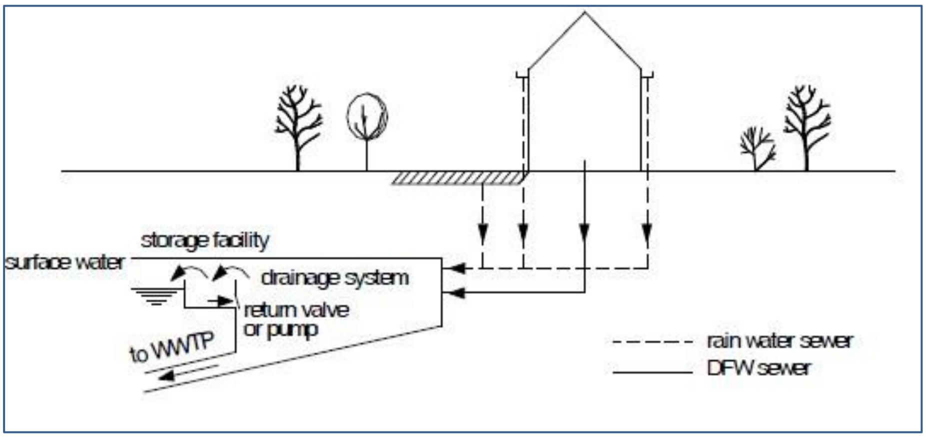

Figure 3 – Combined sewerage system

1.3 Research approach

After some literature study, it is clear that this research focuses on large particles issue. In the first place, the definition of large particles should be clearly described. Thus what kinds of material inside the gully pots in the real site need to be known, what kinds of substance real clog the gully pots, and also other information about the real roadside gully pots need to be collected.

In order to obtain the information of real site gull pot directly, the on-site workers from cleaning company who really clean the gully pot were interviewed. Based on this information, new ideas for several alternatives of gully pot were figured out. Then laboratory experiment to test these alternatives was designed, and a new re-designed gully pot from Wavin Company was also tested. After analyze the experiment results, optimal design for gully pot can be obtained.

1.4 Outline of this thesis

This report starts with the introduction about the gully pot clogging problem. Chapter 2 gives the information about the background study in different kinds of structures of gully pot in different areas. Chapter 3 presents an interview with on-site worker from a cleaning company. Chapter 4 describes the ideas of different new alternatives, the set-up of laboratory experiment, and the hypotheses of water flow patterns on the testing table. Chapter 5 presents the testing results and Chapter 6 is about discussions. This thesis ends with the conclusions and recommendations in Chapter 7.

2. Different gully pot constructions

After literature study, it shows the research on gully pot clogging problem which causing by big particles is very few. Additional, almost every country has own kind of gully pot to adapt different situation. In order to get more information about the different structure of gully pots, the first task is to study different kinds of gully pots all over the world.

2.1 Gully pot in UK

A typical UK cross-section of gully pot is shown in [Figure 4]. This small (90 liter) sump has been provided extensively to retain the heavier solids from road runoff during wet weather in order to avoid problems related to sediment deposition in storm water sewers and receiving waters.

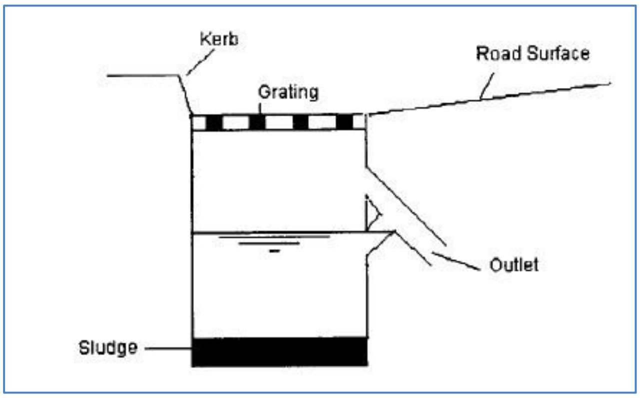

Figure 4 - Typical cross-section of gully pot in UK (Butler et al,. 1998)

Butler and Clark (1995) have reported pot sediment build-up rates in urban areas in the range 14-24 mm/month. The height of sediment bed, however, has been shown to influence sediment trap efficiency to only a limited extent (Butler and Karunaratne, 1995).

2.1 Gully pot in Germany

There are two kinds of gully pots [Figure.5], which are used in the city of Hannover in Germany (Grottker, 1990):

① Dry Gully Pot (DGP). The pollution of the surface runoff is reduced by flowing through the slotted bucket. Large particles and rubbish such as papers, tins, sticks and cigarette-stubs are removed. During and after a storm event, the bucket will be drained by the slots, but the content remains wet for a long time, because the ventilation and the temperature within the gully pot are low.

② Wet Gully Pot (WGP). The surface runoff falls into the small settling pit where pollutants partly accumulate by sedimentation. Small sized particles as well as gross solids and rubbish will be removed and after a storm event the sludge deposits and water will remain within the settling pit.

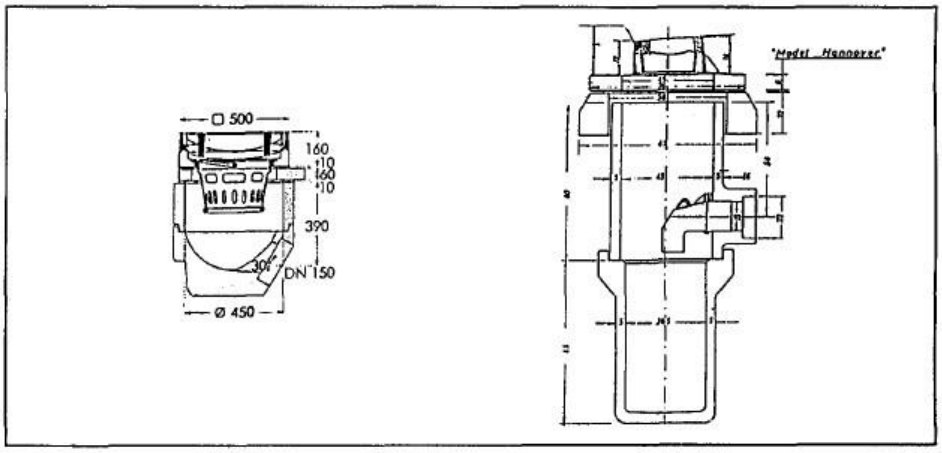

Figure 5 - Dry gully pot and wet gully pot in Germany

2.3 Deodorant gully pot in China

In China, the municipal drainage network in many medium and small cities use the combined sewerage system. The storm water from the road surface is through the grating on the top of gully pot, and passing by short tube which directly connect to the municipal drainage system. This can easily lead to stinky problem, and the flies, mosquitoes, also other insects from the water will come out which cause bad influence to the urban environment. To solve this problem, there is a deodorant design [Figure 6].

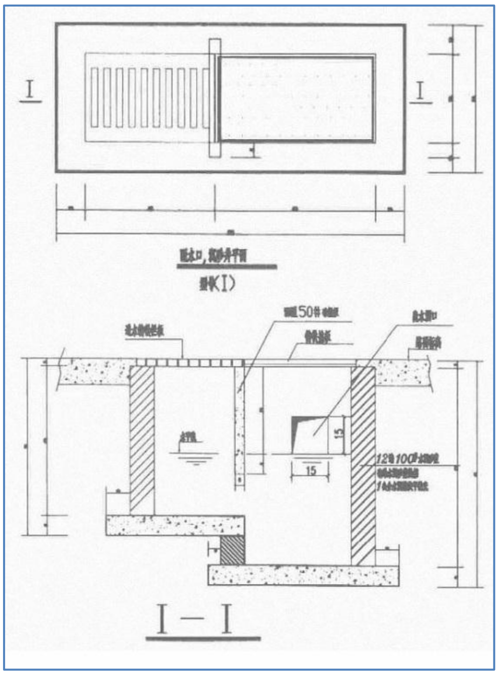

Figure 6 - Detail drawing of the deodorant gully pot in China

The deodorant gully pot (Chaying Yang, 2004) has first chamber and second chamber. The first chamber is the inlet, there is grating on the top of the draining well; the second chamber is the discharge area and settling zone, the outlet pipe sets in the central of the second chamber, and there is a closed steel lid on the top.

The advantage of the deodorant gully pot:

① It is easy to get the materials, making the construction conveniently and economical.

② There are small amount of rainwater in the first chamber to block up the stink and the harmful flying insects from the sewer system, to prevent environmental contamination.

③ The settling zone is easy to be cleaned regularly to reduce the surface sediment rushed into the sewer system.

2.4 Gully pot in southern Brazil

In South American cities, the majority of settlement has happened in a disorganized way, usually not accompanied by any adequate supporting infrastructure, leading to negative impacts on the environment, especially receiving water body quality and biotic impacts resulting from contaminated aquatic sediments.

Studies of sediment particle size have demonstrated the influence this has on the adsorption capacity and transport capability of particulates. These properties impact on surface water management strategies, such as the sediment trapping efficiency of roadside gully pots (Butler and Karunaratne, 1995).

The typical gully pot in southern Brazil is as shown below [Figure 7]. During the sediment sampling period, several samples were obtained from three gully pots from each city from the base of the gully pot using a plastic bag in order to avoid contamination of the material.

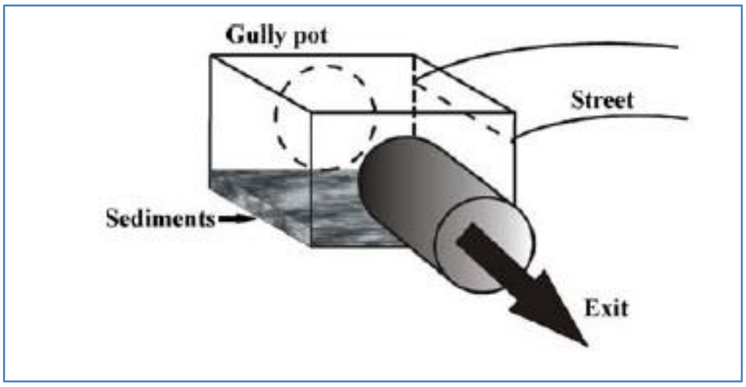

Figure 7 - Diagram of a conventional gully pot in southern Brazil

After analysis (Poleto, et al,. 2009), The results indicate that coarser material is preferentially retained in the gully pot and that the finer, more polluted material is likely to be carried in suspension out of the gully pot with high velocity storm flow across the impermeable road surface.

2.5 Catch basin inserts in Westchester of New York

Methods of addressing the Non-point sources (NPS) pollution problem are commonly called best management practices and are intended to reduce NPS pollutants, particularly those from highway runoff (Struble, et al., 1997), e.g., oil and grit separators, grassed swales, vegetated filter strips, retention ponds, and catch basin inserts (CBIs).

The CBIs are devices that reduce stormwater pollution from runoff, without requiring any land use because it is typically mounted within a catch basin (gully pot).

CBIs [Figure 8] (Kostarelos, et al., 2010) in Westchester of New York are attached to a catch basin and they remove pollutants from the runoff before they enter the storm water sewerage system.

Figure 8 - CBIs in Westchester of New York

The CBI on the left side in Figure 8 is a drop-in device that does not require any special labor for the installation, but does require two people to lift and install. The CBI is supported by a stainless steel frame, fabricated by the manufacturer and custom made to the dimension of the catch basin. Two filters were placed next to each other to cover the inlet area of this particular catch basin.

The CBI on the right side in Figure 8 is frame-mounted and because of the special dimensions of the catch basin, two filters were installed next to each other in order to cover the catch basin inlet area. This is also a drop-in device and, once the grate was removed, no special labor was required for the installation. Two people are needed to lift the CBI.

3 Interview with on-site workers

In order to solve the big particles clogging problem of gully pot, the first step is to define the big particle substance. More information from real site gully pot should be collected, such as what are the real clogging materials inside the gully pot; how will the clogging problems happen; when and where the on-site worker move the clogging materials from the gully pots; how to remove these materials, etc. This information can help to understand the mechanism of clogging problem. With these questions, an interview with the on-site workers from VanderValk + DeGroot Company was processed.

3.1 Different kinds of gully pot in a residential area

The guide from VanderValk + DeGroot Company (cleaning company) shows a residential area, where the on-site workers were just working there to clean the gully pots. Four kinds of gully pots in this area are identified.

3.1.1 The first kind of gully pot

The first kind of gully pot [Figure 9] is setting on roadside and the grating is on the side. For this gully pot, there is a cast-iron baffle plate [Figure 10] on the top of the outlet which is aiming to prevent stink from the sewer system. It also can prevent big objectives going through outlet pipe directly.

Figure 9 - The first kind of gully pot in residential area

Figure 10 - The baffle plate in gully pot

The first kind of gully pot has another version [Figure 11], which is made by concrete, and it has a ‘U’ shape bottom [Figure 12]. The worker indicates the gully pot with ‘U’ shape bottom is preferred more than the flat one. That is because when they use the absorption machine to clean the gully pot, the ‘U’ shape bottom has better air flow, it is easier to suck everything out of gully pot.

Figure 11 - The other version of the first kind of gully pot

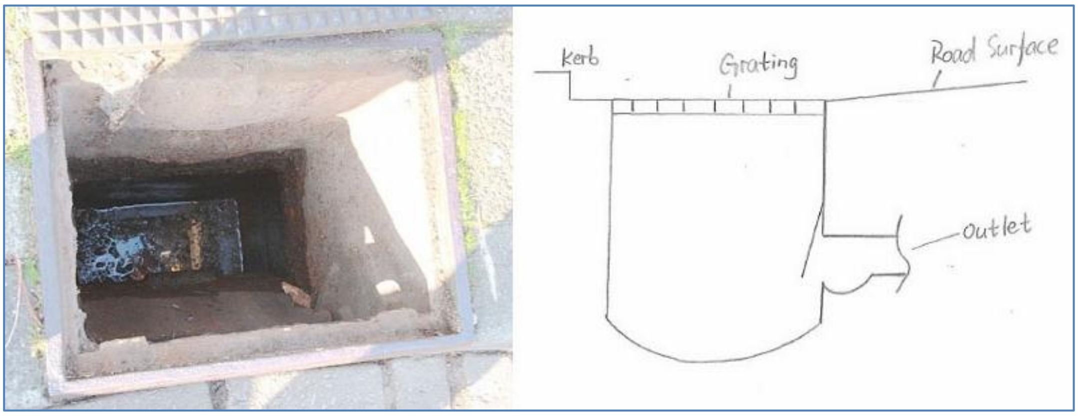

Figure 12 - 'U' shape bottom

3.1.2 The second kind of gully pot

The second kind of gully pot contained water, leaves and small braches inside, but it is still functioned. To open this kind of gully pot has to use some kind of special tool [Figure 13].

Figure 13 **-** The second kind of gully pot in residential area and special tool

The second kind of gully pot also has another version which is setting just on the pavement, and the grating is on the top of the gully pot. The grating of this one is a little bit special, which has lock on side. To open this kind of grating, a special tool [Figure 14] is needed. This is aim to prevent people to open it arbitrarily.

Figure 14 **-** The other version of the second kind of gully pot in residential area and the special tool

3.1.3 The third kind of gully pot

The third one [Figure 15] is also set on the road side, but has a special cover. It is also filled with leaves and branches.

Figure 15 - The third kind of gully pot in the residential area

3.1.4 The fourth kind of gully pot

The fourth one [Figure 16] is a small one which is made by plastic. It is different from the other concrete ones. The guide said they do not like this kind of gully pot at all, because when they use machine to clean this kind of gully pot, the bottom is often be cracked.

Figure 16- The fourth kind of gully pot in the residential area

3.2 The cleaning truck

VanderValk + DeGroot Company have special truck [Figure 17] and machine to do the cleaning work.

Figure 17 - The cleaning truck

There is a big suction tube in front of the truck and a tank on the back. The materials will be sucked from the gully pot into the tank and be stored separately. The inner part of the tank is divided into two parts, one side is for water and the other is for sand, leaves, branches, etc.

On the left side of the truck, there is a transparent plastic pipe [Figure 18]. The water level in the tank can be observed from this pipe, so it can be known when the tank is full.

Figure 18 - The transparent plastic pipe

In the past, workers can put sand and all other materials in somewhere when the tank is full. But this is not allowed anymore, they have to take these sand back to company and there is other specialized company to reclaim this sand and wash them for reusing. This is such good way to deal with these materials, because this is both economical and environment-friendly.

Using this kind of machine to clean gully pots is also very efficient, they just put the suction pipe [Figure 19] into each gully pot for 2 or 3 seconds, everything will be sucked from the gully pot.

Figure 19 - The suction pipe

The truck even has a Global Positioning System (GPS) [Figure 20]. When some gully pots are serious damaged, blocked up by cars or polluted by oil (and any other chemical substances), they will mark the location of these gully pots on map in the GPS. Then they can come back or ask other agency to deal with it. The pollution will be taken care by Environmental Institutions.

Figure 20 - The GPS system in red circle

The guide also shows the instruction of the GPS and the GPS [Figure 21] inside the truck. People can mark the location of the gully pot by just touching the screen and also can record the condition of each gully pot. In the past, if they want to mark broken gully pot, they have to make the sign on the trees or the house number in front of the gully pot. The driver in this truck is on the right side, this is aim to see the road side gully pot more clearly.

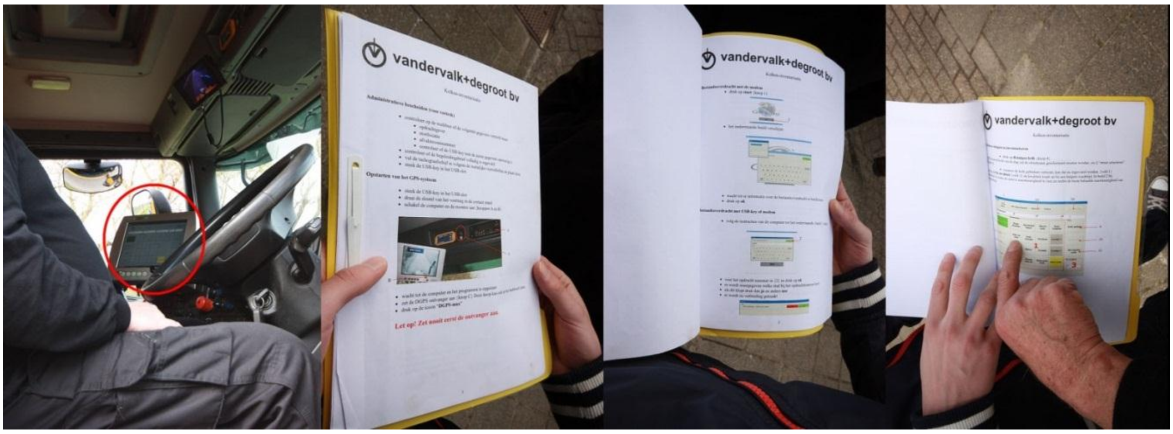

Figure 21 - The GPS system inside the truck and the instruction of GPS system

3.3 Communication with on-site worker

The on-site workers are asked about several questions. The first is ‘what the material is normally found and clogged in the gully pot?’ The answer is: in most cases the material will be leaves, branches and sand.

But sometimes they also find weird things [Figure 22] (such as beer can). Because like the first kind of gully pot mentioned before, the grating is set just on the road side and the space between each grate is big, so everything on the road is possible comes into the gully pot.

Figure 22 - Beer can in the gully pot

Here is a gully pot which is totally clogged [Figure 23], it is not functioned anymore. It is clear that the materials which clog the gully pot are mainly leaves, branches, sand and even some cigarette tips.

Figure 23 - The gully pot is totally clogged

Sometimes, there is another situation causing damage to gully pot. If the gully pot is near construction site or the road is being overhauled or even some resident do fitment in their yard, everything will be flushed into road side gully pot, especially the concrete. The concrete will be concretionary and stick on the bottom of gully pot [Figure 24]. Workers have to break them even use hammer sometimes.

Figure 24 - The concrete stick on the bottom of gully pot

The second question for the on-site worker is ‘How often will they clean the gully pot?’ The answer is that, the company will clean the gully pots once or twice a year. In general, the first time will be September and the next will be the next spring. Sometimes they also do emergency work if the gully pot is broken or clogged.

It is a coincidence when we check these gully pots, a lady who live in that area come to complain that the gully pot in front of her house is always clogged and she had to clean it even four times one year.

The third question is ‘How about the cost of maintenance?’ Workers said if using the machine to clean the gully pots, it will cost 5 - 9 euro for each gully pot. But for some certain situation they have to clean gully pot in the old way, which means by hand and using some special tool (it will be shown later). This will cost a lot which is because in the old way they just can clean limited numbers of gully pot in the same time period and also they need more manual work.

3.4 After the fieldwork

After back to the Company, guide shows the tool [Figure 25] for cleaning the gully pot manually. The guide puts the tool into gully pot with open state (outlined in red), then closes it (outlined in blue), in this way the materials in gully pot will be taken out.

Figure 25 - The tool for cleaning the gully pot manually

In the end, the Director, Mr. John Witkamp was also interviewed. He said that, what materials in gully pot are depending on the area. If there are around trees, the materials in gully pot will be leaves and branches, if not, the materials inside are mainly fine sand and small stones. Also if the gully pots beside some construction site, it will have concrete in the gully pot.

3.5 The samples

In order to define what material real clog the gully pot, several samples are taken from the real site:

For the first sample [Figure 26], leaves, braches, some kind of cotton gauze, sand and plastic paper are found.

Figure 26 - The first sample taken from the real site

For the second sample [Figure 27], leaves, sand and branches are found.

Figure 27 - The second sample taken from the real site

The third sample [Figure 28] is the beer can I found in one gully pot.

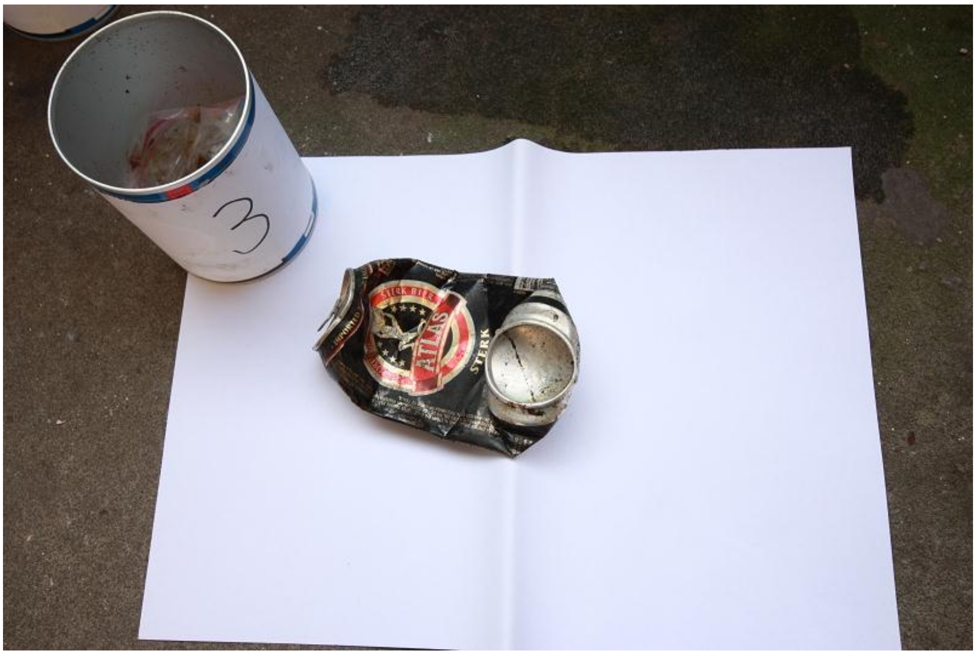

Figure 28 - The third sample taken from the real site

For the fourth sample [Figure 29], there are leaves and sand in water.

Figure 29 - The fourth sample taken from the real site

Based on these samples and the interview with on-site worker, it shows the materials inside gully pot and causing clogged problem are mainly leaves, branches and sand.

4 Experimental research

After the interview with the on-site people, the big particles clogged gully pots are defined, which mainly are leaves, branches and sand.

