FLOOD PREVENTION
KOTA MEDAN – INDONESIA

Overstromingspreventie
Kota Medan - Indonesië

Submitted by

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DISSERTATION

for the Bsc. in Civil Engineering

Hogeschool van Utrecht

Hogeschool van Utrecht
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January 2005

Scriptie ICT 2005 SUSA

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Stephen Susanto

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PREFACE

Medan City is one of the biggest city in Indonesia. In the development of city with the increasing of population and infrastructure, Medan city has it's own problem and one of this problem is river flooding in some area mostly in downstream area (Belawan Area) since the development of Medan city in the past was depended on the river system which located in the middle of the city so the existing river in some period of time bring it's own problem mostly during heavy rain fall in rain season. As part of development of the city into one of the better place to stay, it is an obligation for the Medan government and people of Medan to deal with this flood problem.

This dissertation is trying to give an output by analysis and investigation with study comparible in other project or either literature review to deal with the flood problem. With the study of analysis possibility in implementation of alternative solution design with it's impact so we can get an optimal solution to be implement in the site area in purpose of prevent the flooding or decreasing the negative effect of flooding in Babura – Deli river

From the study analysis it was found that the peak discharge during flood period is 473 m^3/s (according to data record the previous flood is approximately 470 m^3/s). consider the analysis of implementation solution design in the project area like cost, construction, functionality, etc, the author proposed an optimal solution design to construct a dike as a mid-term project. More over the author also proposed Reforestation as a long-term project.

This dissertation has been made in order to complete the final unit of Bsc. course in Civil Engineering, faculty of the Built and Environment, Organised by the two University of Professional Education: *"Hogeschool van Utrecht"* in The Netherlands.

Thousand of hours have been spent to complete this dissertation. Even though I have strive to do my best, there still are some flaws occurred. And I apologise for that flaws, because I needed more knowledge, experience, and of course time to get the better result.

Any critics and suggestion with regards to this dissertation, will be favoured invited in, so that this could be valuable for readers and anyone who interesting at the Floatation of the house and Environment issue and its effect into the project performance.

Utrecht. January 10,2005

Stephen Susanto

ACKNOWLEDGEMENT

I extremely indebted to all people, who through their support and many valuable suggestions for the correction and improvements, who have guided, assisted, supported, helped and encouraged me to finalise this dissertation on time.

- Most grateful to God for giving me health and ability during arrangement of this thesis.
- Mr. Frans van Heerden , Mr. Laurens Stijn, Mr. Henk Jan de Haan, Mr. Paul van Klaveren, Mr. Tom van Linden, thank you very much for your support and guidance during my study and dissertation.
- The whole lecturers from Hogeschool van Utrecht, thank you for your support and guidance during my study.
- All companies and engineers in Netherlands especially for Witteveen+Bos, who have allowed me to do the in-depth interviews and supported me by filling in my questionnaire.
- My lovely family (Papa, Mama, Meily, Yohanes, Fanny); who has supported me to make my dream comes true, and what I have done is all for you.
- Fam Situmeang - Verkade, who have supported me during my study and staying period in Netherlands.
- All of my íriends during my study and staying period in Netherlands (especially Yustinus, Stella, Farida, Joker, Babby, Chandra).
- All my friends and relatives whom I could not mentioned here.

ABSTRACT

In decade the development of **building** and housing in Kota **Medan** increase as the **increasing** of population which had changes the watershed area into **pavement** without **following** by river improvement or **flood** retention, **so** during the heavy rainfall **the** inundation **occurs** in Beiawan (downstream area) **with** a high **damage** to the civilian and industrial.

From the investigation the river flooding (iundation) occurs because of high rainfall intensity **mostly** in rainy **season (average** annual rainfall approximately **2500 mm/year) and combination** with change of land use and also **deforestation which** had increase the **flood discharge and** cannot be accommodate by the river **mostly** in **the** downstream with flat area.

