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Practiced Rain Harvesting in Semarang, Indonesia toward Climate Change Adaptation

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ABSTRACT

The climate change impacts has been slightly increasingly observed at Semarang City, such as increased intensity of inundation at low land areas, shortened wet season, and increasing rainfall volume which is causing increased flood occurrences, and adversely more severe water scarcity due to less rainfall water recharged into the groundwater table. In the long run, the city must have appropriate strategy and anticipation to cope with these impacts of climate change which is slowly and progressively influencing the city's population.

The paper presents the current preparedness of the city's people, assess its vulnerability, identify the strategy, and implement the rain harvesting technology in pilot project scale. The implementation is currently initiated at Wonosari and Tandang sub-regencies. The paper discuss the implementation of rain harvesting approach in Semarang City initiated by some private companies such as by BSB satellite city for Semarang and Graha Candi Golf Residence.

This steadily increasing stakeholders' involvement to implement rain harvesting technology will increase preparedness of the city toward the adaptation to the climate change impacts.

Keywords: Rain Harvesting, Climate Change Adaptation

1. INTRODUCTION

Climate change impacts has been slightly increasingly observed at Semarang City, such as increased intensity of inundation at low land areas, shortened wet season, and increasing rainfall volume which is causing increased flood occurrences, and adversely more severe water scarcity due to less rainfall water recharged into the groundwater table. Due to the increasing impacts of climate change especially to coastal city like in Semarang, the city has conducted a study on Vulnerable Assessment (VA) and City Resiliences Strategy (CRS) with funding from Rockeffeler Foundation and managed by Mercy Corps.

This paper presents the VA and CRS study and pilot project for adaptation to climate change in water sector by Rain Harvesting technique. It also reporting the increasing implementation of rain harvesting as part of the increasing resilience of the city toward climate changes by government offices as well as by private companies.

2. CITY RESILIENCE STRATEGY

The goal of the CRS study is to produce strategies that will be integrated into the city development policy in cope with climate change impacts. Meanwhile, it s objectives are:

a. Identifying existing condition of climate change impacts, the city's vulnerability, and vulnerable group of people.
b. Developing interaction model between the city's development and some climate change scenarios to identify their consequences to the future.
c. Formulating resilience strategies at the city level in a multi dimensional perspective.
d. Formulation on adaptation actions required to increase resilience.
e. Priority selection on adaptation actions to be urgently implemented.

From vulnerable assessment (VA), the most vulnerable groups to climate change impacts are (Mercy Corps, 2009):

a. Lowland regions which are exposed to coastal flood and sea level rise.
b. Settlement areas located along the river banks which are exposed to flooding.
c. Hilly areas which are exposed to high/strong winds.
d. Area which is exposed to land movement and landslides.
e. Residential areas at the city's outskirts which are away from water sources.

Additionally Setiadi and Kunarso (2009) have also mention more vulnerable groups as follows:

a. Areas as a node of movement (such as airports, seaports, train stations, and terminal).
b. Functional central business district.
c. Historical areas (Semarang old town).

Furthermore, the VA study (Mercy Corps, 2009) has identified on areas which are prone to the climate change impacts as well as population groups vulnerable to these impacts. The vulnerable groups are poor residents, elderly, low income families, families subjected or will be subjected to relocation due to government's projects, poor migrants, workers in lowland areas, and single parent families especially headed by woman/widow.

There are five sectors that the Semarang City has to focus on increasing the city's resilient, they are water sector, infrastructures, marine and fisheries, environment, and human resources and institutional improvement (Semarang City Team, 2010).

The strategy on water sector is to ensure that the community have access to water supply (clean water) even under extreme climate conditions, i.e., during flooding or during drought. Meanwhile, the target population for this water sector is those who have not access to pipe water supply (PDAM) services and those who are distant away from water sources (Semarang City Team, 2010). There are some efforts to increase the availability of clean water even during extreme conditions, they are increasing rain harvesting implementation throughout the communities, increasing water saving, increasing affordable water treatment technology, and promoting seawater desalination.

