CHAPTER II

LITERATURE REVIEW

2.1. <u>Drainage</u>

Drainage is the act, process, or mode of draining (Webster, 2018). Suripin (2004) indicated that drainage generally defined as technical action to reduce the excess of water from rainwater, seepage, or irrigation excess from certain region/land, as of land function is not affected. Moreover, Suripin (2004) also specify drainage as an effort to controlling the groundwater quality in relation to salinity, drainage is not only concerned about surface water but also about groundwater. Wesli (2009) differentiate types of drainage based on:

1. Formation (natural and artificial),
2. Flow systems (network, and absorption systems),
3. Constructing purpose (urban, agriculture, runway, highway, railway, dam, sport fields, urban aesthetic, environment health, and additional land),
4. Layout design (surface and subsurface),
5. Functions (single and multi),
6. Constructions (open and closed channel).

Interaction between natural water cycle and human activity is the reason why drainage systems are needed in developed urban area (Butler and Davies, 2004). Butler and Davis (2004) also stated *this interaction has two main forms: the abstraction of water from the natural cycle to provide a water supply for human life, and covering of land with impermeable surfaces that divert rainwater away* *from the local natural system of drainage*. Impermeable surfaces made the artificial drainage systems must be built to accommodate the water in the covered land surfaces. Artificial system of sewers (pipes and structures which collecting and disposing waste water) are considered as the drainage in many urban areas (Butler and Davies, 2004).

2.2. <u>Urban Drainage</u>

In surface water run-off, a watercourse, river, sea, or ground infiltration system, urban drainage has basic function which is removing the sewage with rainwater run-off from buildings, roads, and other impermeable areas, then transport it to every part of sewage treatment works (Stewart, 2012). Butler and Davies (2004) claimed that *urban drainage presents a classic set of modern environmental challenges: the need for cost-effective and socially acceptable technical improvement in existing systems, the need for assessment of the impact of those systems, and the need to search for sustainable solutions*. Butler and Davies stated there are two types of sewer that is accommodated by urban drainage, wastewater and storm-water. Based on Stewart (2012) there are types of urban drainage systems:

1. Foul sewers, encounter with the dirty part of sewage and usually designed using average discharge of society holdings. It is not affected by rainfall events and has 0.75 m/s minimum flow velocity at one-third design flow for self-cleansing,

2. Surface water sewers, encounter with surface water runoff from impermeable area (roofs, driveways, roads, car parks, etc.) and designed based on the type of impermeable area. Rainfall runoff from the impermeable areas are used to cope with specific return period storm event. The minimum flow velocity should be 1 m/s at full pipe flow for self-cleansing,
3. Combined sewers, serving foul and surface water flows and usually designed using rainfall events with extra capability to accommodate the foul flows from the holdings,
4. Highway drainage, designed using the same method with surface water sewers but specially applied in highway.

There are many water issues in urban area regarding with urban drainage. Urban water problem according to Tucci (2001) are mainly due to:

1. low investments in urban drainage facilities,
2. increase in peak and flood frequency due to inadequate drainage management and design,
3. lack of drainage and other sanitary facilities for poor population.

According to Utami (2012), factors affecting urban drainage and causing urban drainage problems are:

1. Sedimentation,
2. Environmental arrangement (housing development, buildings near the canal, and land contour changes),

3. Land use changes (changes in former rice fields not accompanied by the canal design changes, land use changes not suitable with design plan, and minimum of recharge land caused by the land buildings),
4. Canal capacity is unable to accommodate rainwater discharge capacity,
5. Misappropriation of canal drainage function,
6. Low public awareness in throw garbage.

2.3. <u>Flow</u>

Flow has many types and categorized based on certain aspects. Finnemore (2009) categorized flow with respect to time is divided into two types of flow, steady and unsteady. Furthermore, Finnemore (2009) also explained the differences and definition of steady and unsteady. Steady flow means the flow characteristics are consistent in every point but the conditions may be different at different point with respect to time. Unsteady flow is vice versa, flow characteristics of unsteady flow are changed in every point with respect to time.

2.4. <u>Inundation</u>

Inundation is the main topic of analysis in this final project. Inundation happened in urban area often defined as non-existed drainage or not enough drainage to patch the water (Adimas and Hadi, 2018). Inundation can not be described as a flood if it recedes within 1x24 hours, but if an area is inundated more than 1x24 hours included into flood phase (PKK, 2016). PKK (2016) also stated that if the water stagnates after heavy rain with an altitude of no more than 40 cm is considered as an inundation, but if it is more than 40 cm and make a community displaced on a large scale than it is categorized as flood.

2.5. Rainfall

Rain is the most important input in the hydrologic process because the amount of rainfall depth will be transformed into river water flow become surface runoff, interflow, sub surface flow, or groundwater (Handajani, 2005). Rainfall is a prime input for various engineering design such as hydraulic structures, bridges and culverts, canals, stormwater sewer, and road drainage system (Arvind et al., 2017). Rainfall data is important in engineering planning especially for waterworks such as irrigations, dams, urban drainage, harbors, docks, etc. (Prawaka et. al., 2016). In rainfall data, there are related elements and described as follows (Triatmodjo, 2008).

