Water System Research Pekalongan

Mapping and analysing the water infrastructures and drainage systems in Tirto and Kota Pekalongan

Waterboard Schieland and the Krimpenerwaard
Rotterdam University of Applied Sciences
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Semarang
15-12-2016

Preface

This report is written as a third year internship assignment by Thijs de Bruijn and Tim De Waele. Both students are studying Water management at the Rotterdam University of Applied Sciences. Their internship was at the waterboard of Schieland and the Krimpenerwaard (HHSK) from September till December 2016.

This report is written for HHSK in commission of Johan Helmer. Data about floods which occur during high tide were inventoried and analysed. HHSK could use this data to specify further research and give advice to Pekalongan about implementing solutions which will reduce the impact of floods. Besides HHSK, it would be interesting for the stakeholders in kota and kabupaten Pekalongan to glance specific information in this report. Furthermore, this report is for everyone who wants to know more about the water system of Pekalongan.

We would like to thank several people for their contribution to this report. At first Johan Helmer, our internship coordinator at the waterboard of Schieland and the Krimpenerwaard and the people we interviewed at HHSK. The tips which Johan Helmer gave us during his visit to Indonesia where very useful to give the right conclusion in our report. The second person is Jonathan Lekkerkerk who was our internship coordinator from the Rotterdam University of Applied Sciences. The skype meetings every two weeks where pleasant and helpful for our research.
At third, we would like to thank the Indonesian people and organisations. Imam Wayhudi for his tips during our research and all his jokes, the students for all the help in approaching the people in Pekalongan and telling us about their culture. Special thanks to Asip Kholbihi (the Bupati of kabupaten Pekalongan) and Amalia Rosaline for their kindness, accommodation and translation in Pekalongan. The UNISSULA University to invite us in working together and SIMA office who provided a good work site and tools for fieldwork. At fifth, Ulrich Malisius who helped us understanding the culture and the way many organisations operate in Pekalongan. Last but not least, all the stakeholders we have interviewed, the local inhabitants for the support of our research and many more.

We learned a lot about working in a different culture as a result of the interviews, the fieldwork, different kind of meetings and the cooperation with SIMA and UNISSULA. The Indonesian people are very kind and have great hospitality, everyone was ready to provide help where and when needed.

Semarang
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Summary

During this research, the possibilities for drainage using gravity were researched in kota Pekalongan and Tirto, focused on the Northern border area. Second, the role of seawater in the floods was researched for this areas. To complete this research, water infrastructures in kota Pekalongan and Tirto were mapped and information about rivers and canals in these areas was gathered.
Floods occur in North Tirto and kota Pekalongan on a daily base. A strategy to reduce the impact of these floods is needed.

Several methods were used to answer the research questions. Desk research was done to investigate the problem by reading articles and researches about floods in Pekalongan. During desk research an approach to gather all the needed data in Pekalongan was made. During field research in Tirto and kota Pekalongan, water infrastructures, rivers and canals were measured and mapped with a total of 92 measurements. In the field, the needed data was processed in My maps and Google forms. Divers were used to measure the water level in flooded areas and tidal influenced waterways. The data gathered during field research was processed with ArcGIS, Excel and Google Maps. To create an overview of all the stakeholders and involved parties, interviews were done with organisations of kabupaten and kota Pekalongan.

A difference in water level was measured between canal Bremi and the flooded areas around it. A difference in water level was also measured between river Meduri and the flooded areas around it. This difference in water level shows that there is a possibility to drain water using gravity. On four locations there are no water intakes available which could drain water during low tide. Two large intakes between river Meduri and the fishponds should be closed. During high tide, water can flow into the fishponds through these intakes. Further research about the size, management and maintenance about these intakes is recommended. Besides this, it is recommended that kota and kabupaten Pekalongan should work together with the province in an expertise team focused on the floods. This team should develop a long term strategy whereby the impact of the floods in both areas will be reduced.

Table of contents

List of acronyms

BAPPEDA	Badan Perencanaan Pembangunan Daerah
DPU	Public Works / Dinas Pekerjaan Umum Kota
Drainage by gravity	Using water level difference to drain water
HHSK	Waterboard Schieland and the Krimpenerwaard
Intake	Water infrastructure which can regulate water, as seen in figure 17
Kabupaten	Regency
Kecamatan	Sub-district
Kota	City
PSDA	Dinas Pengelolaan Sumber Daya Alam
UNISSULA	Universitas Islam Sultan Agung

Introduction

Pekalongan is located in central Java in Indonesia, see figure 1. The city is famous for its batik industry and is named “The World Batik City” in 2011 (Allo & Piliang, 2015). The batik industry delivers a good income for the city. In contrast with Semarang where populated areas dominate the coast, the ecosystem of Pekalongan is abundant by mangroves, agriculture and aquaculture (Marfai M. , 2014). But Pekalongan has to deal with some serious problems. Pekalongan is sinking just as other cities in Indonesia (Wilms, 2016). Mainly because of water extraction from the ground. This causes the city to lose fertile soil to the sea (Priyanto, 2010). Many parts in Pekalongan have to deal with tidal floods which occur in the night and the early morning. The floods in Kecamatan (sub-district) Tirto, further named as Tirto, and kota (city) Pekalongan are a danger for the inhabitants. The need for a solution is high. Tirto is a sub area of the kabupaten Pekalongan and is shown green in the North East in figure 2. Kota Pekalongan is shown white, East of Tirto.

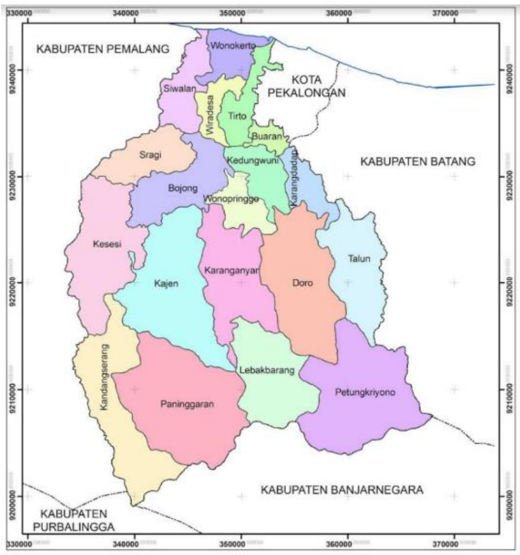


Figure 2, kabupaten Pekalongan is shown above. In the North East is kota Pekalongan shown in white (Diponegoro, 2012)

Figure 1, the location of Pekalongan (map java, 2016)

This report is established to give insight into the water system of the Tirto and the kota area, focused on the border area. The approach of this research is to map the current water infrastructures in the border area of kabupaten and kota Pekalongan and to investigate the possibilities to drain water from flooded areas using the difference in water level.
The border area is chosen because water does not follow the administrational borders and the floods occur within kabupaten and kota Pekalongan in the same water system.

The main research questions for the report are as follow:
"Where in Tirto and kota Pekalongan are the possibilities to drain water using gravity and (present) water infrastructures?"
"How does seawater contribute to the floods in Tirto and kota Pekalongan?"

To answer this research questions several sub questions were defined. The sub questions are as follow:
"Where and what kind of water infrastructures are located in Tirto and kota Pekalongan?"
"What is the current state of the water infrastructures in Tirto and kota Pekalongan?"
"How could water level differences in the Java sea and flooded areas be used to drain water?"
"What causes the floods in Tirto and kota Pekalongan?"
"How many times do these floods occur?"

These sub questions were answered by doing field research in the North East of Tirto and North West of kota Pekalongan. Parties who have a role in the water management are interviewed during our research. Besides fieldwork and interviews, desk research was done to answer these questions correctly.

The structure of the report is as follow. The floods and communication problems between kabupaten and kota Pekalongan are described in chapter one. More insight in the methods which are used during this research can be found in chapter two. Chapter three provides the findings of the research. More information about the current plans and programs to reduce the impact of the floods or improve the living quality in our research area is given in chapter four. Chapter five will describe the role of the stakeholders who have a responsibility in the water management of our research area. A conclusion of the findings is written in chapter six and the recommendation will be provided in chapter seven.

Chapter 1 Problem description

Coastal areas are the most vulnerable areas affected by climate change (Marfai & King, 2007). It is not entirely coincidental that kota Pekalongan and Tirto, areas which are located on the Northern coast of Java, are suffering from climate change. These two areas have to deal with permanently and daily floods caused by groundwater extractions, bad maintenance of water infrastructures, coastal erosion and a rising sea level (Marfai M. , 2014) (Wilms, 2016).
The villages that are flooded during tidal floods in Tirto are Mulyorejo, Jeruksari, Tegaldowo and Karangjompo (Chaerun, 2016). In kota Pekalongan is focused on the areas which are located next to Tirto. The aforementioned problems will be furthers described in this chapter. Besides the floods, insight in the complication of communication between Kota Pekalongan and Tirto is provided.

1.1 The cause of tidal floods in Kota Pekalongan and Tirto

First, as a result of the extraction of groundwater for homes, offices and industries kota Pekalongan are sinking with a speed of 1.8 to 3.9 cm/year, see figure 3 (Wilms, 2016). Wilms writes in his reports that many cities in the North of Java are sinking due to groundwater extraction, so does the Northern parts of Tirto (Wilms, 2016). It is assumed that the Northern parts of Tirto sink with the same speed as the Northern parts of kota Pekalongan (3.1 cm/year) because they are geographically next to each other. Mr. Ismanto, head of Public Works (DPU), tells in an interview that they see no other option for tap water then extracting it from the ground (Ismanto & Niftah, Interview Public Works Kota Pekalongan, 2016). As a result of land subsidence, sea water is able to flow into urban areas. Besides land subsidence, sea level rise contributes to the floods in Pekalongan (Marfai M. , 2014).

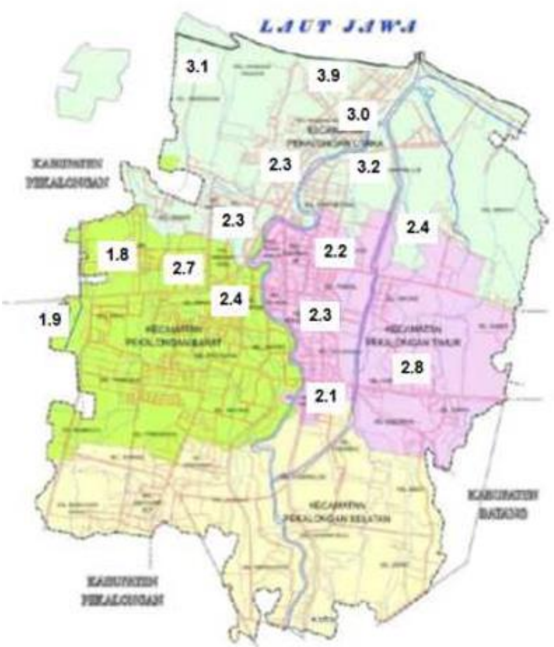


Figure 3, land subsidence shown in kota Pekalongan in cm/year (Pramudyo & Wafid, 2015)

Figure 4, locations where sea water has access to the sub systems

Second, gates/bridges that are made in the Northern parts of Tirto allow seawater to flow in during high tide. The red arrows in figure 4 illustrate the connections between the river Meduri and the fishponds. The yellow arrows illustrate the water flow from the fishponds to sub system 3.1 and 3.2. The blue arrows illustrate the connections between canal Meduri and sub system 2.1. The white arrow shows the opening between river Meduri and sub system 1.1.

Figure 5 and 6 illustrate two of these gates in the North. It is unknown who made the gates but the only people who have interest in a free flow of water are the fishermen. Besides these two gates, there are several culverts which allow a free flow of water from the river to the fishponds. The location of these gates and culverts are shown in figure 4. The big fishponds need fresh water to grow their fish. Residents told that the areas nearby their houses used to be rice fields but because of the floods it was not possible to produce rice anymore. As a result, the rice fields are transformed into fishponds. Local people were forced to switch from agriculture to aquaculture. The quality of this water is slowly getting worse because of the many chemicals which the batik industry is dumping in the water. Currently, it takes five months for the fishpond owners to grow their fish before it is ready for the market. This used to be three months in the past. Assumed is that these fishermen let the seawater in because this is better for their fish and therefore for their income.

Figure 5, bridge where water flows into the fishponds during high tide. There are shields which should prevent the water from flowing in, but they do not function well

Figure 6, bridge where water flows into the fishponds during high tide

Third, the daily coastal erosion in Pekalongan is a serious danger for the residents of Pekalongan. In the period of 2003-2009 the coast of Pekalongan was moved inland with approximately 10.5 meters (Marfai M. , 2014). And during a heavy storm in 2014 a part of the flood defence was broken. Tom Wilms mentions in his report that local authorities have tried to stop or slow down coastal erosion by building revetments made of concrete, stones and sand bags (Wilms, 2016). During field research there is discovered that some of the sand bags are heavy damaged or even lost their function to protect the coast from erosion. There is predicted that coastal erosion in Pekalongan will increase according to the rising sea level (Marfai M. , 2014). Figures 7, 8 and 9 illustrate the coastal protection in Kota Pekalongan.


