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The Impact of Alluvial Land Subsidence Towards Extension of Inundation and Infrastructure Damage At Settlements Around Harbor Area of Tanjung Mas – Semarang

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Abstract-Semarang is the capital of Central Java province of Indonesia, has an area of 373.4 km2 with population of 1.571.341 million. Southern parts of this city are hilly, denudational and volcanic areas, whereas alluvial areas are located in the northern part of this place. In the alluvial areas, the land around keeps undergoing subsidence and this becomes a serious issue especially to the area growing naturally in the estuary area of Semarang River. While high tide is happening, sea water comes to the settlements through some rivers and floods, as a result, settlement infrastructures are damaged and this potentially causes deseases.
This research used survey method, evaluation towards the extention of inundation in the settlement over 941.14 Hectare, the resut would be a change on the extension of inundation in the settlement. Data analysis was conducted by using Geographic Information System (GIS). To know the impact of inundation to the settlement towards infrastructure damage, statistic with cross tabulation was used while deseases suffering by people around and health level due to the inundation, the analysis used the software of Statistical Product Service Solution (SPSS) version 16.
Result of the research showed the year of 1996 (167,25 Hectare), year of 2010 (138,09 Hectare) and year of 2015 (70,25 Hectare) from SPSS analysis in 2010. The result due to the inundation was happened settlement in the estuary in the amount of 20.10%. Between year of 2010 and 2015, was happened at the settlement to the inundation, caused by river normalization of Asin's river and start functioning the pond's retention Semarang river, settlement infrastructures are damaged and this potentially causes deseases.

Keywords: land subsidence, inundation, infrastructure damage, desease incidence

1. Introduction

Semarang is one of the biggest cities in Indonesia, inhabited around 1.571.341 people. It has around 373,4 km^2 wide with population growth rate of 2.10% per year. Referring to geographical condition, this municipality consists of two units of morphology. To the south (up town), geographically it is denudationally structural hills, consisting of Ungaran foothills extending from east to west beginning from the area of Tembalang, Tanah Putih, Tegalsari, Siranda to Gajah Mungkur, while the alluvial is located in the north (down town). Among 16 sub-districts in Semarang, north Semarang and middle Semarang are densely populated areas with the amount of inhibitants, 11.671 and 11.596 per km^2 (BPS Kota Semarang, 2014).

By referring to Tobing et.al. (2003), it is found that the land subsidence in the alluvial land around the harbor of Tanjung Mas striking 8 cm per year, happening in Tanjung Mas to the east to the area of Genuk sub-district and some of the areas of Sayung sub-distrit belonging to Demak Regency, then followed by Badarharjo area and around which is around 10 to 15 cm per year, and next to this is Tanah Mas, Tawang Train Station, Karang Tengah,

Marina and Tawang Mas which is 5 to 10 cm per year. Sayekti et.al. (2000) within his research showed, land subsidence of > 20 cm/year had happened in coastal areas in the nortern part of Semarang (around Tanjung Mas Harbor).

The issue of land subsidence in the alluvial land around Semarang becomes serious as the area in general is settlement. Due to the subsidence, part of the land within the area of settelement locaed around coastline becoming lower than the sea level. Whilst high tide is happening, the water flows to land through river and drainage systems, then drowning the settlement area. Due to the progressing land subsidence, as the consiquence inundation happens to the settlement around the harbor in the area of Bandarjo, Kuningan, Dadapsari and Tanjung Mas.

Types of houses in the settlement around the harbor of Tanjung Mas Semarang consist of a permanent, semi-permanent and permanent house. The house which is not permanently built generally grows and develops organically (organic pattern) with substandard quality engineering. This situation is seen from the condition of the buildings that is not well organized, turning drainage systems which are full of sediment, lack of environmental facilities and infrastructure. In 2014, government has completed the normalization and sediment dredging in Semarang River and Asin River and has started the trial of Semarang river retentive pool.