Study and analysis **were undertaken** to **solve** this problem which focus on **the overflow** of the river **(the capability** of the river in downstream to **accommodate the flow** without inundation) and the probability **flood discharge occurrence .**

Considering other aspect **of** live like Functionality, Environment, Cost, **Construction, etc,** the author proposed an **Optimal Solution** with dike **construction (mid-term** project - **with 2.5** meter high) as a **flood barriers** in downstream **and** to increase the capability of the **river** to **accommodate** high water **level** to **prevent** inundation **within** the high **peak** d i i r g e **during storm rain** or **flash floods.** More over in the author also proposed an altemative **solution** design which is **Reforestation** or watershed **conservation** by **simple measure** as re-greening (as a long term project) in case of the increase high **discharge** more **than** the **measurement**. A green, **forested** area **will** have a **high natural** retention **capacity** and **will retained** the water for a long time, **thus subduing sudden** discharge peaks so at upstream area, which could **be reduce** approximately **25%.**

Wih the **combination** of **this two solution** design (dike in downstream area **and** Reforestation in upstream area) the flooding could be **prevent** through high river levels to **once every 50** years in the coming ten years. This **assumes** the **quality** of the dike and nver **remain** perfect, and the **reforestation were fully establish** in the **next** corning 25 years.

Chapter 1 INTRODUCTION

1.1 DESCRIPTION of the FINAL THESIS

To get the diploma in Civil Engineering it is required to present a final thesis. This thesis at Hogeschool van Utrecht has duration of 3 months. The topic of this thesis is Water Management – Flood Management which can be defined into specific words," Flood Prevention in Medan City – Indonesia". The structural core of this thesis is define in the diagram on figure 1.1.

Medan City is one of the biggest city in Indonesia is suffering for flood problem in this previous years, every 20-25 years major embankment flooding occurs and 10-20 times a year for local flooding (There is a feeling that the frequency of flooding in the city of Medan is increasing). Flood problem occurs mostly in rainy season (August – January) with heavy rainfall (annual rainfall approximately 2500 mm/year). As part of city development into ones of the better places to stay, it is an obligation for the Medan government and people of Medan to solve this flood problem.

From the study and investigation it was found that the flood problem occurs beause in the period of rainy season the amount of water by the large volumes of rain water flow to Deli River and create a high peak of discharge which cannot be accomodate by the river basin and the impact of this matter is the occurence of inundation. There is some assumption what had increasing peak discharge and cause inundation, w h i i are;

1. Rainfall

The average annual rainfall in Medan city according to Polonia station is 2500 mm/year with the characteristic and frequency similar in the different area of Medan. The annual rainfall in some period of time could extremely rise (like on year 2002 with annual rainfall 3400 mm/year). During periods of continuous rainfall in the project area which had create high discharge and cannot be accommodate by existing river system and cause overflow to the surrounding area.

2. Changes Use of Land

- Urban housing development and building development in the catchments area of each river (Macro Drains) passing through the city of Medan, w h i i had changes the watershed area into pavement following by result in increasing of the peak discharge.
- Deforestation, some of the area that used to be agricultural old forest, now have become residential or industrial areas. More over what make it worst is because of illegally logging for example in Leuser Mountain which caused flash floods ("broken dam effect") on November, 2003.

From the analysis its found that the safe carrying capacity of discharge in the downstream river (4 meter from river bed) is approximateiy 200 m^3/s. According rational method calculation and from the data recorded of previous flood the peak discharge was record approximately 470 m^3/s, which mean more than two times than the capability of the river in downstream area, which bring the result of inundation in Belawan area (downstream area).

For this reason proposed measurement and analysis were undertaken to solve this problem. The proposed measures divert from realigning the rivers. rehabiiiion of dikes, setting back of dikes, adding a floodway and adding dams upstream (the structural of the proposed measurement and analysis could be seen in the Fiqurel-l, structural of the thesis).

Despite of the problem was defined in the analysis and according tho the infomation of the local authority, likes;

- There is no budget for larger adjustments, like regular dredging, and land reclamation is a problem (expensive, easements).
- Similarly a maintenance program is not available for the more expensive actions.
- No accuraties information to deterrnine in specific measurement to divert the flood with a retention basin, or flood way.
- *Floodway* from the Deli to the Percut the loan is granted, the design is ready. but only part of the land acquisition was successful.
- The Nomobatang Dam in the upstream of Deli river are long tem plans (> 2010). First priority was the downstream flooding of the river.

Considering problem aspect which mentioned in above the author proposed an Optimal Solution with die construction (mid-term project) as a flood barriers in downstream and to increase the capability of the river to accommodate high water level to prevent inundation within the high peak discharqe during storm rain or flash Roods.