Figure 7, damaged sandbags for the coast of kota Pekalongan (Wilms, 2016)


Figure 8, coastal protection without the use of sandbags


Figure 9, protection of the coast of kota Pekalongan against erosion by sandbags


Figure 10, water hyacinths are blocking the flow of the water in canal Bremi

As fourth, when an area is affected by water (during heavy rainfall or floods) it is important that the drainage system functions well. Because of a lack of maintenance of the water infrastructures and knowledge about draining the system, the system functions not as it should be. Many intakes in Tirto and Kota Pekalongan could not open or close and gates which should block water cannot block water. Inhabitants throw their garbage away in the water which causes clogging. Roads to the houses of the inhabitants are build which not benefit the flow of the water. As a result, water accumulates in the drainage canals and these will eventually flow over.
The water hyacinths in canal Bremi reduce the flow of the water. Figure 10 shows these water hyacinths in canal Bremi. These water hyacinths are found in large amounts in canal Bremi. The density is so high that children play on the hyacinths.

As a result of these problems, water in the fishponds flows into urban areas with high tide in the night. Many interviews with local inhabitants from Tirto and kota Pekalongan confirmed that during the night the water level rises with 10 to 30 centimetres. In the South the floods have a height of around 10 centimetres. Further North the water level increases to a maximum of 30 centimetres. Besides floods from the fishponds, the rivers have an important role in the floods. The combination of rainfall in the mountains and high tide is fatal for North Tirto and kota Pekalongan. Rainwater cannot discharge to sea and the river Meduri and canal Bremi will flood. This is based on interviews with locals. In this research these type is floods are not further investigated.
In the morning when the water level on sea drops, the water retreats to the fishponds and eventually to the rivers and sea. Only houses and roads which are raised and areas that can drain using gravity will not be flooded during low tide. Permanently flooded areas are created as a result of land subsidence due to groundwater extractions and raised roads.

1.1.1 Permanently flooded areas

The permanently flooded areas are mainly located on the upper North side of Kota Pekalongan and Tirto, see figure 11 and 12 (Pekalongan P. K., 2016) (Ismanto H. M., Penanganan Banjir Dan Rob Pada Sub Sistem Bandengan Kota Pekalongan, 2016). In these areas the land level is the lowest (Nirwansyah, 2015). The inundation problems occur because the sea level is higher than the land level. Therefore, water is only able to flow in. The current ways to get rid of the water is the usage of pumps and evaporation. These areas still have to deal with the tidal differences from the Java sea. Which means that the water level fluctuates from 10 to 30 centimetres a day.

Figure 11, urban permanently flooded areas in Kota Pekalongan

Figure 12, urban permanently flooded areas in Kota Pekalongan

1.2 Complication of communication between Kota Pekalongan and Tirto

The communication between kota Pekalongan and Tirto is complicated. Tirto is under the leadership of kabupaten Pekalongan and kota Pekalongan has its own leadership. Both stakeholders within these areas only work and focus between their administrational borders (Rumingsih, Wisnugroho, & Anita, 2016). BAPPEDA from as well kota Pekalongan and Tirto told during an interview that there is a cooperation between the two parties, but it does not work out well. During a cooperation between the two parties, the province of Central Java is involved to oversee their cooperation (Rumingsih, Wisnugroho, & Anita, 2016). During interviews it became clear that both parties are not aware of the plans of the other stakeholders to solve the floods (Rumingsih, Wisnugroho, & Anita, 2016) (Nugroho, 2016). Figure 13 and 14 illustrates the lack of coherence between kota and kabupaten Pekalongan. To solve floods in both areas a cooperation is needed. Most of the plans are not overcrossing the border. Chapter four will give further insight into the current plans of kota Pekalongan and Tirto.

Figure 13, the drainage canal to river Meduri in kota Pekalongan ends at the border with kabupaten Pekalongan

Figure 14, the flood defence wall in kabupaten Pekalongan next to river Meduri ends at the border with kota Pekalongan

Chapter 2 Methodology

In this chapter the methods which are used during the internship in described. These methods were used to answer the main research questions. The project was divided into several stages, at first the preliminary investigation which was done in the Netherlands. The tasks in Indonesia started with interviews in Jakarta. Furthermore, the activities in Semarang which are divided in chapter 2.3. And the fieldwork and surveys in Pekalongan. Here starts a circle between Semarang and Pekalongan, where data collection and data processing follow each other. And in the end the final report was written.

2.1 Preliminary investigation
Preliminary investigation at HHSK was done in the first two weeks of the project. At the waterboard as much information as possible about Pekalongan was collected by looking into the available reports and presentations. Furthermore, there were several interviews with anybody that had any experience with working in Indonesia and with people that could provide information to help starting the research. The interviews led to valuable information about working in Indonesia and lead to suggestions about the project approach.

2.2 Interviews in Jakarta
In Jakarta interviews were used to gather information about the cultural differences and Pekalongan. Information about cultural differences were obtained by an interview with Indhira Meliala from Nuffic NESO. During this interview the focus was on the cultural differences and how to be appropriate in the Indonesian culture. Furthermore, there was interview with Tom Wilms from Witteveen en Bos, he did research about coastal erosion in Pekalongan. He did not really focus on tidal floods, but still had some useful information about the cause of the floods in Pekalongan.

2.3 Activities in Semarang
In Semarang several activities were done. The activities can be divided into literature studies, preparation of the fieldwork and surveys in Pekalongan and processing the gathered data from Pekalongan.

2.3.1 Literature study
Data collection by gathering information from different researches was done in Semarang. The literature was translated to English or Dutch if needed. The literature was collected by both, literature found on the internet and hard copy reports collected from the several interviews.

2.3.2 Preparation fieldwork and surveys
To make sure that the fieldwork was as efficient as possible good preparation was done. The preparation consisted several activities such as making surveys for the different stakeholders in Pekalongan and arranging a meeting with them. Furthermore, the most efficient way to collect data and process data was searched. This was found by using Excel, My maps, ArcGIS and surveys. To make sure the fieldwork was well prepared a trail fieldwork in Semarang was done. This led to several improvements in the system of collecting the data.

Excel
All the collected data from fieldwork was inserted in several Excels, see appendixes 4 and 6. These Excels can be found in the folder Excel as delivered with this report. If you do not have access to this excel please send an email to thijswillem@msn.com. All the data will be send. In total there a three main Excels, one with information about the water infrastructures, one with information about the waterways and the final one with data collected from the divers. A guide for the use of these Excel sheets is provided.

My maps
My maps is an application which allows the user to pinpoint his location. The application also allows to add notes at the location and divide the pinpoints into several layers (Google, My maps, 2016). If shared other users can also add pinpoints on the map. Therefore the application was picked because it was simple, easy to use and other people could also use it in the future. In the field, a layer is chosen to make a pinpoint in. Set the pinpoint on your location and add information. The maps that are made are accessible on the computer. Appendix 1 informs more about how to use My maps.

ArcGIS
ArcGIS was used to make maps and combine the Excels with the pinpoints. The problem that was encountered was that the quality of the maps was low. Therefore, Google Earth and Adobe Illustrator were eventually used to make the maps. ArcGIS was necessary to combine the excel and pinpoints to eventually create the Google Earth map will all the data.

Google Forms
An innovate way to collect data and process the data was searched and found by Google Forms. Google Forms was made to use a survey (Google, Forms, 2016). The survey consists several questions which allows the user to go straight to the correct water infrastructure or waterway. After this, several questions about this specific water infrastructure or waterway had to be filled in. The results are presented in Excel Online and are placed to a normal Excel. An example survey and more information can be found in appendix 2.

2.3.3 Processing data
Processing data from the fieldwork and surveys in Pekalongan was done in Semarang. All the information gathered from the fieldwork surveys needed to be processed in Excel. Furthermore, all the photos had to be renamed to match them with the associated water infrastructure or waterway. The interviews with the related surveys were also processed in Semarang. The excel information was combined with ArcGIS. This also allowed ArcGIS data to be converted into Google Earth data. Appendix 3 shows the steps to convert ArcGIS data to Google Earth. In the folder ArcGIS on the delivered USB all the ArcGIS information can be found. When the USB in not delivered with this report, please send an email to thijswillem@msn.com. All the data will be send. The same applies to the maps of Google Earth.

2.4 Fieldwork and surveys in Pekalongan

Fieldwork in Pekalongan, total 18 days, led to information about the water system. The location and other details about water infrastructures were measured. This information was gathered by doing field research on the scooter and with measurement equipment. The location was pinpointed and the survey about the water infrastructure or waterway were done immediately on sight. Furthermore, pictures of the waterways or water infrastructures were made. Information about water level differences was gathered by using divers and doing measurements by hand. In total three divers were available, one of them was always hanging in the air and the two others were in the water. This because the divers measured water- and air pressure, so the air pressure needed to be subtracted. Two of the used divers were the DI501-10m divers and one of them which was also had the option of measuring salinity was a CTD-Diver 50mm all of them from swstechnology.
In Pekalongan also several interviews with different stakeholders were done. Information about the stakeholders can be found in chapter 5. Appointments with these stakeholders were done by email or phone. There was also help of Amel, who works for kabupaten Pekalongan, and Ulrich Malisius, a German researcher who lived in Pekalongan. They sometimes helped with arranging meetings and they did translations during the interviews.

Chapter 3 Water system analyses

The water system area as researched during the project is shown in figure 15. The green line from North to South is the border between kabupaten and kota Pekalongan. The area on the West side belongs to kabupaten Pekalongan. The area on the East side belongs to kota Pekalongan. This chapter explains which type of flood occur is each sub system and how many times the flood occur. Besides that, the possibilities for drainage using gravity are explained in this chapter.

The researched area is divided into four different areas, with each system having their own sub systems. Sub system 1 is fully located in Tirto, kabupaten Pekalongan. Sub systems 2, 3 and 4 are both located in kabupaten and kota Pekalongan. In these areas the water system analysis is executed. Within this water system analysis, the water infrastructures are examined and the possibilities of drainage using gravity are researched. The borders of these four sub systems are made by searching for barriers in the water system. Rivers and high roads are barriers because water could not cross this. Within these four subsystems areas are specified which drain water separately, as shown in figure 16. It is important to mention that the approach of this research is to investigate the possibilities to drain water from flooded areas using gravity (difference in water level). When drainage using gravity is possible, the water level in the flooded areas will drop. Information about the duration and the volume of the discharge is a simulation of the reality and is changing during the year.

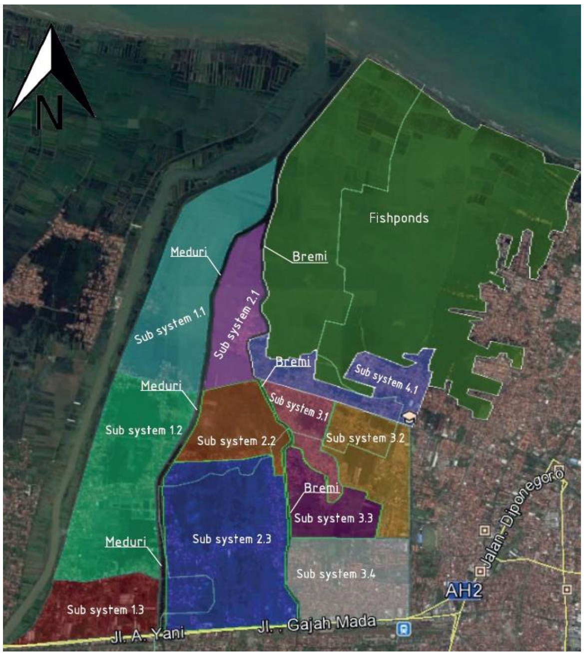


Figure 15, all sub systems where research is done are shwon. The left side of the green line belongs to kabupaten Pekalongan, the area on the right sight of the green line belongs to kota Pekalongan

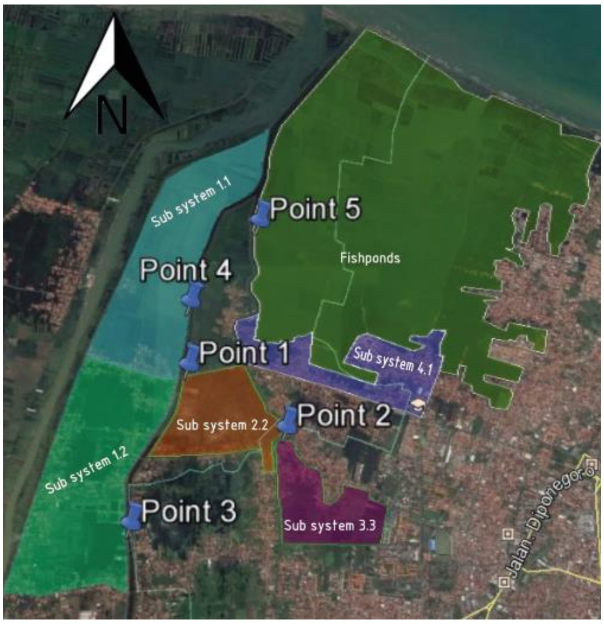


Figure 16, all sub systems where a water level difference is measured are shown. The fishponds are part of sub system 4.1. The points on the map are the points where a difference in water level is measured between the sub systems and the river

3.1 Sub system 1

This sub system is totally located in Tirto which is a sub area of kabupaten Pekalongan. This sub system is bordered by the river Sengkarang on the West side and river Meduri on the East side. On the South side this sub system is bordered by Jl. A. Yani. This sub system is divided into 3 sub systems. These areas are not connected with each other and drain water separately. Sub system 1.1 is mostly fishpond. Sub system 1.2 is a permanently flooded urban area. In these two areas floods from sea occur on a daily base. Drainage using gravity is possible for sub systems 1.1 and 1.2. Drainage using gravity to the Meduri is not possible for sub system 1.3. Figure 15 shows to location of the mentioned sub systems. The specific type of floods in subs system 1.3 are not defined. Currently, there are two intakes where water is drained using gravity, see figure 17 and 18. These intakes are located in the sub system 1.1. During high tide, pumps are used to drain water. Information about this location is shown below in table 1, which is point 4 in figure 16. Table 2 provide information about drainage in sub system 1.2, which is point 3 in figure 16.