4.1 Ideas about new alternatives

First there is a normal original gully pot from Wavin Company as:

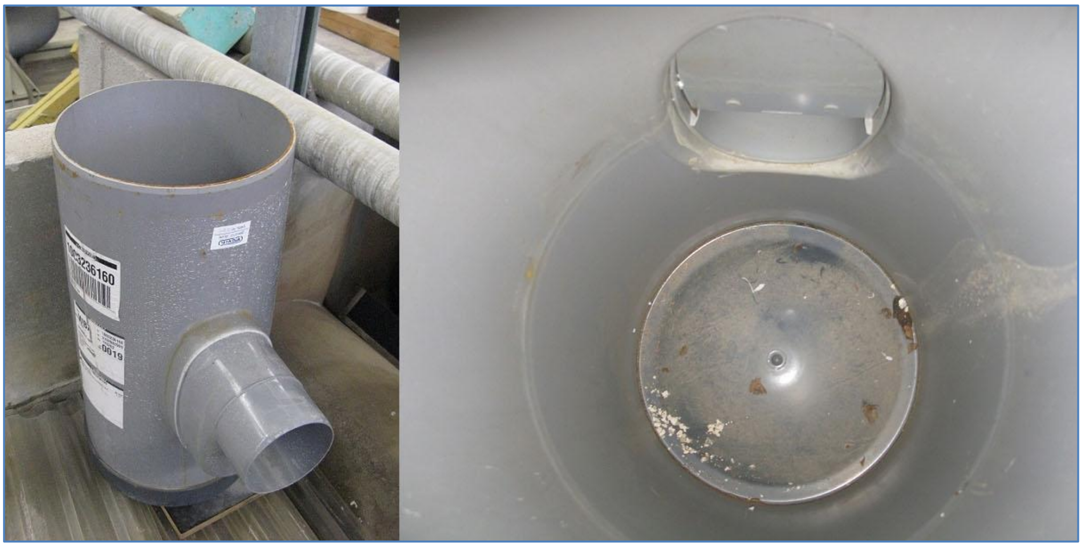

Figure 30 - The original gully pot

Based on all existed information, possible alternatives for reducing original gully pot clogging problems are considered. The design of constructions could be separated into two aspects:

① Set a net or sack inside the gully pot to catch big particle materials;

② Using new grating design to keep big particle materials outside the gully pot.

Based on these aspects, several alternatives were designed:

◆ Alternative 1:

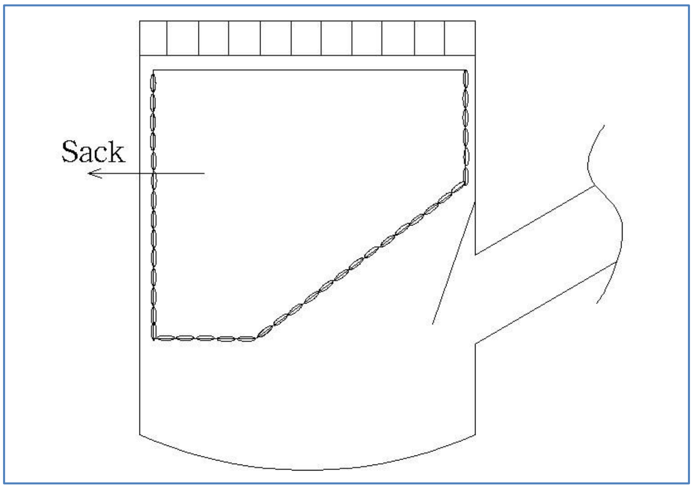

Figure 31 - Alternative 1 of new design

As shown in the figure above, there is a bucket inside the gully pot. The material of this bucket could be net (like fishing net) or metal. The bucket is with circular holes around it, this is mean to catch all big part materials from the street and in the meantime let water go through these circular holes as soon as possible. The bucket is movable, which is easy for cleaning. This design aims to prevent big part materials going inside gully pot directly, and reduce the possibility of clogging occur at the outlet part.

◆ Alternative 2:

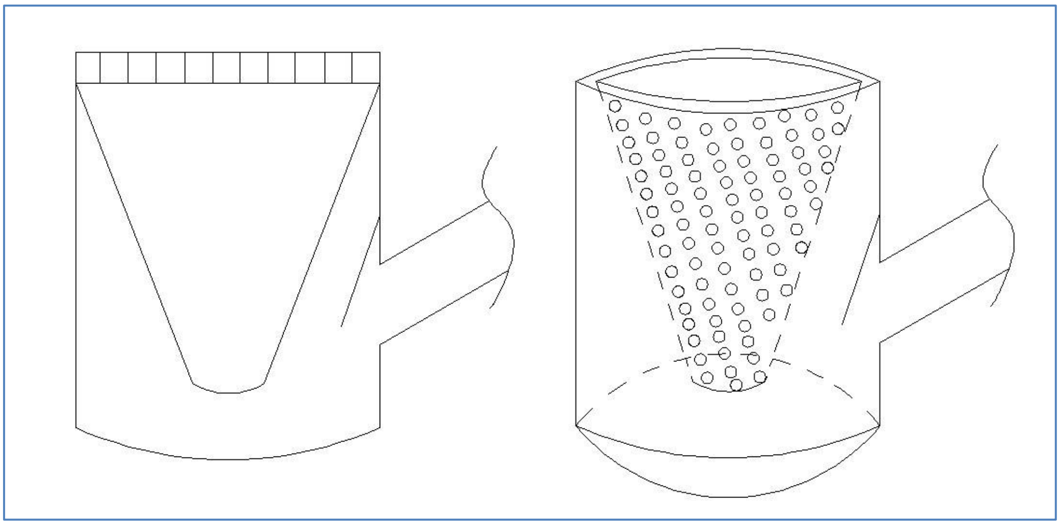

Figure 32 - Alternative 2 of new design

This design has a cone shape bucket with circular holes around. The advantage of this alternative is that, when the bucked is clogged at the bottom, it still has enough space for water flow. Also this design gives more space for water inside the gull pot.

◆ Alternative 3:

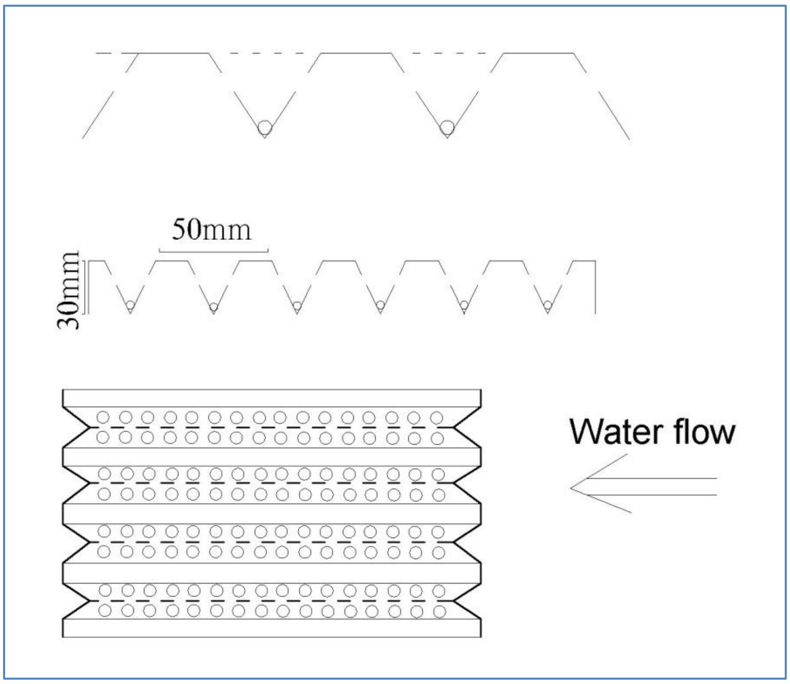

Figure 33 - Alternative 3 of new design

This alternative aims to keep big part materials outside the gully pot. The dirt can be trapped on the grating part. This grating design has excellent advantage which is to use the water flow to flush the materials directly which trapped on the grating.

◆ Alternative 4:

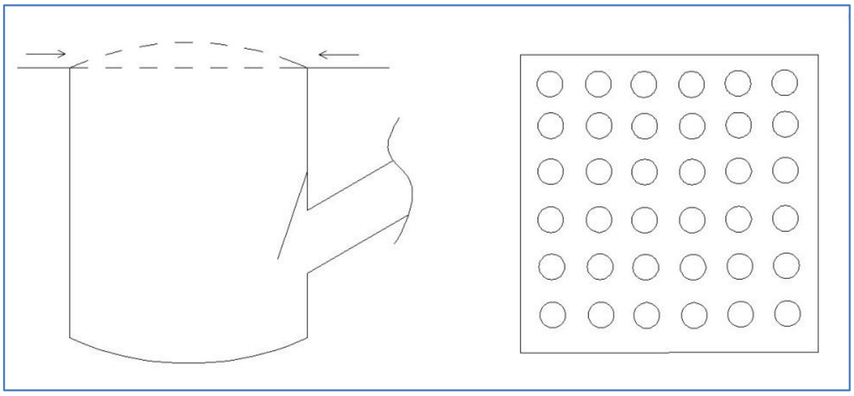

Figure 34 - Alternative 4 of new design

This alternative also aims to keep big part materials remain outside the gully pot, it has a curved top. During storm event, water carry materials come from different side. This design can keep large size materials stay around the grating. The materials carried by water are not easy to cover the top of the grating.

◆ A new gully pot from Wavin Company:

Figure 35 - The new design of gully pot

A plastic baffle with circular holes around the outlet is found in this new gully pot, which means to prevent the outlet clogging problems. Also this new gully pot has a bigger size than the original gully pot.

4.2 Experimental Set-up

In order to test these alternatives, the experiment is set-up in the water lab. A sketch of the test table is shown in Figure 36:

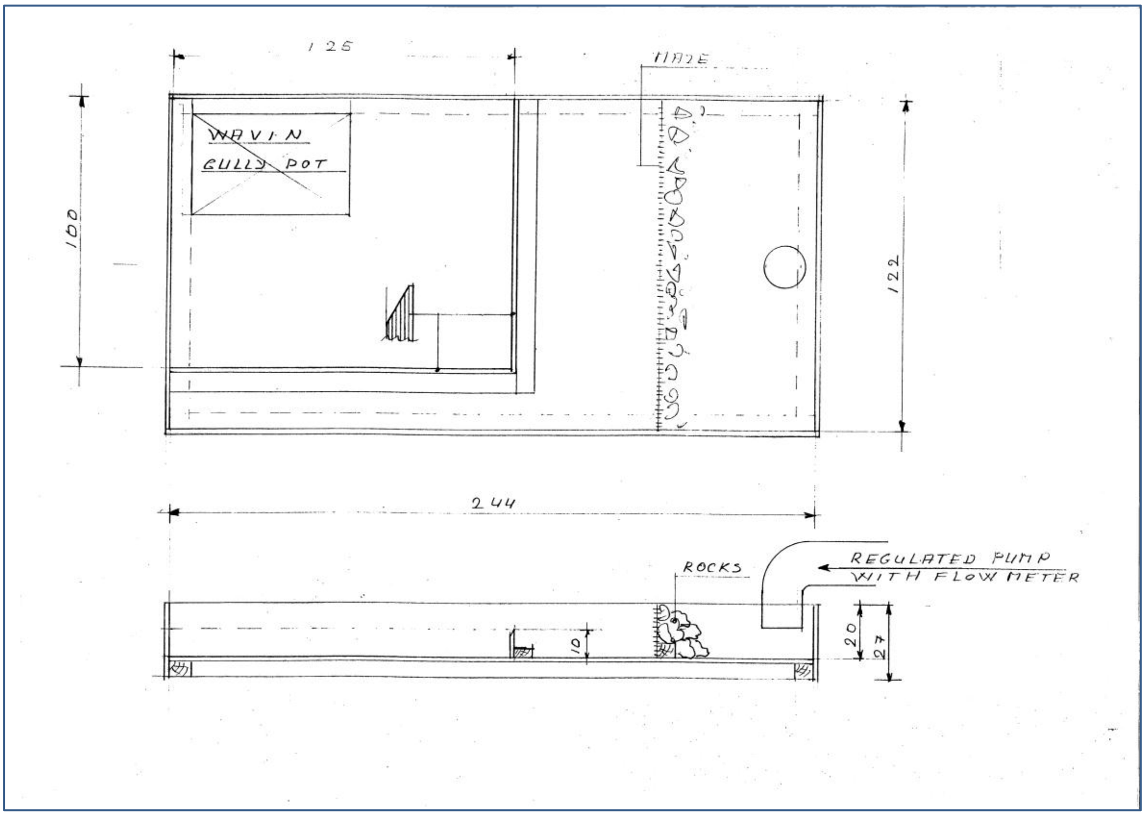

Figure 36 - The sketch of test table for lab experiment

Later on, the test table is set up in the water lab:

Figure 37 - The top view and the under view of the test table

Figure 38- The experiment set-up

The water for this experiment is in a circular system, the pump keeps pumping up the water under the test table. Then the water flows over a weir into testing area. After water go inside the gully pot, the discharge will go out through outlet pipe which is back to the under part of the test table.

There is a device to control the pump to have different flow capacity and also to read this capacity:

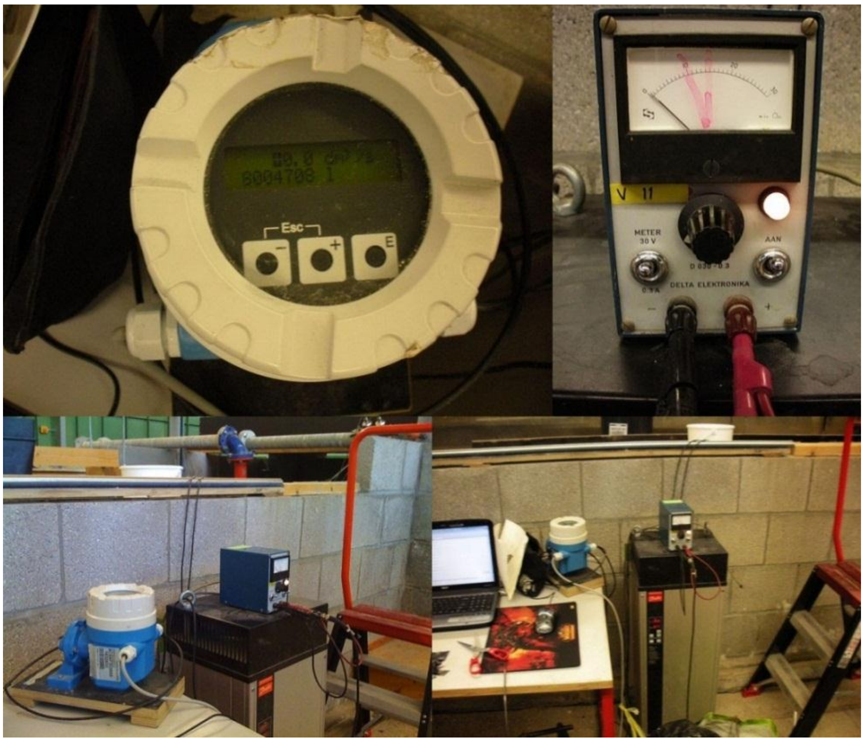

Figure 39 - The device to control and read the flow capacity

In order to measure the water level on the test table, Figure 40 is set on the side of the test table.

Figure 40 - The device to measure the water level on the test table

The alternatives are made for laboratorial testing:

Alternative 1	Alternative 2	Alternative 3	Alternative 4

Figure 41 - Alternatives for laboratorial testing

4.3 Selection of the materials for testing sample

After interview with the on-site workers, several samples [Figure 42] from on-site gully pot are taken back. The materials inside the gully pot which cause the clogged problem are normally leaves, branches and sand.

Figure 42 - Samples from real on-site gully pots

The testing sample can be chosen base on leaves and branches. At the beginning of the experiment, we plan to find some kind of artificial samples to instead of real leaves. This aims to make sure testing samples for each test will be equal.

4.3.1 Try out with plastic leaves

For the try out test, different kinds of artificial leaves which made by different kinds of plastic are tested:

Leaves A	Leaves B	Leaves C	Leaves D

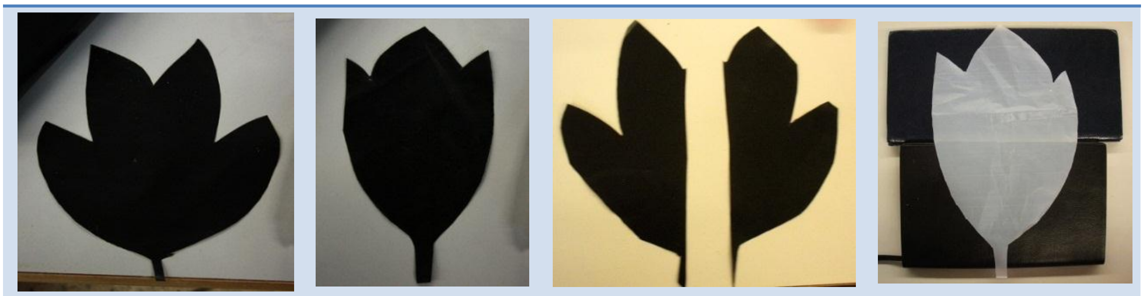

Figure 43 - Different kind of artificial leaves

After lots of try-out testing, problem with these artificial leaves is shown. The plastic leaves cannot easily go through the grating. This is because the plastic leaves will stick together after they are getting wet. The plastic leaves which close to the grating will be hold by the other leaves.

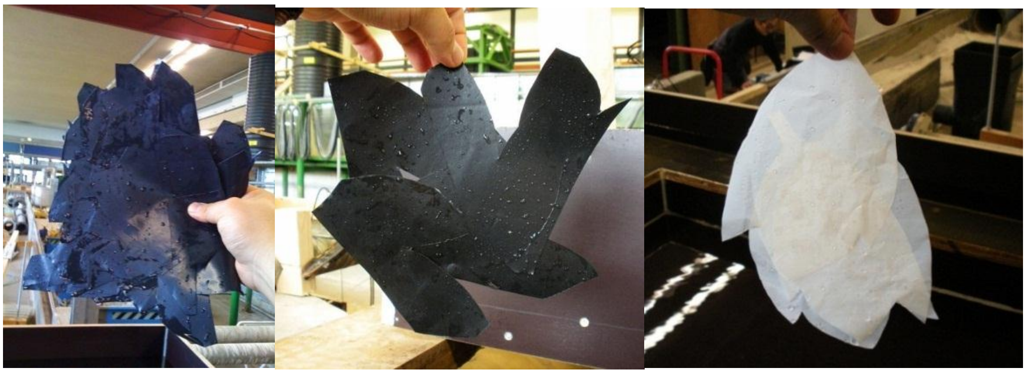

Figure 44- The plastic leaves stick together after getting wet

So the plastic artificial leaves are not a good choice.

4.3.2 Try out with totally dry leaves and branches

For the next step, several try out tests with dry leaves mixed with branches are done. The results show that dry leaves are too easy to be smashed into small debris. So the dry leaves also are not a good option for the lab experiment.

Figure 45 - Testing with dry leaves and branches

4.3.3 Try out with real fresh leaves and braches

In the end, several tests with real leaves and mixed with braches is run. The results show that the behavior of real leaves which transported by water is better than all other materials.

Figure 46 - Testing with real fresh leaves and braches

Based on the results, we decided to choose **real leaves mixed branches** for the test samples.

4.3.4 Quantify the test samples

For quantify the samples, a plastic bucket is used. After fulfilled with samples, the bucket is weighed. It takes 5 times and gets the average value which is about 301g (without the weight of bucket).

Figure 47 - The bucket to quantify the test samples

4.4 Testing process

In reality, the clogging problem of gully pot occurs in a very long period. After the interview, it is clear this time period should be one year or half year, sometimes even three months. Normally, the simplest approach is to require one gully pot per 200m^2 of impervious area (Butler et al., 2004). In some particular area like parking lot, it requires one gully pot maybe per 100m^2. For normal condition, one gully pot per 200m^2, if the rainfall intensity is 27mm/h (Karunaratne, 1995), then the constant flow is about 1.5L/s. In the other hand, for laboratorial test, there just have a 10 minutes time interval for each flow capacity. So, using rather large flow capacities to create the conditions for clogging and simulate the extreme even is considered. For this lab testing, it normally start at 2.0 L/s, and then turn up to 4.0 L/s, 6.0 L/s, 8.0 L/s, and end with 9.0 L/s.

After a number of try out tests, it shows that if using the two types of new grating design (Alternative 3 and alternative 4) for lab testing, there is almost nothing will go through the cover into gully pot. This let the inside designs (alternative 1 and alternative 2) are not making an important role in the laboratorial tests. This implies the inside alternatives might not be really tested. So, the next step, lab testing is focus on the alternatives of grating design. The laboratory experiment process is divided in two steps:

① Open the cover, let the samples in the gully pot to test the inside alternatives;
- (1) Test with sack inside gully pot
- (2) Test without alternatives inside gully pot

② Test different new alternatives of cover to compare with the original cover.

In addition, after testing with the original gully pot, the new gully pot which is an already improving designed is tested.

4.5 Laboratorial testing data collection

For the data collection of the laboratorial testing during different flow capacity, all relevant data is recorded in Table 1:

Type of alternatives			
Type and amount of samples			
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Remarks (Water level on the test table [cm])
2.0	10		
4.0	10		
6.0	10		
8.0	10		
9.0	10		

Table 1 - Data collection for the laboratorial testing

4.6 Hypotheses of hydraulic factors

For analysis of hydraulic factors, a study boundary [Figure 48] is defined from the test table.

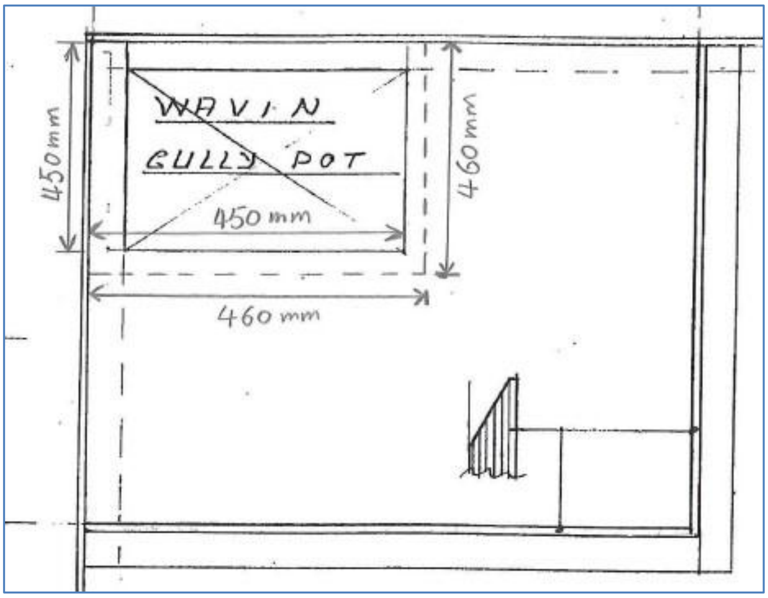

Figure 48 - Study boundary for theoretical analysis

From Figure 48, study boundary is within dotted line. The boundary is 100mm to our gully pot. We got the width of study boundary 'b' equals to 920 mm.

The experiment results give flow capacity 'Q', study boundary width 'b', and the water level on the test table 'h', the water velocity 'v' can be solved by v = Q/b*h.