Within the ACCCRN (Asian Cities for Climate Changes Resilience Network), the rain harvesting pilot project has been implemented in two kelurahans (sub-district), i.e., at Kelurahan Tandang and Kelurahan Wonosari, Semarang. Moreover, the implementation of rain harvesting in Semarang City has actually been practiced by BLH (City Environmental Board), some private companies and others.

3. NATIONAL POLICY ON RAIN HARVESTING

In national level, the implementation of rain harvesting has been recommended and institutionalized by the announcement of the Minister of Environmental Regulation No 12/2009 about rain harvesting. Principally, it is obligatory for each building and any development to apply rain harvesting technology to catch rain water, either to store and use it or to store and infiltrated/recharged into the groundwater. The purpose of this rain harvesting is to reduce surface run off, increase rain water recharge, and increase use of rain water such as for watering garden, etc.

Table 1. Guidelines for Rain Harvesting Facilities

RH Type	Impervious Cover (m^2)	Vol. (m^3)	Remarks
RH Storage	50	1.5	Every 25-50 m^2 of roof-top cover, needs additional unit of RH storage
Recharge Well Shallow	50	1	Every additional 25–50 m^2 of roof-top cover needs additional unit of 1 m^3 recharge well
Recharge Well deep	1000	-	Every additional 500 – 1000m^2 roof-top cover, needs additional 1 unit
Biopori	20	3 x 0.25	Every additional roof-top cover of 7 m^2 needs additional 1 unit of Biopori

Source : The Minister of Environmental Regulation No 12/2009.

Nationally, the regulation on water resources (UU No. 7/2004) has stipulated on more attention on water conservation including rain harvesting.

4. REGIONAL POLICY ON RAIN HARVESTING

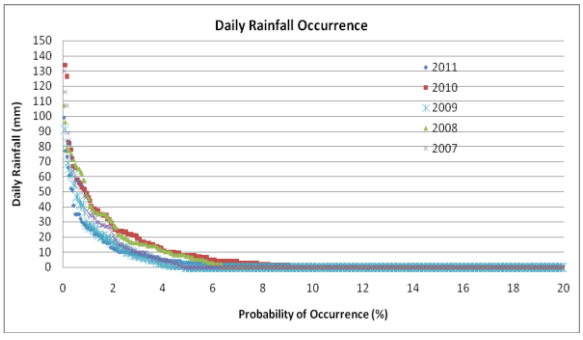
The City of Semarang has anticipated the climate change impacts by conducting the study on vulnerability assessment (VA) and City Resilience Strategy (CRS). Additionally, the actions identified in the study has also been accommodated in the city's regulation in Perda No 7/2010 about green space provision (RTH=Ruang Terbuka Hijau) and Perda No. 14/2011 about regional planning (RTRW). In those regulations, the government urges all stakeholders to take part in the increase of green open space, increase the groundwater recharge, and reducing the additional overland flow due to any development. The stipulation can be seen, for example, that those who want to build a house, private as well as developers, must provide a recharge well. This stipulation is also applicable to big company as well, before they get a permit from the city's government.

5. FACTORS IN RAIN HARVESTING

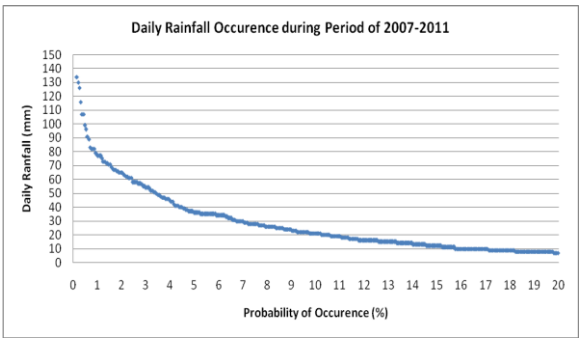
In principal, the rain harvesting activity is to collect rain water into a certain kind of storage. The collected water can either be use for municipal needs or recharging groundwater. There are several factors, however, need to be considered such as its quality, rainfall characteristics, area of rain harvesting, appropriate technology, and the preparedness of the community.