Figure 17, intakes are open during the day when drainage using gravity is possible. Fishponds are drained to river Meduri

Figure 18, intakes are closed at night when the river Meduri is too high to drain water from the fishponds

Point 4	**Anser**
Information	Fishponds could drain to river Meduri
Salt water measured in Meduri?	Yes, same measurement as point 1
Location	Fishpond to Meduri
Is drainage using gravity possible?	Yes
Indication of the maximum difference in water level in cm	15
Indication of the duration of possibility using gravity drainage	4,5 hours
Indication of the time of drainage using gravity	05:00 - 14:00
Current water infrastructures	2 intakes which are used to drain water
Urban or rural area	Rural
Surface which could be drained in m^2 (sub system 1.1)	881563
Total amount water could be drained using gravity m^3	132234,45

Table 1, information about the possible drainage from sub system 1.1 to river Meduri.

Point 3	Anser
Information	Fishponds could drain to river Meduri
Salt water measured in fishponds?	Yes
Location	Fishpond to Meduri
Is drainage using gravity possible?	Yes
Indication of the maximum difference in water level in cm	23
Indication of the duration of possibility using gravity drainage	14 hours
Indication of the time of drainage using gravity	04:00-20:00
Current water infrastructures	Not available
Urban or rural area	Urban
Surface which could be drained in m² (sub system 1.2)	995381
Total amount water could be drained using gravity m³	228937,63

Table 2, information about the possible drainage from sub system 1.2 to river Meduri

3.2 Sub system 2

This sub system is located in kabupaten and kota Pekalongan and in bordered by river Meduri and canal Bremi. On the South side this sub system is bordered by Jl. Gajah Mada Bar. The system is divided into 3 sub areas which drain almost separately from each other. Sub systems 2.1 and 2.2 are primarily fishponds with urban areas in the East and in the South. Sub system 2.3 in the South is larger and can be described as an urban area. Floods from sea occur in sub system 2.1 with an estimated height of 30 centimetres. In combination with rain the floods can be 10 centimetres higher. In sub system 2.2 the influence of high tide is approximately 10 centimetres. Currently, sub system 2.3 is affected by floods from sea at the same level at sub system 2.2. During field research a raised road is discovered, which makes this road the border between sub system 2.2 and 2.3. Because of this road, it is expected that the tidal influenence of the Java sea is reduced in sub system 2.3. There is chosen to define the areas as separate areas because water level differences on the borders are measured multiple times.

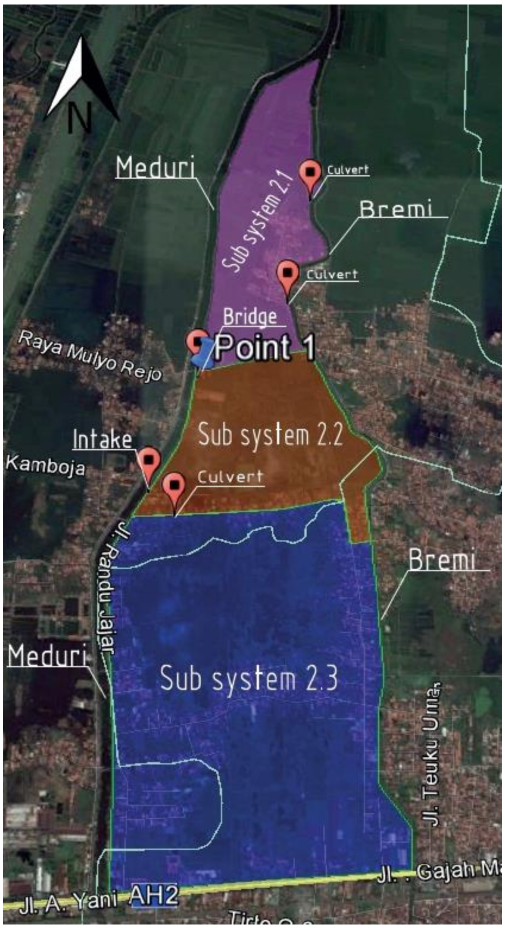


Figure 19, connections between the sub systems are shown. Drainage using gravity is possible to river Meduri at West side of sub system 2.2

Currently, sub system 2.1 and sub system 2.3 are connected with sub system 2.2 with one opening each, see figure 19 for the location of these openings. It is measured that the water level of the fishponds in sub system 2.2 is sometimes higher that the water level of river Meduri. This difference shows that there is a possibility to drain water using gravity. It is unknown how much sub systems 2.1 and 2.3 could benefit in the future from the drainage in sub system 2.2 to the river Meduri. The intake which is shown between Meduri and sub system 2.2 is In_021116_19 and could function to drain to river Meduri. It is estimated that a bigger intake should be built to increase the capacity.

Kota Pekalongan is currently investing in the drainage of their part of sub system 2.3. See chapter 4.1.4 for more information about this project of Kota Pekalongan.

Table 3 below shows information about this possibility of drainage using gravity in sub system 2.2, which is point 1 in figure 16.

Point 1	Anser
Information	Fishponds could drain to river Meduri
Salt water measured in Meduri?	Yes
Location	Fishpond to Meduri
Is drainage using gravity possible?	Yes
Indication of the maximum difference in water level in cm	20
Indication of the duration of possibility using gravity drainage	10 hours
Indication of the time of drainage using gravity	05:00 - 14:00
Current water infrastructures	Not available
Urban or rural area	Rural
Surface which could be drained in m² (sub system 2.2)	375923
Total amount water could be drained using gravity m³	75184,6

Table 3, information about the possible drainage from sub system 2.2 to river Meduri

3.3 Sub system 3

This sub system is located in kabupaten and kota Pekalongan. This sub system is bordered by Jl. Patriot in the North, Jl. Bahagia in the West, Jl. Gajah Mada Bar on the South side and canal Bremi on the West side. There are 4 sub systems defined which will drain water separately in the future. The borders within sub system 3 are based on interviews with locals, field research and analysing maps provided by the DPU kota Pekalongan (DPU, 2016). Floods from sea occur in sub systems 3.1, 3.2 and 3.3. Sub system 3.4 is not affected by seawater and will only flood during rainfall.

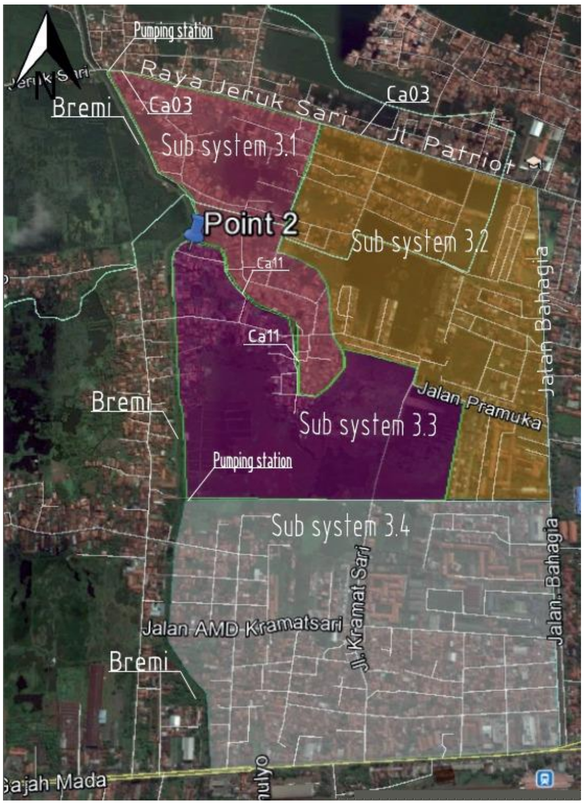


Figure 20, borders and useful canals are shown of sub system 3

Figure 20 will clarify the following paragraph. Sub systems 3.1 and 3.2 are urban areas which drain water to canal_03 in the North. This water will be pumped to canal Bremi in the future. A new canal, canal_11, will drain water from sub system 3.3 to a pumping station which pumps it to canal Bremi. There are 2 intakes between Ca_11 and canal Bremi. One of these is available to drain water from Ca_11, the other one is bent and could not open. Sub system 3.4 is not affected by floods from sea and will drain water to canal Bremi by the pumping station at the North West (DPU, 2016). The bad drainage system and a lack of storage for water are the causes of the flood during rainfall in this sub system.

Table 4 below provides information about the possibility of drainage using gravity in sub system 3.3, which is point 2 in figure 16.

Point 2	Anser
Information	Canal Ca_11 could drain to canal Bremi
Salt water measured in Bremi?	No
Location	Ca_11 to Bremi
Is drainage using gravity possible?	Yes
Indication of the maximum difference in water level in cm	7
Indication of the duration of possibility using gravity drainage	7 hours
Indication of the time of drainage using gravity	3:30-11:00
Current water infrastructures	Pumping station and intakes
Urban or rural area	Urban
Surface which could be drained in m² (sub system 3.3)	309450
Total amount water could be drained using gravity m³	21661,5

Table 4, information about the possible drainage from sub system 3.3 to canal Bremi

3.4 Sub System 4

This sub system is located in kabupaten and kota Pekalongan. This is small subsystem which is bordered by canal Bremi on the West, the fishponds on the North and Jl. Patriot on the South. It is unclear what the East border of this sub system is. Sub system 4.1 is affected by floods from sea.
A difference in water level between the fishponds in the North of sub system 4.1 and canal Bremi is measured. So there is possibility to drain water to canal Bremi using gravity. When the water level in the fishponds is dropped, sub system 4.1 can drain water to the fishponds.
The water level in the fishponds can only drop if some specific culverts and intakes cannot let in during high tide. A solution for this problem is to install covers for the intakes at the river side. Water is blocked during high tide but could drain water during low tide.
See figure 21 for the biggest gate where water is able to flow in the fishponds during high tide. This gate should be closed before drainage at point 5 is possible, shown in figure 22. The best location to drain water from the fishponds to canal Bremi is South of the intake (In_121016_06). The location on the intake is shown at point 5 in figure 22. During high tide the water level will rise less behind the intake because there is a gate which prevents most of the water to flow further upstream in the Bremi. As a result water behind the gate is lower, what gives the possibility to discharge more water in the Bremi. The current way to drain water is by using pumps, figure 23 and 24 illustrate the drainage of sub system 4 to the fishponds. Table 5 below provides information about the possibility of drainage using gravity for the fishponds to canal Bremi. Location of point 4 is shown in figure 16.

Point 5	Answer
Information	Fishponds could drain to canal Bremi
Salt water measured in Bremi?	Yes
Location	Fishponds to Bremi
Is drainage using gravity possible?	Yes
Indication of the maximum difference in water level in cm	21
Indication of the duration of possibility using gravity drainage	24 hours
Indication of the time of drainage using gravity	Always
Current water infrastructures	Not available
Urban or rural area	Rural/urban
Surface which could be drained in m² (sub system fishponds)	3991067
Total amount water could be drained using gravity m³	838124,07

Table 5, information about the possible drainage from fishponds to canal Bremi

Figure 21, gate where water is able to flow into the fishponds during high tide. Gate is marked in figure 22

Figure 22, drainage using gravity is possible when the gate is closed. The blue arrows show that water could be drained to the fishponds and canal Bremi

Figure 23, flooded area next to fishponds on the North in sub system 4

Figure 24, water is drained on the fishponds in the North of sub system 4 by using a pump

As mentioned above in chapter 3.1 till 3.4, water level differences are measured between the flooded areas, canal Bremi and river Meduri. This is based on one measurement on each location. The given fact that water will always flow to the lowest point, gives the opportunity to drain water. The drainage using gravity is only possible when the water level in the river is lower than the draining area. During rainfall and high tide, the water level will rise in the rivers and pumps are needed to discharge water. Investing in pumps is a good decision with the future in mind. As a result of land subsidence, the amount of water what could be discharged using gravity will get less during the time.
It was not possible to observe the divers, the equipment which measured the water height, all night. So the change on mistakes is present and it is important to do further research before action is taken. Further recommendations are written in chapter 7.