There are several hypotheses for the water flow patterns on the testing table:

◆ **The first hypothesis:**

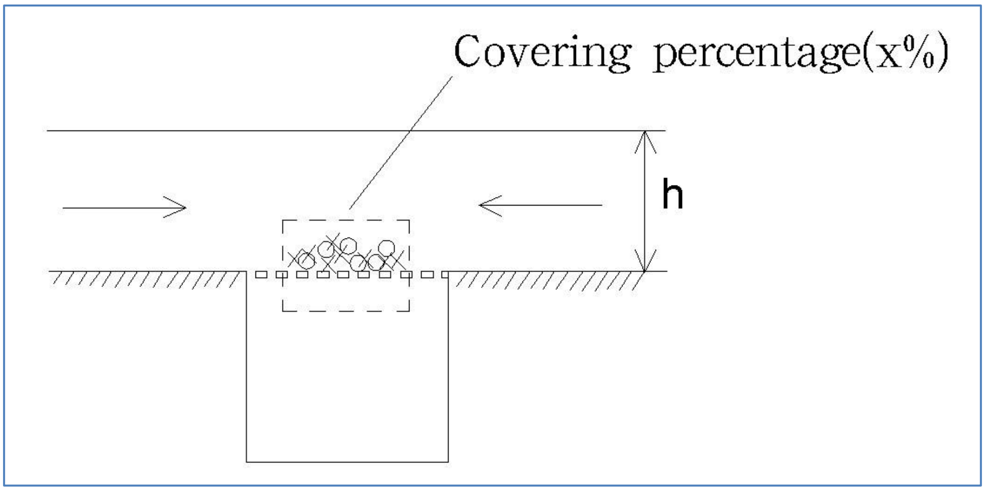

Figure 49 – The first hypothesis for the pattern of water flow on the testing table

For this hypothesis, it is like a submersion situation. Based on Bernoulli's equation, the expected reference equation for water going through the grating is:

$$v_r = \sqrt{2gh} \quad [1]$$

$$Q_r = \sqrt{2gh} * A * (1\text{-}x\ \%) * \eta \quad [2]$$

The area of the cover is 'A' and the original opening percentage of the cover is 'η'. The visual covering percentage of grating (Figure 49) during different flow capacity is x%.

For example: for following figure, the covering percentage is around 40%

Figure 50 – The grating covering percentage around 40%

◆ **The second hypothesis:**

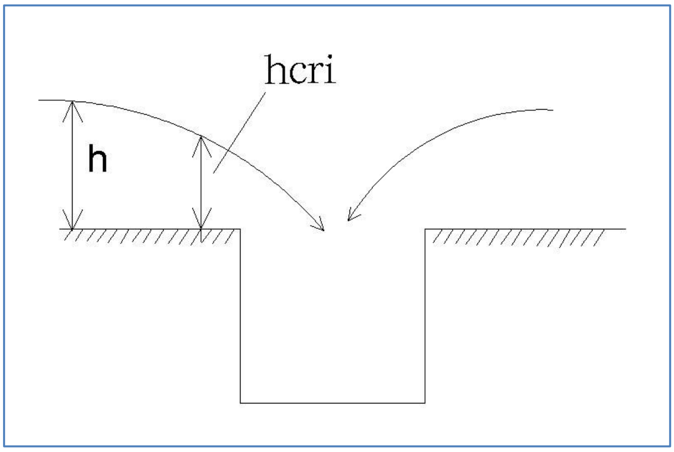

Figure 51 – The second hypothesis for the pattern of water flow on the testing table

For this hypothesis, water goes into gully pot without samples, the observed water level (h) on the testing table is different from the critical water level ($h_{Critical}$), and the expected reference equation:

$$v_{Critical} = \sqrt{g\, h_{Critical}} \quad [3]$$

Q = c* $v_{Critical}$* $h_{Critical}$; (c is the perimeter of the grating) [4]

For this kind of flow pattern, h_{obs} is measured within study area, $h_{Critical}$ is just close to the opening of gully pot. Since here the Froude Number is 1, which means $F_r = \frac{v_{Critical}}{\sqrt{g\, h_{Critical}}} = 1$. So the relation between h_{obs} and $h_{Critical}$ is expected as $h_{obs} > h_{Critical}$.

- **The third hypothesis:**

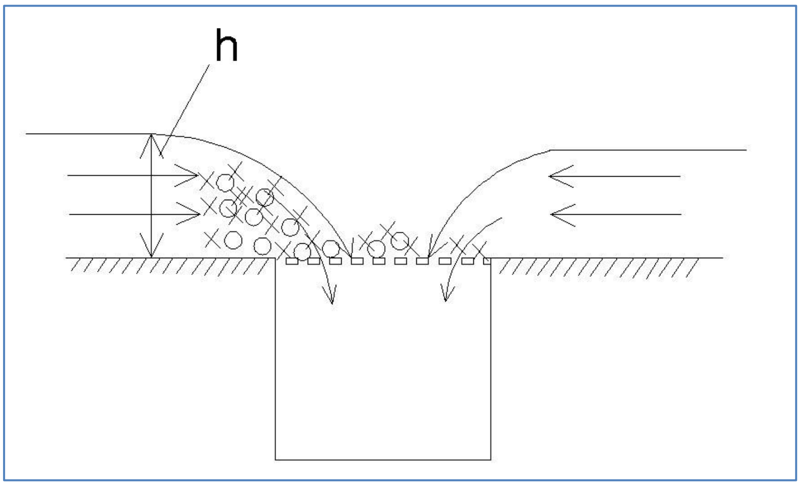

Figure 52 – The third hypothesis for the pattern of water flow on the testing table

For this flow pattern, notice the water flow goes through the samples on the testing table, which will be affected by resistance from samples. Due to theoretical analysis, assumes an ideal model as follow.

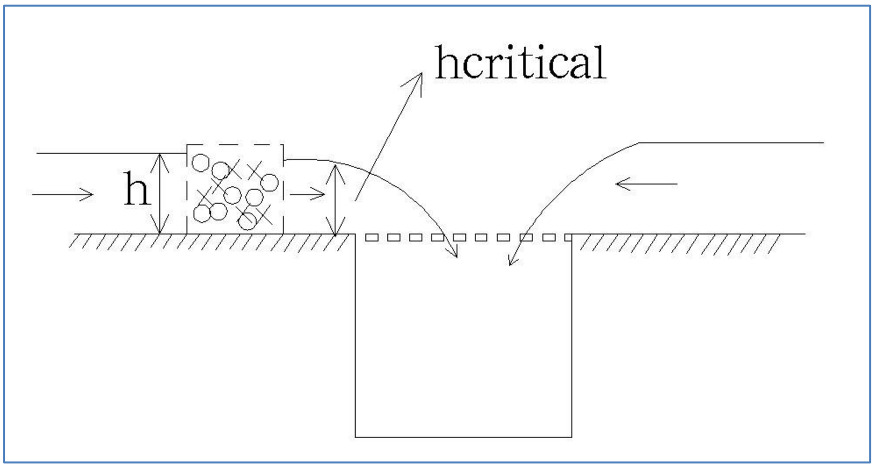

Figure 53 – The ideal model for the third hypothesis

Assume the water flow close to the grating has the same $h_{Critical}$ as mentioned in the second hypothesis. Observed water level h is measured before water go through the samples. There is a pressure difference ΔP causing by water level difference, which is due to the resistance from samples. The expected equation will be:

$\Delta P = \rho * g * \Delta h = \xi * v^2$ [5]

$v = Q/b*h$ [6]

Here ξ is a coefficient which relates to the intensity of the samples on the testing table, so we could consider ξ is also relate to the resistance from samples to water flow. The v is the mean water velocity on the testing table.

◆ **The fourth hypothesis:**

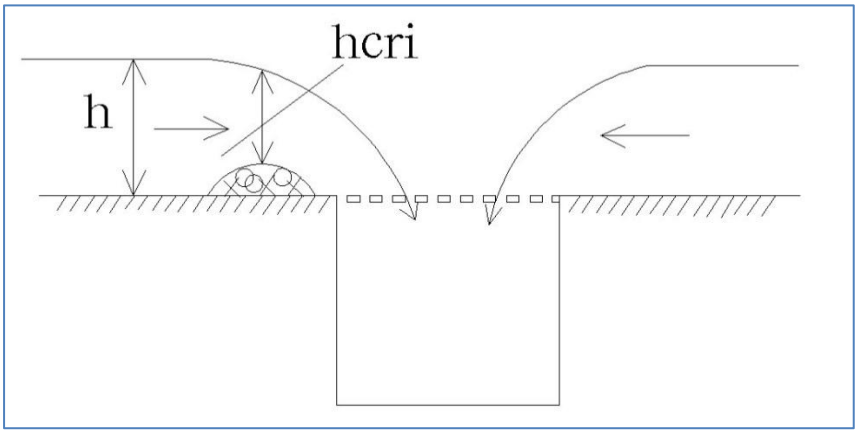

Figure 54 – The fourth hypothesis for the pattern of water flow on the testing table

For this hypothesis, the critical water level is above the sediment, so the $h_{Critical}$ is different from the second hypothesis.

5 Experimental Results

After the laboratorial testing, the monitoring results and calculated results are collected.

5.1 Test with sack inside gully pot

① Test with trapezoid-shaped (alternative 1) inside the gull pot with 2.5 buckets of samples [the details could be found in Appendix P77 to P79]:

Figure 55 – Testing of alternative 1 without cover

The results:

Type of alternatives	**Alternative 1 (trapezoid-shape sack)**		
Type and amount of samples	Put 2.5 buckets of samples inside the sack at the beginning		
Flow capacity [dm^3/s]	Duration [min]	Results	Remarks
2.0	10		
4.0	10		
6.0	10		
8.0	10		
8.5		Completely overloaded	

Table 2 - Results of testing alternative 1 without cover

② Test with cone-shaped (alternative 2) inside the gull pot with 2.5 buckets of samples [the details could be found in Appendix P75 to P77]:

Figure 56 - Testing of alternative 2 without cover

The results:

Type of alternatives	Alternative 2 (cone-shaped sack)		
Type and amount of samples	Put 2.5 buckets of samples inside the sack at the beginning		
Flow capacity [dm^3/s]	Duration [min]	Results	Remarks
2.0	10		
4.0	10		
6.0	10		
8.0	10		
8.5		Completely overloaded	

Table 3 - Results of testing alternative 2 without cover

From the results of testing alternative 1 and alternative 2, the behavior of each alternative in the gully pot is almost the same, although from the picture you could find the volume of alternative 2 should be smaller than alternative 1.

For the inside sacks, results show they are not the main factor to influence the inside capacity of gully pot. But for reducing the frequency of cleaning the gully pot, a bigger volume of the sack will be expected.

5.2 Test without alternatives inside gully pot

Test without alternatives inside gully pot with 1 bucket of samples [the details could be found in Appendix P84 to P86]:

Figure 57 - Test without any alternatives

The results:

Type of alternatives	Without any alternatives		
Type and amount of samples	Put 1 bucket of sample inside gully pot		
Flow capacity [dm^3/s]	Duration [min]	Results	Remarks
2.0	10	Water level inside gully pot is about 42cm	
3.0	3	Gully pot is clogged	Few pieces of samples went out of outlet pipe

Table 4 - Results of testing without any alternatives

From the results, it shows the outlet pipe is totally clogged when the flow capacity is up to 3.0l/s. In the end, there are about 10 pieces of sample come out of the outlet pipe.

After analyzing the results, it implies the clogged moment is not depend on how much amount of the samples inside the gully pot and how long is the flush time. Since the height of the outlet in the gully pot is about 30cm [Figure 58], if there are enough samples suspended in the water and enough flow to let the water level above around 45cm in the gully pot, the outlet will be clogged.

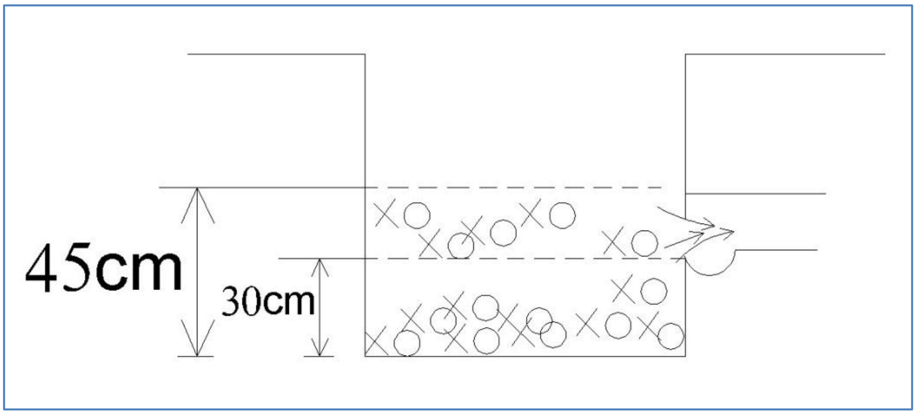

Figure 58 - Samples clogging in the gully pot

5.3 Test with different kinds of covers

For the testing of grating designs, original cover, alternative 3 and alternative 4 is tested separately with different amount of test samples.

Original cover	Alternative 3	Alternative 4
		

Table 5 - Different grating designs

5.3.1 Test of original grating

The results for testing the **original grating** with **1 bucket** of test sample [the details could be found in Appendix P97 to P98]:

Type of alternatives	with **original cover**		
Type and amount of samples	Start with **1 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	15%	2.09
4.0	10	40%	3.39
6.0	10	45%	4.84
8.0	10	80%	5.69
9.0	10	90%	7.99

Table 6 - Data for testing original grating with 1 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.021	0.10	15%
0.004	0.034	0.13	40%
0.006	0.048	0.14	45%
0.008	0.057	0.15	80%
0.009	0.080	0.12	90%

Table 7 - The calculated results for testing original grating with 1 bucket test samples

The results for testing the **original grating** with **2 bucket** of test sample [the details could be found in Appendix P99 to P101]:

Type of alternatives	with **original cover**		
Type and amount of samples	Start with **2 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	25%	2.44
4.0	10	60%	4.28
6.0	10	95%	5.39
8.0	10	99%	6.49
9.0	10	99%	8.84

Table 8 - Data for testing original grating with 2 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.024	0.09	25%
0.004	0.043	0.10	60%
0.006	0.054	0.12	95%
0.008	0.065	0.13	99%
0.009	0.088	0.11	99%

Table 9 - The calculated results for testing original grating with 2 bucket test samples

The observed results for testing **original grating**:

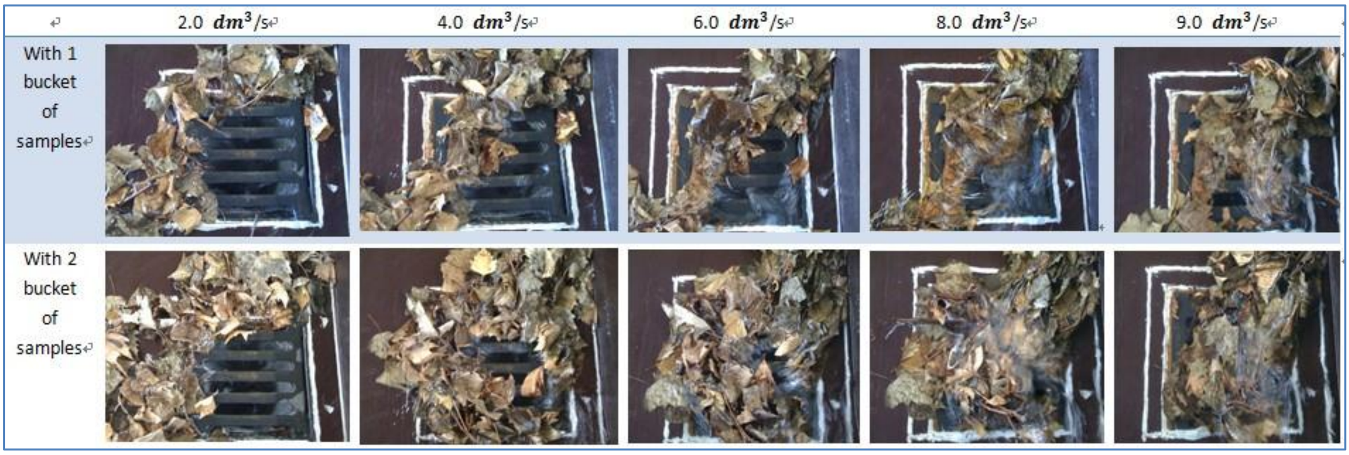

Figure 59 - The observed results for testing original grating (see cd-rom/ testing videos/ testing original cover.wmv)

In the end of test, for both two conditions, there are plenty samples remained inside the gully pot:

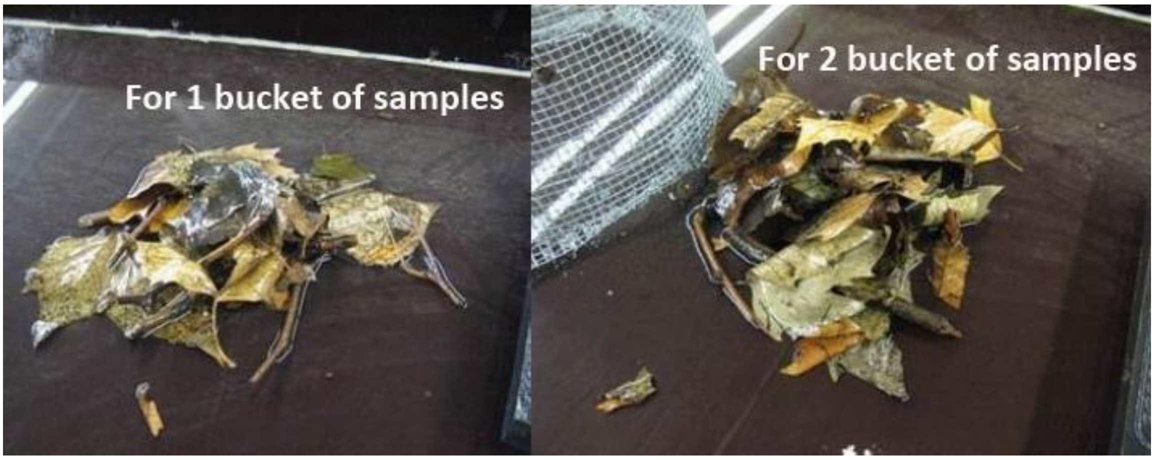

Figure 60 - Samples remained in the gully pot for testing the original grating

5.3.2 Test of alternative 3

The results for testing the **alternative 3** with **1 bucket** of test sample [the details could be found in Appendix P88 to P90]:

Type of alternatives	with **alternative 3** and cone-shape sack		
Type and amount of samples	Start with **1 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	10%	1.94
4.0	10	35%	3.39
6.0	10	50%	4.49
8.0	10	80%	5.09
9.0	10	90%	7.52

Table 10 - Data for testing alternative 3 with 1 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.019	0.112	10%
0.004	0.034	0.128	35%
0.006	0.045	0.145	50%
0.008	0.051	0.171	80%
0.009	0.075	0.130	90%

Table 11 - The calculated results for testing alternative 3 with 1 bucket test samples

The results for testing the **alternative 3** with **2 bucket** of test sample [the details could be found in Appendix P91 to P92]:

Type of alternatives	with **alternative 3**		
Type and amount of samples	Start with **2 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	15%	2.64
4.0	10	30%	5.14
6.0	10	60%	6.44
8.0	10	90%	7.29
9.0	10	98%	7.74

Table 12 - Data for testing alternative 3 with 2 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.026	0.08	15%
0.004	0.051	0.09	30%
0.006	0.064	0.10	60%
0.008	0.073	0.12	90%
0.009	0.077	0.13	98%

Table 13 - The calculated results for testing alternative 3 with 2 bucket test samples

The observed results for testing **alternative 3**:

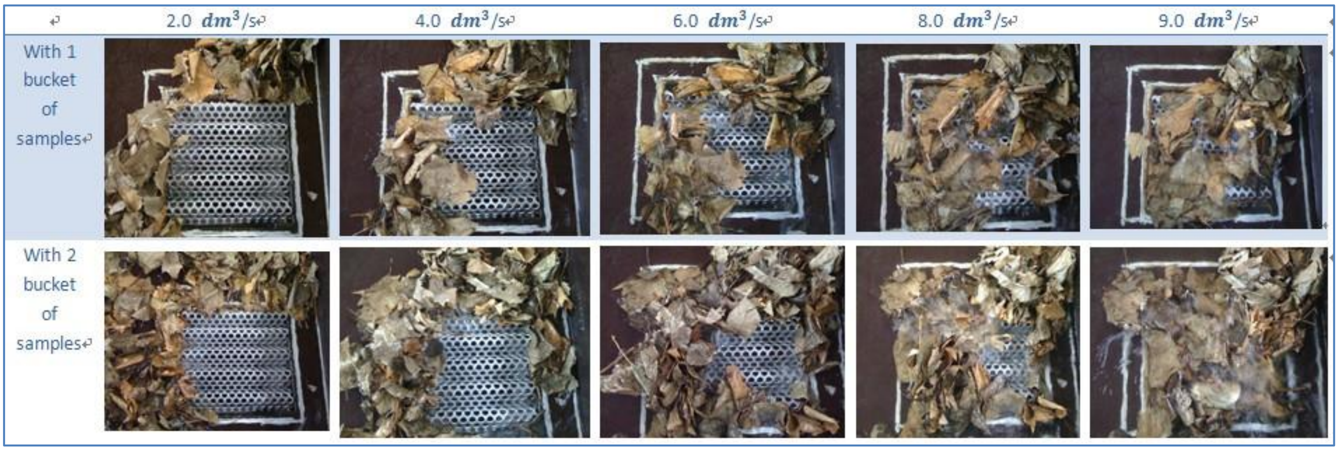

Figure 61 - The observed results for testing alternative 3 (see cd-rom/ testing videos/ testing Alternative 3.wmv)

In the end of test, for both two conditions, there are very limited samples remained inside the gully pot:

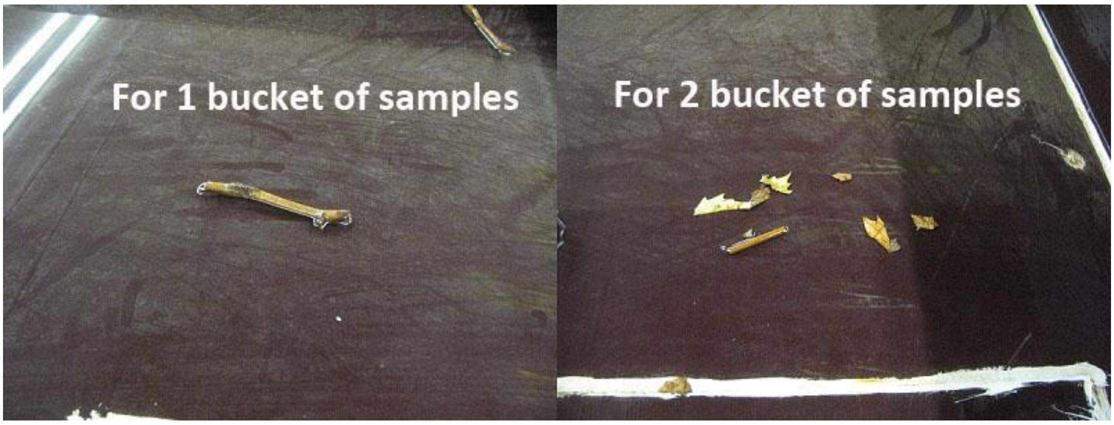

Figure 62 - Samples remained in the gully pot for testing alternative 3

5.3.3 Test of alternative 4

The results for testing the **alternative 4** with **1 bucket** of test sample [the details could be found in Appendix P93 to P94]:

Type of alternatives	with **alternative 4**		
Type and amount of samples	Start with **1 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	5%	2.84
4.0	10	20%	4.44
6.0	10	45%	5.49
8.0	10	80%	6.52
9.0	10	90%	6.94

Table 14 - Data for testing alternative 4 with 1 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.028	0.08	5%
0.004	0.044	0.10	20%
0.006	0.055	0.12	45%
0.008	0.065	0.13	80%
0.009	0.069	0.14	90%

Table 15 - The calculated results for testing alternative 4 with 1 bucket test samples

The results for testing the **alternative 4** with **2 bucket** of test sample [the details could be found in Appendix P95 to P97]:

Type of alternatives	with **alternative 4**		
Type and amount of samples	Start with **2 bucket** of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	5%	3.040
4.0	10	35%	5.390
6.0	10	50%	6.990
8.0	10	85%	7.790
9.0	10	95%	9.440

Table 16 - Data for testing alternative 4 with 2 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.030	0.07	5%
0.004	0.054	0.08	35%
0.006	0.070	0.09	50%
0.008	0.078	0.11	85%
0.009	0.094	0.10	95%

Table 17 - The calculated results for testing alternative 4 with 2 bucket test samples

The observed results for testing **alternative 4**:

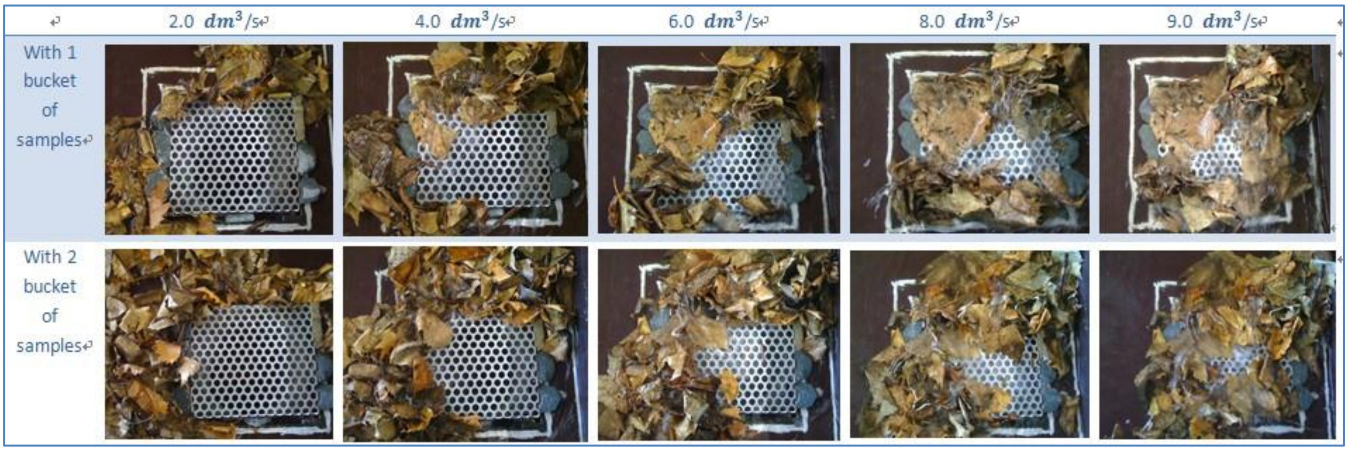

Figure 63 - The observed results for testing alternative 4 (see cd-rom/ testing videos/ testing Alternative 4.wmv)

In the end of test, for the first condition, there is nothing remained inside the gully pot, and for the second condition, there is just some debris of leaves remained inside gully pot:

Figure 64 - Samples remained in the gully pot for testing alternative 4

5.4 Test of the new gully pot

5.4.1 Test of the new gully pot with cover

The results for testing the **new gully pot (with cover)** with **1 bucket** of test sample [the details could be found in Appendix P102 to P104]:

Type of alternatives	New gully pot with cover		
Type and amount of samples	Start with 1 bucket of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	5%	1.79
4.0	10	20%	3.54
6.0	10	45%	4.37
8.0	10	50%	4.59
9.0	10	60%	5.29

Table 18 - Data for testing new gully pot (with cover) with 1 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.018	0.12	5%
0.004	0.035	0.12	20%
0.006	0.044	0.15	45%
0.008	0.046	0.19	50%
0.009	0.053	0.19	60%

Table 19 - The calculated results for testing new gully pot (with cover) with 1 bucket test samples

The results for testing the **new gully pot (with cover)** with **2 bucket** of test sample [the details could be found in Appendix P105 to P107]:

Type of alternatives	New gully pot with cover		
Type and amount of samples	Start with 2 bucket of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10	10%	2.34
4.0	10	40%	4.09
6.0	10	50%	4.54
8.0	10	80%	6.14
9.0	10	95%	6.29

Table 20 - Data for testing new gully pot (with cover) with 2 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	v (m/s)	Visual covering percentage (%)
0.002	0.023	0.09	10%
0.004	0.041	0.11	40%
0.006	0.045	0.14	50%
0.008	0.061	0.14	80%
0.009	0.063	0.16	95%

Table 21 - The calculated results for testing new gully pot (with cover) with 2 bucket test samples

The observed results for testing **new gully pot (with cover)**:

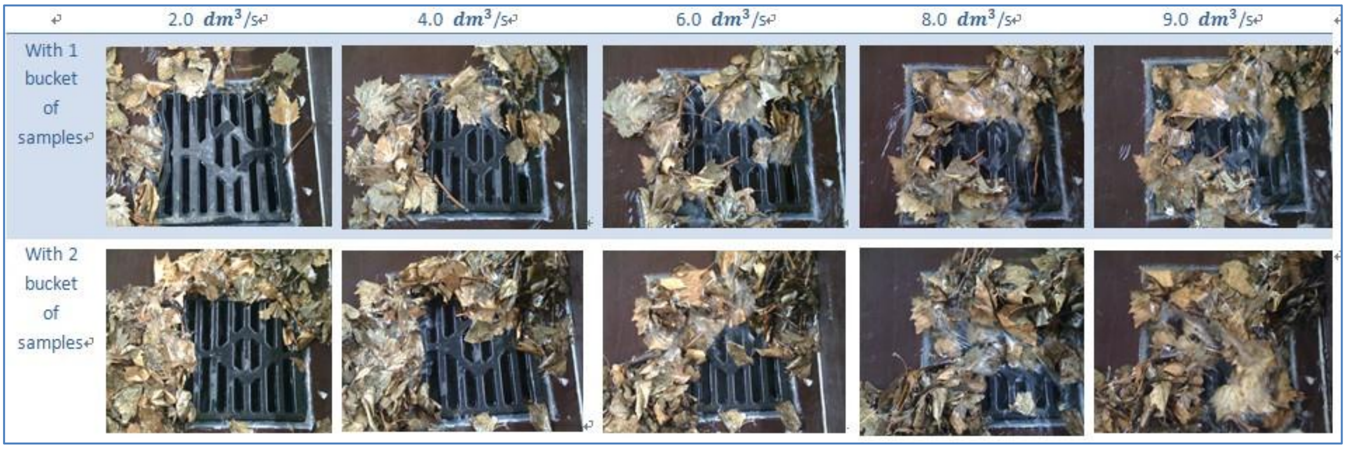

Figure 65 - The observed results for testing new gully pot [with cover] (see cd-rom/ testing videos/ testing new gully pot.wmv)

In the end of test, for both two conditions, there are plenty samples remained inside the gully pot:

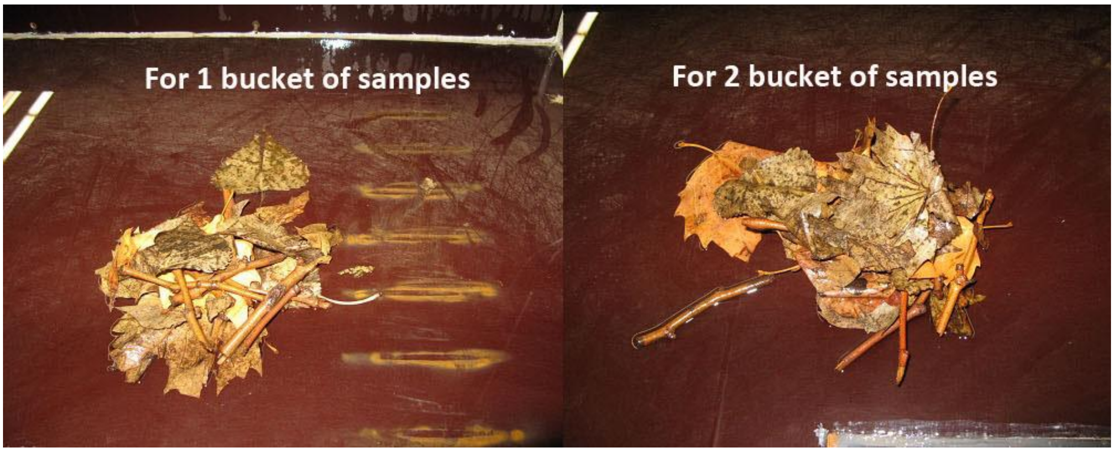

Figure 66 - Samples remained in the gully pot for testing new gully pot (with cover)

5.4.2 Test of the new gully pot without cover

The results for testing the **new gully pot (without cover)** with **1 bucket** of test sample [the details could be found in Appendix P107 to P108]:

Type of alternatives	**New gully pot without cover**		
Type and amount of samples	Start with 1 bucket of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10		1.09
4.0	10		1.69
6.0	10		2.09
8.0		overflowed	

Table 22 - Data for testing new gully pot (without cover) with 1 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	q (m^2/s)	v (m/s)	Visual covering percentage (%)
0.002	0.011	0.004	0.20	
0.004	0.017	0.009	0.26	
0.006	0.021	0.013	0.31	
0.008				overflowed

Table 23 - The calculated results for testing new gully pot (without cover) with 1 bucket test samples

The results for testing the **new gully pot (without cover)** with **2 bucket** of test sample [the details could be found in Appendix P109 to P110]:

Type of alternatives	**New gully pot without cover**		
Type and amount of samples	Start with 2 bucket of samples on the test table		
Flow capacity [dm^3/s]	Duration [min]	Results (covering percentage)	Water level on the test table [cm]
2.0	10		1.17
4.0	10		1.64
6.0	10		2.12
8.0		overflowed	

Table 24 - Data for testing new gully pot (without cover) with 2 bucket test samples

The calculated results:

Q (m^3/s)	h (m)	q (m^2/s)	v (m/s)	Visual covering percentage (%)
0.002	0.012	0.004	0.37	
0.004	0.016	0.009	0.53	
0.006	0.021	0.013	0.62	
0.008				overflowed

Table 25 - The calculated results for testing new gully pot (without cover) with 2 bucket test samples

The observed results for testing **new gully pot (without cover)**:

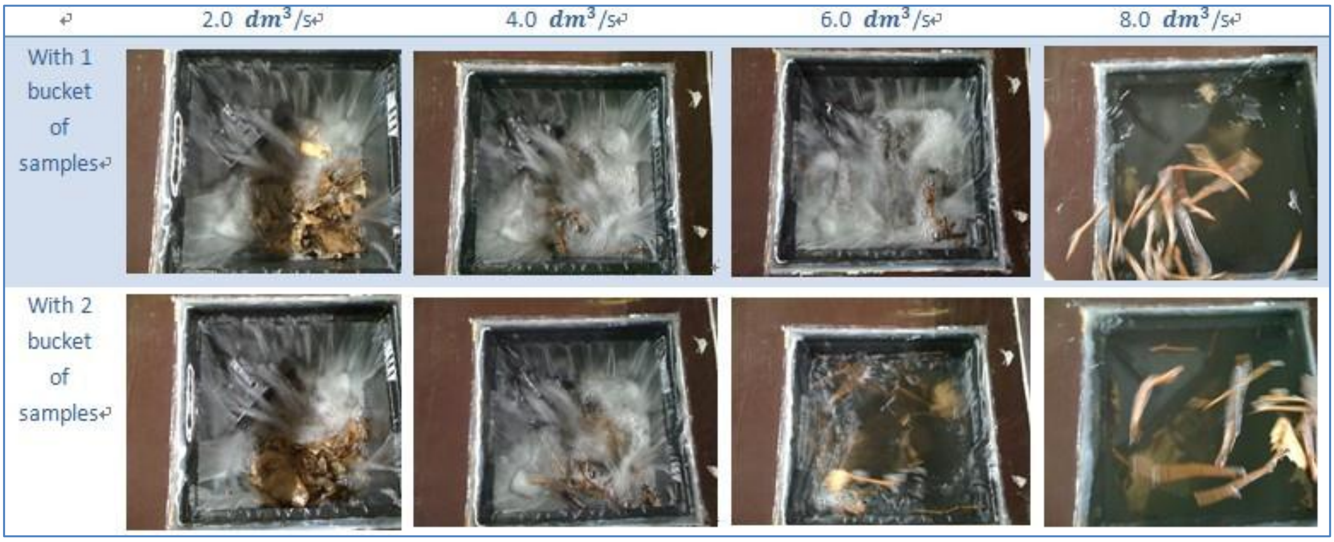

Figure 67 - The observed results for testing new gully pot (without cover)

6 Discussion

6.1 Observed flow process

6.1.1 Observations

In the lab experiment, the flow patterns change during different flow capacities.

At the start of the experiment, the water flow goes through the samples on the testing table and pushes samples towards to the grating (during the flow capacity is around 2l/s, 4l/s):

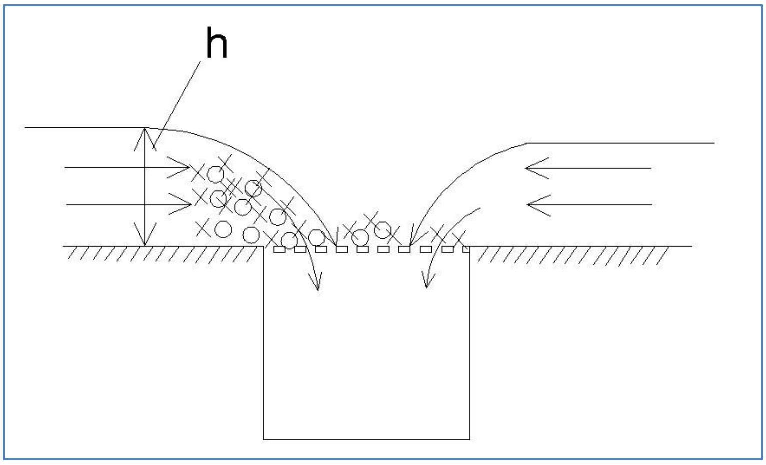

Figure 68 – Flow pattern during low flow capacity

Samples are then flushed to the top of the grating when the flow capacity keeps increasing (during the flow capacity is around 6l/s, 8l/s):

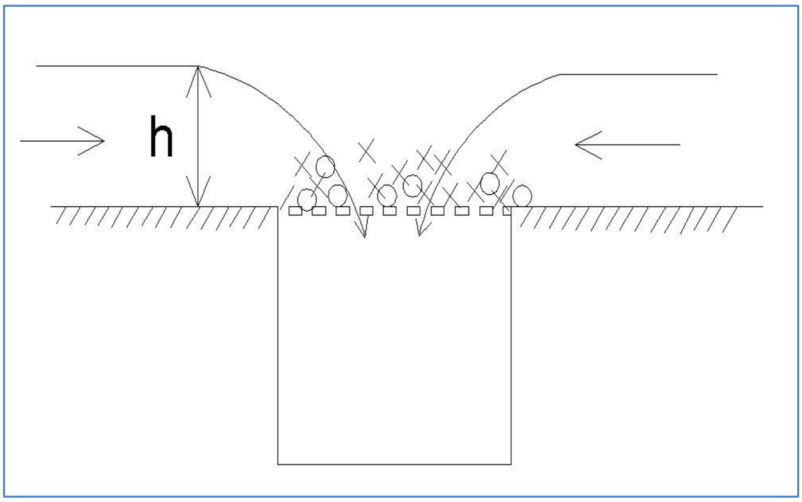

Figure 69 – Flow pattern during flow capacity keeps rising

At the end of the test, the water flow shows submersion behavior which means that the gully pot has already overflowed (during the flow capacity is around 8l/s, 9l/s):

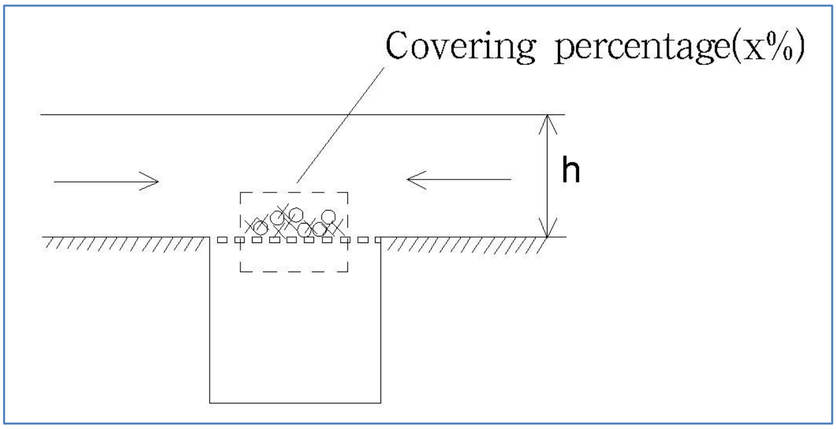

Figure 70 – Flow pattern during submersion situation

The figures shown above give us a general picture of the different water flow patterns on the testing table under different flow capacity circumstance.

6.1.2 Observed testing results

The lab experiment gave the observed results for different alternatives. The comparisons are shown in terms of figures.

- **Comparison of observed results between water level 'h' and flow capacity 'Q':**

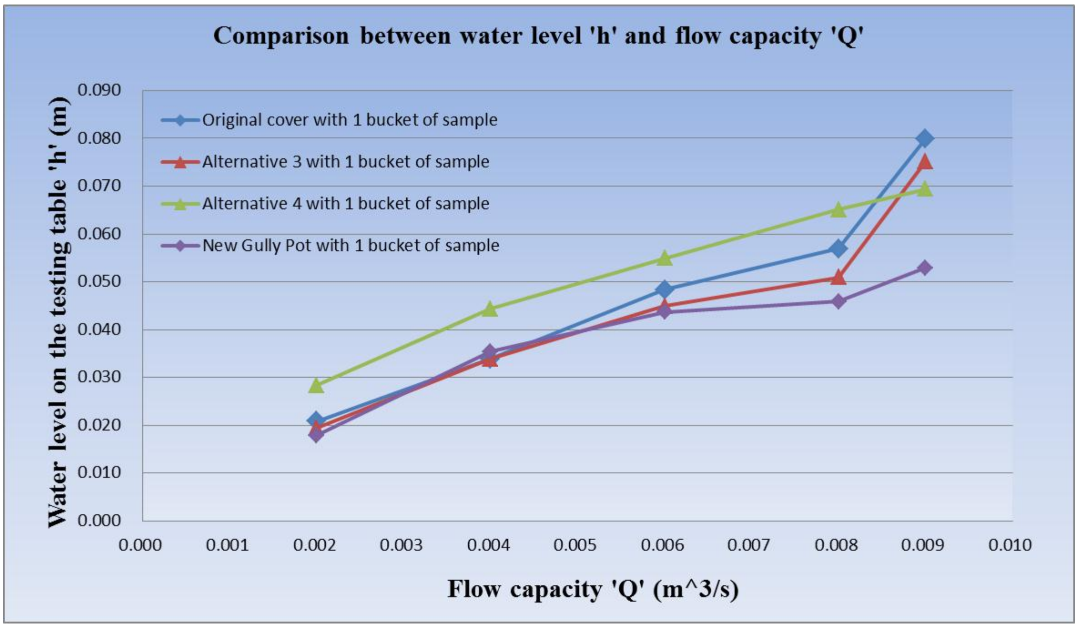

Figure 71 - Comparison of different alternatives between water level 'h' on the testing table and flow capacity 'Q' with 1 bucket test samples

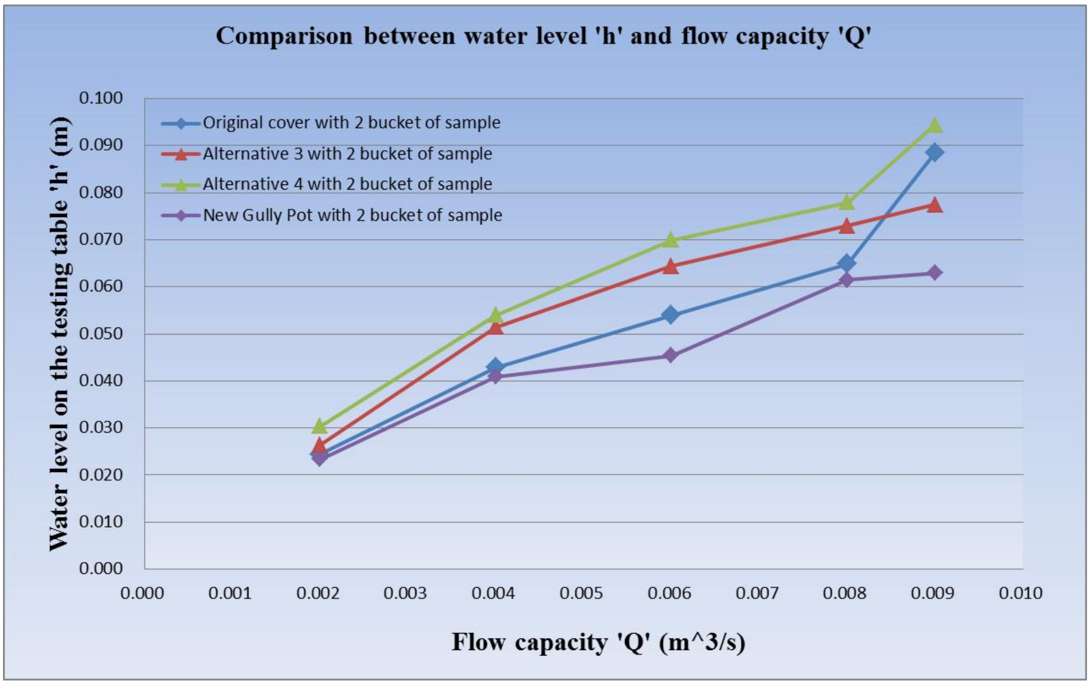

Figure 72 - Comparison of different alternatives between water level 'h' on the testing table and flow capacity 'Q' with 2 bucket test samples

From the figures given above, the results for the three alternatives which are based on the first gully pot show almost the same trend. The water level increases as the flow capacity rises. The Alternative 4 has the highest water level because it keeps most of the samples accumulated around the grating, and this causes more opening space on the grating during different flow capacities.

There are inflexion points at the end of several lines in the figures, which means that the water level on the testing table increases rapidly from these points. This is especially the case under high flow capacity, which means that the gully pot will have totally overflowed.

For the first figure, the inflexion points are on the blue line (original cover) and the red line (Alternative 3) when the green line (Alternative 4) goes smoothly. This implies there was no severe clogging problem for Alternative 4 under high flow capacity. Additionally, the original cover had a higher water level than Alternative 3 when testing with 1 bucket of samples.

For the second figure, there was clear change at the end of red line (Alternative 3) and the green line (Alternative 4). The inflexion points are on the blue line (original cover) and the green line (Alternative 4) this time. The Alternative 3 goes smoothly which means that it has better performance under high flow capacity when testing 2 buckets of samples. In addition this time, Alternative 3 has a higher water level than the original cover, which is because alternative 3 kept most samples around the grating, thus causing water level on the testing table to increase.

With the new gully pot, since there is a bigger size of grating and tank, it is not fair to directly compare it with the other alternatives which are based on the original gully pot. However, both figures show that the water level for new gully pot is lower than in the case of the others, especially during high flow capacity. The explanation for this probably lies in the fact that the new gully pot has a rather bigger grating which causes the covering percentage of the grating and the amount of samples remaining on the table to be less.