The quality of rainwater is not always in good quality, especially in the city area where there have been a lot of industrial and transportation activities. The industrial and transportation activities may affect the quality of the air, and therefore affect the quality of the rainwater. It is therefore, requires disposing rainwater caught in the first ten minutes. After ten minutes of rainfall, it is expected that the air quality is better. Additionally, when the rainwater is collected from roof top, the roof top is likely to be dirty as well.

Characteristic of rainfall is very important on deciding the amount of rainfall to be collected. The higher the rainfall to be collected, the bigger the storage facility to be provided and the higher the initial cost. The smaller rainfall to be collected, the smaller storage required but will be quickly used up. The following figure shows the probability of occurrences of daily rainfall at Mangkang rainfall station, Semarang.



a. Year by year



b. The last five yeras

Figure 1. Probability of Daily Rainfall Occurrence at Semarang.

6. RAIN HARVESTING ON THE FRAMEWORK OF ACCCRN

During the year 2012 and under the framework of ACCCRN and sponsored by the Rockeffeler Foundation, the city team has implemented a pilot project on rain harvesting for both individual households and collective households or communal. The location for this pilot projects are in Kelurahan Tandang and Kelurahan Wonosari. The construction employs people lives surrounding the site as part of community development and thus increasing the people's understanding and preparedness. It conducts community development to prepare the beneficiaries in operating and maintaining the rain harvesting (RH) facilities constructed.

The objective of the piloting activity are 1) to construct a pilot project for RH (individual and communal system) which later can be replicated by the community on their own, 2) involving the community on the processes of site selection, design, and construction, 3) facilitating the community on the preparation, operation and maintenance of the RH facilities, and 4) preparing the community on the monitoring and evaluation of the facilities.

5.1. Individual RH at Wonosari

The location experiences some frequent flooding from Bringin River. The housings are located on the low land along the River. Due to bottle neck of a bridge, during floods, water will rise up and inundated the surrounding housings. The water level can rise up to more than 2.0 m height and last for more than 3 days. During this situation, the people have no sources of clean water. They mostly rely on water supply from outside and expensive. Most families living in the area are low income families. Therefore, the provision of rain harvesting facilities for some households will reduce their vulnerability.

The RH facility constructed at Kelurahan Wonosari is individual type for 5 households. Each system is mainly a water barrel of 4 @ 200 liter volume to catch rainwater from rooftop of each household. In its entrances, it is provided with screen. Usually, the first ten minutes of any rainfall event is not good quality of rainwater due to possible pollutant in the air and on the roofs. Therefore, the first ten minutes of rainwater is collected into the first barrel. After the intake pipe, it is installed a floating mechanism to divert rainwater when the first barrel is full. Afterwards, the rainwater will be flowed into the second barrel. The water collected in the second barrel will flow to third barrel which consist of a slow sand filter. The water from the third barrel has practically filtered and ready for use as source of clean water. This clean water is flowed into the fourth barrel. This barrel is connected to household water tap in a bathroom or for other usages. Additionally, should the rainfall is higher than the capacity of the barrels' volume, the excess rainfall will overspill the barrels. This over-spilled rainwater is caught into a small recharge well on the ground, allowing water to seep in groundwater table. This shows description of individual RH facility constructed at Wonosari.

Figure 2. Installed RH Facility in Household.

Figure 3. Small Recharge Well Made Underneath the Barrels.

The beneficial of this individual household RH facility is as follow. The design daily rainfall is 20 mm (which has the probability occurrence of 10 %. (It shows that almost 90% of daily rainfall is below 20 mm). The volume of rainfall water caught at 50 m^2 rooftop is approximately 0.70 – 0.90 m^3, which is sufficient for use in a family for one day. During rainy period, there is 90% probability that all daily rainfall are caught or harvested in every household, implying that each household do not contribute to overland flow. The ability of this RH facility in reducing overland flow from 60% to 80% out of 15 mm rainfalls are demonstrated in Suripin (2010).