3.5 Water infrastructures

Water infrastructures as found during field research can be found in the Excel sheet and maps that are coming with this report and in appendixes 4 to 7. In these Excels, information about the water infrastructures and waterways can be found. A quick overview is made in figure 25 and 26 to see what type of water infrastructures are measured and what the status was of the three most measured infrastructures. Number 1 means a bad status and not functioning anymore and number 4 is a water infrastructure in great status

The ownership of the infrastructures is a grey area (Ismanto & Niftah, Interview Public Works Kota Pekalongan, 2016). Most of the smaller pumping stations are managed by local people. For the other water infrastructures it is not clear who does the maintenance. This makes it hard to approach organisations about their responsibilities.
Using the pumps in a logical and more strategical way would improve the drainage of the flooded areas. A second problem of the maintenance of the water infrastructures, even when the administrator is clear. Many intakes could not operate as a result of a lack of maintenance.
During the interviews it became clear that there was no budget for maintenance (Nugroho, 2016).

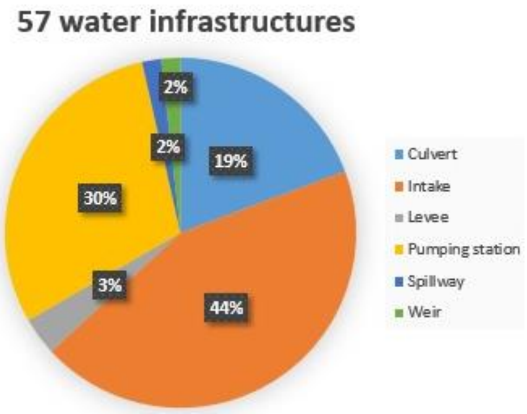


Figure 25, pie chart where the amount of water infrastructures is shown

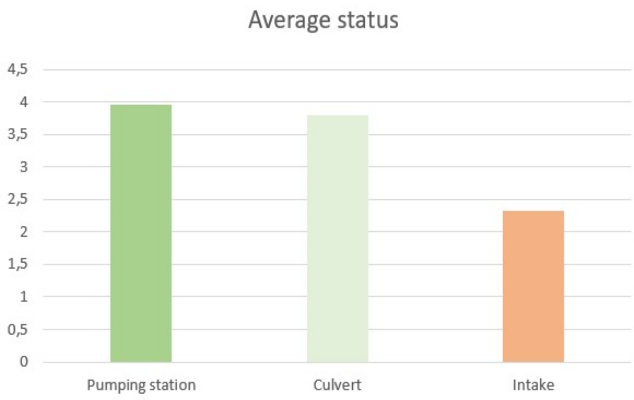


Figure 26, the average status of the most measured water infrastructures

3.6 Polder Sibulanan in kota Pekalongan

In kota Pekalongan, there is already an existing polder since 2012, shown in figure 27 in purple. The polder has a surface of 150 hectares and is named Sibulanan (Wilms, 2016). The polder is bordered by the river Pekalongan on the West and a new canal named Banger on the East side (Google, 2016). The water discharges to this new canal. This canal is made to change the sedimentation flow of the main river (Wilms, 2016). This benefits the harbour from having less sedimentation around the harbour. The central government helped to fund this polder (Rumingsih, Wisnugroho, & Anita, 2016). In 2012 regulations changed which caused that the old approach, such as the process, organisation and involved parties cannot be used anymore (Rumingsih, Wisnugroho, & Anita, 2016). BAPPEDA kota Pekalongan mentioned that it only took two years to finish the polder, one year of planning and research and one year of construction.

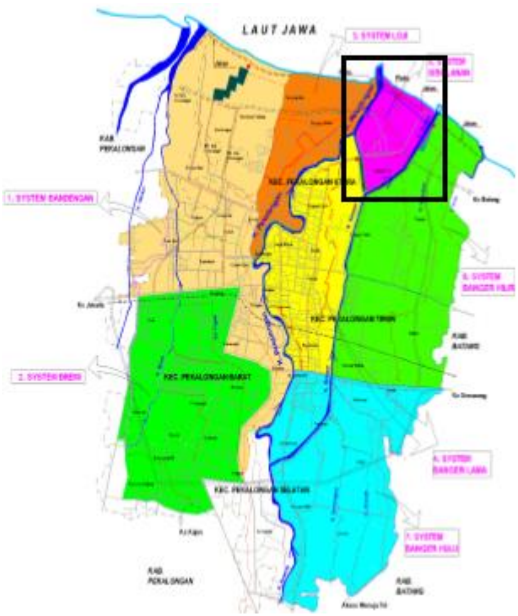


Figure 21, polder Sibulanan is shown in purple on the map (Wilms, 2016)

Chapter 4 Current solutions

This chapter explains the current plans as collected from the stakeholders. The plans are collected during interviews, presentations and email contact. There are uncertainties about the plans, because not all the provided information was clear.

4.1 Plans that are already in action

There are currently three known plans that are already executed or that are in progress in Tirto and kota Pekalongan.

4.1.1 Investment in upgrading poor neighbourhoods

The province of Central Java invests money in poor neighbourhoods, they especially focus on the Northern kota area (Nugroho, 2016). The focus on this area is logic, because North kota Pekalongan is more populated than North Kabupaten. Furthermore, people in the Northern parts are most affected by the floods. The invested money by the province goes to renewing and raising roads and houses (Astu, 2016). The province provides stones and sand and the local people can use them to raise their house or raise the roads The investment costs of this project are kept secret. Figure 28 and 29 illustrate this way of working. The problem of the investment is that it is executed without any cohesion with other plans. The province provide the flooded areas with stones and sand, but not in collaboration with a plan to protect the houses from flooding. This is unfortunate because good infrastructure plans, such as raising roads and use these roads as a levee could really provide some help against flooding.

Figure 28, photo of truck deposing stones to raise the road

Figure 29, photo of stones that are used to raise the roads and houses seen during fieldwork

4.1.2 Levee Bandengan

BAPPEDA Kota Pekalongan told about a plan to protect Bandengan. A levee next to the sea will be built and will protect Bandengan. The levee will approximately cost 100 million IDR and is financed by the province of Central Java (Rumingsih, Wisnugroho, & Anita, 2016). The levee will stop at the border with Kabupaten Pekalongan. The research to make the levee is done by Public Works. The levee is planned to be finished in 2017. The idea is that if Bandengan is protected from flood other areas also protected because Bandengan is seen as the main source of the flood problems in kota Pekalongan (Ismanto & Niftah, Interview Public Works Kota Pekalongan, 2016).

4.1.3 Improving drainage in sub system 2.3

During fieldwork it was discovered that kota Pekalongan is investing in the drainage system in sub system 2.3. The canal is crossing this sub system and will drain water to river Meduri with the use of a pump with a capacity of 1,2m^3/s. Water could flow into this canal with the use of pipes which allow the water to flow from the flooded area in the canal. Figure 30 illustrates these pipes, there are visible slightly above the water level of the canal. This project will probably lower the water level permanently and will reduce the impact of the floods in this sub system.
An interesting fact is that the canal stops at the border of kota and kabupaten Pekalongan. On the other side, the flood defence wall of kabupaten Pekalongan begins at their side of the border.

Figure 30, pipes are made in the side to allow water to flow in the canal during floods

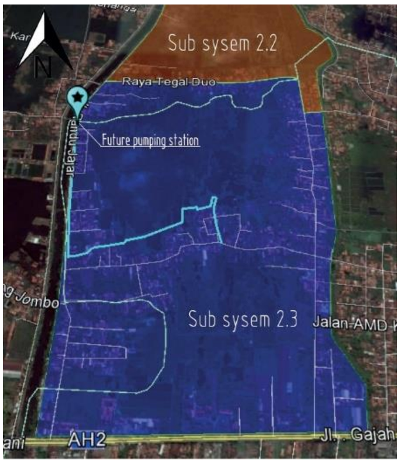


Figure 31, new drainage canal in kota Pekalongan which will drain water to river Meduri by a pumping station in the future

4.2 Future plans

There are several plans that kabupaten as well as kota Pekalongan want to proceed, even though these plans are not yet started.

4.2.1 The 3 system plan

The idea to make 3 systems to prevent areas from flooding is an idea of the province of Central Java and the national government (Rumingsih, Wisnugroho, & Anita, 2016) (Nugroho, 2016). The plan is to make one levee in the North to protect parts of Kabupaten and Kota Pekalongan. This levee is shown as a blue line in figure 32. The three different systems are system Wonokerto, system Mulyorejo and system Jeruksai Bandengan. Each system will have their own pump(s) and retention areas (Antayo & Prawukanto, Interview PSDA, 2016).

Figure 32, 3 sub systems (polders) which will be protected by a levee in the North. Border between kota and kabupaten is shown green. It is unclear if the blue and green areas will be built in the future.

Furthermore, PSDA kabupaten planned to use the new levee as a road. This plan crosses the administrational border which is shown green in system Jerkusari Bandengan. Plans which are crossing the border are good and illustrates the approach of the province of Central Java and the national government.

There are some uncertainties about this plan. According to PSDA kabupaten, the finance of the plan is already confirmed on national level and this project will be finished in 2018 or 2019. The DED[1] of this plan should be ready in December 2016.
BAPPEDA kabupaten recognized that the idea for systems Wonokerto and Mulyorejo are not confirmed and that this is only the idea of PSDA without confirmation about anything (Nugroho, 2016). BAPPEDA did confirmed that system Jeruksari Bandengan, shown in red, will be built in the future. Some parts of Tirto are more luckily then intentional involved in system Jeruksari Bandengan (Nugroho, 2016). BAPPEDA and PSDA kabupaten contradict each other in their messages.
Second, it is not clear what will happen with rivers which will cross the new levee. River Sengkarang and river Meduri, which border the System Wonokerto on the West and East side are able to flow to sea. But canal Bremi, between the green and red systems, will get blocked. The DED will give more depth in the research in December 2016.

4.2.2 Northern ring road as a levee

Public works (DPU) kota Pekalongan have a plan to make a road in the North, which will be used as a levee, see figure 33. This idea is separate from the 3 system plan, which is mentioned above (Ismanto & Niftah, Interview Public Works Kota Pekalongan, 2016). A new 5700 meter long road will be built in the North of kota Pekalongan and will serve as a levee (Ismanto H. M., Penanganan Banjir Dan Rob Pada Sub Sistem Bandengan Kota Pekalongan, 2016).

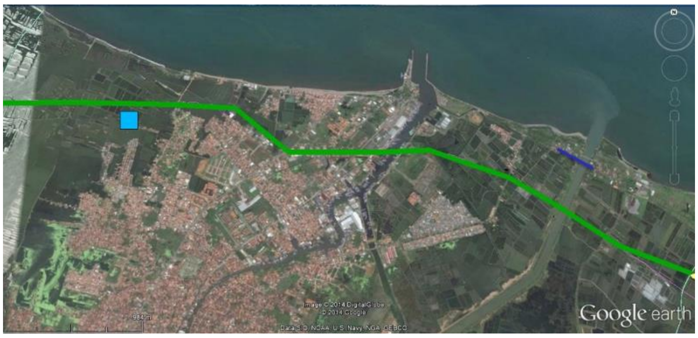


Figure 33, the road in the North of kota Pekalongan which will function as a levee

Public works sees several advantages and disadvantages in their project. The advantages are described as follow: "Most of the fishponds could function, the road will function as a levee, budget from the central government is available and the road improve the flow of traffic.
But they also see disadvantages mentioned: "Not all areas benefit from this project and the costs are high."

[1] DED: Detailed Engineering Design

Chapter 5 Stakeholders

This chapter is about the different stakeholders in Pekalongan. Stakeholders are persons, groups or organisations who have an interest or a concern in a project. In this chapter the stakeholders which will be described are all governmental parties who have interests in the water system of Pekalongan.

5.1 DPU

Public Works is in Bahasa Dinas Pekerjaan Umum (DPU). Public works make plans and realise projects on the following items: road access, building residencies, urban planning projects and water management (Ismanto & Niftah, Interview Public Works Kota Pekalongan, 2016) (Astu, 2016). Kota and kabupaten have this organisation. DPU kabupaten Pekalongan does not have influence in water management related subjects. This is the task of PSDA kabupaten.

5.2 PSDA

PSDA is the abbreviation of Dinas Pengelolaan Sumber Daya Alam and is the water management department of kabupaten Pekalongan. The main tasks of PSDA are: controlling floods, taking care of the irrigation system, beach treatment, indexing their water resources and taking care of small rivers and canals (Antayo & Prawukanto, Interview PSDA, 2016). Furthermore, PSDA does the communication about water related changes with the local inhabitants. Kota Pekalongan does not have a separate water management department as the Kabupaten does, these tasks are placed by DPU (Malisius, Interview Ulrich Malisius, 2016).