2. Objectives

Based on the background and the problem formulation, the following research objectives are set as follows:

1. Reviewing and evaluating the vast changes of inundation in the settlements suffering from subsidence aroung the alluvial areas.
2. Assessing and evaluating the effect of inundation on the settlement infrastructure damage in the alluvial land due to being frequently flooded of rain and sea water.

3. Research Method

This study used a survey method, the target was the inhabited settlements in the alluvial land Semarang in Semarang estuary 941.14 hectare wide, the land consisted of relativelly young alluvium rock composition, which was still hundreds of years of age what made it continuously undergo compaction.

Land subsidence has been widely studied, among others Rappley (1933) in Poland and Devis (1969); Holtz and Kanvaes (1981), Whittaker and Reddish (1989), Johnson (1991), Fulton (1997), Yin et al (2006), Carbogin (2003) Donelly (2006), Piend and Natalaya (2008). The results of the study describes the general causes of land subsidence, among others: the decline of groundwater, aquifer compaction of clay, mining and sediment compaction, compression of natural alluvial deposits, soil deposits and loading of the building.

Stagnant water in the settlements are potentially damaging houses and infrastructure, such as roads and drainage. To obtain asphalt mixture that is resistant to water on the road layers arranged by referring to Indonesian National Standard (SNI) 03-6753 – 2002. SNI provides guidance on standards of the test specimen and measuring changes in diametric tensile strength obtained from the saturation of the diametrical tensile strength obtained from saturation in the discussion of asphalt mixture specimen.

Concrete road can suffer from common damage on the slab and its basic land layer. Damage on the concrete road consists of structural damage and surficial characteristic

damage, such as cracks on the pavement layers, fault and deformation. Faut on the pavement layers is related to attraction and pressure due to load. Referring to the law of material power degradation on te fault proocess and road damage depend on the maintenance (Hong et.al, 2008). Dowson (2006) articulates that the water coming in the paving block connection causing earlier road damage, water under the paving block can cause erosion and clear up sand among pavement, due to instable pavement condition (Emer, 1993).

To know the extensive change inundation, this research used *geographic Information System (GIS), Software Are GIS Distop 92* from *Environmental System Research* using *Inverse Distance Weighted Interpolation* (IDW) and *Extensive Spatial Analyst Facility*. Value generated by these methods were based on value range from interpolation points. IWD Methods used average distance, therefore the generated values were bigger than minimum values and smaller than maximum (Waston and Philip, 1985).

Resut of the research was map of the extension of inundation in the research area in 2010 and 2015. Then, the extension of inundation in the settlement in 1996 in overlay with the extension of inundation in the settlement in 2010 and in 2015, therefore, this can be understood that the increase of inundation was due to land subsidence, normalization of drainage system and restensive pool operation of Semarang River. To know the impact of inundation in the settlement towards infrastructure damage and environmental power support, survey metod using descriptive analysis was used. To kow settlement infrastructure damage level of the research, statistic and cross tabulation were used, for measuring environmental power support, functional relation between *dependent variable* in the form of settlement infrastructure damage such as inundation happening in the house, yard, road and drainage what made it be recognizable in term of how big the impact was *Independent Variable* towards *Dependent Variable*. The analysis of which was using supporting tool *Software Statistical Product and Service Solution (SPSS)* Version 16.

4. Result And Discussion

Inundation at the settlement due to land subsidence in the alluvial land potentially damaged houses and settlement infrastructure. This research was conducted in the estuary of Semarang River consisting of 4 villages, among which were: Kuningan, Dadap Sari, Bandarhardjo and Tanjung Mas which were 941.14 acre wide, belonged to subdistrict of north Semarang. Land layers generally consist of relativelly young alluvium rock composition, only hundreds of age what makes it have compaction. The process of this land subsidence was fastened due to load addition for building settlement, in addition to this, location of the settlement was situated at the estuary of Semarang River. When high tide happened sea water came and flooded the area what made it damage the settlement infrastructure, below is figure 01 of research areas:

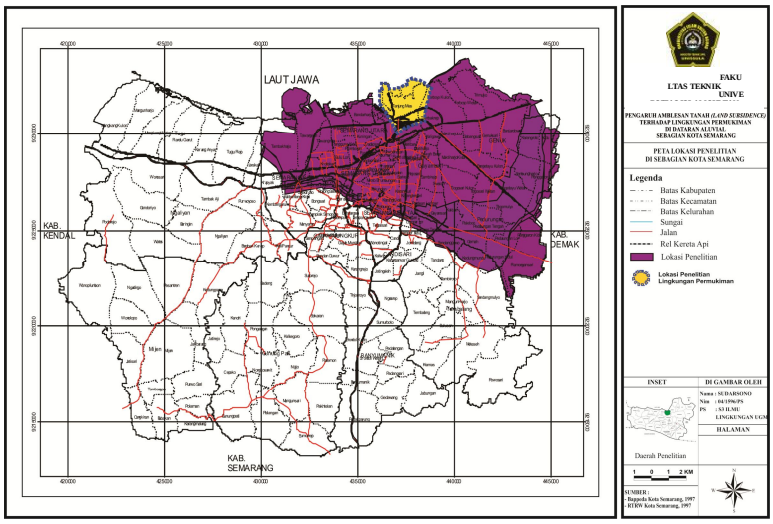

Figure 1. Location of Research

After validating data, doing observation at research location and being analyzed, next process was making inundation map of the areas such as Kuningan, Dadap Sari, Bandarhardjo, and Tanjung Mas, in the year of 1996 (research result) as shown in the Figure 02.

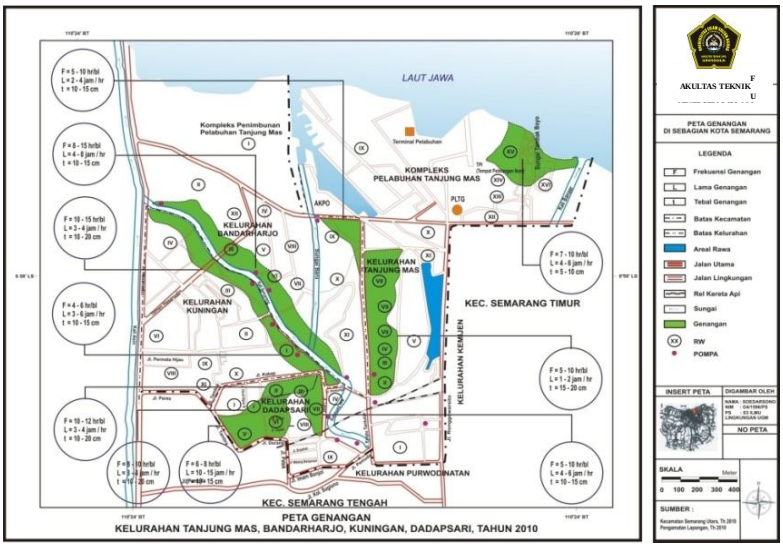

Figure 02 Inundation Map in 1996

To check change of inunation extension in the settlement, *overlay* inundation map was done in 1996 (secondary data) with inundation map in 2010 (research result), the result was a map of wider extension of inundation around the settlement, as shown on the table 03

Table 1. Area and inundation in 1996 and 2000

Location	Area (Hectare)	Inundation in 1996 (Hectare)	Inundation in 2010 (Hectare)	Inundation change (Hectare)	Remark
Village of Tanjung Mas	373,73	44,02	48,55	4,53	Increase
Village of Bandarharjo	342,65	42,95	27,65	-15,30	Increase
Village of Dadapsari	83,25	8,36	25,57	17,21	Increase
Village of Kuningan	141,51	13,74	36,92	23,18	Increase
Total	941,14	109,07	138,69	29,62	

Source: Soedarsono, (1997)

Based on the figure 02 and table 01, this can be understood that during 14 years, there was increase of inundation in the four villages of 29.62 hectare with extension generally on the right and left side of Semarang River, on the edge of the drainage systems and at the settlement having low topography. The change of inundation in the four villages (research location) in 1996 and in 2010. This can be seen from figure 03.