The simulation using daily rainfall fed to individual housing RH facility in the first month (January) is shown in the following Figure and Table. It shows that even with RH capacity of 0.8 m^3 for each household, it can still able to harvest rainfall of more than 70%. Overland flow occurred only during higher rainfall intensity than the RH facility.

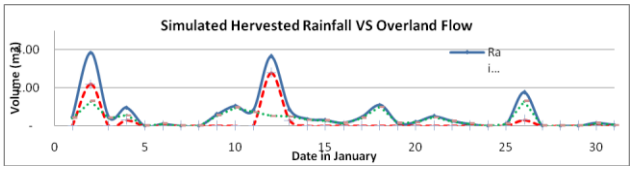


Figure 4. Simulated Harvested Rainfall VS Overland Flow.

Table 2. Simulation of Rain Harvesting in Individual RH.

Water usage = 0.48 m^3/day
Capacity of RH Facility= 0.80 m^3
Area of Roof Top = 50.00 m^2

Day No.	Daily Rainfall (mm)	Vol Rainfall (m^3)	Pot. Harv (m^3)	Storage S_t (m^3)	Usage (m^3)	Storage S_{t+1} (m^3)	Overland (m^3)	Harvested (m^3)	%overland	%Harvested
1	9.00	0.45	0.41	-	0.48	-	-	0.41	-	90.00
2	77.00	3.85	3.47	-	0.48	0.80	2.19	1.28	56.75	33.25
3	9.00	0.45	0.41	0.80	0.48	0.73	-	0.41	-	90.00
4	19.00	0.95	0.86	0.73	0.48	0.80	0.30	0.56	31.58	58.42
5	-	-	-	0.80	0.48	0.32	-	-	-	-
6	2.00	0.10	0.09	0.32	0.48	-	-	0.09	-	90.00
7	-	-	-	-	0.48	-	-	-	-	-
8	-	-	-	-	0.48	-	-	-	-	-
9	12.00	0.60	0.54	-	0.48	0.06	-	0.54	-	90.00
10	21.00	1.05	0.95	0.06	0.48	0.53	-	0.95	-	90.00
11	16.00	0.80	0.72	0.53	0.48	0.77	-	0.72	-	90.00
12	73.00	3.65	3.29	0.77	0.48	0.80	2.77	0.51	75.89	14.11
13	17.00	0.85	0.77	0.80	0.48	0.80	0.29	0.48	33.53	56.47
14	7.00	0.35	0.32	0.80	0.48	0.64	-	0.32	-	90.00
15	6.00	0.30	0.27	0.64	0.48	0.43	-	0.27	-	90.00
16	3.00	0.15	0.14	0.43	0.48	0.08	-	0.14	-	90.00
17	9.00	0.45	0.41	0.08	0.48	0.01	-	0.41	-	90.00
18	22.00	1.10	0.99	0.01	0.48	0.52	-	0.99	-	90.00
19	3.00	0.15	0.14	0.52	0.48	0.17	-	0.14	-	90.00
20	4.00	0.20	0.18	0.17	0.48	-	-	0.18	-	90.00
21	10.00	0.50	0.45	-	0.48	-	-	0.45	-	90.00
22	5.00	0.25	0.23	-	0.48	-	-	0.23	-	90.00
23	2.00	0.10	0.09	-	0.48	-	-	0.09	-	90.00
24	-	-	-	-	0.48	-	-	-	-	-
25	2.00	0.10	0.09	-	0.48	-	-	0.09	-	90.00
26	35.00	1.75	1.58	-	0.48	0.80	0.30	1.28	16.86	73.14
27	-	-	-	0.80	0.48	0.32	-	-	-	-
28	-	-	-	0.32	0.48	-	-	-	-	-
29	-	-	-	-	0.48	-	-	-	-	-
30	3.00	0.15	0.14	-	0.48	-	-	0.14	-	90.00
31	1.00	0.05	0.05	-	0.48	-	-	0.05	-	90.00