5.3 BAPPEDA

BAPPEDA is the abbreviation of Bahasa Badan Perencanaan Pembangunan Daerah is umbrella organisation in kota and kabupaten Pekalongan. Kota and kabupaten have both their own BAPPEDA. They make planning's and are managing the finances for all departments (Nugroho, 2016). Besides planning and development the organisation does the communication with the province level about budget dividing. They divide the budget based on priority (Nugroho, 2016).

5.4 Province of Central Java

The province of Central Java is responsible for larger rivers as well as in kota and Kabupaten Pekalongan. These rivers are river Sengkarang and river Meduri. Furthermore, they do maintenance for the levees along these rivers (Antayo & Prawukanto, Interview PSDA, 2016). The province is also approached to facilitate the cooperation between kota and Kabupaten (Rumingsih, Wisnugroho, & Anita, 2016). Furthermore, the province is working on upgrading the poor neighbourhoods, more information about this can be found in chapter 4.1.1.

5.5 Waterboard Schieland and the Krimpenerwaard

The Waterboard Schieland and the Krimpenerwaard (HHSK) is a Dutch organisation which will probably cooperate with kota and kabupaten in the future. Their contribution will be helping kota and kabupaten with the management and maintenance of their projects, as described in chapter 4.2 and other water management related projects which will be started in the future.

Chapter 6 Conclusion

To develop a strategy how the impact of the floods in Tirto and kota Pekalongan can be reduced, sub questions and main questions are answered during this research. These findings help Tirto and kota Pekalongan to develop their strategy for reducing the impact of the floods. To reduce this impact it is important that water could is discharged from flooded areas to sea. Besides using pumps, drainage using gravity could be used to drain water. This method is seen on one location in the research area and it there is a possibility that is can be used for four other locations.

The water infrastructures which are located in Tirto and kota Pekalongan mainly consist out of pumping stations, culverts and intakes. During field research 17 pumping stations, 13 culverts and 25 intakes are located out of a total of 59 water infrastructures. The exact location and status of all water infrastructures can be found in appendix 5 and 7. The pumping stations have an average status of 4 out of 4 which means that they do function and are not damaged. The culverts have an average status of 4 which means that they let water flow. On the other hand, the intakes have an average status of 2.5 which means that they do not open and are hard to repair.

The floods from sea in Tirto and kota Pekalongan occur on daily base. In the Southern areas floods occur from sea with a height of maximum 10 centimetres a day, floods do not occur in sub system 3.4. Further North, the height of the floods increases till a maximum height of 30 centimetres. The tidal floods are caused by gates and other openings connected with fishponds and canal Bremi or river Meduri. As a result of these gates, these fishponds (and urban areas) are under influence of the tidal range of the Java sea.
The flooded areas can be divided into three different areas. There are areas which are always flooded, areas which only flood during high tide and areas which only flood during heavy rainfall. The always flooded areas are flooded as a result of land subsidence and a bad drainage system. Water is locked in these areas with always flooded areas as a result. Raised roads and semi raised houses are the places which are only flood during high tide. These places are raised so they are not always flooded but are still flooded during high tide on the Java sea. Sub system 3.4 is an area where floods only occur during rainfall. The bad drainage system and a lack of storage for water are the causes of these floods here.

In sub system 1.1, water level differences between the fishponds and river Meduri are used to drain water. The differences in water level of the Java sea are essential for drainage using gravity. During low tide of the sea, the water level in river Meduri and Bremi is at some points lower than the water level of the flooded areas around these rivers. The given fact that water always flows from high to low gives the opportunity for kabupaten and kota Pekalongan to drain water using gravity. By installing intakes, the discharge of water to the rivers could be regulated. During low tide, the intakes should be opened and water could discharge into the rivers. The rivers discharge into the sea. During high tide the intakes should be closed, this prevents water from flowing into the flooded areas and making the floods worse.

The main research questions which are answered below are:
"Where in Tirto and kota Pekalongan are the possibilities to drain water using gravity and (present) water infrastructures?"
And:
"How does seawater contribute to the floods in Tirto and kota Pekalongan?"

The possibilities to drain water using gravity in Tirto and kota Pekalongan can be found in sub systems 1.1, 1.2, 2.2, 3.3 and 4.1. As a result this possible drainage, the water level in the flooded areas will drop. This will reduce the impact of the floods.
A difference in water level is measured between canal Bremi and sub system 3.3 and 4.1. Between river Meduri and sub systems 1.1, 1.2 and 2.2 a difference is water level is also measured. A difference in water level in the rivers and the sub systems means that there is a possibility to drain water using gravity.
In sub system 1.1, current intakes are used to drain water. There are no current water infrastructures in sub system 1.2 found which could drain water to river Meduri. In sub system 2.2 there is a small intake which could be used drain water to the river Meduri. It is estimated that bigger intakes should be built to increase the capacity.
In sub system 3.3 there are 2 intakes between Ca_11 and canal Bremi. One of these is available to drain water from Ca_11, the other one is bent and could not open. Sub system 3.3 is draining water into Ca_11.
There are no intakes for sub system 4.1 to drain water to the fishponds. There are several culverts which could drain water from the fishponds to river Meduri during low tide. This will only have effect when two large intakes in the North are closed. These intakes allow large amounts of water to flow into the fishponds during high tide. In addition, intakes should be placed behind the intakes in canal Bremi.

Seawater contributes to the floods in Tirto and kota Pekalongan by flowing into river Meduri and through intakes into the fishponds. This is shown with red arrows in figure 34. The fishponds will eventually flow to sub system 4.1, 3.1 and 3.2, shown with yellow arrows.
The two openings with canal Bremi and sub system 2.1, shown with blue arrows.
The last opening in shown with a white arrow where river Meduri could flow into sub system 1.1.

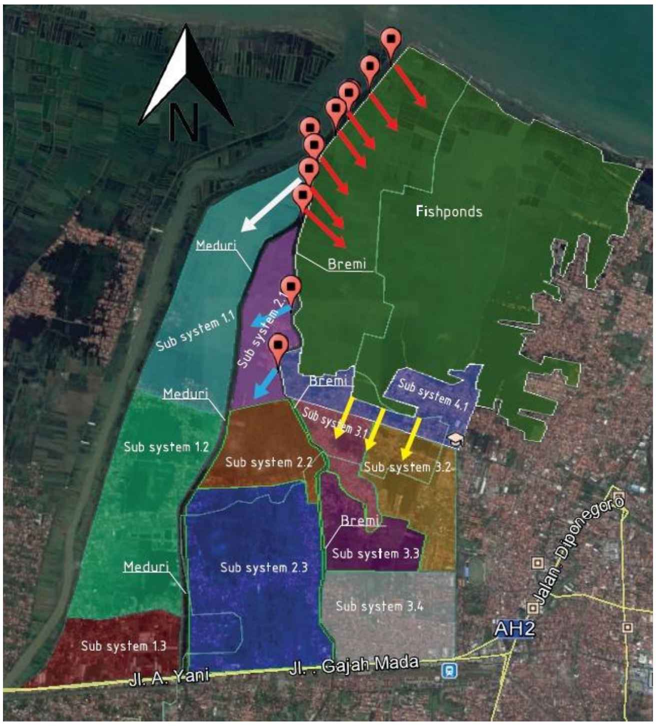


Figure 34, water flows during high tide of the sea are into the subsystems are shown on this map.

Chapter 7 Recommendations

There are several recommendations for reducing the impact of the floods in Tirto and kota Pekalongan. These recommendations can be divided into the following topics: improving the cooperation between kota and kabupaten Pekalongan, further research how drainage using gravity could work the most efficient, the future use of intakes and creating a long term strategy to prevent floods in the future.

The first recommendation is creating a new team which will focus on the floods and on upgrading the flooded areas. Within this party, representatives of kota and kabupaten Pekalongan and the province of Central Java, with knowledge about water management, can work together. This team should focus on floods and upgrading the flooded areas. This way money which is normally separated invested in floods and neighbourhood upgrading can be combined. Raised roads could function as a levee in the future.
This will help to see the flooded areas as one and will strengthen to cooperation. Together with this team help of other parties, such the waterboard HHSK and Aa and Maas, the impact of the floods can be reduced.

The second recommendation is to do more research about the fluctuation of the water level. Canal Bremi, river Meduri and the flooded areas next to these rivers should researched. In this research the possibilities of drainage using gravity for sub system 2 to canal Bremi and for sub systems 3.1 and 3.2 to Ca_03 should be further investigated. The two openings which connect sub system 2.2 with 2.1 and 2.3 are also worth investigating. Instead of making three different drainage systems, sub system 2.1 and 2.3 could drain water to sub system 2.2. Further research is recommended to know if making three different drainage systems or one big drainage system is the best solution.
It is very likely that the places where the measurements are done, are not the best places to place the intakes. With attention on the current infrastructure, research about the best places to build the intakes is required.

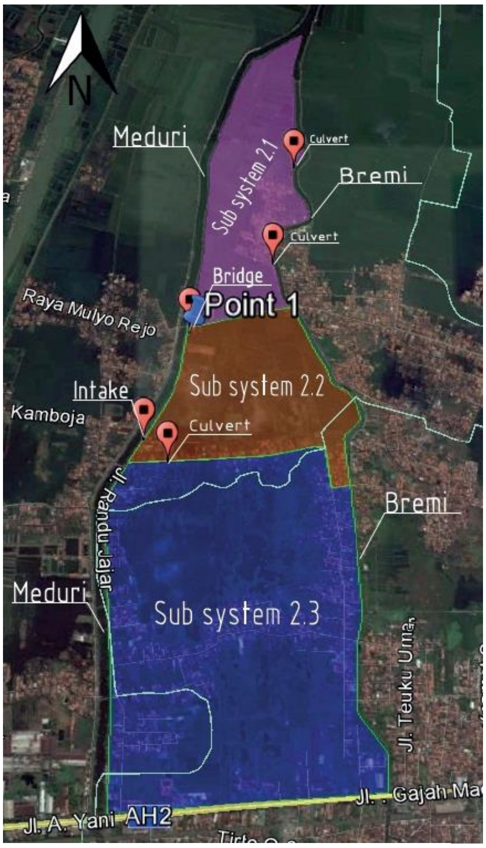


Figure 35, sub systems in system 2 are shown with the gates between them. The opening of sub system 2.1 with canal Bremi are shown with red dots

The third recommendation for kota and kabupaten Pekalongan will be approaching the person(s) or organisation which is opening these gates. The intakes in sub system 1.1 where drainage using gravity is done are an example for other locations in the future. There are people needed who open and close the intakes, these people could be recruited with help of this person(s) or organisation. Besides doing more research, it is important that kota and kabupaten Pekalongan provide more funds to build the intakes in the future and create the team which is mentioned in recommendation one.

The fourth, and last, recommendation is that kota Pekalongan, kabupaten Pekalongan and the province of Central Java create a long term plan for the flooded areas in Tirto and kota Pekalongan. These parties should work together because the floods occur in their areas.
As a result of the land subsidence, the water system will change more in the future. The changes to drain water using gravity will be less and a polder[2] system is recommended to keep dry feet. For example, sub system 1.3 is already too low to drain water to river Meduri with the use of gravity. Kota and kabupaten Pekalongan could be assisted by the waterboards HHSK and Aa and Maas to gain more benefits out of their long term plans. Fishermen and residents should be involved in the planning because the polder will be built for their safety.

