CHAPTER II

LITERATURE REVIEW AND BASIC THEORY

2.1. Literature Review

A rise in sea level had been occurs since ages, and those impact had been observed continuously. The most common impact of sea level rising is inundation (Hoffman, Keyes, & Titus, 1990). This problem occurs in most country that located on coastal area. One-meter rising of sea level would inundate 17% of Bangladesh and 2-meters rising of sea level would inundate over half populated islands of atoll Republic of Maldives (Hoffman et al., 1990). Meanwhile in Indonesia, 60-centimeters of sea level rising predicted to inundate around 34000 kilometres square land, in the future (Marfai & King, 2008b).

Sea level rising in Semarang has been observed (Cahyadi et al., 2016; Indrawan et al., 2011). Indrawan et al., (2011) stated that sea level rising in Semarang is about 6 mm/year, and most of river did not adequate to accommodate 10 years return period of floods. On the other hand, Cahyadi et al., (2016) conduct research on sea level rising using linear regression method based on previous 3-years sea level anomaly. The result found that sea level in Semarang rising 12.83 mm/year. However, the calculation using linear regression shown the determination coefficient (R2) is 0.0233, that means relation between dependent and independent variable relatively weak and need further observation.

Sea level rising is proved to be one of major factors that contribute to the inundation that happened in Semarang (Ramadhany et al., 2012). The research shows the largest inundated area is North Semarang District with 508.28 hectares. Second place is Genuk sub-district with 377.68 hectares inundated area. Coastal inundation area determined by calculating the difference between monthly highest high-water level (HHWL) and mean sea level (MSL). Then, the result correlated with ground level that gathered from digital elevation model (DEM) data. Highest high mean monthly average rainfall intensity during observation is 40 mm/hr.

Abidin et al., (2013) has been tried to investigate land subsidence in Semarang. According to Abidin et al., (2013), groundwater extraction and load of building and structure believed as main factor that cause land subsidence in North Semarang. The observation conducted using GPS (Global Positioning System) survey method. The result shown subsidence average rate about 6-7 cm/year, and maximum rate 14-19 cm/year. Whereas another method to measure subsidence shown different result. Table 1 shows the subsidence in Semarang through 4 different method and different time of observation. The result shown that subsidence in Semarang ranging about 0-19 cm/year. The impact of land subsidence can be seen in the form of coastal inundation, and its affected area enlarge over time.

Table 1. Land subsidence in Semarang

No.	Method	Subsidence rates (cm/year)	Observation period
1.	Levelling	0-17	1999-2003
2.	GPS Surveys	0-19	2008-2011
3.	PS InSAR	>8	2002-2006
4.	Microgravity	0-15	2002-2005

Source: Abidin et al., (2013)

2.2. Basic Theory

2.2.1. Frequency Analysis

Frequency analysis put simply, is a forecasting method to get probability of hydrologic event that happened, in a form of discharge designed rainfall return period. Often used for hydrologic design calculation as a prevention action.

1. Distribution of Data

Distribution of rainfall data determined by maximum daily rainfall in a year. Distribution type that usually used in Indonesia are Normal distribution, Log Normal, Gumbel, Log Pearson III. Table 2 shows criteria for each type of distribution method.

Table 2. Distribution Type

No.	Distribution Type	Criteria
1.	Normal	$Cs \approx 0$ $Ck \approx 3$
2.	Log Normal	$Cs = 3Cv$ $Cs > 0$
3.	Gumbel	$Cs \approx 1.130^6$ $Cv = 5.4002$
4.	Log Pearson III	Except criteria 1,2,3