5.2. Collective RH at Tandang

The location is more elevated, and at some part of the regions, there are no water supply facilities to the area. Most families living in the area are also low income families. A deep well has been provided by the government and the community must operate it to get clean water. The operation cost of this deep well pump increases during dry season. The provision of rain harvesting at communal level is expected to reduce the burden to the community. The RH facilities are constructed in Primary School area of SDN 03 Tandang (see Figure 3) because of wide area for harvesting rain at its roof top. There were three storages constructed, they are storage A and B each with 28 m^3 capacity and storage C of 18 m^3 capacity. Storage A and B are used for households next to the School, while the storage C is used for the school's use. Therefore, there are some water taps placed at the outer side of the wall of storage A and B.

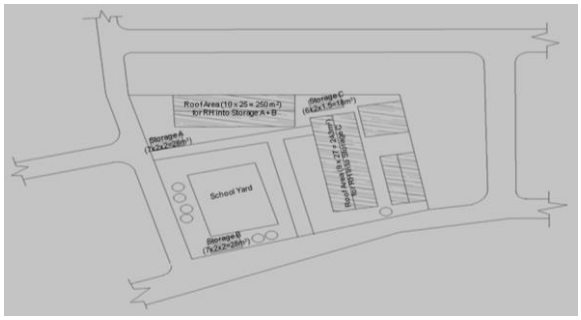


Figure 5. Location of Storage A, B, and C for Communal RH Facility.

The system for communal RH facilities is principally similar with the individual one, except that the material is made from brick or concrete structures. The first chamber is to collect the first ten minutes rainfall which is not good quality. When the first chamber is full, the floating ball will close the entrance pipe into it and divert the flow into the second chamber. From the second chamber, it flows to the up-flow sand filter. The water flowing out of the sand filter has already in good quality used as the source of clean water.

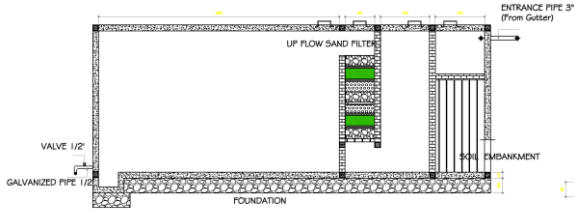


Figure 6. Cross Section of Storage A and C which is Provided with up-flow Sand Filter.

Figure 7. Completed Storage A with Water Taps Outside.

The communal RH facilities must be design to catch higher daily rainfall. It uses 100 mm of daily rainfall which has 2 % probability of occurrence for designing storage C. It implies that about 98% of time the daily rainfall is less than 100 mm and therefore able to be stored into storage C. With 250 m^2 roof top area, the volume of rainwater caught is 20 m^3.

Table 3. Simulated RH for Communal.

Water usage 10 families= 4.80 m^3/day
Capacity of RH Facility= 18.00 m^3
Area of Roof Top = 250.00 m^2