Figure 3. Map of Inundation Change in 2010

To check the damage level of infrastructure around the settlement in the area frequently flooded, primary data gained from questionnaire were used, deep interview and direct obseration on the research location. After tabulating cross tabulation on the damage level of settlement infrastructure in 2010 as shown on the table 02.

Table 2. Damage level of settlement infrastructure frequently flooded by rain and sea water in 2010

Paved Road	Damaged	Sightly Damaged	Normal
	37,10 %	42,70 %	15,20 %
Jalan *Paving Block*	Damaged	Sightly Damaged	Normal
	22,50 %	49,70 %	27,80 %
Jalan Beton	Damaged	Sightly Damaged	Normal
	26,20 %	15,50 %	62,30 %
Saluran Drainase	Damaged	Damaged	Normal
	23,90 %	41,70 %	34,30 %

Source: Soedarsono, (1997)

To check the impact of inundation in the settelement on the environmental support power in 2010, software of SPSS version 16 was used. Result of which showed that damage level of settlement infrastructure was predicted (y) that was affected by inundation happening at house, yard, road and drainage as big as 20.10%, the rest was caused by other factors.

In 2014, Normalization and sediment dredging in Semarang River and Asin River were completely done and retensive pool of Semarang River firstly began to function, the result of which, the change of inundation width and infrastructure damage in 2015 as seen in the figure 04 and table 03.

Table 3. Area and Inundation in 1996, in 2010, and in 2015

Location	**Area (Hectare)**	**Inundation In 1996 (Hectare)**	**Inundation In 2010 (Hectare)**	**Inundation In 2015 (Hectare)**	**Remark**
Kelurahan Tanjung Mas	373,73	44,02	48,55	27,50	Decrease
Kelurahan bandarharjo	342,65	42,95	27,65	10,50	Decrease
Kelurahan Dadapsari	83,25	8,36	25,57	12,25	Decrease
Kelurahan Kunungan	141,51	13,74	36,92	20,00	Decrease
Jumlah	**941,14**	**107,07**	**138,69**	**70,25**	

(Soedarsono, 2015; Hartono, 2015; Radityo, 2015)