- **Comparison of observed results between visual covering percentage and flow capacity 'Q':**

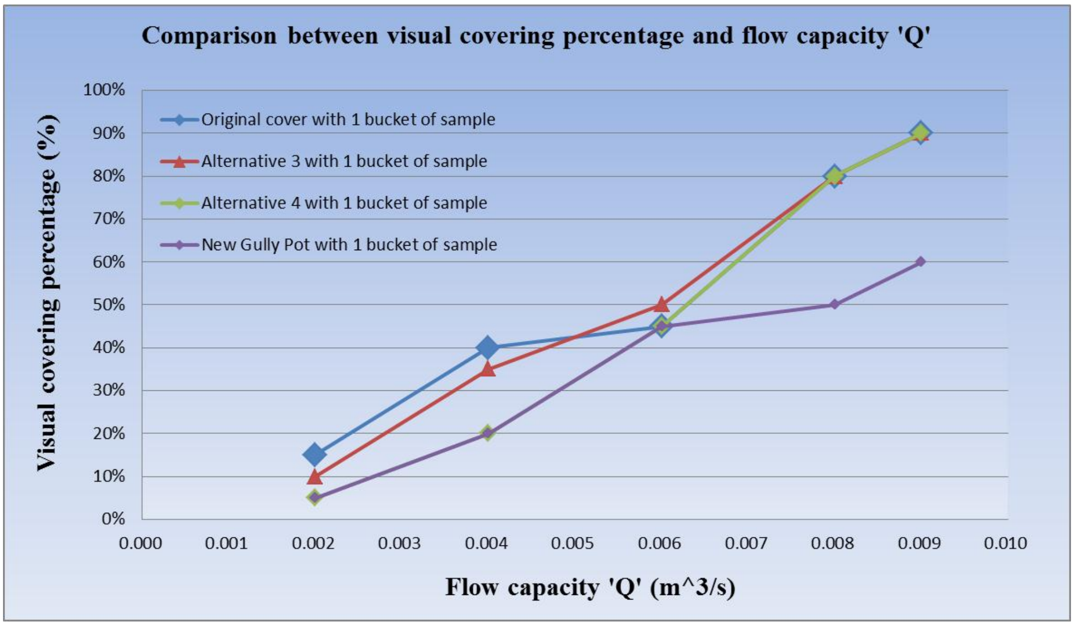

Figure 73 - Comparison of different alternatives between visual covering percentage and flow capacity 'Q' with 1 bucket of samples

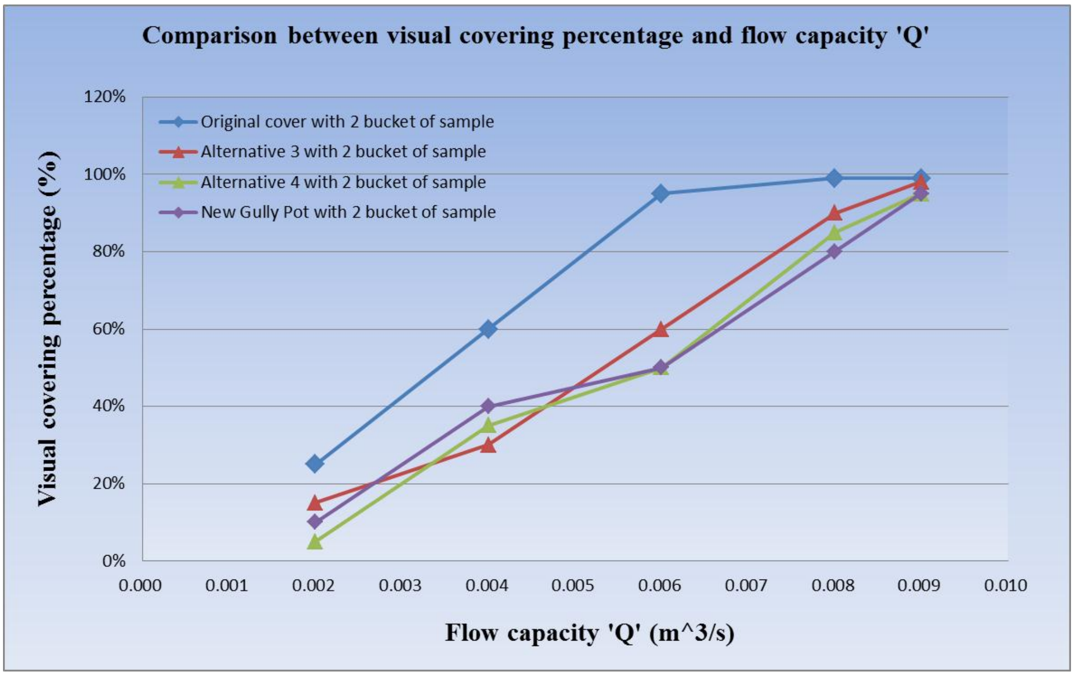

Figure 74 - Comparison of different alternatives between visual covering percentage and flow capacity 'Q' with 2 bucket of samples

The figures above provide a comparison between the visual covering percentage and flow capacity. Results show that Alternative 4 and the new gully pot have a lower covering percentage. The original cover has a higher covering percentage when compared to the other alternatives. Alternative 3 demonstrates average performance. In the first figure, the new gully pot has the best performance. The covering percentage for new gully pot ends up to be 60% below the highest flow capacity 9 l/s. In the second figure, the original cover has the worst performance. It has quite a high covering percentage and even starts at 6l/s. All the results show that the covering percentage increases as the flow capacity increases.

- **Comparison of observed results between water level ‘h’ and visual covering percentage:**

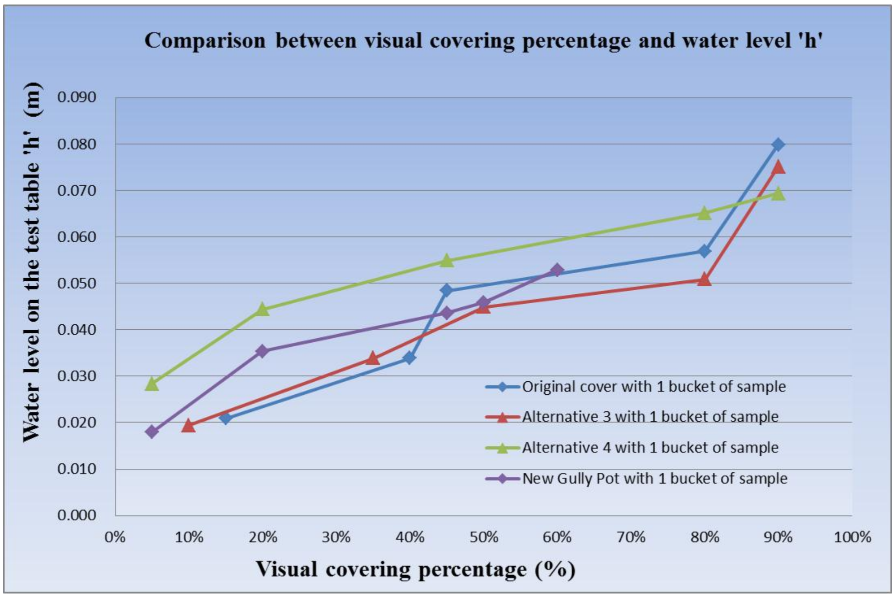

Figure 75 - Comparison of different alternatives between water level 'h' on the testing table and visual covering percentage with 1 bucket test samples

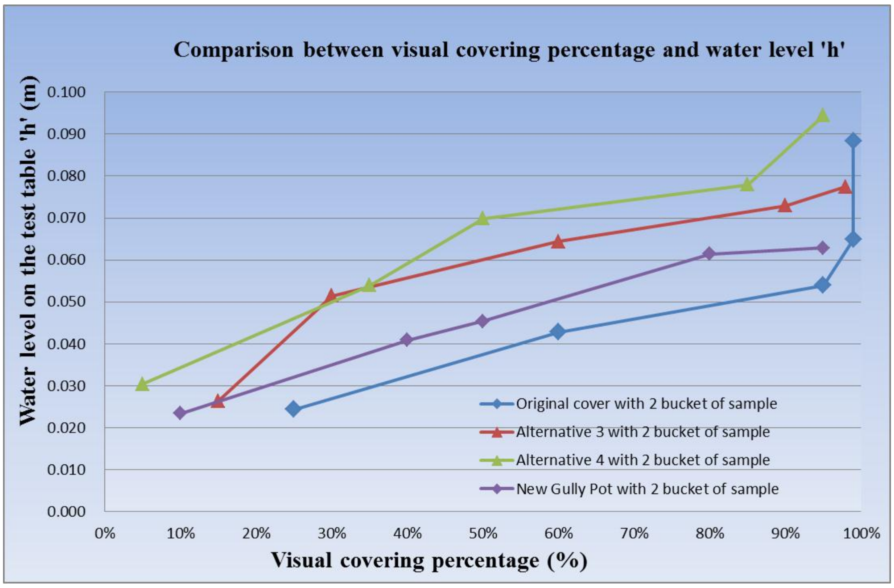

Figure 76 - Comparison of different alternatives between water level 'h' on the testing table and visual covering percentage with 2 bucket test samples

The figures given above show the relationship between the water level and the covering percentage of the grating. Alternative 4 still has a higher water level because it keeps most samples around the grating.

For the first figure which was tested with 1 bucket of samples. The results show that Alternative 4 goes smoothly when the inflexion points appears on the blue line (original cover) and the red line (Alternative 3) which implies that overflow happened at the backend under high flow capacity. Actually, the blue line (original cover) has two inflexion points, the first of which shows when the flow capacity turned to 6 l/s, and the water level has a jump which is caused by the covering percentage increasing rapidly at this point. The second one is at the backend under a flow capacity that is 9 l/s.

For the second figure which is tested with 2 buckets of samples, which the inflexion points appear at the backend of the green line (Alternative 4) and the blue line (original cover) when the red line (Alternative 3) goes smoothly. This result is the same as the comparison between water level and water capacity (Figure 72). So it shows that Alternative 3 has better performance with bigger amounts of samples. Additional, the original cover has a rather higher covering percentage even starting at 6 l/s, which is almost close to 95%.

Out of all these alternatives, the new gully pot still has a rather low water level. The covering percentage for the new gully pot stopped at 60% when the others ended at around 90% during testing with 1 bucket of samples. The new gully pot also has a lower covering percentage when testing with 2 buckets of samples. The bigger size gives new gully pot a great advantage.

6.1.3 Conclusions from the observations

- Alternative 3 and Alternative 4 reduce the covering percentage of grating during the lab testing, especially under high flow capacity;

- Alternative 4 performances well during test with 1 bucket of samples. The line (Figure 71) for Alternative 4 goes smoothly and without water level sharp increasing in the end of testing.

- Alternative 3 performances well during test with 2 bucket of samples. The line (Figure 72) for Alternative 3 goes smoothly and with no water level jump during high flow capacity.

- Alternative 4 and Alternative 3 cause a rather high water level on the testing table, especially Alternative 4.This is because these two alternatives keep samples around the grating instead of covering it, which leave more opening on the grating, but causing a rather high water level.

- Original cover has a rather low water level under low flow capacity. But it is easy to be clogged under rather high flow capacity which leading a high water level. Additionally, samples are more easy go through the original cover, when there is almost nothing going through Alternative 3 and Alternative 4.

- The new gully pot has a quite good performance during lab testing. Since the grating and inside tank for new gully pot is bigger than the other alternatives, it is obvious not easy to be clogged.

6.2 The flow pattern hypotheses

Several hypotheses for the flow patterns during the lab testing were formulated in Chapter 4. The next part involving observed behavior and expected behavior based the various hypotheses will now be discussed. The fourth hypothesis (Figure 54) did not occur in our lab experiment, which will not be further discussed.

6.2.1 Lab testing without samples on the testing table

Hypothesis 2 (Figure 51) is expected to explain water pattern of testing without samples on the testing table. The expected equation for hypothesis 2 is [3] and [4], here we have:

$$\mathrm{Q}_{obs} = \mathrm{c}{*}\, v_{Critical} {*}\, h_{Critical} \qquad [7]$$

Here, c= 1.42m which is the perimeter of the grating for the new gully pot. The lab experiment data gives observed flow capacity Q_{obs} and observed water level h_{obs}. After substitution of the expected equation:

$$\mathrm{Q}_{obs} = \mathrm{c}{*}\sqrt{g\, h_{Critical}} {*}\, h_{Critical} \qquad [8]$$

The $h_{Critical}$ can be computed by the observed flow capacity Q_{obs}. With computed results (Table 26), the relation between h_{obs} and the $h_{critical}$ can be found.

Since the original gully pot is tested without grating at beginning of the lab experiment when the device for measuring water level hasn't set. So the data for h_{obs} of original gully pot is missing. The comparison between h_{obs} and $h_{critical}$ is only for the new gully pot.

Q_{obs} (m^3/s)	$h_{critical}$ (m)
0.002	0.006
0.004	0.009
0.006	0.012
0.008	0.015
0.009	0.016

Table 26 - The computed result $h_{critical}$ for testing new design gully pot without cover

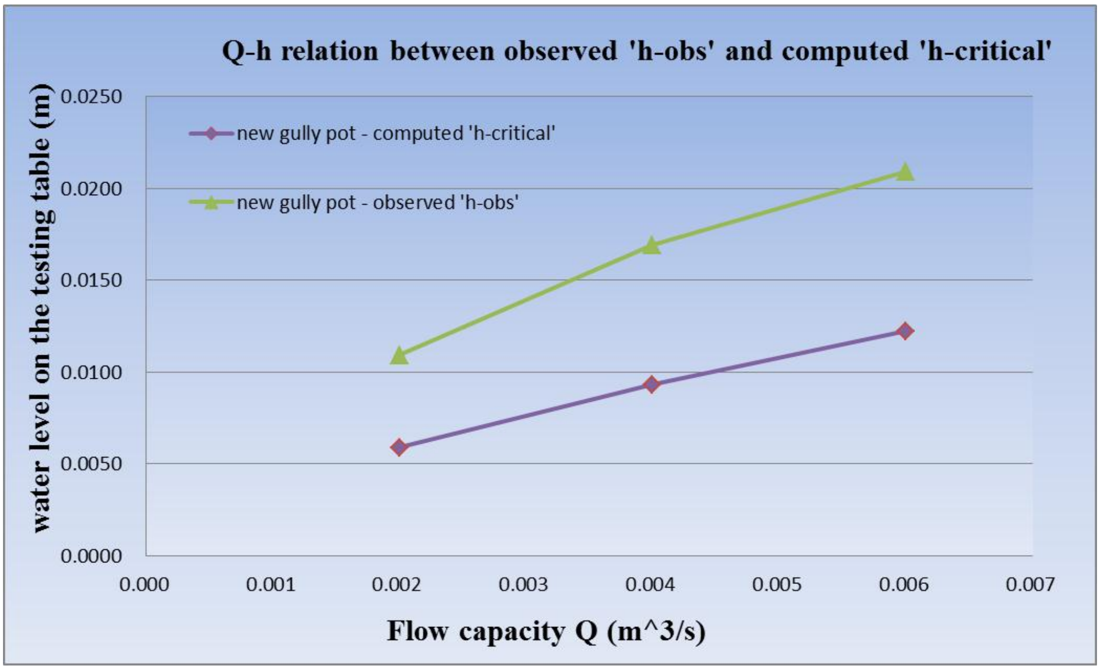

Figure 77 - The Q-h relation for h_{obs} and $h_{critical}$ for new gully pot

Since in real laboratorial test, the new gully pot is totally overflowed when the flow capacity is around 8 l/s, so three points which represented 2 l/s, 4 l/s and 6 l/s are shown in the figure above. The result shows $h_{obs} > h_{critical}$, which conformed our expected in hypothesis 2.

6.2.2 Lab testing with samples on the testing table

Based on the explanations of different flow patterns for the continuous experimental process (Figure 68, 69 and 70), three assumptions for different stages are considered.

Flow capacity	Flow patterns
2 l/s – 4 l/s	Hypothesis 3
6 l/s – 8 l/s	Transition
8 l/s – 9 l/s	Hypothesis 1

Table 27 – Assumptions of different water flow stages

6.2.2.1 Flow up to 6 l/s

For the first stage, flows below 6 l/s. Assume the hypothesis 3 (Figure 52 and 53) gives the most valid picture of the process. The expected equation (see chapter 4) is [5] and [6].

Observed data gives b is the width of study boundary, h_{obs} is observed water level on the testing table, and Q_{obs} is observed flow capacity.

Water velocity on the testing table could be computed by:

$v_{obs} = Q_{obs} / (b*h_{obs})$ [9]

Water level difference for the ideal model (hypothesis 3) could be calculate by

$\Delta h = h_{obs} - h_{critical}$ [10]

Here $h_{critical}$ is already computed in hypothesis 2 by [8].

For [5], here let ξ =ρ*R. R is the estimate resistance from samples to water flow. After substitution yields:

$R = \xi / \rho = g*(h_{obs} - h_{critical}) / v_{obs}^2$ [11]

The computed results of R for different alternatives as below:

	Original	Alternative 3	Alternative 4	New designed gully pot
Q (m^3/s)	R [-]	R [-]	R [-]	R [-]
0.002	3.21	2.47	9.06	2.00
0.004	3.46	3.46	8.61	4.24
0.006	4.64	3.59	7.10	3.45
0.008	4.19	2.85	6.62	2.12
0.009	10.06	8.21	6.29	2.64

Table 28 – The computed results of R for different alternatives (with 1 bucket of samples)

	Original	Alternative 3	Alternative 4	New designed gully pot
Q (m^3/s)	R [-]	R [-]	R [-]	R [-]
0.002	5.45	7.10	11.33	4.98
0.004	7.62	13.94	16.27	6.85
0.006	6.67	12.03	15.73	3.94
0.008	6.54	9.63	11.98	5.69
0.009	14.01	9.05	17.34	4.75

Table 29 – The computed results of R for different alternatives (with 2 buckets of samples)

The comparisons of results show below:

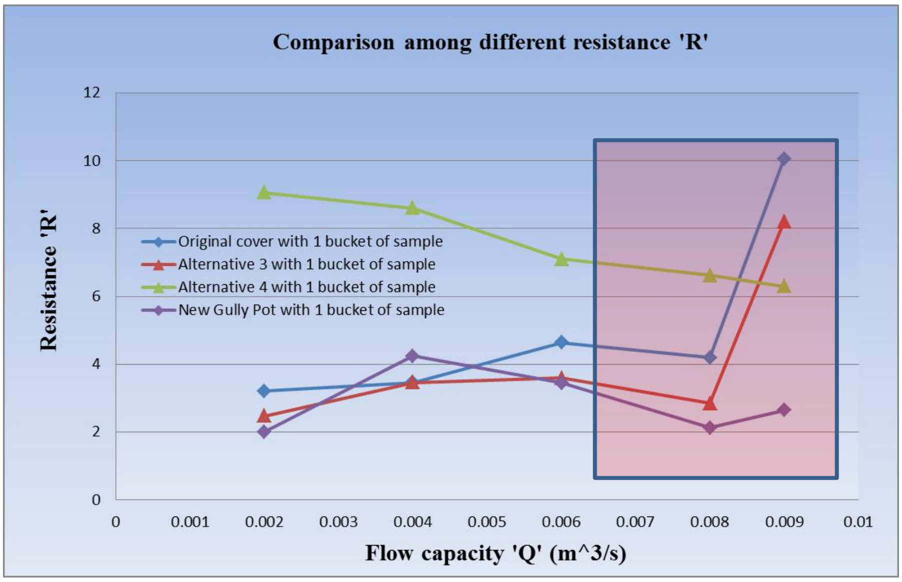

Figure 78 – Comparison between coefficient ‘R’ and flow capacity ‘Q’ (1 buckets of samples)

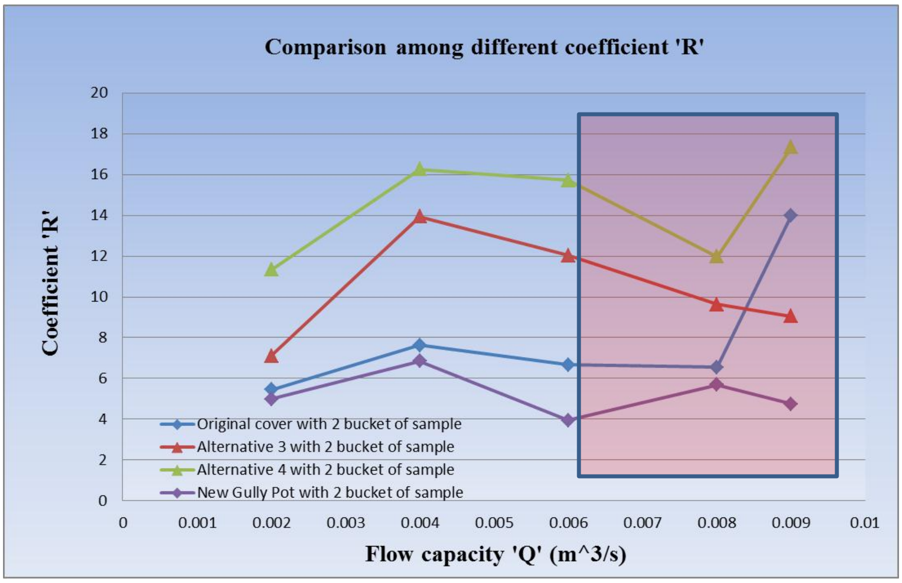

Figure 79 – Comparison between coefficient ‘R’ and flow capacity ‘Q’ (2 buckets of samples)

From the figures given above, the results for testing 2 buckets of samples under flow capacity > 6 l/s (in red box area) and the whole group of results of testing 1 bucket of samples show chaotic behavior. Actually, Figure 59, 61, 63 and 65 show that the flow pattern as water going through samples on the testing table is happened under rather low flow capacity (2l/s, 4l/s, 6l/s), especially when testing with 2 buckets of samples. After that, the samples are flushed to the top of grating. Since the coefficient 'R' is relate to the resistance from samples on the testing table, so the first three points on each line in the Figure 79 will be taken into account in this analysis.

The results show almost the same trend. Under low flow capacity (2l/s), samples are rather sparse on the testing table. Then the flow capacity rises to 4l/s, the samples on the testing table are pushed to get together and tighter, which leads a increasing of R. After that, flow capacity is up to 6l/s, the samples start moving to the top of grating which causes a decreasing of R. For Q > 8 l/s, the samples are not remained on the testing table, but start clogging the grating, the results is not correct anymore.

Alternative 4 and alternative 3 have a higher R which implies these two covers let more samples remain on the testing table during the tests. This actually matches the observed results. In the other hand, the original cover and new gully pot have a lower R, which means most samples are flushed to the top of grating. Additional, the observed results show a certain amount of samples go inside the gully pot in the end of the test for both original cover and new gully pot.

The **estimate R** for each alternative is defined by the average value of the first three reasonable R in Table 29.

Original	Alternative 3	Alternative 4	New designed gully pot
$R_{original}$	$R_{alt\ 3}$	$R_{alt\ 4}$	$R_{new\ GP}$
6.6	11.0	14.4	5.3

Table 30 – The estimate R for different alternatives

Since the estimate R is defined for each alternative, the estimate water level h_{est} can be computed by reversing the calculation using [11] (from hypothesis 3). Estimate water velocity v_{est} could be calculated from:

$$v_{est}=Q/\ b*h_{est}. \quad [12]$$

The equation for R turns to:

$$R = g*(h_{est} - h_{critical})/\ {v_{est}}^2 \quad [13]$$

$$R = g*(h_{est} - h_{critical})/\ (Q^2/\ (b^2*{h_{est}}^2)) \quad [14]$$

$$\frac{R*Q^2}{b^2*{h_{est}}^2} = g*(h_{est} - h_{critical});$$

$$\frac{R*Q^2}{b^2*g} = {h_{est}}^2*(h_{est} - h_{critical});$$

$$\frac{R*Q^2}{b^2*g} = {h_{est}}^3 - {h_{est}}^2*h_{critical} \quad [15]$$

The individual estimate R values for different alternatives are shown in Table 30. With equation given above, h_{est} can be solved.