According to the (data record) the previos flood is approximately 470 m^3/s and the rational method measurement with value of discharge 473 m^3/s. Or this reason the height of the dike will be design in 2.5 meter high in order to increase the inundation by increasing the water level or capability to store water during flood flow. More over in the author also proposed an alternative solution design which is Reforestation or watershed conservation by simple measure as re-greening (as a long term project) in case of the increase high discharge more than the measurement. A green, forested area will have a high natural retention capacity and will retained the water for a long time. thus subduing sudden discharge peaks co at upstream area, which could be reduce approximately 25%.

By this combination solution design (dike in downstream area and Reforestation in upstream area? the flooding could be prevent through high river levels to once every 50 years in the coming ten years. This assumes the quality of the dike and river remain perfect, and the reforestation were fully establish in the next coming 25 years.

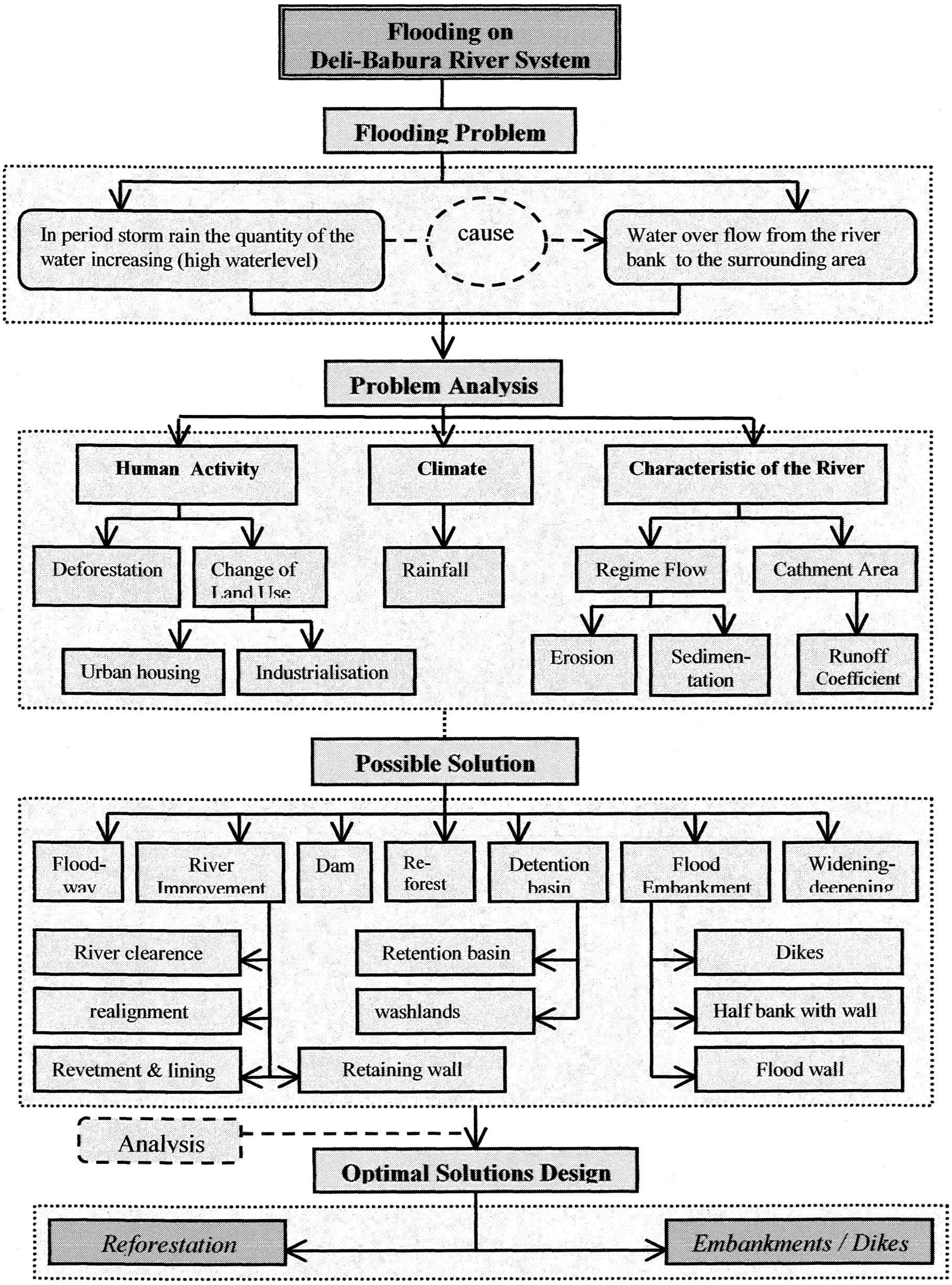


Figure 1.1. Structural of the Thesis

1.2 PROBLEM IDENTIFICATION

The flood probiem could be defined beause of *in the some period of time (rainy season), the amount of water by the large volumes of rain water flow to Deli River ande create a high peak discharge which cannot be accommodate by the river basin and overflow to the surronding area.* And In specific factor which increasing high peak of discharge and cause inundation because of;

- Climate (Rainfall).
- Change of Land Uses (Deforestation and Urban Housing).
- Condition of the existing river basin

For that reason, this final thesis will cover assignment trying to fulfil all the expectation to take this problem with a research and analysis to prevent inundation the in Deli - Babura river system, by proposed an Optimal Solution Design.

1.3 AIMS AND BOUNDARY OF THE STUDY