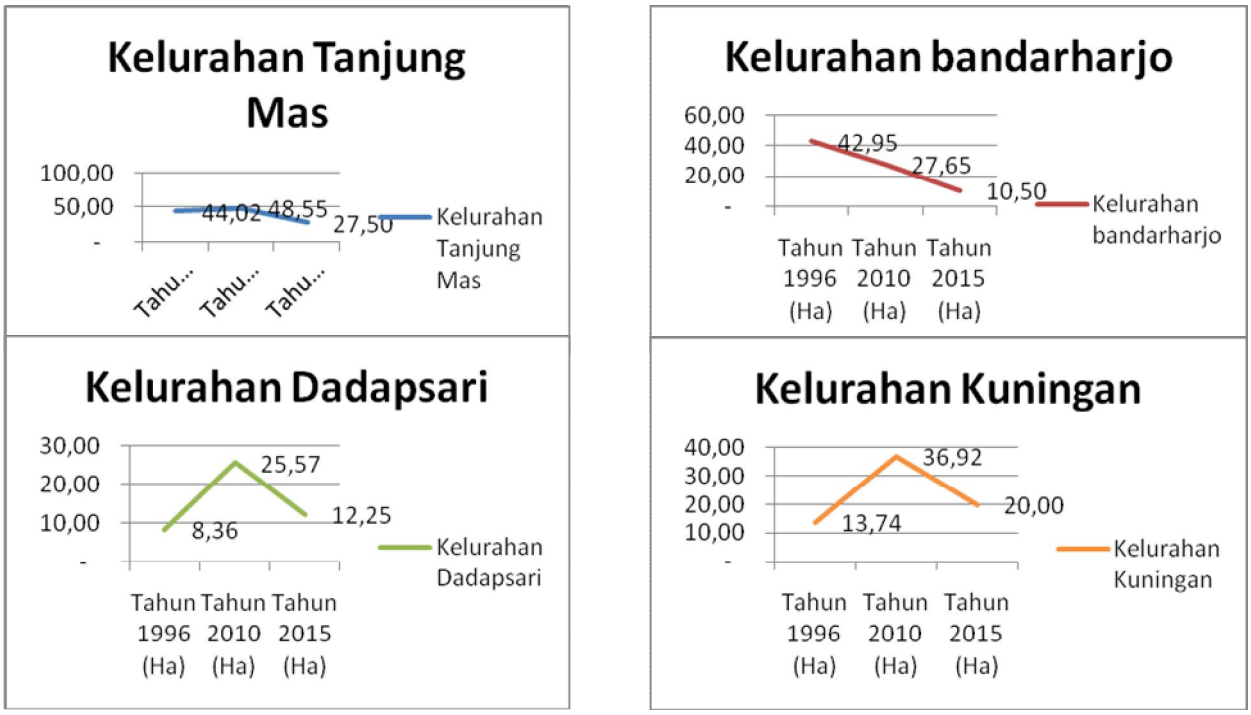

Figure 4. Graphic of Area and Inundation in 1996, in 2010, and in 2015

Table 4. Damage level of settlement infrastructure frequently flooded by rain and sea water in 2014

Paved Road	Damaged	Slightly Damaged	Normal
	24,11 %	27,75 %	48,14 %
Paving Block Road	Damaged	Slightly Damaged	Normal
	13,50 %	24,85 %	61,65 %
Concrete Road	Damaged	Slightly Damaged	Normal
	10,48 %	6,20 %	83,32 %
Drainage System	Damaged	Damaged	Normal
	14,34 %	25,02 %	60,64 %

(Soedarsono, 2015; Hartono, 2015; Radityo (2015)