1. rain duration (rainy time from it started until it stopped).
2. rain depth (amount of rain in the surface land which is considered evenly distributed in the entire catchment area).
3. rainfall intensity (comparison between rain duration and rain depth).

2.6. Return Period

Return period or recurrence interval is defined as hypothetic time, when discharge or rainfall happens within certain value (rainfall in mm), and will have the same value or even surpassed in certain period of time (Triatmodjo, 2009). In the drainage canal planning, used return period is depends on the drainage canal function and catchment area that is drained (Wesli, 2009). Wesli (2009) also explained the return period for the types of the canal: quaternary (1 year), tertiary (2 years), secondary (5 years), and primary (10 years); but return period also can be defined based on economics considerations.

2.7. Runoff Coefficient

Runoff coefficient is the comparison between the amount of rainwater that is flows or overflows above the soil surface (surface runoff) with the amount of rainwater falling from the atmosphere (Wesli, 2009). Wesli (2009) also stated that the amount of coefficient value of the runoff is ranged between 0 – 1 and depends on the types of soil, vegetation types, land use characteristics, and construction types in the land surface which affects the rainwater unable to absorb to the soil and resulting almost 100% surface runoff. Runoff coefficient table showed in Table 2.1. and Table 2.2. Both of the table are presented in order to complement the parts that are not available in each other details and content of table.

Table 2.1. Runoff Coefficient and Impervious Percentage.

Land Use	**Characteristics**	**C**	**Im (%)**	**Information**
Trade and Office Centers		0.90	100	
Industrial	Compacted building	0.80	80	Decreased for incompact building
Residential districts (intermediate - high density)	20 houses/ha	0.48	30	Comparing impervious area with another area
	30 houses/ha	0.55	40	
	40 houses/ha	0.65	60	
	60 houses/ha	0.75	75	
Residential districts (low density)	10 houses/ha	0.40	< 20	CN=85 (Curve Number)
Park	Flat area	0.30	0	
Rural Area	Sandy soil		0	C = 0,20; CN = 60
	Heavy soil		0	C = 0,35; CN = 75
	Irrigation area		0	C = 0,50; CN = 85

Source: SNI 2415, 2016

with:

C = runoff coefficient

Im = impervious ratio (%)

Table 2.2. Runoff Coefficient Based on Area and Surface Area.

Area Description	Runoff Coefficient (C)
Business	
Downtown	0.70 - 0.95
Neighborhood	0.50 - 0.70
Residential	
Single-family	0.30 - 0.50
Multiunits, detached	0.40 - 0.60
Multiunits, attached	0.60 - 0.75
Residential suburban	0.25 - 0.40
Apartment	0.50 - 0.70
Industrial	
Light	0.50 - 0.80
Heavy	0.60 - 0.90
Parks, Cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.35
Railroad yard	0.20 - 0.35
Unimproved	0.30 - 0.30
Surface Character	
Pavement	
Asphaltic and concrete	0.70 - 0.95
Brick	0.70 - 0.85
Roofs	0.75 - 0.95
Lawns, sandy soil	
Flat, 2%	0.05 - 0.10
Average, 2-7%	0.10 - 0.15
Steep, 7%	0.15 - 0.20
Lawns, heavy soil	
Flat, 2%	0.13 - 0.17
Average, 2-7%	0.18 - 0.22
Steep, 7%	0.25 - 0.35

Source: Dickinson, 2017

2.8. Catchment Area, Route, and Segment

Catchment area is area that functioned as water catchment area and needed in maintaining the sustainability of water source functions in regional area (Pamungkas, 2017). Moreover, Pamungkas (2017) also stated, catchment area is upstream area which acts as water supply and play a role in maintaining the hydrological cycle in watershed. Catchment area can be determined with using boundary of the canal, upstream, and downstream of the canal (Utami, 2012). Route is mileage from the upstream to downstream and segment is route that is divided into parts based on dimension and road curvature (Utami, 2012)

2.9. Drainage Design

In designing the urban drainage, Hasmar (2012) revealing the steps of the planning with the planning data as follows:

1. Problems data (inundation location, inundation duration, inundation height, inundation loss value, community’s aspirations and government role, population social economic data, residential environmental health, upstream flood (if available), location map and channel path measurement, rainfall data, and local building material data),
2. Topography data,
3. Land use data,
4. Soil types,
5. Master plan of the city,
6. Infrastructure and utility data,

7. Production data of drainage,
8. Demographic data,
9. Institutional authority,

Generally, drainage building project is using the steps below (Hasmar, 2012).

1. programming and planning
2. implementation
3. operation and maintenance
4. evaluation and monitoring

Specifically, urban drainage project planning is described as follows (Hasmar, 2012):

1. Things needed in order to know the exact cause of inundation,
2. Compile the inundation prevention efforts alternative, discharge reduction, additional channels construction, channel repair/normalization, and sluice/watergate construction,
3. Determine the definitive design of the network scheme, flow direction, canal and building dimension, detailed plan drawing.