The aim of this dissertation is *"How the principle of water management in flood prevention with implementation of optimal solution design in the project area can stimulate creative processes and new insights to prevent the river flooding in the Deli - Babura River of Medan City".*

In specific words the aims which are expected to reached in this thesis is to defined the problem of flooding and the optimal solution design to prevent inundation in Deli-Babura River Basin, therefor this report should be used for reference purposes.

For addition the study analyses will oniy deals with main river flooding cause by high value of discharge (high water level), no information is added on the flooding in the city, negative effect of flooding, water quality and ecology, on drinking water, on waste water treatment et cetera. Only when it influences or it had big impact to the river flooding, are taken into account in this report.

1.4 OBJECTIVES

The objectives of the thesis that present in this paper will include:

1. To find out the main flood problem on the Deli-Babura River by analyse the occurrence of the flood on the project area.
2. To find out the others possible solutions design with it's analyses to prevent river flooding mostly in inundation prevention to surrounding area in Deli-Babura River System.
3. How is water management could stimulate creative processes and new insights to find optimal solution in flood prevention in Deli-Babura River System.
4. Implementation of the optimal solution (new insight) to prevent negative effect of flooding.

1.5 CONCEPTUAL FRAMEWORK

The **conceptual framework** of this dissertatiin is to analyse the flooding on **Deli-Babura** River and analyses the possibility of possible solutions, in order to find an **optimal solution** design **to prevent** the inundation on **Deli-Babura** river and **it's surrounding** area.

Starting with understanding the project area **and the flood problem which** occurs on Deli-Babura **River** System. The **next** steps is the **study** of the water management **concepts** and **principles especially** in the flood prevention and **within it's** effect Based **on** analyse and **literature** review, the author **will conclude the optimal solution** to **prevent flooding**.