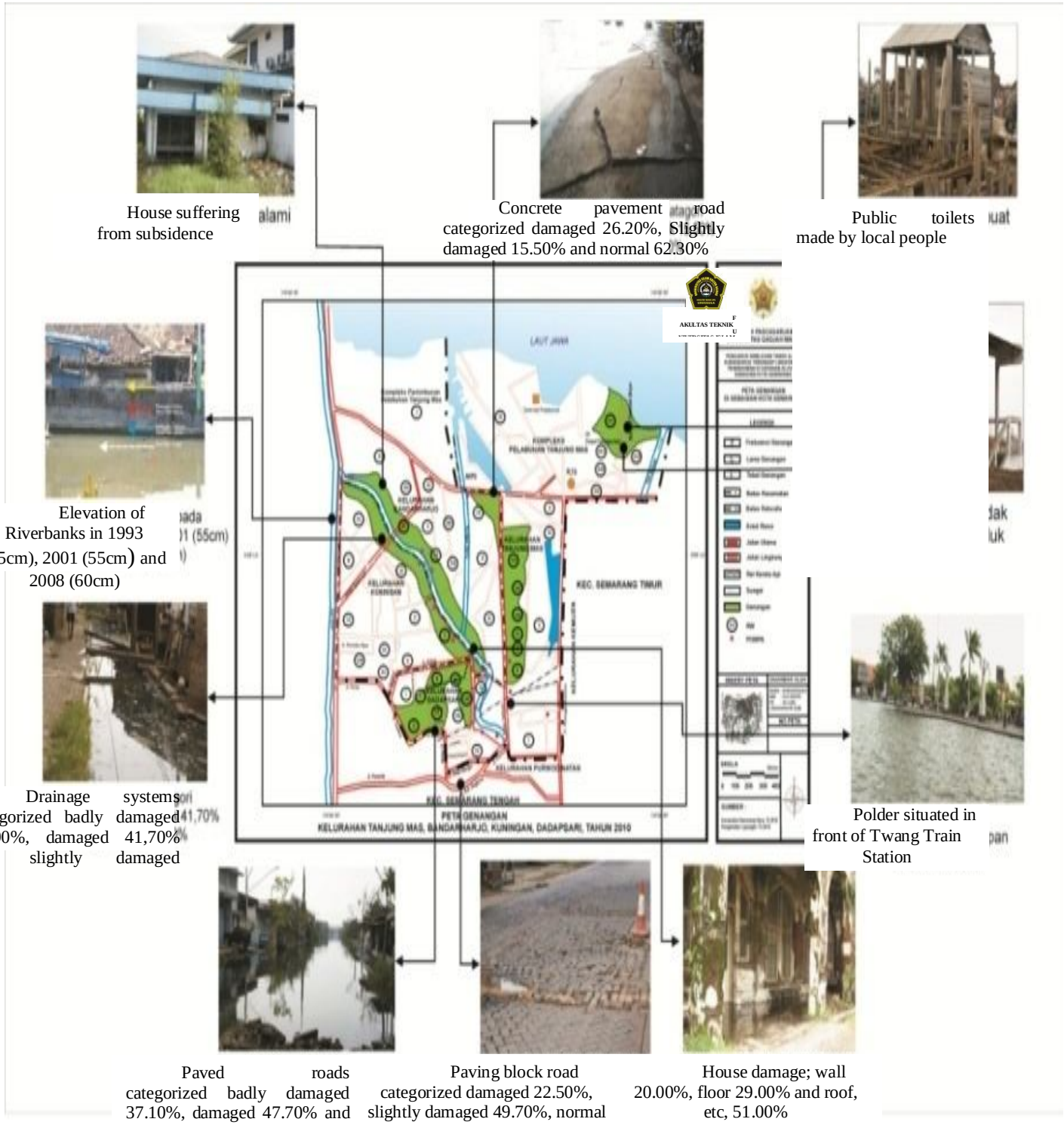

Figure 4. condition, house location and infrastructure suffering from damage due to inundation at the settlement in 2010

Figure 05 Condition, house location, and infrastructure sufferin from damage due to inunation at the settlement in 2015

5. Discussion

Land on the location of research which was relativelly young alluvial land, just hundreds years of age (http//www.semarang.ne), therefore, compaction was happening to the land. Load above the land which was settlement, smaller support power and confined aquifer what made it get lower (Soedarsono, 2011), as consequence the land susidnce kept going. Based on the research held by Tobing et.al (2000), it showed that land subsidence happening to the alluvial land was varied around 5 to 15 cm/year.

There were several rivers pass this Settlement around Tanjung Mas harbor Semarang; Ain River, Semarang River and Baru River, while it is raining, water came to the settlement,

as well as when high tide was happening, it went to the settlement through some rivers and flooded around the research location.

Inundation in the research location in the four villages; Tanjung Mas, Bandarharjo, Kuningan and Dadapsari was getting wider and wider. During 14 years, between the year of 1996 to 2010, the inundation width in the four village was getting wider as wide as 29.62 hectare, this was due to the land in the settlement kept experiencing subsidence. In addition to the case, decrease to inundation of 15.30 hectare, in the area of Bandarjo, was caused by landfill which was as high as 1.65 m used for warehouse expansion of Tanjung Mas harbor.

In 2015, there were two kinds of events happened, first was the inundation decreased of 68.44 hectare and second, the decrease of infrastructure damage of the settlement due to normalisation happening to Semarang and Asin River, by sediment dredging to those two rivers as well as improvement of the estuary the water could flow well, besides, this was the first time for Semarang River restensive pool to be operated, as a result, when high tide was happening the door of restensive pool was closed to which this was able to partly block the sea water coming to the River.