2.10. <u>Drainage Alternatives</u>

Drainage alternatives solutions applied in order to create better drainage systems or repair the existing drainage and explained below (Utami, 2012).

1. Improving the existing drainage with ways as follows.
   a. straighten flow direction from the drainage channel so that it cuts the winding section,
   b. build an embankment along the edge of the channel will effectively increase channel loading capability,
   c. dredging and digging the channel is common way to increase channel capacity,
   d. coat the certain area of channel (cliff) or the entire area of the channel (from bottom of cliff) to increase the ability of the existing channel because of Manning coefficient is degraded.
2. Diverting the flow, channel diversion helps the following purposes: diverting overflowing flood flow to the river or other canals and diverting partial flow area then the flow will be discharged into other drainage basins.
3. Flow resisting, hold the flow concerns the provisions of flood reservoir to flatten the peak of flood flow. If a flood hydrograph passes through the reservoir, some of the flood water will be temporarily detained, which results in flattening of flood peak, flow holding concept can be applied to reduce the flood flow from small or large catchment area.

4. Pumping, two application of pumping:
   a. flood reservoir pumping (temporary, from entire or partially diversion into certain reservoir outside river flow and pump it back to the drainage canal when the flood subsides),
   b. low land pumping (drainage does not have exit canal or water that can come out is very limited especially in low land area, it is necessary to install the pump to lift the drainage to another flow area).

Other than methods above, Suparmanto (2012) stated the other alternative solutions to improve drainage in the inundation area are drainage canal renovation, retention basin, and infiltration wells. Drainage canal renovation is used to fix existed drainage in the certain area that is prone to inundation or the inundation easily happened in the area. It helps to repair the drainage system from the occurrence of canals overflow which caused inundation. Retention basin or retention ponds is used to reduce the inundation with certain design concept to accommodate overflow water discharge and designed considering location condition (to determine the depth of retention basin), appropriate land use, and soil (type and texture) that can absorb water with high rate of infiltration. Infiltration wells helps to reduce the inundation in certain area and recommended to be built in every house that still has open space.

Details of infiltration wells and construction regulation is regulated in SNI 8456 (2017). In the SNI (2017), to calculate the infiltration wells needed in the inundated area, soil type of data is required. Based on Hatmoko (2013), type of soil in Sanata Dharma Auditorium construction is listed in the Table 2.3. From the data, it is assumed that the area in the research area has similar type of soil. These type of soil helps to determine formula that is used to calculate amount of infiltration wells needed in the research area to reduce the inundation.

Table 2.3. Sanata Dharma Auditorium Construction Soil Data.

Depth (m)	B1-2				B1-1			
	Type of Soil	**G**	**N-SPT**	**γ (t/m³)**	**Type of Soil**	**G**	**N-SPT**	**γ (t/m³)**
1.00 - 2.50	Medium grain sand	2.62	9	1.82	Medium grain sand	2.62	10	1.82
2.50 - 4.50	Coarse grain sand	2.62	15	1.82	Coarse grain sand	2.62	20	1.82
4.50 - 6.50	Fine grain sand	2.62	18	1.82	Fine grain sand	2.62	20	1.82
6.50 - 8.50	Silt sand	2.62	18	1.82	Silt sand	2.62	17	1.82
8.50 - 10.50	Coarse grain sand	2.62	22	1.82	Coarse grain sand	2.62	21	1.82
10.50 - 12.50	Medium grain sand	2.62	21	1.82	Medium grain sand	2.62	34	1.82
12.50 - 14.50	Fine grain sand	2.6	26	2.15	Fine grain sand	2.6	25	2.15
14.50 - 16.50	Coarse grain sand	2.6	35	2.15	Coarse grain sand	2.6	41	2.15
16.50 - 18.50	Sand stone	2.6	50	2.15	Sand stone	2.6	50	2.15
18.50 - 20.00	Sand stone	2.6	50	2.15	Sand stone	2.6	50	2.15
M. A. T.				-12.5				
Sample	-3.00		-8.00	-15.00	-3.00		-8.00	-15.00

SNI 8456 (2017) stated about the calculation of infiltration wells that needed in the certain area. Based on the condition of the area (Table 2.1.), it is concluded that the type of soil the research area is fine grain soil type with porous empty well (porous type is chosen because to make the water from area around the location is able flows into the infiltration well). So, the formula that is used to calculate the infiltration wells needed in the certain area is in the equation 2-1 below.

$$H = \frac{Q}{5 \pi r K} \quad (2\text{-}1)$$

with:

Q = discharge (m^3/s)

π = phi = 3.14

r = well radius (m); assumed to have 1 m radius

K = impervious coefficient (m/hr)

= 8.64 m^3/m^2/day = 8.64/24 (m/hr) = 0.36 m/hr (SNI 8456, 2017)

Besides the solutions, Suripin (2004) stated that drainage maintenance is needed in order to keep the drainage system run properly in service in planned time period and divided into three parts of activities and explained as follows.

1. security and prevention activity, consist of: routine inspection, prohibit garbage disposal in channels or ponds, and prohibit damaging drainage buildings,
2. treatment activity, consist of: routine maintenance and regular maintenance,

repair and replacement activity.