Day No.	Daily Rainfall (mm)	Vol Rainfall (m^3)	Pot. Harv (m^3)	Storage S_t (m^3)	Usage (m^3)	Storage S_{t+1} (m^3)	Overland (m^3)	Harvested (m^3)	%overland	%Harvested
1	9.00	2.25	2.03	-	4.80	-	-	2.03	-	90.00
2	77.00	19.25	17.33	-	4.80	12.53	0.00	17.33	0.00	90.00
3	9.00	2.25	2.03	12.53	4.80	9.75	-	2.03	-	90.00
4	19.00	4.75	4.28	9.75	4.80	9.23	-	4.28	-	90.00
5	-	-	-	9.23	4.80	4.43	-	-	-	-
6	2.00	0.50	0.45	4.43	4.80	0.08	-	0.45	-	90.00
7	-	-	-	0.08	4.80	-	-	-	-	-
8	-	-	-	-	4.80	-	-	-	-	-
9	12.00	3.00	2.70	-	4.80	-	-	2.70	-	90.00
10	21.00	5.25	4.73	-	4.80	-	-	4.73	-	90.00
11	16.00	4.00	3.60	-	4.80	-	-	3.60	-	90.00
12	73.00	18.25	16.43	-	4.80	11.63	0.00	16.43	0.00	90.00
13	17.00	4.25	3.83	11.63	4.80	10.65	0.00	3.83	0.00	90.00
14	7.00	1.75	1.58	10.65	4.80	7.43	-	1.58	-	90.00
15	6.00	1.50	1.35	7.43	4.80	3.98	-	1.35	-	90.00
16	3.00	0.75	0.68	3.98	4.80	-	-	0.68	-	90.00
17	9.00	2.25	2.03	-	4.80	-	-	2.03	-	90.00
18	22.00	5.50	4.95	-	4.80	0.15	-	4.95	-	90.00
19	3.00	0.75	0.68	0.15	4.80	-	-	0.68	-	90.00
20	4.00	1.00	0.90	-	4.80	-	-	0.90	-	90.00
21	10.00	2.50	2.25	-	4.80	-	-	2.25	-	90.00
22	5.00	1.25	1.13	-	4.80	-	-	1.13	-	90.00
23	2.00	0.50	0.45	-	4.80	-	-	0.45	-	90.00
24	-	-	-	-	4.80	-	-	-	-	-
25	2.00	0.50	0.45	-	4.80	-	-	0.45	-	90.00
26	35.00	8.75	7.88	-	4.80	3.08	-	7.88	-	90.00
27	-	-	-	3.08	4.80	-	-	-	-	-
28	-	-	-	-	4.80	-	-	-	-	-
29	-	-	-	-	4.80	-	-	-	-	-
30	3.00	0.75	0.68	-	4.80	-	-	0.68	-	90.00
31	1.00	0.25	0.23	-	4.80	-	-	0.23	-	90.00

The storage of A and B has higher volume. It is able to catch higher daily rainwater. Therefore, most of the time, the storage A and B are not full and tend to be low volume (nearly empty). At the moment, the storage A and B are also used to store clean water from deep well, especially during dry period.

7. RAIN HARVESTING BY PRIVATE COMPANIES

7.1. RH at BSB

BSB (Bukit Semarang Baru) is a new development area of 1,000 Ha and located at the south part of Semarang City. It is a private company who develop the area for housing, trade, light weight industrial park, recreational park and educational zone. The company is developing housings which are provided with small recharge wells with

capacity of 1.0 m^3 each. Additionally, in order to comply with the city's regulation, the company has also developed some small dams for impoundment as follow.

Table 4. Small dams constructed at BSB complex.

No	Name	Area (m^2)	Capacity (m^3)	Constructed
1.	Palapa	55,000	250,000	2002
2.	GTB	2,400	1,800	2003
3.	Jatisari 1	4,400	8,000	2003
4.	Jatisari 2	4,500	10,000	On going
5.	ROW40	1,360	3,500	2012
6.	Industry	950	1,250	On going
7.	PAG	2,925	2,200	2013

Impoundments at Lake PAG

Lake at Jatisari 1.

7.2. RH at UNNES

UNNES is a state university located at the south part of the city which is mostly is recharge area of the city. The university has long commitment on developing green campus and put more conservation concern in their education and development. It provides the balance between development and conservation to achieve more environmentally sustainable and resilient campus.

One of its efforts is the allocation of minimal 30% of the campus area for greenery allowing any rainwater to seep in the groundwater and provide with more plantation and park. The university has also developed some recharge wells in the campus. Additionally, there is also one small impoundments and park developed as seen on the following figure. The impoundment has the area of 43 m x 46 m = 1,978 m^2, and capacity of 2,976 m^3.

Figure 8. Small impoundments park at UNNES as Rain Harvesting facility.