The computed results as:

	Original	Alternative 3	Alternative 4	New designed gully pot
Q (m^3/s)	h_{est}	h_{est}	h_{est}	h_{est}
0.002	0.018	0.020	0.022	0.016
0.004	0.028	0.032	0.034	0.025
0.006	0.036	0.042	0.045	0.033
0.008	0.044	0.050	0.055	0.040
0.009	0.047	0.054	0.059	0.043

Table 31 – The estimate h_{est} for different alternatives

The comparison results as:

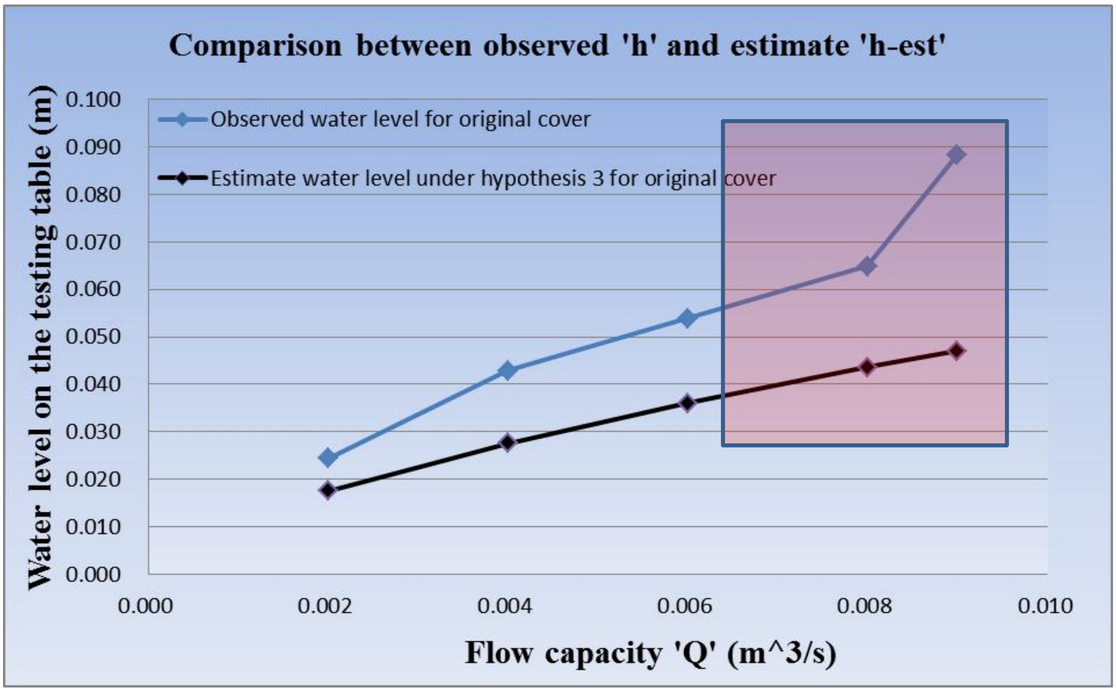

Figure 80 – Comparison between observed h and estimate h_{est} for original cover

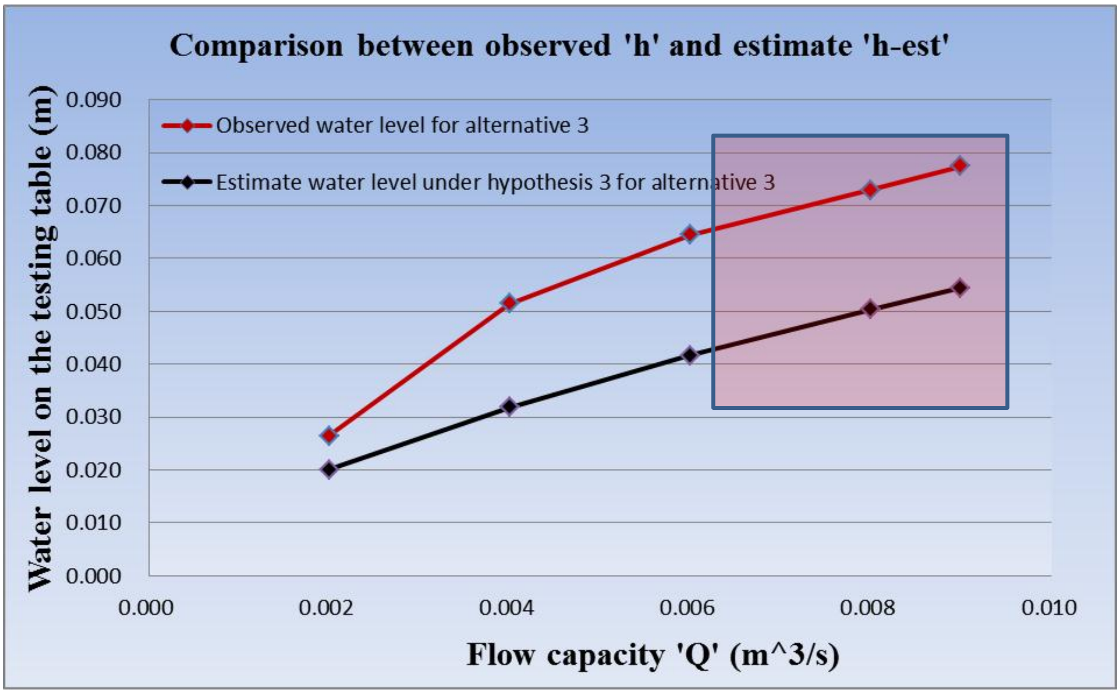

Figure 81 – Comparison between observed h and estimate h_{est} for alternative 3

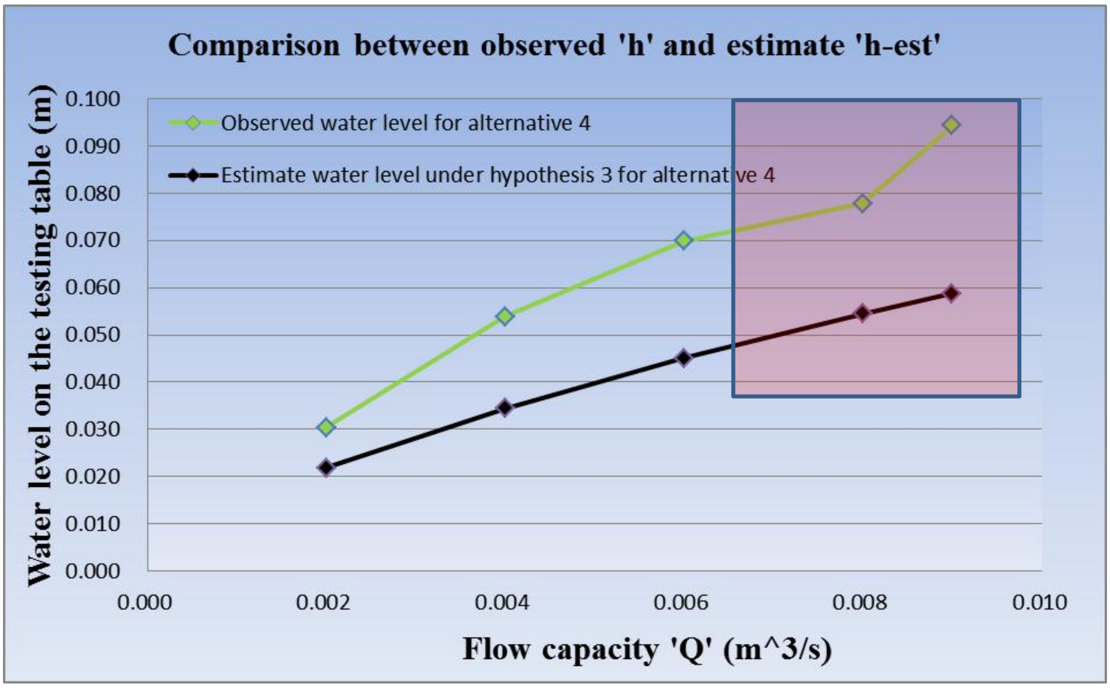

Figure 82 – Comparison between observed h and estimate h_{est} for alternative 4

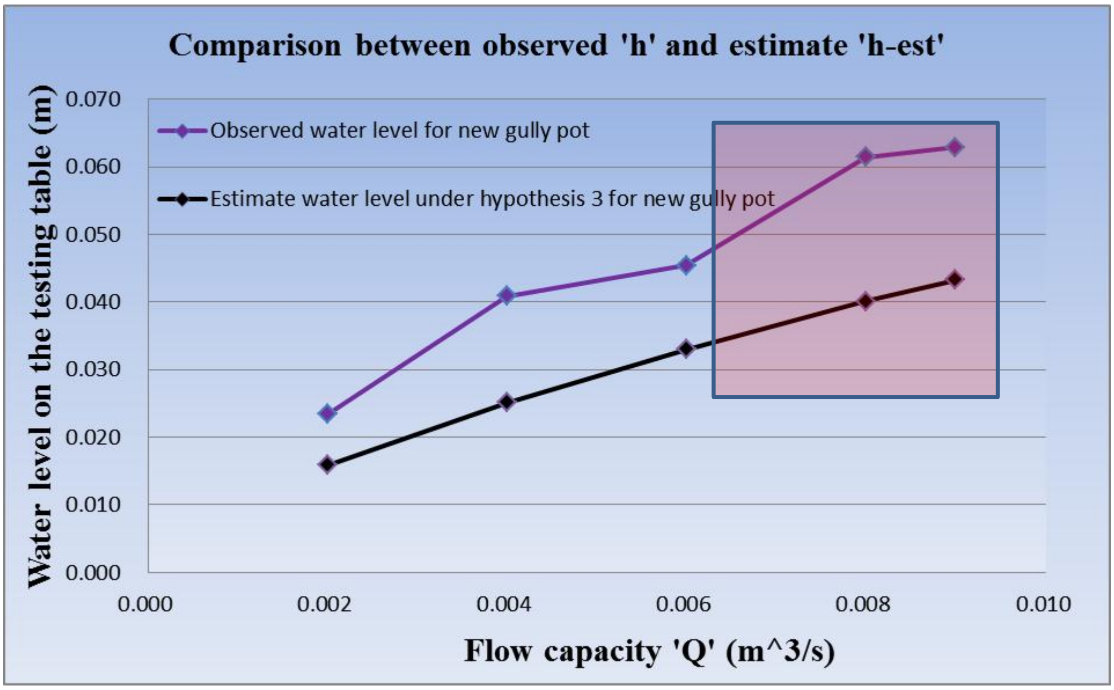

Figure 83 – Comparison between observed h and estimate h_{est} for new gully pot

The results show that the estimate water level is lower than the observed water level and the results within red box area when flow capacity is higher than 6 l/s are not in range. Because samples are all flush to cover the grating after 6 l/s.

Water will be affected by a resistance when goes through the samples on the testing table. This resistance is depending on the amount and density of the samples on the testing table, which will cause the water level increasing. The relation between h_{obs} and h_{est} implies the resistance in real lab testing is bigger than the estimate resistance, which is caused by very chaotic situation in the real lab work.

The estimate resistance is considered as yielded by samples which are proportionally distributed on the testing table, and also the movement of samples is considered to be proportional. However, the observed results in real experiment show a much more chaotic process. The distribution and movement of samples are rather random and so is the clogging process.

Additional, the lines for estimate water level moves smoothly, and the real water level always has some jump points under certain flow capacity. For the observed results, as the gully pot is overflowed, the water level increases rapidly which cause inflexion points on the backend of line chart.

Based on figures and analysis given above, it can be expected that if change the parameters of the grating, the estimate water level could be much closer to the observed water level. For example, make the holds much bigger on the grating, or use bigger size of grating, etc.

6.2.2.2 Flow over 8 l/s

For the second stage, flow pattern is under flow capacity 6 l/s to 8 l/s. This is a transition stage (Figure 69), samples are all flushed to the top of grating, but the overflow is not happening yet.

For the third stage, the flows over 8 l/s is close to hypothesis 1 (Figure 49). The expected equation (see chapter 4) is [1] and [2], here we have:

$$Q_r = \sqrt{2g\mathrm{h}_{obs}} * \mathrm{A} * (1-\mathrm{x}_{obs}\ \%) * \eta \qquad [16]$$

This flow pattern happened under high flow capacity, and it should be a stable (steady state) submersion situation. Flow capacity 8 l/s and 9 l/s are taken into account this time. However overflow situation is usually observed with 9 l/s, not 8 l/s.

For the expected equation, h_{obs} is observed water level; A is the area of grating; x_{obs}% is covering percentage of grating under different flow capacity; η is original opening on the grating, then the Q_r could be solved. However, if let Q_r equal to Q_{obs}, the estimate water level h_{est} can be defined by reversing the calculation.

$$\mathrm{Q}_{obs} = \sqrt{2gh_{est}} * \mathrm{A} * (1-\mathrm{x}_{obs}\ \%) * \eta \qquad [17]$$

$$h_{est} = (\mathrm{Q}_{obs} / (\mathrm{A} * (1-\mathrm{x}_{obs}\ \%) * \eta))\ \hat{}\ 2/2\mathrm{g} \qquad [18]$$

Here, A is 0.08 m^2 for original gully pot, and 0.13 m^2 for new gully pot. The value of η is 80% for Alternative 3 and Alternative 4; 50% for original cover and the cover of new gully pot. The observed results for x_{obs} % can be found in Chapter 5.

The computed results of estimate water level h_{est} are shown below:

	Original	Alternative 3	Alternative 4	New designed gully pot
Q_{obs} (m^3/s)	h_{est}	h_{est}	h_{est}	h_{est}
0.008	0.047	0.018	0.018	0.003
0.009	0.240	0.094	0.094	0.007

Table 32 – The estimate h_{est} for different alternatives with testing 1 bucket samples

	Original	Alternative 3	Alternative 4	New designed gully pot
Q_{obs} (m^3/s)	h_{est}	h_{est}	h_{est}	h_{est}
0.008	18.940	0.074	0.033	0.021
0.009	23.971	2.341	0.375	0.416

Table 33 – The estimate h_{est} for different alternatives with testing 2 buckets samples

The comparison results between observed water level and estimate water level are given below:

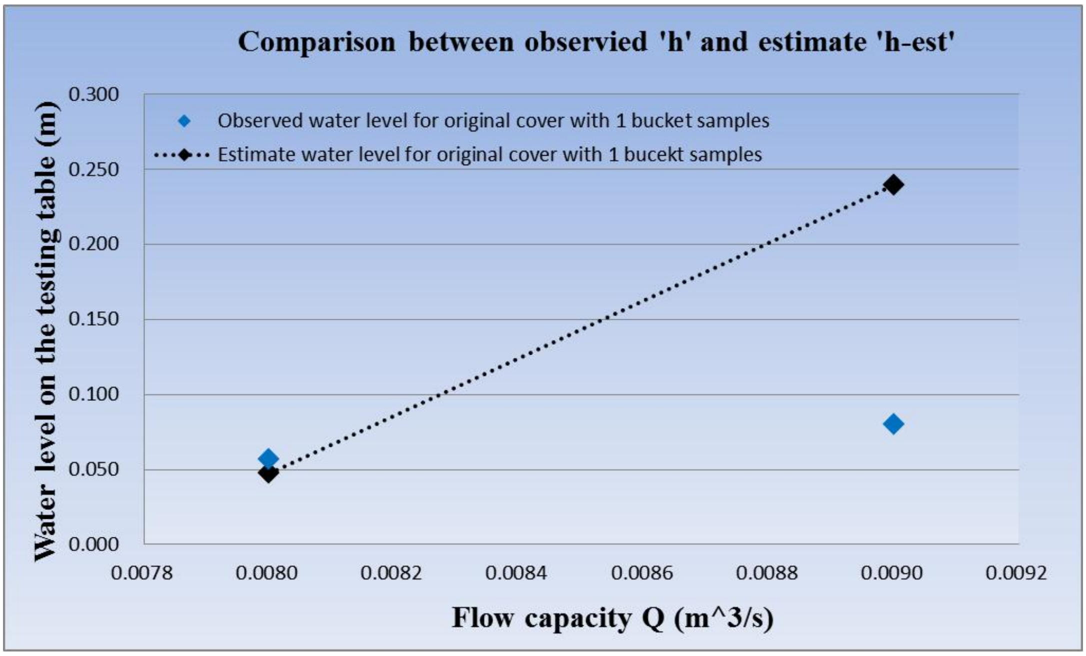

Figure 84 – Comparison between h_{obs} and h_{est} for original cover (1 bucket of samples)

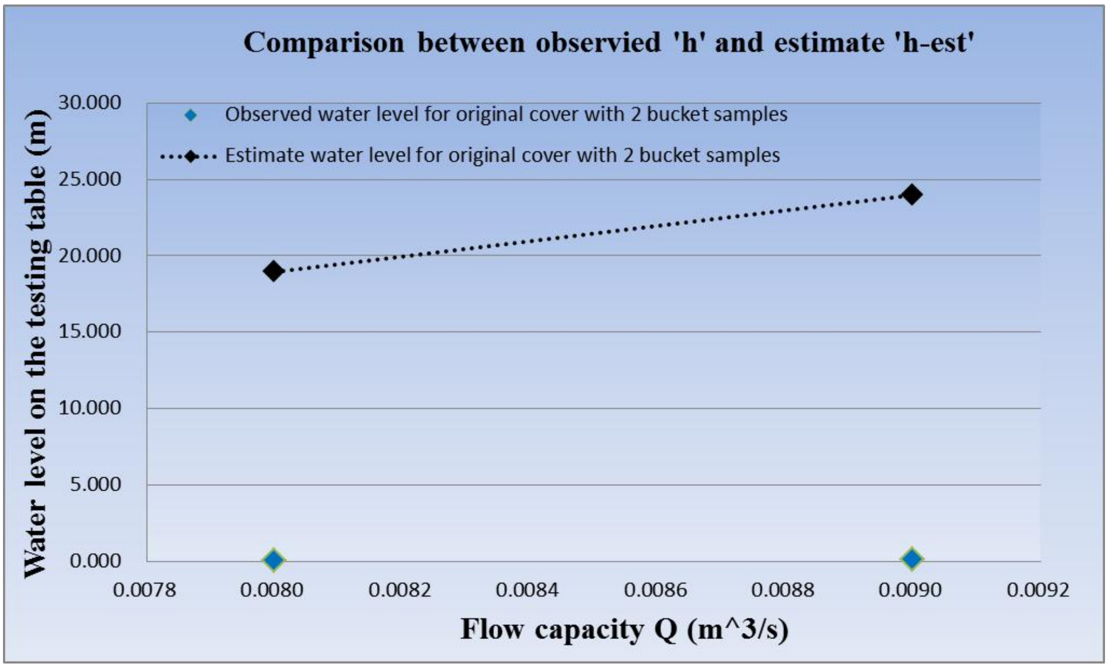

Figure 85 – Comparison between h_{obs} and h_{est} for original cover (2 bucket of samples)

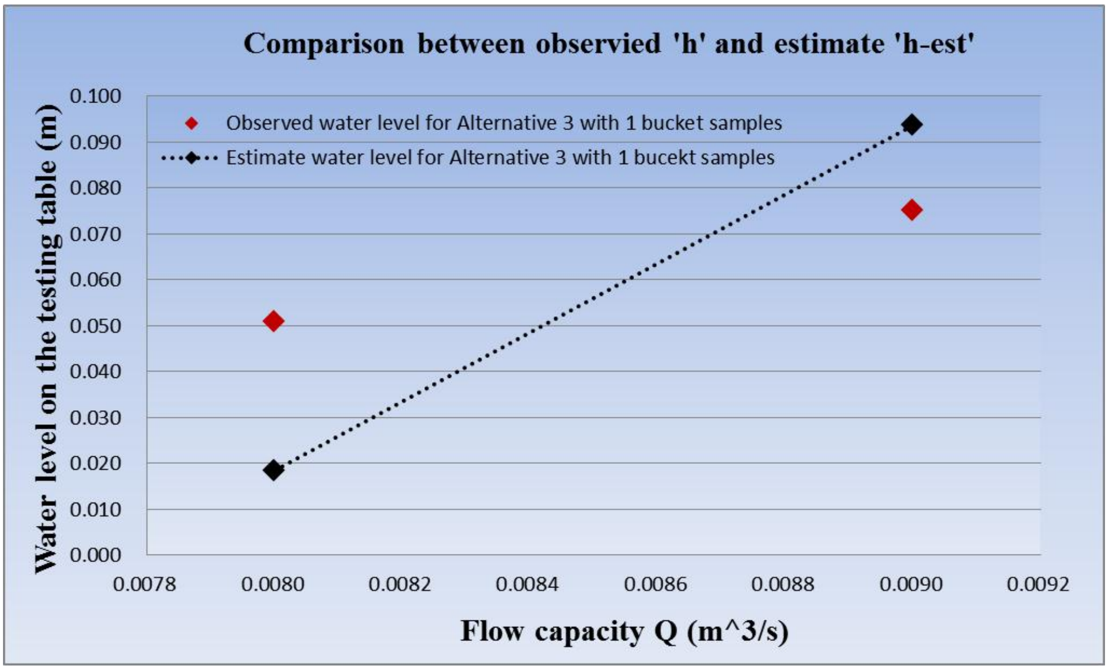

Figure 86 – Comparison between h_{obs} and h_{est} for Alternative 3 (1 bucket of samples)

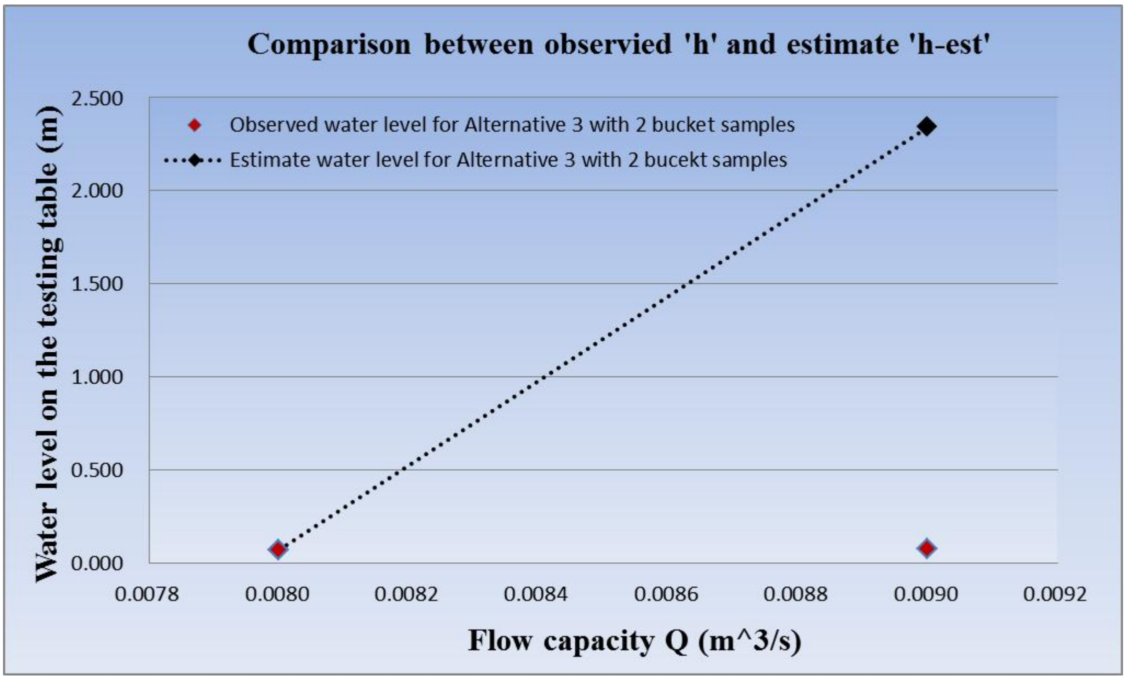

Figure 87 – Comparison between h_{obs} and h_{est} for Alternative 3 (2 bucket of samples)

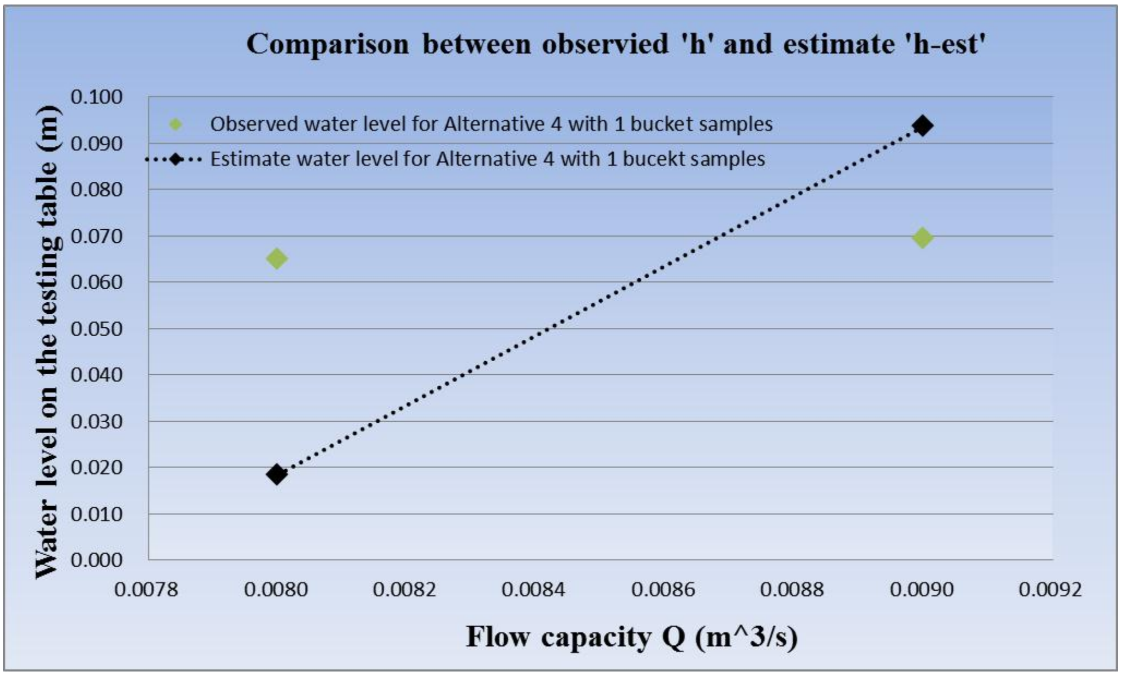

Figure 88 – Comparison between h_{obs} and h_{est} for Alternative 4 (1 bucket of samples)