[2] Building levees around an area, creating retention and use pumps to drain water out of this area

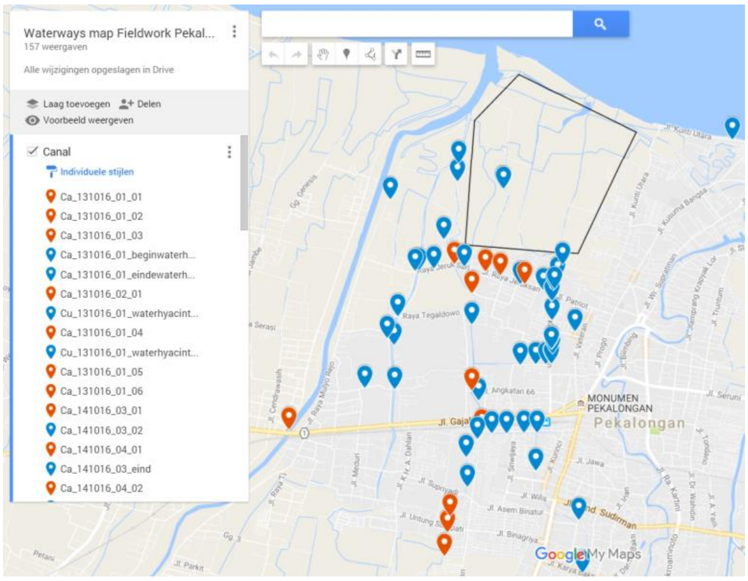
Appendixes

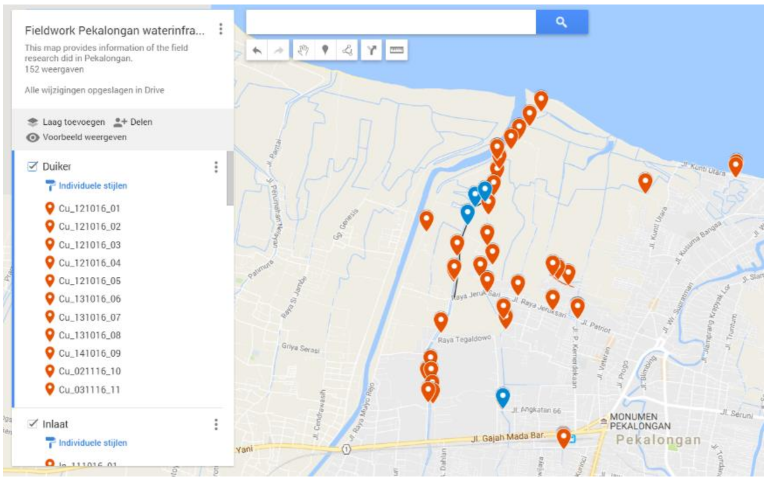
Appendix 1 Guide for using my maps

My maps is an online application which allows the user to pinpoint his location in a map. The application support to add notes at the location and divide the pinpoints into several layers (Google, My maps, 2016). Sharing the map is possible, so other users will be able to add pinpoints at the map. My maps can be used as well on a computer as on a mobile phone. Using my maps on the computer allows the user to see the latitude and longitude of the pinpoints. To use my maps a Google account is required. The maps can be seen using the links. Any changes can be made to the map by using the link and click on edit.

The link to the map of the water infrastructures as found during field research:
https://drive.google.com/open?id=1nqswhqwINKbd3uVb6IVsScrWe08&uspsharing

The link to the of the waterways as found during field research:
https://drive.google.com/open?id=1Uhz_h3vGnSgWOY4TYO4AjIeT5Os&usp=sharing



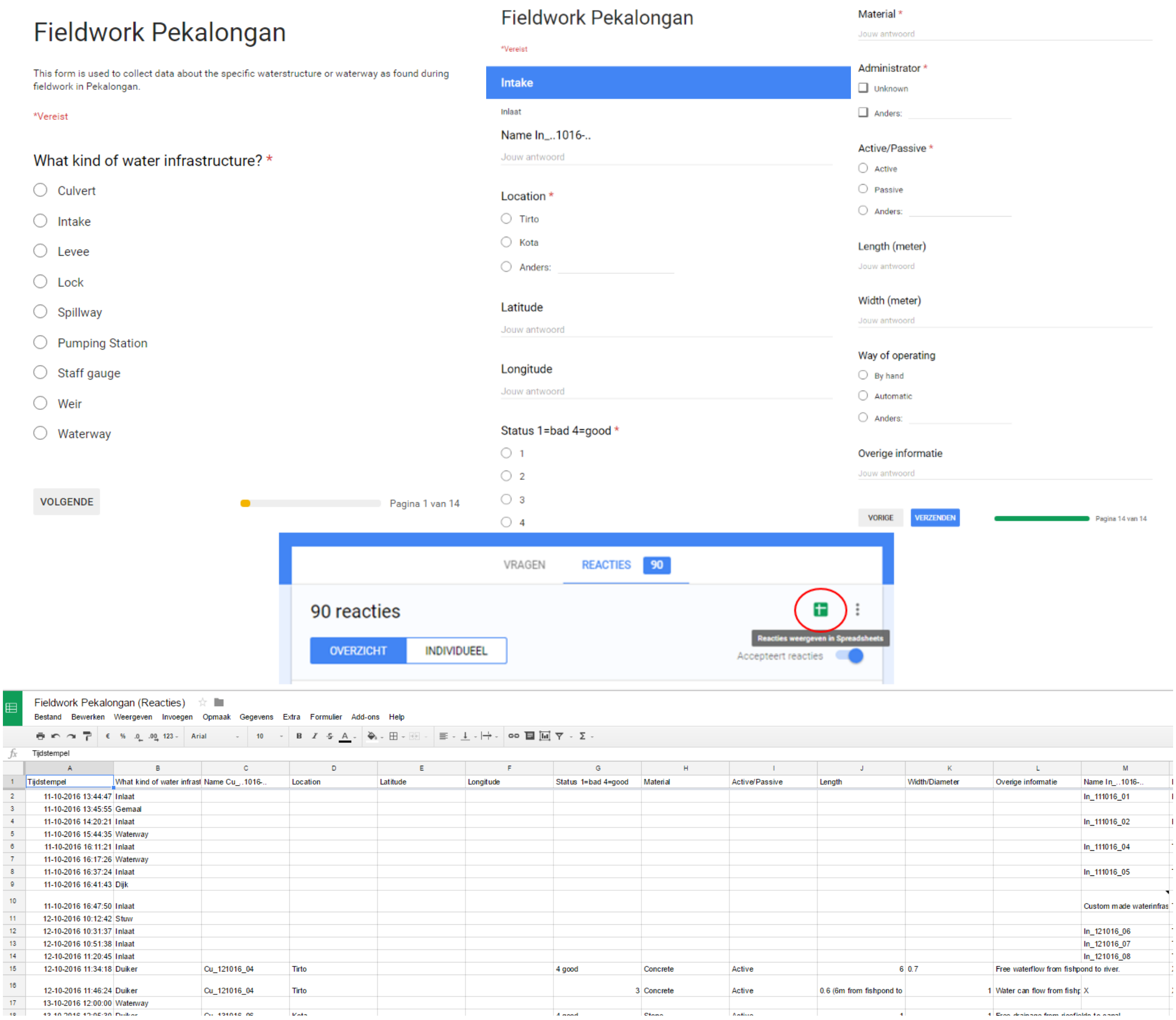


Appendix 2 Guide for using Google Forms

Google Forms is a program developed by Google to make surveys (Google, Forms, 2016). The survey consists several question which allowed the user to go straight to the correct water infrastructure or waterway. Several questions about the waterway are asked to gather the needed data. An example of a survey can be seen in the screenshots below.
The results of the survey are presented in Excel Online, as shown in the bottom screenshot. Copying this data to a normal Excel page is the easiest way to process the data.

Any changes in the survey can be made by using the following link:
https://docs.google.com/forms/d/16IyRrbxm5_k8TvIWJlTJ_bxE6gPvqRxVwhQVfyFfpyU/edit?usp=sharing

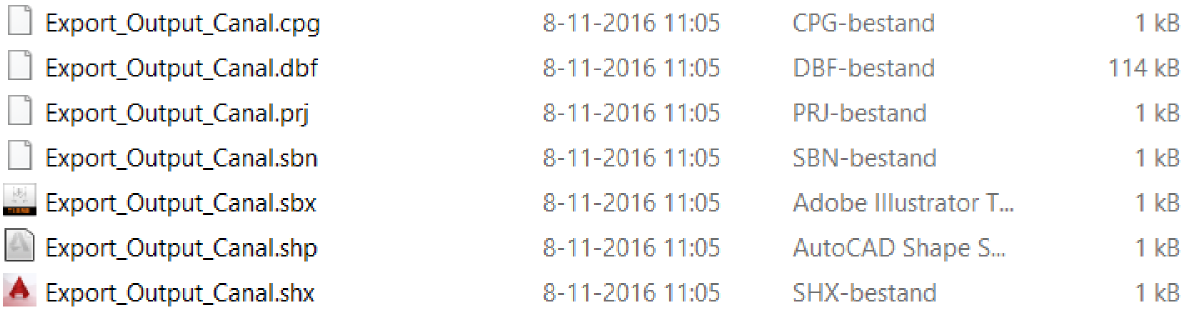
The link to the finished survey, that can be used during fieldwork is:
https://goo.gl/forms/H2EFOKPo45TPencm1



Appendix 3 Guide to transfer ArcGIS data to Google Earth

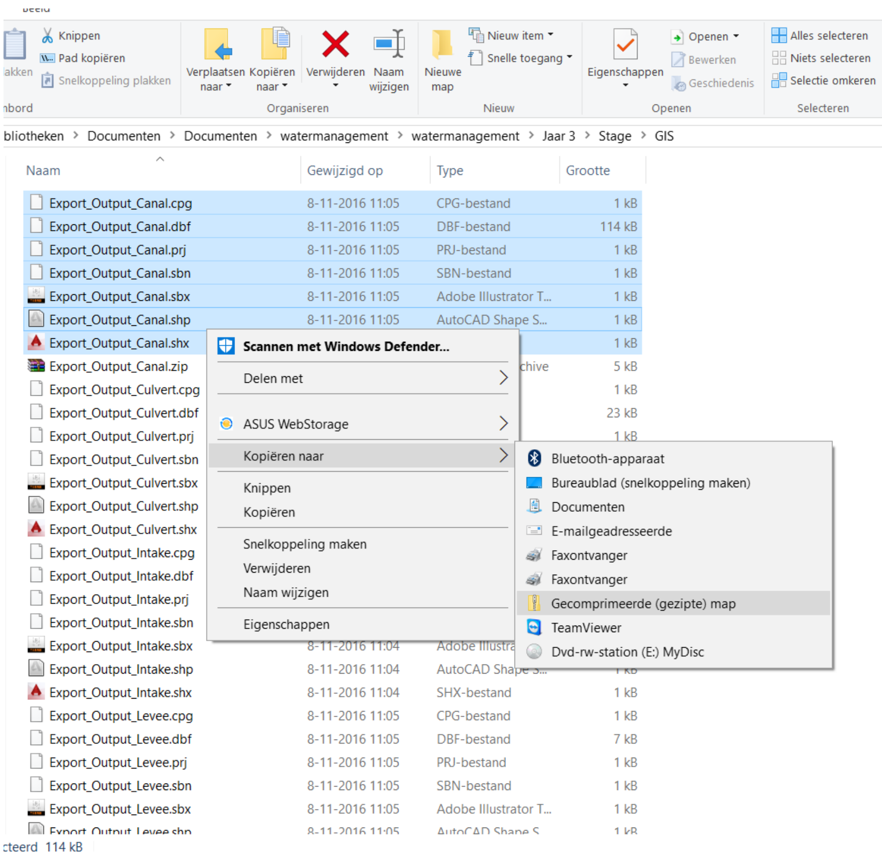
The ArcGIS data is transferred to Google Earth data. The following steps show how this is done. Google Earth will eventually show the pinpoints on the map. The pinpoints will contain the data which is transferred from ArcGIS.

1. Open the ArcGIS data folder



2. Combine all the files of one specific subject
   a. All files: .cpg .dbf .prj .sbn .sbx .shp .shx

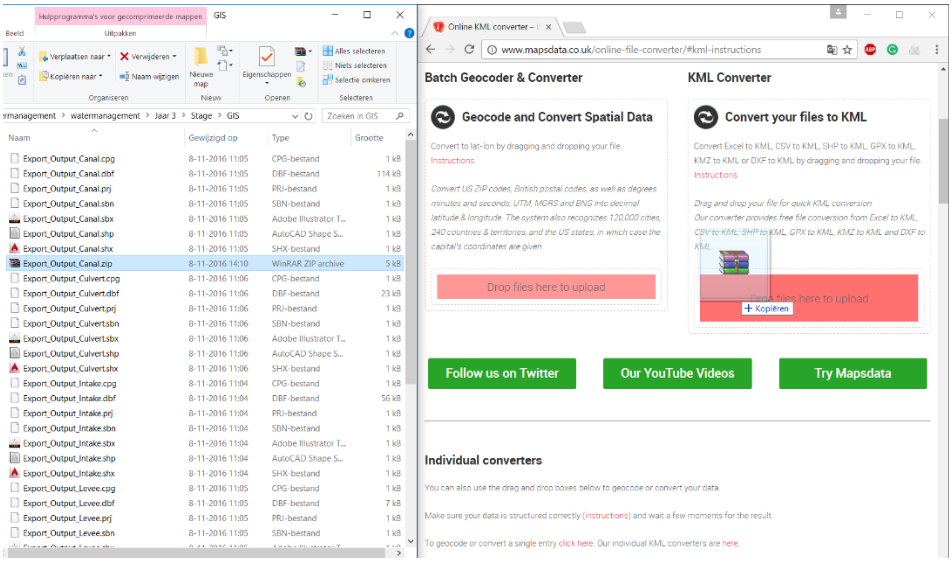
3. Select these files and combine them to one zip folder.