Source: Badan Standardisasi Nasional, 2016

Calculation of Standard Deviation (SD), Skewness Coefficient (Cs), Variant Coefficient (Cv), Kurtosis Coefficient (Ck) needed to determine the distribution type. Calculation of standard deviation using equation as follow:

$$SD = \sqrt{\frac{\sum(Xi - \bar{X})^2}{n-1}} \quad (2.1)$$

where,

SD = Standard Deviation

$\bar{X}$ = Average Rainfall

Xi = Rainfall year-i

n = Number of rainfall data

Skewness coefficient (Cs) determined using equation:

$$Cs = \frac{n . \sum(Xi - \bar{X})^3}{(n-1).(n-2).SD^3} \tag{2.2}$$

where,

Cs = Skewness coefficient

SD = Standard Deviation

$\bar{X}$ = Average Rainfall

Xi = Rainfall year-i

n = Number of rainfall data

Kurtosis coefficient (Ck) determined using equation:

$$Ck = \frac{n^2 . \sum(Xi - \bar{X})^4}{(n-1).(n-2).(n-3).SD^3} \tag{2.3}$$

where,

Ck = Kurtosis coefficient

SD = Standard Deviation

$\bar{X}$ = Average Rainfall

Xi = Rainfall year-i

n = Number of rainfall data

Variant coefficient (Cv) determined using equation:

$$Cv = \frac{SD}{\bar{X}} \tag{2.4}$$

where,

Cv = Variant coefficient

SD = Standard Deviation

$\bar{X}$ = Average Rainfall

2. Smirnov-Kolmogorov Test

Smirnov-Kolmogorov test exist to verify whether the chosen distribution method might potentially represent the distribution of sample data. This test is done by finding the difference value of each variant, according to empirical dan theoretical distribution, symbolized by D. Maximum D value have to be smaller than D critical.

The probability of each rainfall data calculated using Weilbull equation as follows:

$$P = \frac{m}{n+1} 100\% \tag{2.5}$$

where,

P = Probability (%)

m = Serial number of data

n = Number of rainfall data

Then, the maximum differences of D empirical and D theoretical found using equation:

$$D_{maximum} = maximum \left| P_{theoritical} - P_{empirical} \right| \tag{2.6}$$

When D maximum smaller than D critical corresponding to Smirnov-Kolmogorov critical as shown on Table 3, the distribution is accepted.

Table 3. Smirnov-Kolmogorov critical value

n	A			
	0.20	0.10	0.05	0.01
5	0.45	0.51	0.56	0.67
10	0.32	0.37	0.41	0.49
15	0.27	0.30	0.34	0.40
20	0.23	0.26	0.29	0.36
25	0.21	0.24	0.27	0.32
30	0.19	0.22	0.24	0.29
35	0.18	0.20	0.23	0.27
40	0.17	0.19	0.21	0.25
45	0.16	0.18	0.20	0.24
50	0.15	0.17	0.19	0.23
>50	$\frac{1.07}{\sqrt{n}}$	$\frac{1.22}{\sqrt{n}}$	$\frac{1.36}{\sqrt{n}}$	$\frac{1.63}{\sqrt{n}}$

Source: Badan Standardisasi Nasional, 2016

3. Log Pearson III

Log Pearson III is distribution method to predict the upcoming rainfall. This method used to calculate rainfall on several return period (T). the rainfall value calculated using following formula:

$$Log\ X_T = Log\ X_{ave} + (KT \times SD) \quad (2.7)$$

where,

$Log\ X_T$ = Rainfall design value with return period (T)

$Log\ X_{ave}$ = Average value of Xi

K_T = Standard variable

SD = Standard deviation

Xi = Maximum rainfall

2.2.2. Rainfall Discharge

Rainfall discharge here means total water from the rainfall flowing through a canal at any given point; and the water comes from the rain. Rainfall discharge calculated using practical rational method that reflect the relation between runoff discharge and rainfall value. The discharge calculated using equation:

$$Q = 0.278\, C.I.A \tag{2.8}$$

where,

Q = Discharge on peak flood (m^3/s)

0.278 = Constanta, used when the areas on km^2 units

C = Runoff coefficient

I = Rainfall intensity during time concentration (mm/hour)

A = Area (km^2)

The rainfall intensity is a measured amount of rain that falls over time (Floodsite Project, 2008b). Rainfall intensity calculated using Mononobe method as follows:

$$I = \left[\frac{R_{24}}{24}\right]\left[\frac{24}{t_c}\right]^{\frac{2}{3}} \tag{2.9}$$

where,

I = Rainfall intensity (mm/hour)

t_c = Rainfall time concentration (hour)

R_{24} = Maximum rainfall in 24 hour (mm)