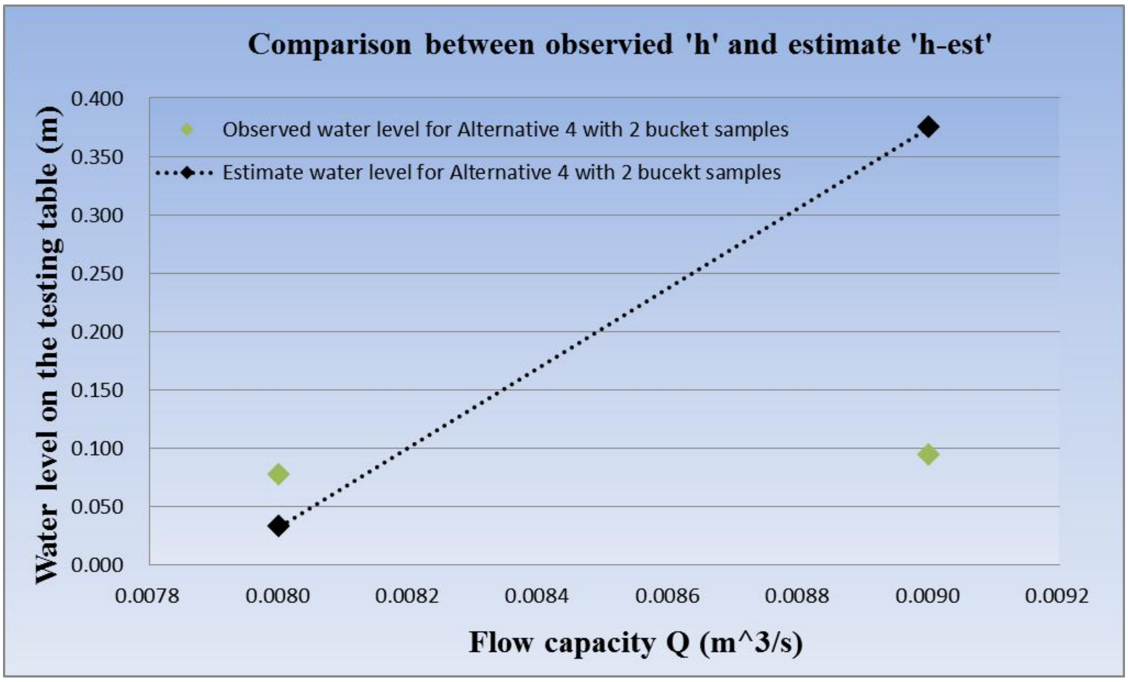

Figure 89 – Comparison between h_{obs} and h_{est} for Alternative 4 (2 bucket of samples)

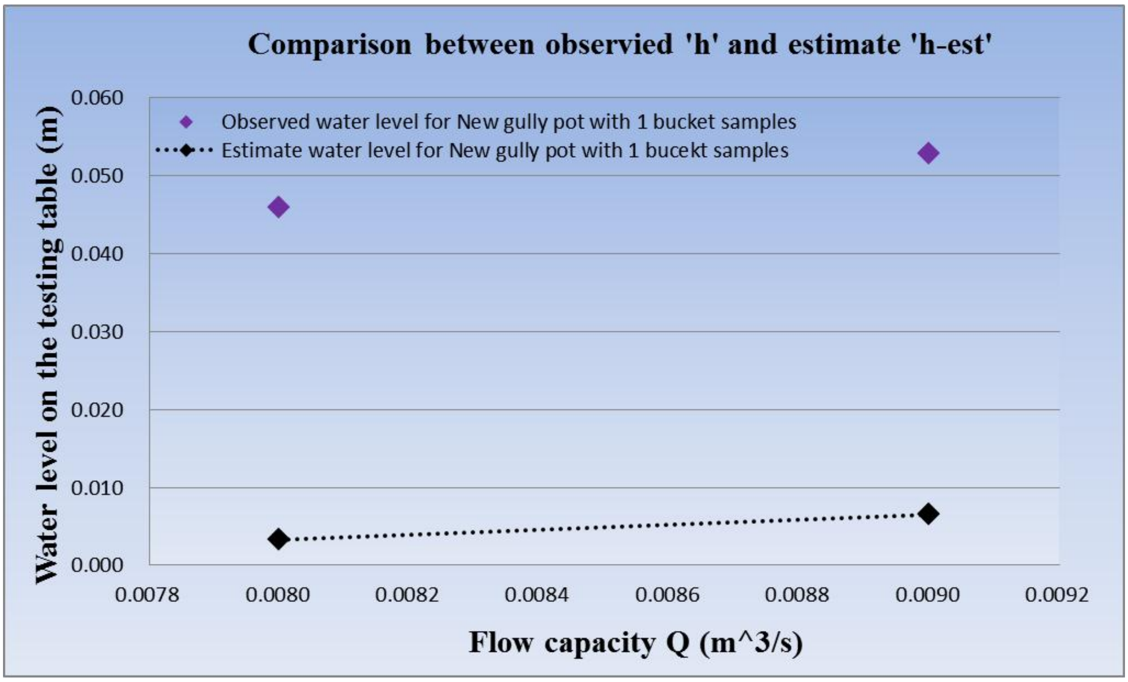

Figure 90 – Comparison between h_{obs} and h_{est} for New gully pot (1 bucket of samples)

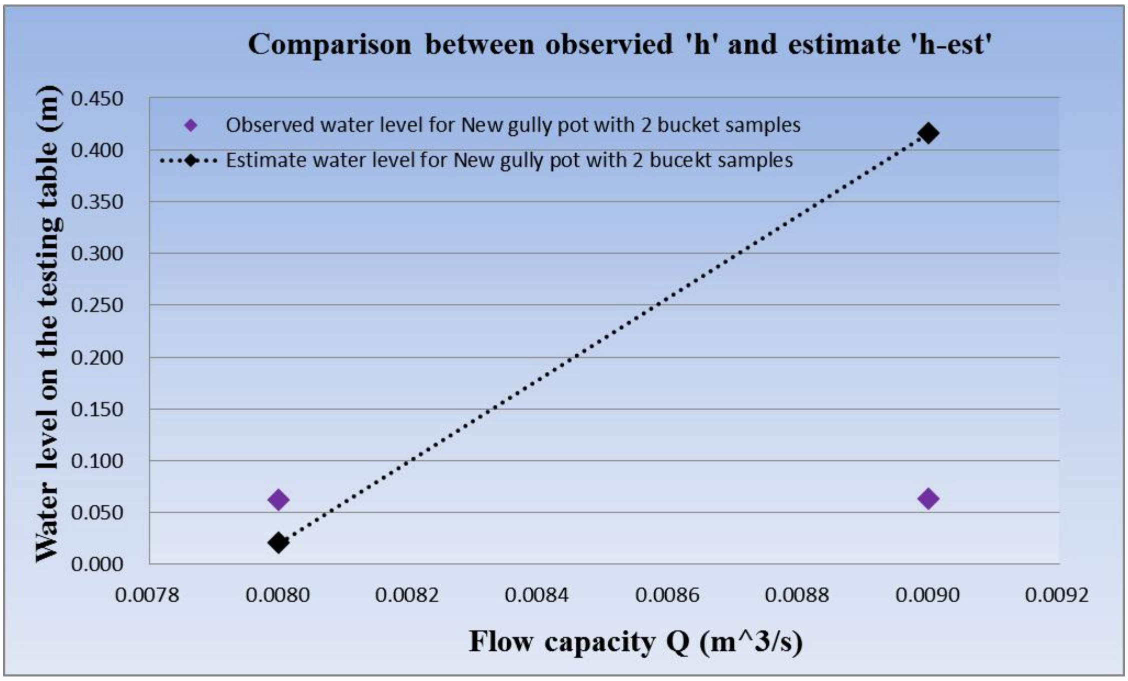

Figure 91 – Comparison between h_{obs} and h_{est} for New gully pot (2 bucket of samples)

Most of results show h_{obs} are higher than h_{est} or equal to h_{est} at flow capacity is 8 l/s. In the other hand, h_{est} is much higher than h_{obs} at 9 l/s. Notice that, when using the expected equation to define the discharge through the grating, the results depend on the covering percentage of grating (x_{obs} %) very much. Also the expected equation assumes the covering area of grating is totally clogged which means the water cannot through this part. However, the truth is the water can still go through the covered part by the space among testing samples (leaves and branches) in real lab experiment. This explained h_{est} level is much higher than h_{obs} at 9 l/s, especially for Figure 85.

Figure 85 is a little bit weird, since the h_{est} is far higher than h_{obs} for both points (8 l/s to 9 l/s). The covering percentage in Figure 85 is already reaching 99% at 8 l/s, this means the grating is considered to be totally clogged which will lead such a high h_{est}.

Additional, Figure 90 is also weird due to the estimate water level is very small, which is around 0.3 cm to 0.7 cm. The explanation is also depending on covering percentage, the x_{obs} % is end up at 60% when flow capacity is 9 l/s. consequently, a very low water level is expected by the equation, although this is not true in real lab testing.

6.2.3 Conclusion from flow pattern hypothesis

In this subsection, observed results and hypothesis have been discussed.

- The results after analysis hypothesis 2 (Figure 51), show the observed water level h_{obs} is higher than theoretical critical water level, which fits expectation very well.

- Hypothesis 3 cannot explain the whole process because it is focused on the resistance given by samples on the testing table. However, the samples are flushed to the top of grating after 6 l/s – 8 l/s in the real lab experiment.

- Hypothesis 1 aims to set the model for submersion situation. However, the discharge which is calculated from the expected equation depends on the covering percentage very much since it assumes the covered part is totally clogged by samples. The truth is water can still go through the covered part by the small space among the samples in the real lab testing.

- The new gully pot has the best performance of the resistance of the samples on the testing table. However this comparison seems not so fair, since the new gully pot with a bigger grating and tank which is a totally different design from the original gully pot.

7 Conclusions and recommendations

7.1 Conclusions

This thesis study aims at reducing the gully pot clogging problem which is caused by large particles. The research question is whether we could reduce the gully pot clogging problems by improving the design of the grating and outlet of gully pot.

During the literature study period, different gully pot constructions all over the world are studied. The constructions of gully pots are different due to different sewage system, road, pumping station set. There are two parts of gully pot that are easy to be clogged by large particles. In order to define the large particles which in fact clog the gully pot in real world, a field work to interview the on-site workers from cleaning company is done. After that, the feedback shows the real clogging materials inside gully pot is mainly leaves and branches.

Based on this information, 4 kind of new alternatives are proposed. Two are inside sack design (to hold the materials inside gully pot), and the other two are grating design (aims to keep materials outside gully pot).

The next step, a laboratory experiment is designed to test these alternatives and also a new re-designed gully pot provided by Wavin Company. Four theoretical hypotheses of different water flow pattern are provided before the lab testing.

At the beginning of the laboratory experiment, lots of try out tests have been done to find proper material for testing sample. Afterwards, real leaves and branches are chosen as the testing sample. In addition, after a number of try out tests, it shows the grating played a decisive factor in this experiment. So the next step, testing focus on different alternatives of grating design.

At the end of the laboratory experiment, observed data is collected which include water level on the testing table (h), the visual covering percentage of the grating (x %), water flow capacity (Q). After comparison of these factors in figures, it turns out that the new alternatives of grating design have good performance for solving the gully pot clogging problem.

- Alternative 3 and Alternative 4 reduce the covering percentage of grating during the lab testing, especially under high flow capacity;

- Alternative 4 perform well during test with 1 bucket of samples. The line (Figure 71) for Alternative 4 goes smoothly and without water level sharp increasing for $Q \geq 8$ l/s.

- Alternative 3 perform well during test with 2 bucket of samples. The line (Figure 72) for Alternative 3 goes smoothly and with no water level jump during high flow capacity. So Alternative 3 seems less sensitive for clogging under high large particle load.

- Alternative 4 and Alternative 3 cause a rather high water level on the testing table, especially Alternative 4.This is because these two alternatives keep samples around the grating instead of covering it, which leave more opening on the grating, but causing a rather high water level.

- Original cover has a rather low water level under low flow capacity. But it is easy to be clogged under rather high flow capacity which leading a high water level. Additionally, samples are more easily to go through the original cover, when there is almost nothing going through Alternative 3 and Alternative 4.

During lab test, the water pattern of testing without grating is expected as hypothesis 2 (Figure 51). For the water patterns of testing with grating, 3 stages (Figure 68, Figure 69 and Figure 70) are found.

	Flow capacity	Flow patterns
Stage 1	2 l/s – 4 l/s	Hypothesis 3
Stage 2	6 l/s – 8 l/s	Transition
Stage 3	8 l/s – 9 l/s	Hypothesis 1

Table 34 – The 3 stages of water flow patterns in lab test

By analyzing these theoretical hypotheses, the computed results are obtained according to expected equations. The coefficient R is related to the resistance given by samples on the testing table; h_{est} is estimate water level for different alternatives; $\text{h}_{critical}$ is the critical water level close to the grating when testing without samples on the testing table. After comparing the estimate results and the observed results, it turns out that none of the single model can explain the whole process of lab experiment, since the real testing is a continuous changing process.

- The results after analysis hypothesis 2 (Figure 51), show the observed water level h_{obs} is higher than theoretical critical water level, which fits expectation very well.

- Hypothesis 3 cannot explain the whole process because it is focused on the resistance given by samples on the testing table. However, the samples are flushed to the top of grating after 6 l/s – 8 l/s in the real lab experiment.

- Hypothesis 1 aims to set the model for submersion situation. However, the discharge which is calculated from the expected equation depends on the covering percentage very much since it assumes the covered part is totally clogged by samples. The truth is water can still go through the covered part by the small space among the samples in the real lab testing.

- **Original gully pot performance**

Based on all experiment results and the discussions above, we can reach the conclusion that the new alternatives designed for the original gully pot can reduce the gully pot clogging problem which is a positive answer to my research question. It is concluded in two sides: Advantage and Disadvantage

A**dvantage:**

- The new grating design Alternative 3 and Alternative 4 can significantly reduce the incidence of gully pot clogging problem by limiting the amount of materials going inside the gully pot (Figure 60, Figure 62 and Figure 64);

- Alternative 3 and Alternative 4, it can reduce the covering percentage of the grating during the extreme rain fall event and leave more opening space on the grating (Figure 59, Figure 61 and Figure 63);

- The inside sack (Alternative 1 and Alternative 2), the frequency of cleaning work can be highly reduced, which might reduce the maintenance cost.

Disadvantage:

- The laboratorial results shows that Alternative 3 and Alternative 4 can raise the water level on the testing table a little bit higher (Figure 71 and Figure 72);

- The bicycle safety on the road should be considered due to the shape of the new cover designs;

- The materials for producing the new cover design should be in such a way that the cost issue and the grating strength should be included. (In case of the cars run over the cover).

- **New gully pot performance**

On the other side, the new gully pot from Wavin Company has a bigger settling tank and grating than the original gully pot. So it cannot be directly compared with the other alternatives which are designed based on original gully pot. However, considering the behavior of new gully pot in lab testing, the performance of new gully pot is better than the original gully pot.

For the inside capacity testing (test without cover), when the flow capacity reaches 3.0 l/s, the original gully pot is totally clogged and overflowed. But for the new design, the overflow happens at flow capacity of 8.0 l/s.

In addition, the big grating of new gully pot also has a good behavior for reducing the covering percentage of the grating during extreme water flow, and has the best performance of the resistance of the samples on the testing table (Figure 78 and Figure 79). It is believed that the big size of gully pot design will also be a good choice for reducing clogging problem in the future.

7.2 Recommendations:

- The laboratory experiment set should be more complete to get more careful observed data, such as the water level on the testing table, water level on the top of grating. Also the water level inside the gully pot and the flow capacity out of the outlet pipe should be observed, which helps to analyze the inside capacity and resistance of the gully pot;

- Consider using other materials (including sand, stone, etc.) as sample for the laboratory testing.

- Consider the cost and materials for making new grating design. Also the maintenance cost difference between original gully pot and new designs is a concern;

- Consider that the new grating will cause materials residues outside the gully pot, extra cleaning work is needed.

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Appendix

Excerpts from lab experiment journal.

3-10-2011 Monday

For today's test, I will put all mixed samples inside the sack at the beginning.

The first one is the cone-shaped:

I start with the flow capacity 2.0 dm^3/s for about 10 minutes:

Also we can see the outlet pipe.

Then I turned the flow capacity to 4.1 dm^3/s for 10 minutes:

After that I turned the flow to 6.0 dm^3/s for 10 minutes:

Then I continued turn the flow to 8.0 dm^3/s for 5 minutes:

In the end, I used the flow capacity 8.5 dm^3/s, the gully pot was overloaded:

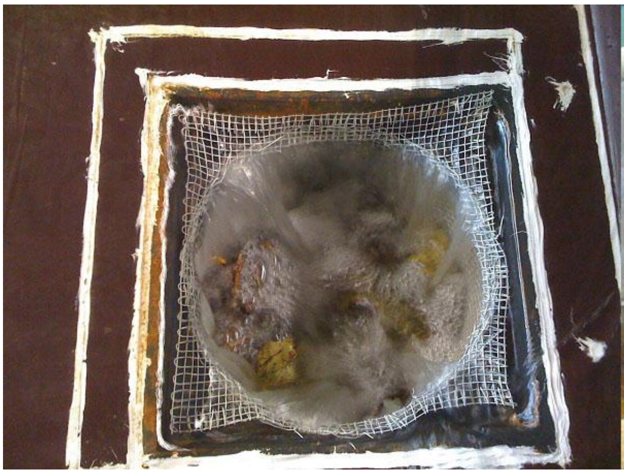

For the **second test**, I test the other sack with fulfilled test samples:


I start with the flow capacity 2.0 dm^3/s for about 10 minutes:


Then I turned the flow to 4.0 dm^3/s for 10 minutes:

After that I turned the flow capacity to 6.0 dm^3/s for 10 minutes:

Then I continued turn the flow to 8.0 dm^3/s for 5 minutes:

In the end, I used the flow capacity 8.5 dm^3/s, the gully pot was overloaded:



For today's two tests, I would say that the behavior of each sack in the gully pot is almost the same, although the volume of cone-shaped one should be smaller than the other one. We should find some way to compare the difference between these alternatives.

For the next step, I will take the inside sack out and let the samples go into the gully pot directly.

6-10-2011 Thursday

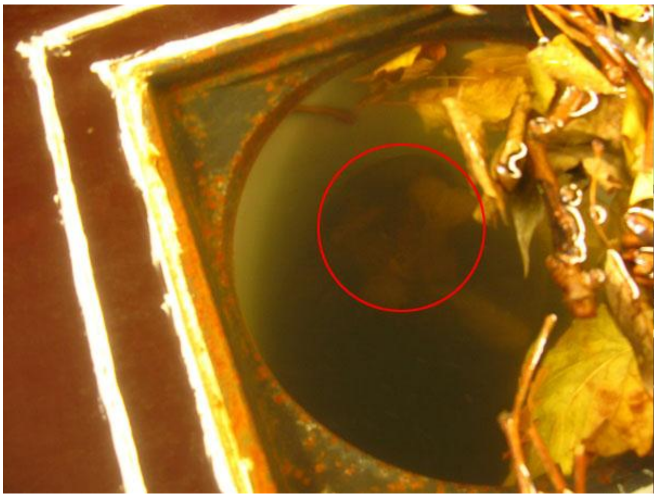
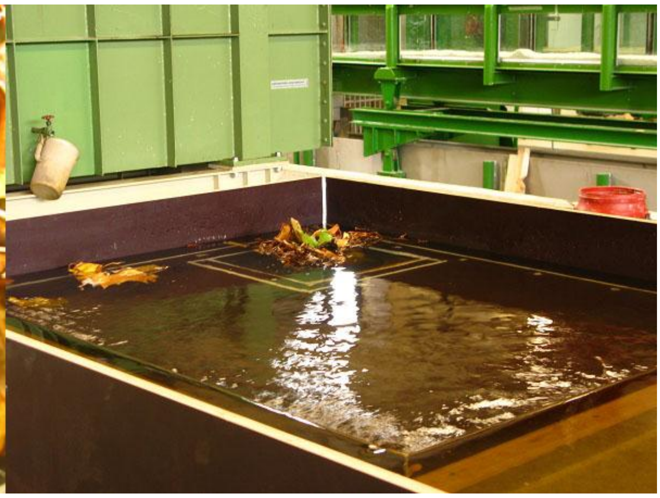
For today's test, I plan to change the flow capacity slower each time period. For example, first I will use 2.0 dm^3/s, and then turn the flow to 3.0 dm^3/s, after that use 4.0 dm^3/s. This mean to see is the flow capacity will be the significant reason to influence the clogged moment in the gully pot.

For the **first test**, I put 2 buckets of the samples on the test table:

I start the test with flow capacity 2.2 dm^3/s for 10 minutes. We can find in the picture that the water level in the gully pot is around 43cm:

Then I turned the flow capacity to 3.1 dm^3/s for 10 minutes. We also could find that the water level in the gully pot is around 63cm:

After that I turned the flow to 4.0 dm^3/s, after 1 minutes the gully pot was overflowed:

We could find that in the picture which is in red circle, the outlet pipe is totally clogged by the samples.

Also we could find there are samples came out of the outlet pipe. There is about 0.8 bucket of sample.



In the end, we could find the samples remain in the gully pot:

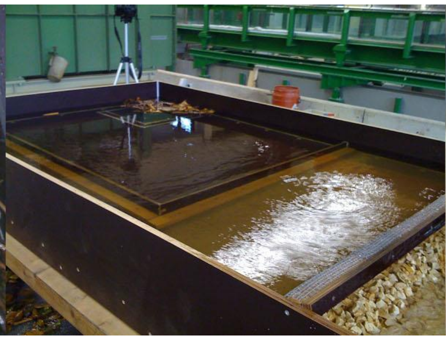
For the **second test**, I try to double check the results. I do the same procedure. I start the test with 2 buckets of samples on the test table, and I use 2.1 dm^3/s for 10 minutes. We could find that the water level in the gully pot is around 41cm:

Then I turned the flow capacity to 3.0 dm^3/s for 10 minutes. We could find that the water level in the gully pot is around 43cm:



(This time with the flow capacity which is 3.0 dm^3/s, not so much samples went into the gully pot taken by water flow. I would say that the water flow take the sample is a little bit random, so this time the water level in the gully pot is just 43cm.)

Then I turned the flow to 4.1 dm^3/s, after 2 minutes the gully pot is completely overloaded:






Also we could find that the samples come out of the outlet pipe is about 0.5 bucket.

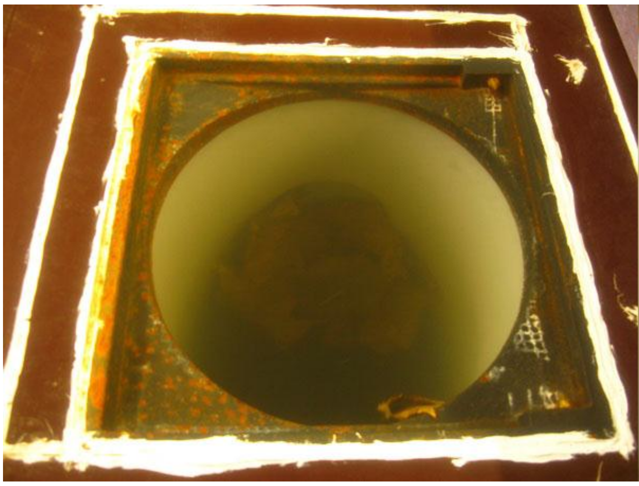
Since that I consider the water flow take the samples is a little bit random, for the next test I will try to put the samples inside the gully pot at the beginning and try different flows.