There are some issues idntified as the cause of inundation: (a) flat topography of the settlement, referring to gravity, rain and sea water (*rob*) were found to be relativelly long from coming back to sea; (b) the land was soft due to being flooded; (c) high groundwater (1-2 m) due to the fact that the water was hardly absorbed; (d) the land kept suffering subsidence and; (e) settlement was located to the estuary of Semarang river. Length of inundation was caused by the natural growing of settlement based on the economic capability of the people, what made the settlement be not well arranged, drainage slope (*i*) less than 2% and did not meet the technical requirement, as a result the flooding water needed about 3 to 5 hours to flow back to the sea. Result in the inundation included but not limited to floor, wall and house of physical components were fragile, moreover, the house built did not meet technical standard. The effort of improving house done by the people related to economic capacity, half of the people had got their house improved at least once in 14 years by fully repairing or just elevating the floor to avoid inundation, while for those who could not afford it, they would let their house be flooded.

The impact of sea water frequently flooding the settlement areas could be seen from the damage of the building and infrastructure. Sea water would soon damage the building in the area frequently flooded especially to the building made of mortar consisting of porland cement (PC) and sand, chemically, sea water was able to release compound within the cement, as a consequence, the building was easily fragile (Kusnandar, 2009). Infrastructures suffering from damage were roads with pavement of asphalt, concrete and paving blocks.

Prabowo (2009) conducted research using mixed design of thin layer of asphalt concrete of worn-out layers, explained the higher acidity of the water and the longer being submerged in sea water, the faster it would be peeling the asphalt mixture. Road damage with asphalt pavement happening in Jl. Dorang, Jl. Tombo and Jl. Empu Tantular were much caused by sea water immersion.

Damage of road construction with concrete layer in Jl. Usman Janatin was the impact of structure damage, such as cracks on the pavement layers (upper layer), but did not happen to the basic of *slab* concrete. Road damage with concrete pavement layer in Jl. Usman Janatin in the area of Tanjung Mas was mostly caused tender basic soil layer due to being submerged by water and the road itself was frequently passed by heavy leaden vehicle. Road damage with pavement lalyer *paving block* was caused by discharge of the lower sand layer *paving*

block because of the water submerging, displacement of sand under the pavement (*bedding sand*) caused instable road layers (Hatta et.al, 2003). Road damage in Jl. Layr and Jl. Kolonel Sugiono using paving block, besides it was frequently submerged, this was also because of heavy leaden vehicle passing by.

The condition of drainage system in the research location was party broken in the left and right side of the channel, most of which were full of sediment and household waste, existing drainage systems were turning following condition of the settlement with the slope (*i*) lesser than 2%, as a resut while raining and high tide, the water would flood the settlement.

From the stastical analysis using SPSS program version 16 conductd in 2010, it can be infered that the inundation at the settlement affected around 20% towards house damage and settlement infrastructure whilst the rests were possibly because of quality of the building materials, quality of construction and other aspects.

6. Conclussion

1. Inundation at the settlement happening around the rivers and the drainage systems, while raining or high tide, sea water would come to the settlement through Asin River, Semarang River, Baru River, and Banger River. The primary cause of this inundation were: densely populated settlement, soft and flat topography, land was suffering from subsidence, sea water which was going far further to headwater, increasingly widespread inundation. Between the year of 2010 to 2015 in the research location, decrease of the inundation width of 68.44 had happened.
2. Water flooding to settlement in 2010 could damage house and settlement infrastructure. Infrastructure such as road with badly broken asphalt pavement layers, for paving block and concrete road, they had better condition, due to being resistent to water. Parts of drainage systems did not work well because of their flat topography, too many turnings, broken channels and sediment.
3. There was decrease on the infrastructure damage level in 2015 caused by normalization of Semarang River, Asin River and the beginning of retensive pool.

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