Time concentration is time required for water to travel from water drop point in the sub catchment to the point of collection (HydroCAD Software Solutions LLC, 2019). Time concentration (t_c) calculated using Kirpich formula as follows:

$$t_c = 0.0195\ L^{0.77}\ S^{-0.385} \tag{2.10}$$

where,

t_c = Rainfall time concentration (minute)

L = Slope length (m)

S = Slope (m/m)

Besides rainfall intensity and time concentration, runoff coefficient has an important role to calculate the discharge. Runoff coefficient used to convert the rainfall amounts to runoff and it represent the effect of catchment loses (Goel, 2011). Runoff coefficient in Indonesia can be defined by land use of an area. Table 4 shows the runoff coefficient from land use of an area based on SNI 2415:2016.

Table 4. Runoff Coefficient

Land Use	Characteristic	C
Shopping and Office area		0.90
Industrial area	Full building	0.80
Residential (medium to high)	20 house/ha	0.48
	30 house/ha	0.55
	40 house/ha	0.65
	60 house/ha	0.75
Residential (low)	10 house/ha	0.40
Park	Flat area	0.30
Village	Sandy soil	
	Heavy soil	
	Irrigation area	

Source: Badan Standardisasi Nasional, 2016

2.2.3. Catchment Area

Catchment area, basically is the area for each drop of precipitation that falls into catchment area ends up in the same river (Floodsite Project, 2008a). The time from the farthest area drop of water to the river on a catchment area defined as time concentration (t_c).

2.2.4. River Profiles

River profile shows the cross-section of a river at a certain point along the river (BBC Bitesize, 2020). The cross-section could be different at any point.

2.2.5. Sea Level

Level of water surface that measured from some point of elevation determine as sea level. Rosenberg (2019) reveals, a few factors such as sinking or uplift of landmasses, change of total amount water in the ocean, and temperature, affected the water to expand or contract. However, the upcoming sea level could be projected by using statistical technique for data analysis called linear regression method.

2.2.6. Land Subsidence

Land subsidence is a movement of surface downwards refer to a point. Land subsidence that happened in northern part of Semarang believed as an impact of groundwater extraction and load of building and structure above. According to

Abidin, 2013 the rates of land subsidence in Semarang range up to 19 centimeter yearly during observation period 2008-2011.

2.2.7. Linear Regression

Generally, linear regression is an approach to describe linear cause and effect relations between two variables. Jain & Singh (2003) point out the objective of linear regression is to predict a dependent variable based on an independent variable. Prediction calculated using following formula:

$$y = a + bx \tag{2.11}$$

where,

y = dependent variable

x = independent variable

a = the intercept (the value of y when x = 0)

b = the slope of the line

2.2.8. Flood

Flood is overflowing water from river and submerges to dry land that may lead to inundation. In this research, flood inundation done by analysing data using Hydrologic Engineering Center River Analysis System (HEC-RAS) software. The flood calculation focused on steady flow simulation.

2.2.9. Steady Flow

Steady flow are all conditions at any point in a stream are constant with respect to time (Finnemore & Franzini, 2009). In this research, flow simulation was modelled using HEC-RAS. The calculation using energy equation known as standard step method.

$$y_2 + Z_2 + \frac{\alpha_2 {V_2}^2}{2g} = y_1 + Z_1 + \frac{\alpha_1 {V_1}^2}{2g} \tag{2.12}$$

where,

Y_1, Y_2 = height of flow

Z_1, Z_2 = elevation of the main canal invert

V_1, V_2 = average velocities (total discharge divided by total flow area)

α_1, α_2 = coefficient (velocity weighting coefficient)

g = gravitational acceleration

h_e = energy head loss

The energy head loss between two cross-sections is comprised of friction losses and contraction or expansion losses. The energy head loss equation as follows:

$$h_e = L\bar{S}_f + C\left|\frac{\alpha_2 {V_2}^2}{2g} - \frac{\alpha_1 {V_1}^2}{2g}\right| \tag{2.13}$$

where,

L = discharge weighted reach length

$\bar{S}f$ = representative friction slope between two cross-sections

C = expansion or contraction loss friction