For the **third test**, I put 1 bucket of samples inside the gully pot and start with the flow 2.0 dm^3/s for 10 minutes. We could find that the water level in the gully pot is around 42cm:

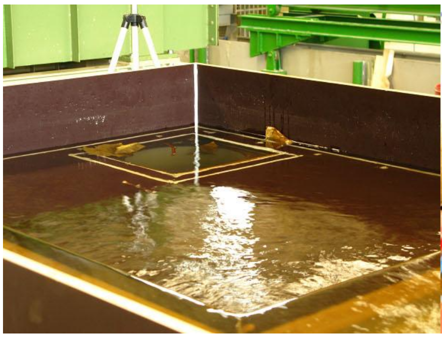




Then I turned the flow capacity to 3.0 dm^3/s. After 3 minutes, the gully pot is totally overloaded. We could find that the outlet is completely clogged:




Also there are some pieces of sample come out of the outlet pipe:

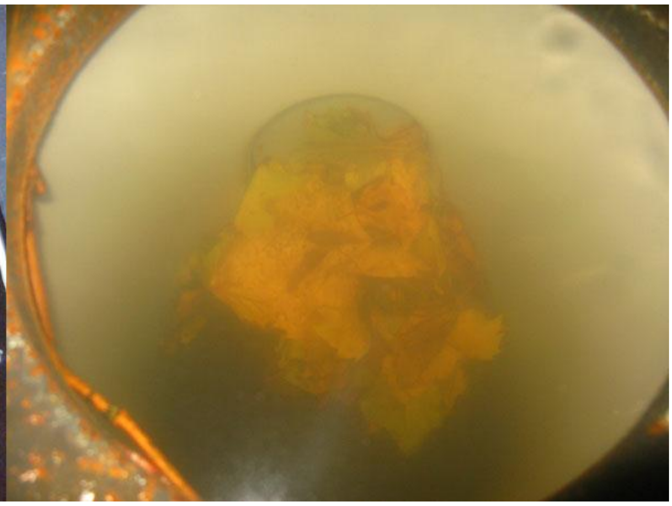
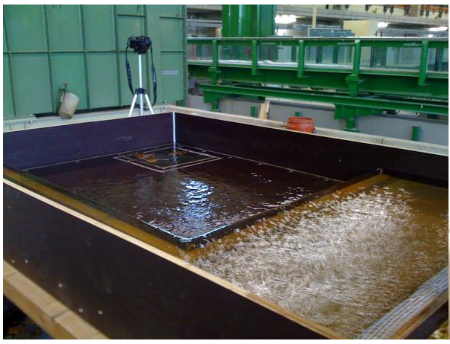


The samples remained in the gully pot:


For the double check, I run the **fourth test** with the same procedure. I put 1 bucket of samples inside the gully pot and start with the flow capacity 2.1 dm^3/s for 10 minutes. We could find that this time the water level in the gully pot is around 38cm:



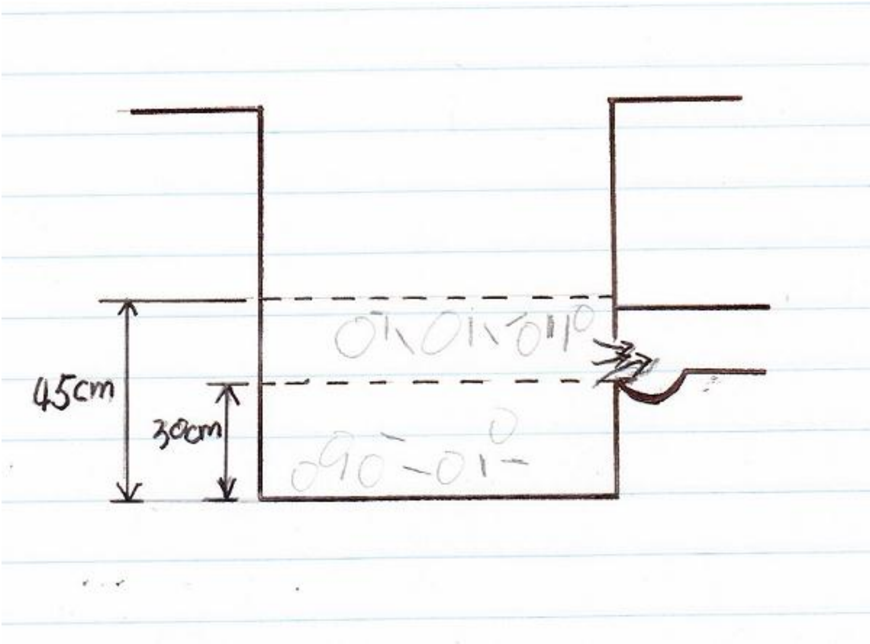
Then I turned the flow capacity to 3.0 dm^3/s, after 3 minutes the gully pot is overloaded. We could find that the outlet is totally clogged, and about 10 pieces of samples come out of the outlet pipe:



After today's tests, I would say that the clogged moment is not depend on big amount of the samples in the gully pot and how long the flush time. If there is enough samples suspended in the water and enough flow to let the water level above about 45cm in the gully pot, the outlet pipe will be clogged.

Since the height of the outlet in the gully pot is about 30cm:



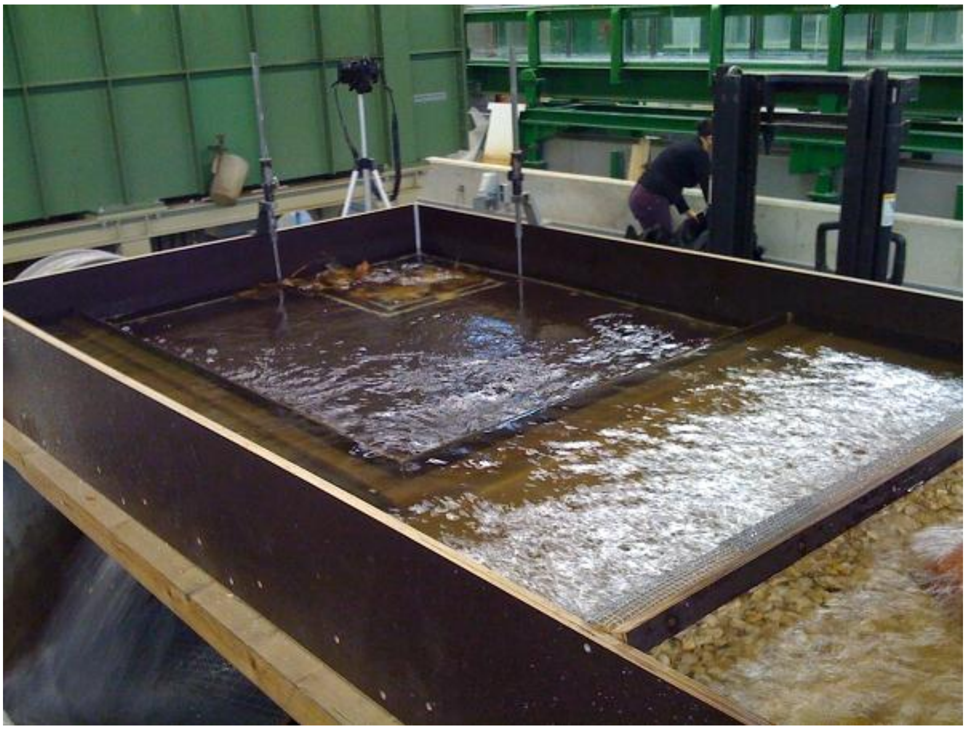
Also I would say that our goal for my project should be keeping as much martials outside the gully pot as possible to avoid the cogging problem.

30-11-2011 Wednesday

The second test, I use the alternative 3 with 1 bucket of samples

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		10%	18.0	18.5
4.0 dm^3/s		35%	19.4	20.0

6.0 dm^3/s		50%	20.6	21.0
8.0 dm^3/s		80%	21.5	21.3
9.0 dm^3/s		90%	23.8	23.85



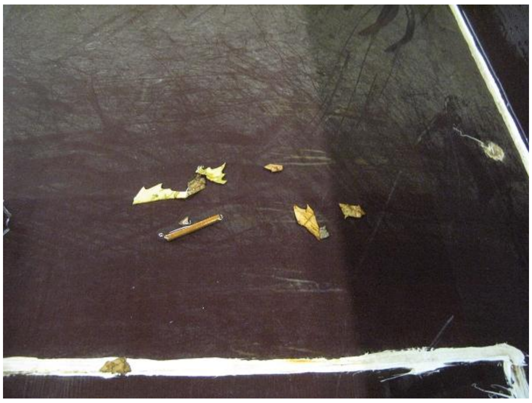
In the end, one small piece of branch went into the gully pot:

The third test, I use alternative 3 and 2 buckets of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		15%	18.7	19.2
4.0 dm^3/s		30%	21.0	21.9
6.0 dm^3/s		60%	22.4	23.1

8.0 dm^3/s		90%	23.4	23.8
9.0 dm^3/s		98%	24.1	24.0

In the end, just few debris went into gully pot:



1-12-2011 Monday

Today's test I use alternative 4 and 1 bucket of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		5%	19.0	19.3
4.0 dm^3/s		20%	20.5	21.0
6.0 dm^3/s		45%	21.4	22.2

8.0 dm^3/s		80%	22.65	23.0
9.0 dm^3/s		90%	23.3	23.2

In the end, nothing went through the grating:

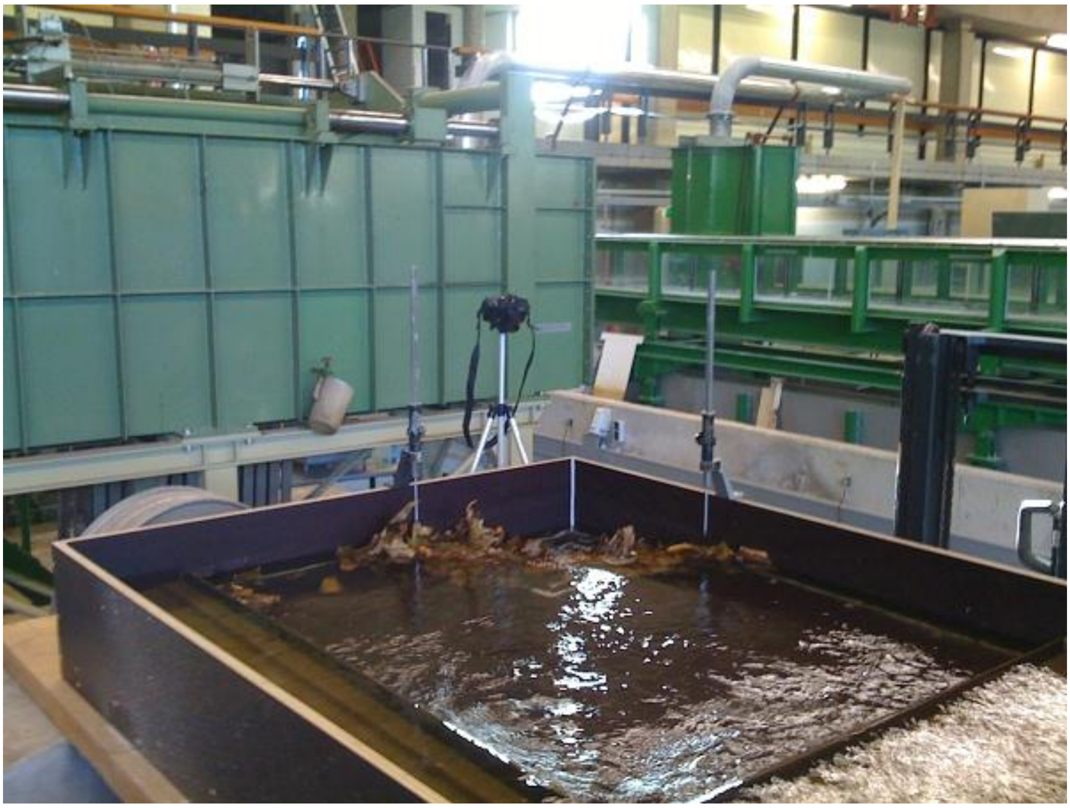
2-12-2011 Tuesday

For today's first test, I use **alternative 4** and 2 buckets of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		5%	19.1	19.6
4.0 dm^3/s		35%	21.6	21.8
6.0 dm^3/s		50%	23.1	23.5

8.0 dm^3/s		85%	23.7	24.5
9.0 dm^3/s		95%	25.5	26.0

When the flow capacity is reach 6.0 dm^3/s, the water level on the test table is getting high because of that lots of samples gather together around the grating:



In the end, also nothing went inside gully pot:


For the **second test**, I re-check the original one's behavior, use original cover with one bucket of sample:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		15%	18.2	18.6
4.0 dm^3/s		40%	19.5	19.9

6.0 dm^3/s		45%	20.9	21.4
8.0 dm^3/s		80%	21.7	22.3
9.0 dm^3/s		90%	24.25	24.35

In the end, there are samples went into gully pot:

For the **third test**, I use original cover with two buckets of sample:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		25%	18.3	19.2
4.0 dm^3/s		60%	20.28	20.9
6.0 dm^3/s		95%	21.4	22.0

8.0 dm^3/s		99%	22.6	23.0
9.0 dm^3/s		99%	25.0	25.3

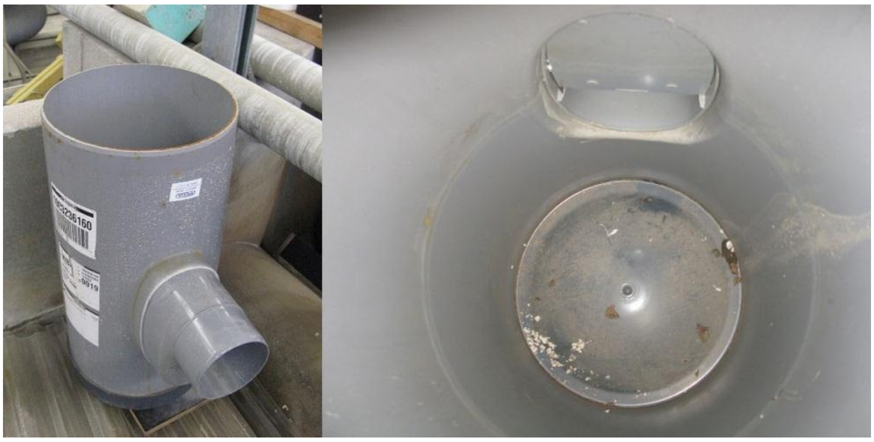
When the flow capacity reaches 8.0 dm^3/s, the gully pot is already overloaded:

In the end, several samples found inside gully pot:

14-12-2011 Wednesday

For today's test, I run 4 tests with the other new type gully pot from Wavin Company. This one is already an improved design. There is a plastic baffle with circular holes around the outlet, which mean to prevent the outlet clogging problems.

Original one:



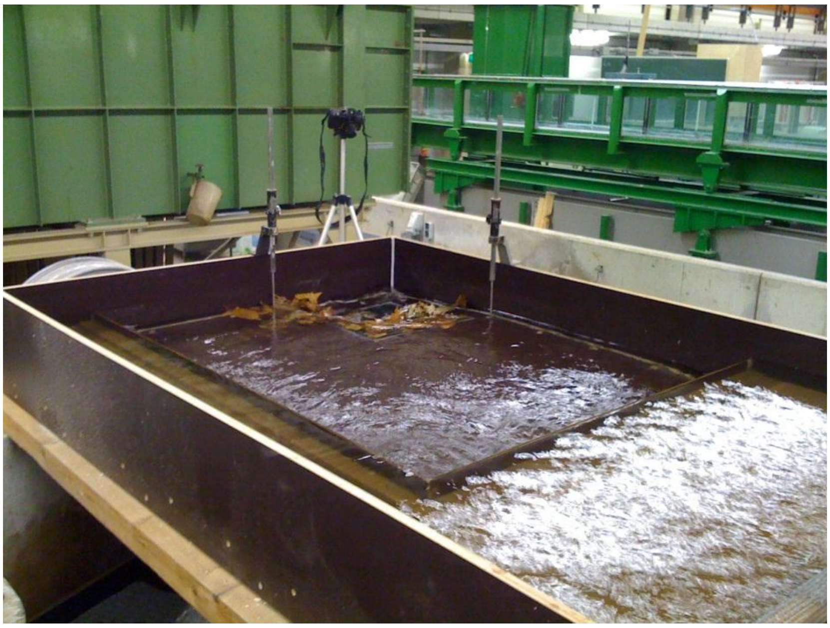
New type of gully pot:

For the first test, I test the new gully pot with 1 bucket of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		5%	18.0	18.2
4.0 dm^3/s		20%	19.4	20.3
6.0 dm^3/s		45%	20.35	21.0
8.0 dm^3/s		50%	20.5	21.3

9.0 dm^3/s		60%	21.5	21.7

During high flow capacity:



In the end, the samples remained inside the gully pot:

For the second test, I test the new gully pot with **2 bucket** of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s		10%	18.4	18.9
4.0 dm^3/s		40%	20.0	20.8
6.0 dm^3/s		50%	20.65	21.05

8.0 dm^3/s		80%	22.6	22.3
9.0 dm^3/s		95%	22.8	22.4

During the high flow capacity:

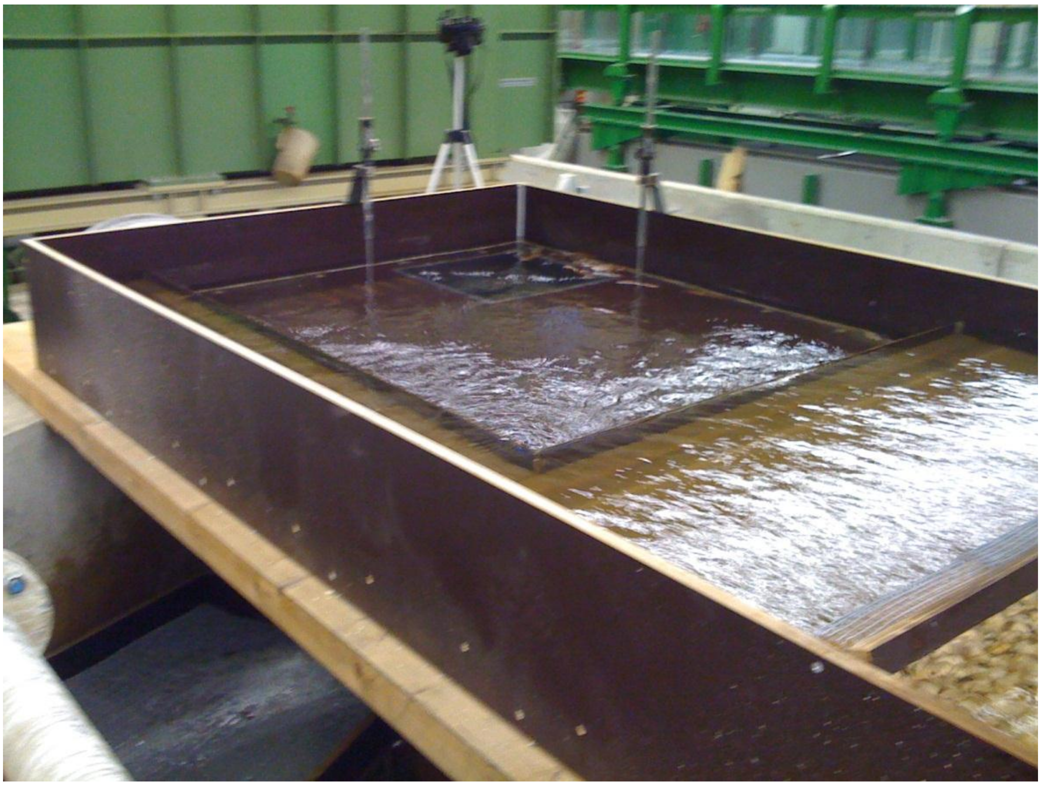
In the end, the samples remained inside the gully pot:

For the third test, I tested the new gully pot with the cover opened and used 1 bucket of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s			17.25	17.55
4.0 dm^3/s			17.8	18.2

6.0 dm^3/s			18.3	18.5
8.0 dm^3/s		overflowed		
9.0 dm^3/s				

In the end, the gully pot is overflowed:

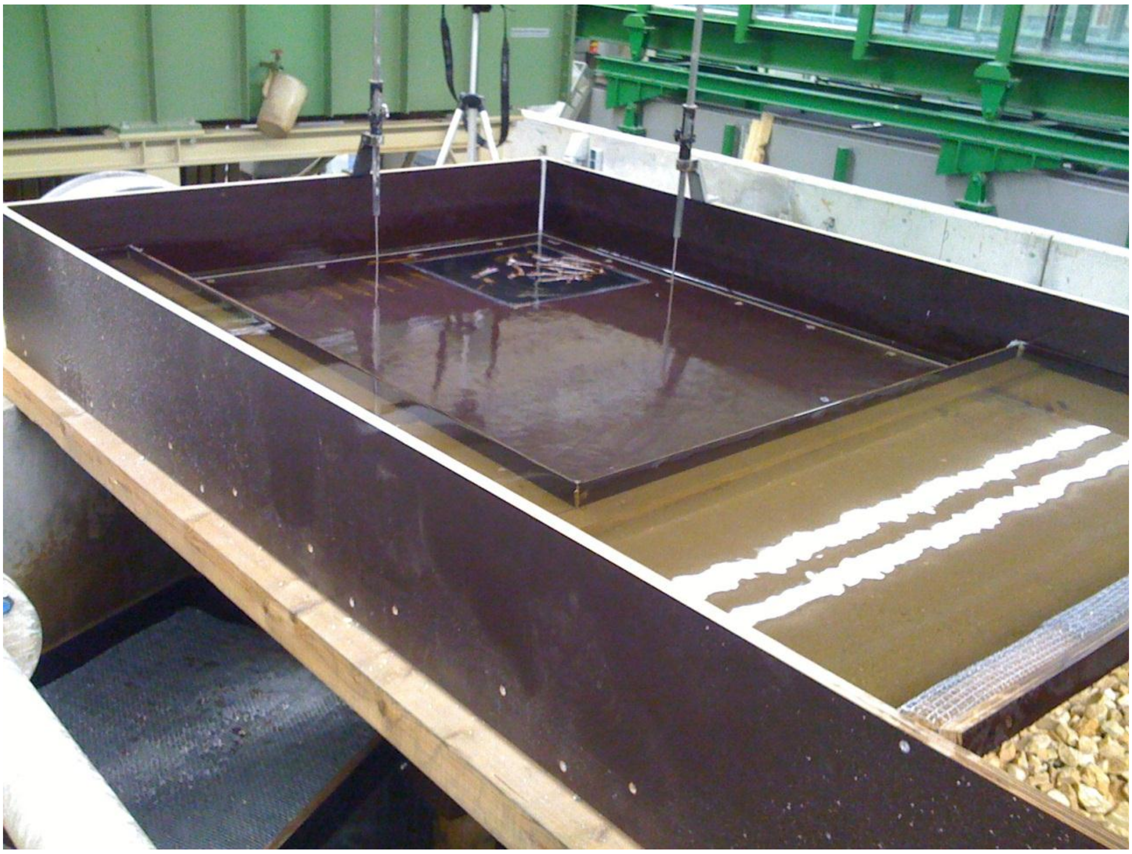


For the fourth test, I test the new gully pot with 2 bucket of samples:

Flow capacity	picture	Covering percentage	h1 (cm)	h2 (cm)
2.0 dm^3/s			17.3	17.65
4.0 dm^3/s			17.8	18.1
6.0 dm^3/s			18.25	18.6

8.0 dm^3/s		overflowed		
9.0 dm^3/s				

In the end of the test, the gully pot is totally overflowed:



Notice: This lab experiment journal is a short version. The full version of experiment journal which include all tests will be around 70M file.