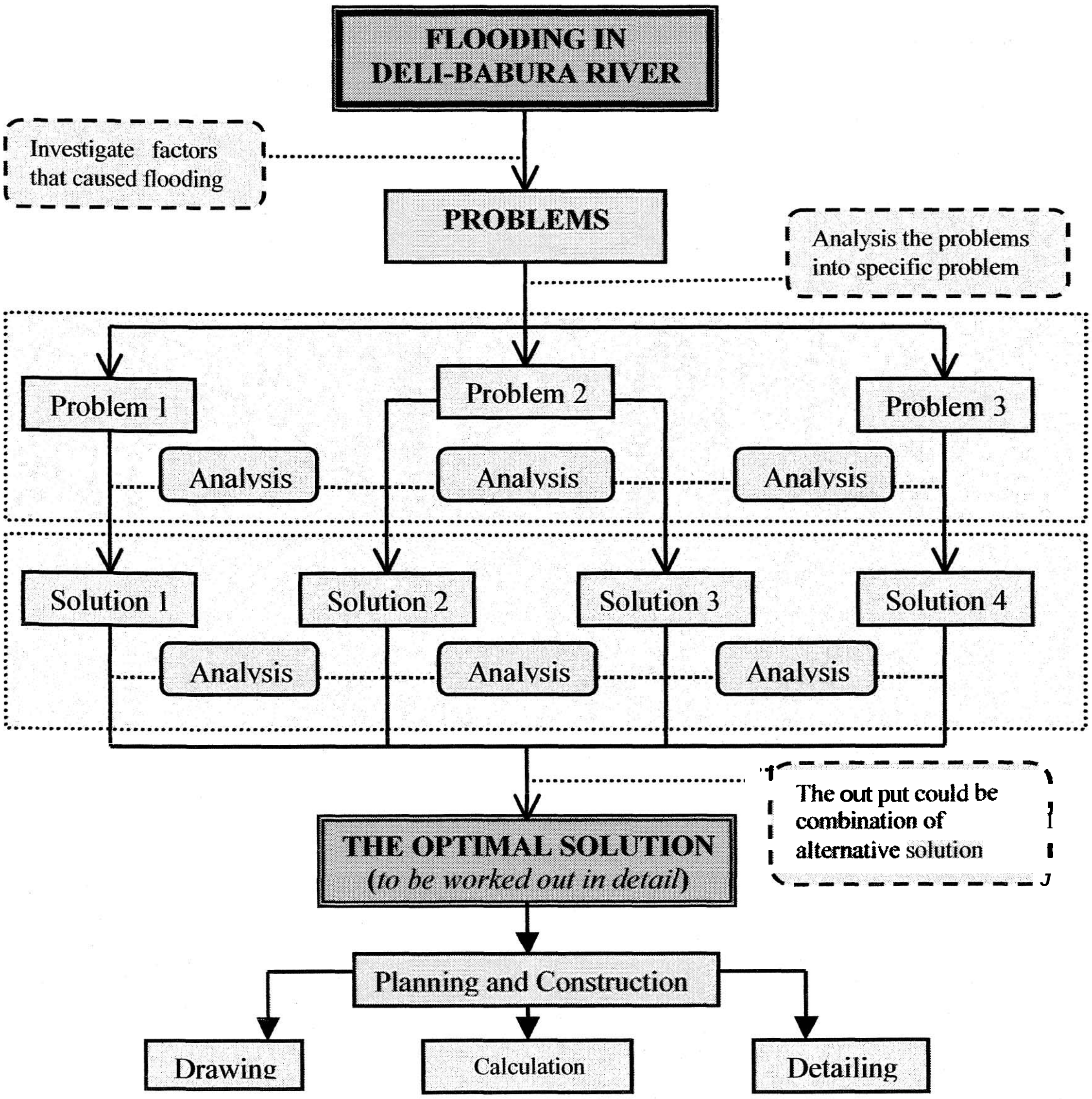


Figure 1.2. Conceptual Framework of the thesis

Chapter 2

BACKGROUND OF THE PROJECT AND PROJECT AREA

2.1 MEDAN CITY

2.1.1 Geography

Medan, city in western Indonesia, capital of North Sumatra Province, on the island of Sumatra and is the largest *city* on Sumatra with multi ethnic, and Sumatera island it self is part of Indonesia territory, and located closely to other deveiopment country in South East Asia like Malaysia, Singapore, and Thailand. (for more detail information see appendix A.1).