4. Go to internet and open: http://www.mapsdata.co.uk/online-file-converter/#kml-instructions

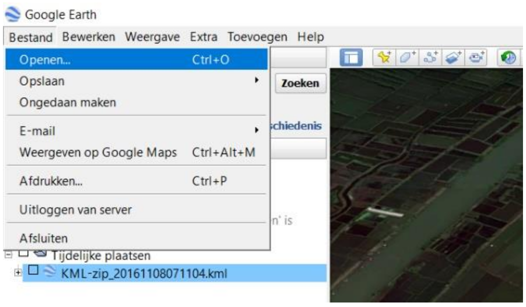
5. Drag the zipped folder to “Convert your files to KML”

6. The website automatic generates a KML file.



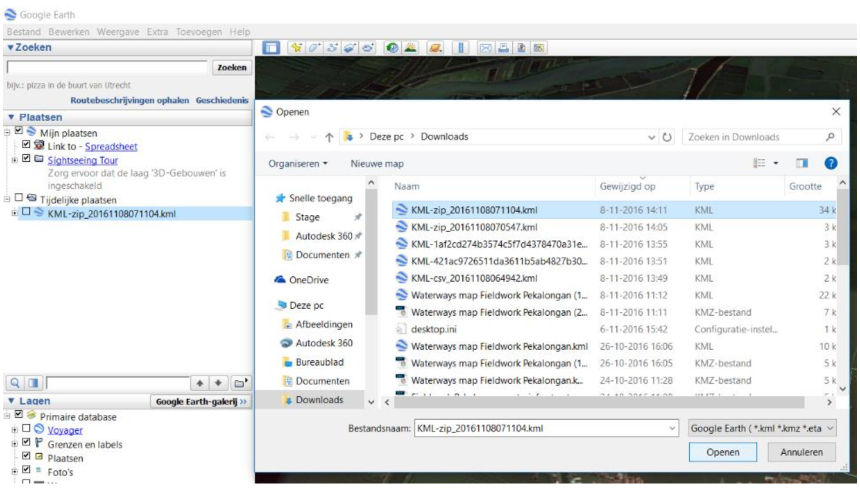
7. Open Google Earth

8. Go to file (Top left corner)

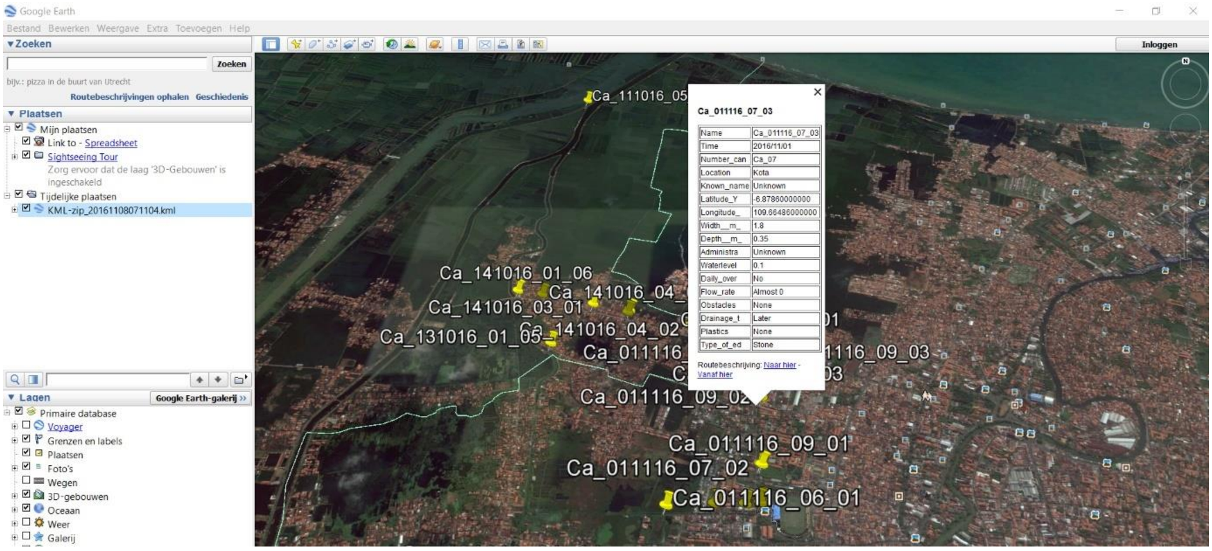


9. Click open and go to the location of you saved KML file

10. Click open again and your points with data are now inserted in Google Earth



11. The points with the data are now shown in Google Earth



Appendix 4 Excel water infrastructures

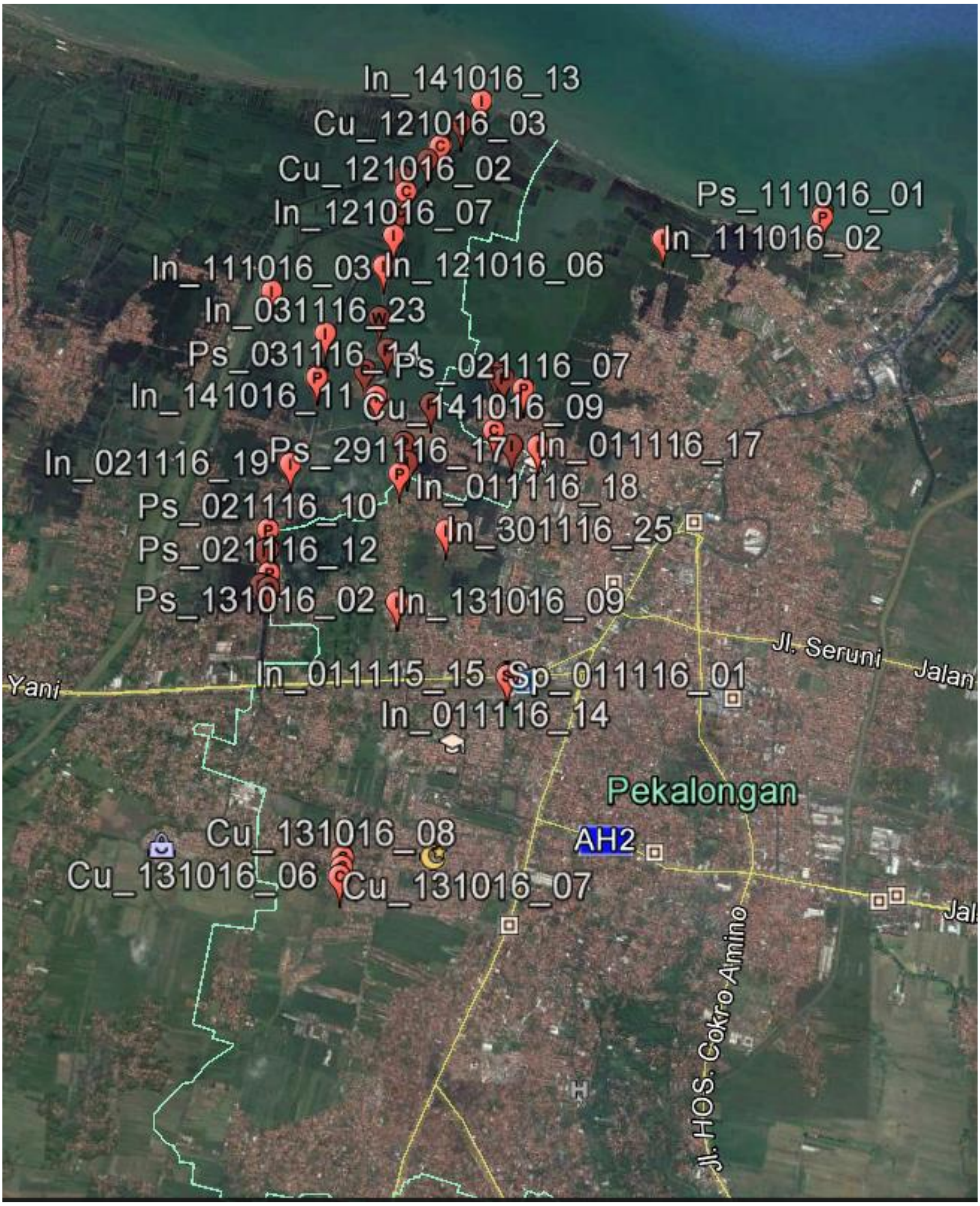
The Excel data on the delivered USB can be found in the folder Project Pekalongan -> Excel. If access to this folder is not possible, please send an email to thijswillem@msn.com and all data will be delivered.

Type of waterinfrastructu	Name	Location	Lattiude Y	Longitude X	Status	Material	Administrator	Active/Passive
Culvert	Cu_021116_10	Tirto	-6,87076	109,65341	2	Concrete	Unknown	Active
Culvert	Cu_031116_11	Tirto	-6,87117	109,6503	4	Contrete	Unknown	Active
Culvert	Cu_121016_01	Tirto	-6,85952	109,65538	4	Concrete	Unknown	Active
Culvert	Cu_121016_02	Tirto	-6,85804	109,6557	4	Concrete	Unknown	Active
Culvert	Cu_121016_03	Tirto	-6,85469	109,6579	3	Concrete	Unknown	Active
Culvert	Cu_121016_04	Tirto	-6,85456	109,65801	4	Concrete	Unknown	Active
Culvert	Cu_121016_05	Tirto	-6,85301	109,65927	3	Concrete	Unknown	Active
Culvert	Cu_131016_06	Kota	-6,90406	109,65307	4	Stone	Unknown	Active
Culvert	Cu_131016_07	Kota	-6,90347	109,65318	4	Stone	Unknown	Active
Culvert	Cu_131016_08	Kota	-6,90287	109,6532	4	Stone & concrete	Unknown	Active
Culvert	Cu_141016_09	Tirto	-6,87464	109,66201	4	Unknown	Unknown	Passive
Culvert	Cu_021116_10	Tirto	-6,87076	109,65341	2	Concrete	Unknown	Active
Culvert	Cu_031116_11	Tirto	-6,87117	109,6503	4	Contrete	Unknown	Active
Intake	In_111016_01	Kota	-6,85869	109,68377	1	Wood and concrete	Unknown	Passive
Intake	In_111016_02	Kota	-6,86095	109,67302	1	Concrete and steel	Unkown	Passive
Intake	In_111016_04	Tirto	-6,85696	109,65541	2	Steel	Unknown	Active
Intake	In_111016_03	Tirto	-6,86539	109,64701	1	Steel	Unknown	Passive
Intake	In_111016_05	Tirto	-6,85696	109,65544	3	Bamboo, wood and	Local fisherman	Active
Intake	In_121016_06	Tirto	-6,8634	109,65439	4	Steel	Unknown	Active
Intake	In_121016_07	Tirto	-6,86119	109,65498	3	Bamboo	Fishponds owner	Active
Intake	In_121016_08	Tirto	-6,85571	109,65708	2	Wood	Unknown	Active
Intake	In_131016_09	Kota	-6,88636	109,65606	1	Steel	Unkown	Passive
Intake	In_131016_10	Kota	-6,87696	109,65643	4	Steel	Unkown	Active
Intake	In_141016_11	Tirto	-6,87254	109,65424	2	Steel	Unkown	Passive
Intake	In_141016_12	Tirto	-6,87254	109,65423	3	Steel	Unkown	Active
Intake	In_141016_13	Tirto	-6,85129	109,66063	4	Concrete	Unkown	Active
Intake	In_011116_14	Tirto	-6,89082	109,66325	1	Steel	Unknown	Passive
Intake	In_011115_15	Kota	-6,89093	109,66323	3	Steel	Unknown	No access
Intake	In_011116_16	Kota	-6,87564	109,66323	1	Steel	Unknown	Passive
Intake	In_011116_17	Kota	-6,87561	109,66494	1	Steel	Unknown	Passive
Intake	In_011116_18	Kota	-6,87566	109,66494	1	Steel	Unknown	Passive
Intake	In_021116_19	Tirto	-6,8773	109,64878	4	Steel	Unknown	Active
Intake	In_021116_20	Tirto	-6,88311	109,64759	4	Steel	Locals	Active

Intake	In_021116_21	Tirto	-6,88319	109,64735	2	Wood and steel	Unknown	Passive
Intake	In_031116_22	Tirto	-6,87124	109,65035	4	Steel	Locals	Active
Intake	In_031116_23	Tirto	-6,86824	109,6507	1	Steel	Unknown	Passive
Intake	In_031116_24	Tirto	-6,88314	109,64712	1	Steel	Unknown	Passive
Intake	In_301116_25	Kota	-6,88151	109,65908	2	Steel	Unknown	Passive
Levee	Le_021116_02	Kota	-6,87174	109,66389	2	Concrete	Unknown	Active
Levee	Le_111016_01	Tirto	-6,85695	109,65543	3	Sand and rocks	Unknown	Active
Pumping station	Ps_111016_01	Kota	-6,85907	109,68372	3	Pvc	Locals	Active
Pumping station	Ps_131016_02	Kota	-6,88626	109,65612	3	Open	Locals	Active
Pumping station	Ps_131016_03	Kota	-6,87694	109,65644	4	Steel	DPU	Active
Pumping station	Ps_131016_04	Kota	-6,87566	109,65615	4	Pvc	Locals	Active
Pumping station	Ps_141016_05	Tirto	-6,86926	109,65484	3	Pvc	Locals	Active
Pumping station	Ps_141016_06	Tirto	-6,87294	109,65785	4	Steel	Locals	Active
Pumping station	Ps_021116_07	Kota	-6,87174	109,66389	4	Pvc	Locals	Active
Pumping station	Ps_021116_08	Kota	-6,87105	109,66259	4	Pvc	Locals	Active
Pumping station	Ps_021116_09	Kota	-6,87062	109,662	4	Pvc	Locals	Active
Pumping station	Ps_021116_10	Tirto	-6,88179	109,64752	4	Pvc	Locals	Active
Pumping station	Ps_021116_11	Tirto	-6,8831	109,64757	4	Pvc	Locals	Active
Pumping station	Ps_021116_12	Tirto	-6,88468	109,64773	4	Pvc	Locals	Active
Pumping station	Ps_021116_13	Tirto	-6,88565	109,64776	4	Pvc	Locals	Active
Pumping station	Ps_031116_14	Tirto	-6,87132	109,65026	3	Steel	Locals	Active
Pumping station	Ps_031116_15	Tirto	-6,87103	109,65032	4	Steel	Locals	Active
Pumping station	Ps_031116_16	Tirto	-6,88548	109,64722	4	Steel	Locals	Active
Pumping station	Ps_291116_17	Kota	-6,87776	109,65592	4	Steel	DPU	Active
Spillway	Sp_011116_01	Kota	-6,89101	109,66328	n.v.t.	Stone	Unknown	Active
Weir	We_121026_01	Tirto	-6,86702	109,65423	2	Wood	Unknown	Passive

Appendix 5 Google earth map water infrastructures

The Google earth maps can be found on the delivered USB in the folder Project Pekalongan -> Google earth. If access to this folder is not possible, please send an email to thijswillem@msn.com and all data will be delivered.