7.3. RH at Graha Candi Golf

Graha Candi Golf is a developer who develops golf area surrounded with housings complex and recreational facilities. As the name implies, it has 18 holes golf area. In the golf area, there are two storages/impoundments constructed collecting water flow from upstream drainage channels. These storages are mainly used as scenery in the golf course. Environmentally, it increases the groundwater filling, reducing overland flow, and provides greener surroundings.

The developer also made a weir to make some impoundment behind the weir. The water is then pump out to the water treatment installation, resulting clean water. This clean water is use to supply the residence in the housings complex.

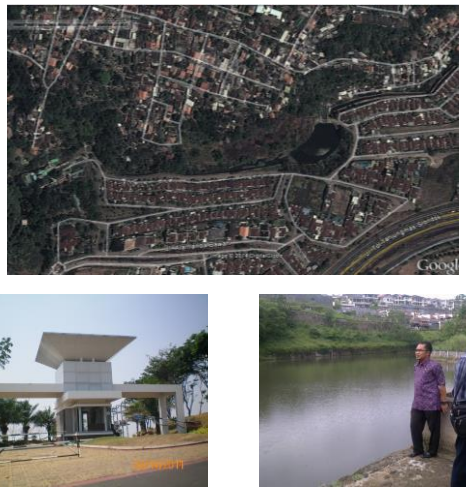


Figure 9. Impoundments behind a weir used as a source of clean water.

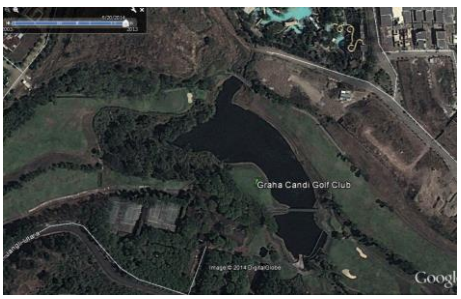


Figure 10. Impoundmens at Graha Candi Golf

7.4. RH developed by Agricultural Office

The Agricultural office at Semarang Regency has constructed several small impoundments which are used mainly to supply water to paddy field or plantations during low rainfall or during early dry season (during the

end of planting season II and during planting season III). Their practices show their preparedness in the anticipation for prolonged dry season to sustain their crop productions.

Table 5. Small Dams and Recharge Well Constructed by Department of Agricultural, Kabupaten Semarang.

No	Location : Village/District	Year of Construction
A	***Embung (Small dam)***	
1	Boto, Bangak	2007
2	Semowo, Pabelan	2007
3	Rejosari, Bancak	2009
B	***Recharge Well***	
1	Kenteng, Susukan	2007
2	Kawengen, Ungaran Timur	2007
3	Jati Jajar, Bergas	2007
4	Mukiran, Kaliwungu	2007
5	Bener, Tengaran	2009
6	Bancak, Bancak	2009
7	Truko, Bringin	2009
8	Semowo, Pabelan	2009
9	Kalirejo, Ungaran Timur	2010
10	Kalongan, Ungaran Timur	2010
11	Banyubiru, Banyubiru	2010
12	Kebondowo, Banyubiru	2010
13	Pasekan, Ambarawa	2010
14	Ngampin, Ambarawa	2010
15	Brongkol, Jambu	2010

7.5. RH implemented by Environmental Office

The environmental office in the city is called Bappedalda (Badan Pengendalian Dampak Lingkungan Hidup). For the last five years, the office has implemented to develop rain harvesting for individual households and recharge well. Their program focused at low income families in the city.

8. CONCLUSION

1. The government of Semarang City has put some efforts to move to more resilient and sustainable city by facilitating the implementation of rain harvesting to any stakeholders.
2. As one of the city in the ACCCRN, the city has formulated its strategy toward the adaptation to climate change and has acted accordingly.
3. The implementation of rain harvesting has also been initiated by some private companies.
4. The pilot project implemented under the Rockeffeler Foundation funding and managed by Mercy Corps has initiated the increase on the society's awareness toward climate change issues and on how to adapt it in their scale of capability.
5. There is still need more examples, best practices, and stipulation as well as funding on the facilitation of rain harvesting technique to all stakeholders.

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