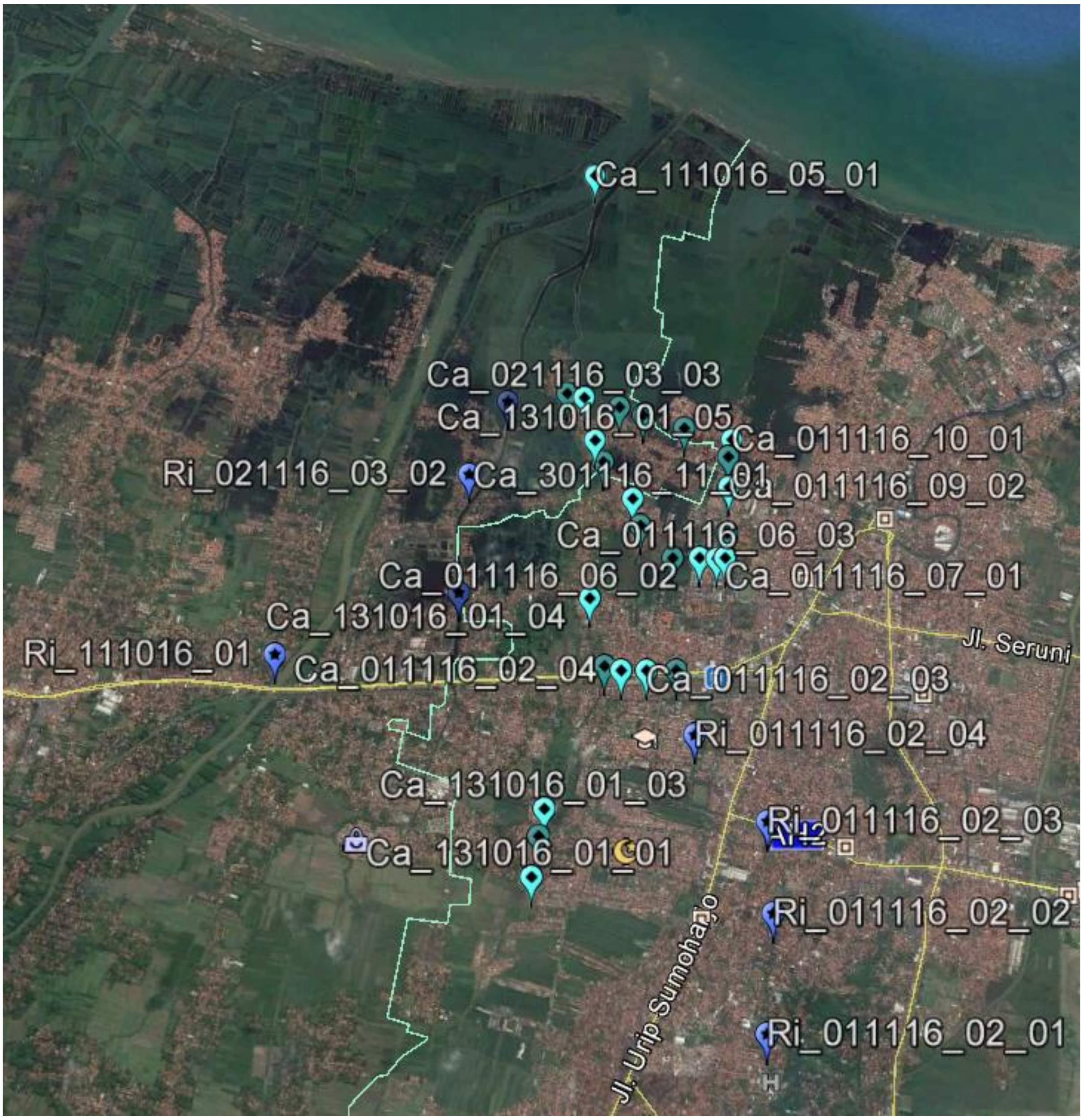
Appendix 6 Excel waterways

The Excel data on the delivered USB can be found in the folder Project Pekalongan -> Excel. If access to this folder is not possible, please send an email to thijswillem@msn.com and all data will be delivered.

Type of waterway	Name	Number canal	Location	Known name	Latitude	Longitude	Width (m)	Depth (m)	Administrator	Waterlevel fluctuation (m)	Daily overflow	Flow rate (m³/s)	Obstacles
Canal	Ca_131016_01_01	Ca_01	Kota	Kali Bremi	-6,90444	109,65298	8	1.50	Province Central Java	0.20	No	Not measured	Some plants near edge. No big obstacles
Canal	Ca_131016_01_02	Ca_01	Kota	Kali Bremi	-6,90185	109,65333	8.50	1.50	Province Central Java	0.3	No	Not important	Many plants and sedemint along the banks of the canal
Canal	Ca_131016_01_03	Ca_01	Kota	Kali Bremi	-6,90011	109,65362	8	1.5	Province Central Java	0.4	No	0.18	High sediment banks with vegation.
Canal	Ca_131016_01_04	Ca_01	Kota	Kali Bremi	-6,88634	109,65604	12.60	1.30	Province Central Java	0.3	No	Almost 0	Fullud with water hyacentes.
Canal	Ca_131016_01_05	Ca_01	Kota	Kali Bremi	-6,87566	109,65603	14.30	0.4-1.6	Province Central Java	Unknown	No	0	Filled with water hyacentes.
Canal	Ca_141016_01_06	Ca_01	Tirto	Kali Bremi	-6,87248	109,65408	9.6	1.2	Province Central Java	0.25	No	3.8	None
Canal	Ca_131016_02_01	Ca_02	Kota	Sungai Asem Binatu	-6,89079	109,65714	6.5	0.5-0.8	DPU Kota Pekalongan	Later	Yes	1.3	None
Canal	Ca_011116_02_02	Ca_02	Kota	Sungai Asem Binatu	-6,89094	109,66178	7.4	0.5	DPU Kota Pekalongan	Unknown	No	Not measured	Plants near the edge
Canal	Ca_011116_02_04	Ca_02	Kota	Sungai Asem Binatu	-6,89105	109,65823	5.5	0.5 - 0.5 - 0.8	DPU Kota Pekalongan	Unknown	No	1	Bamboo structures used to build wall
Canal	Ca_011116_02_03	Ca_02	Kota	Sungai Asem Binatu	-6,89101	109,65986	5.6	0.5	DPU Kota Pekalongan	Unknown	No	Not measured	None
Canal	Ca_141016_03_01	Ca_03	Tirto	No name	-6,87333	109,65757	3.2	0.9	PSDA Kabupaten Pekalonga	0.1	Yes	0.3	Many bridges in the water and bamboo sticks to get garbage ou
Canal	Ca_141016_03_02	Ca_03	Tirto	No name	-6,87384	109,65915	2.8	0.8	PSDA Kabupaten Pekalonga	0.1	Yes	0.3	Many low bridges
Canal	Ca_021116_03_03	Ca_03	Tirto	No name	-6,87274	109,65522	3.7	0.9	PSDA Kabupaten Pekalonga	0.6	Yes	Not measured	Many low bridges
Canal	Ca_141016_04_01	Ca_04	Tirto	No name	-6,87371	109,65922	2.2	0.55	PSDA Kabupaten Pekalonga	0.1	No	0.03	Many bridges in the water
Canal	Ca_141016_04_02	Ca_04	Tirto	No name	-6,87466	109,66190	3.6	0.9	PSDA Kabupaten Pekalonga	0.1	No	Not measured	Many bridges blocking the flow of the water
Canal	Ca_111016_05_01	Ca_05	Tirto	No name	-6,85696	109,65541	4.70	0.30	PSDA Kabupaten Pekalonga	Unknown	No	Not measured	None
Canal	Ca_011116_06_01	Ca_06	Kota	No name	-6,88351	109,66136	2	0.9	DPU Kota Pekalongan	0.3	0.3	Not measured	Water hyacentes
Canal	Ca_011116_06_02	Ca_06	Kota	No name	-6,88344	109,66311	2.8	0.8	DPU Kota Pekalongan	0.3	0.3	Almost 0	Low bridges
Canal	Ca_011116_06_03	Ca_06	Kota	No name	-6,88346	109,66423	3.1	0.5	DPU Kota Pekalongan	0.3	No	Almost 0	None
Canal	Ca_011116_07_01	Ca_07	Kota	No name	-6,88340	109,66478	1.7	0.2	DPU Kota Pekalongan	0.15	No	0	None
Canal	Ca_011116_07_02	Ca_07	Kota	No name	-6,88174	109,66482	1.9	0.3	DPU Kota Pekalongan	0.1	No	Almost 0	None
Canal	Ca_011116_07_03	Ca_07	Kota	No name	-6,87860	109,66486	1.8	0.35	DPU Kota Pekalongan	0.1	No	Almost 0	None
Canal	Ca_011116_07_04	Ca_07	Kota	No name	-6,87655	109,66485	2	0.35	DPU Kota Pekalongan	0.1	No	Not measured	None
Canal	Ca_011116_08_01	Ca_08	Kota	No name	-6,88337	109,66484	1.6	0.4	DPU Kota Pekalongan	Unknown	No	Almost 0	None
Canal	Ca_011116_09_01	Ca_09	Kota	No name	-6,88176	109,66487	1.3	0.2	DPU Kota Pekalongan	0.1	No	Almost 0	Many plants in the water
Canal	Ca_011116_09_02	Ca_09	Kota	No name	-6,87862	109,66493	1.1	0.1	DPU Kota Pekalongan	0	No	0	Very much leefs
Canal	Ca_011116_09_03	Ca_09	Kota	No name	-6,87653	109,66492	1.4	0.5	DPU Kota Pekalongan	Unknown	No	Almost 0	Many water hyacentes
Canal	Ca_011116_10_01	Ca_10	Kota	No name	-6,87537	109,66505	1	0.4	DPU Kota Pekalongan	0.4	0.4	Almost 0	None
River	Ri_111016_01	Ri_01	Kota	Sungai Sengkarang	-6,89062	109,63585	60	Unkown	Province Central Java	Unkown	No	Unkown	None
River	Ri_011116_02_01	Ri_02	Kota	Sungai Asem Binatu	-6,91372	109,66800	6.8	0.5	DPU	Unknown	No	Not measured	None
River	Ri_011116_02_02	Ri_02	Kota	Sungai Asem Binatu	-6,90628	109,66827	6.6	0.25	DPU	0.1	No	0	None
River	Ri_011116_02_03	Ri_02	Kota	Sungai Asem Binatu	-6,90051	109,66781	6	0.25	DPU	0.1	No	Not measured	None
River	Ri_011116_02_04	Ri_02	Kota	Sungai Asem Binatu	-6,89510	109,66307	4.7	0.40	DPU	0.1	No	Not measured	None
River	Ri_021116_03	Ri_03	Tirto	Sungai Meduri	-6,87316	109,65016	21	2.2	Province Central Java	0.3	No	6.67	None
River	Ri_021116_03_02	Ri_03	Tirto	Sungai Meduri	-6,87823	109,64783	25	2.5	Province Central Java	0.5	No	Not measured	None
River	Ri_031116_03_03	Ri_03	Tirto	Sungai Meduri	-6,88621	109,64753	35	2.6	Province Central Java	Later	No	Not measured	Bridge is only 23m width, river is 35m

Appendix 7 Google earth map water ways

The Google earth maps can be found on the delivered USB in the folder Project Pekalongan -> Google earth. If access to this folder is not possible, please send an email to thijswillem@msn.com and all data will be delivered.



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