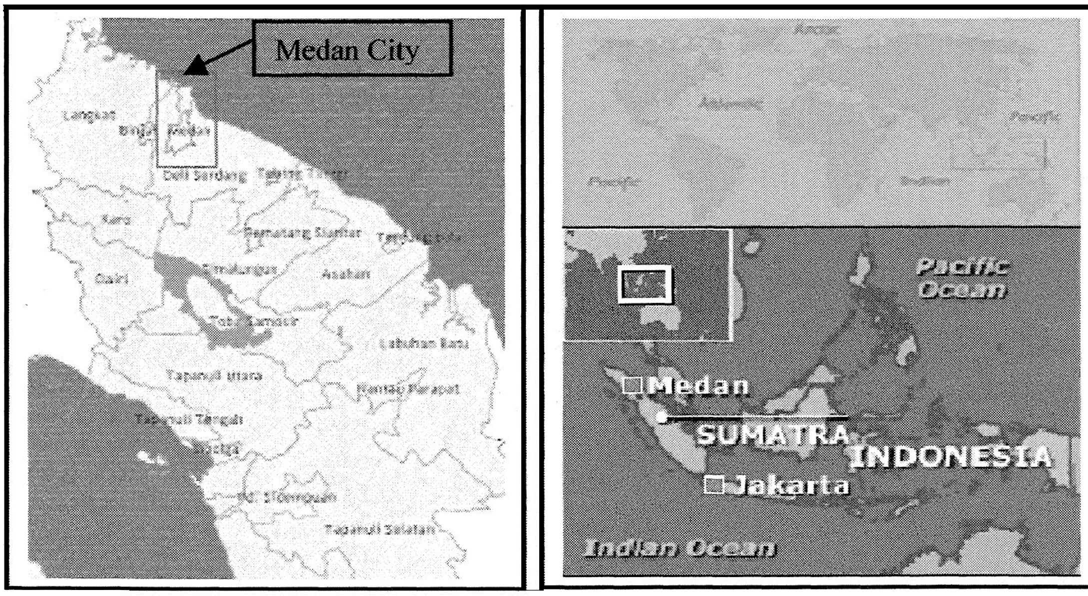


Figure 2.1. Map of Medan *city* - Indonesia

2.1.1.1 Situation and Elevation

Medan is located at the confluence of the Deli and Babura rivers. Medan city, having area land approximately 26,520 Ha (265.10 Km^2) or 3.6 % of North Sumatera. Administratively bordered on the east, west and south is Government of Deli Serdang Municipality, and on the north Malacca Strait. At this moment the population approximately 1,941,702 People and Commuters approximately 566,611 people (1997 Estimate).

2.1.1.2 Geology and Soils

Engineering Geological Map of Medan lays between 112°38'17" – I12'50' East Longitude and 7'10' – 7°20' South Latitude with its area of 261 km^2. The area is divided into 5 morphology units: coastal swamp plain, river dyke plain, soft wave plain or flood waste, low wave plain, and medium wave hills. Each unit has its geology and engineering problem such as, flood, coastal abrasion and corrosion of concrete foundation.

2.1.1.3 Climate

2.1.1.3.1 Temperature

Medan City has a **tropical climate.** According to **Polonia station** the minimum temperature in year 2001 is approximately **23,2°** C - **24,3°** C and maksimum temperature is approximately **30,8°** C - **33,2°** C, The **rate** of Air Humidity of **Medan** city approximateiy 84 - 85%. And the Wind Speed approximately 0.48 **m/sec**. The **Evaporation each month** approximateiy 104.3 **mm/month.**

2.1.1.3.2 Precipitation

The rainfall in **Medan** City on year approximateiy 2700 mm **/year** and approxirnately 4,4 **mm/hour**. According to **Polonia Climatology** Station, the **rainfall** in **Medan** city in year 2001 **approximately 3.594** mm lyear, **with** 230 rainy days in a year. This **value** is **quite higher** than 1997.

2.2 MEDAN FLOOD PROBLEM

2.2.1 General


Figure 2.2. Flooding in Deli River

In recently years, **Medan** had suffering for **flood problem** in **which** some area are **flood** mostiy near river **basin** which darnaged the surrounding area **(for** example Pasar **Mati** Padang Bulan, **Jln Bunga** Cempaka, Pasar **III Medan Selayang,** Jln **Jamin** Ginting Pasar III). September 26, 2004 surrounding **Deli-Babura** river are **flooded because** of heavy **rain** in the day before. From the **early assumption** and **according** to the information received **from Medan authorities** and people **who** live in the surrounding area, in **general** the **city** of **Medan suffering** from flood embankments problems 3-4 times a year, which is an excess of water **from** rainfall in **the** project area that **cannot** be discharged of **timely** and **sufficiently through** the **existing** river system which causing high water level **overflow from** the river bank and **flooding** in the **surrounding**. From **the** data record of **the** previous flood had **reach** the maximum flood **discharge** approximately 470 m^3/s.

2.2.2 Background of the Project

Divesting of **flood problem** in **recently** years **mostly** in **rain** season with heavy **rain fall, with** an **average** 3-4 times a year, this project was created to solve **the problem,**. For that reason, **this final** thesis **will** cover assignment **trying** to **fulfil all** the **expectation** to take this problem **with** a research and analysis to **prevent** the flooding **cause** by **overflow** water in **Deli - Babura** river system, by proposed an **possible solution** design **with** an output as **optimal solution** design.

2.2.3 Area Characteristation

The rivers that directly influence the Medan urbanised area can be subdivided in three main catchment area's

- the Belawan River
- the Deli River (Project area of the thesis)
- the Percut River

The southern and upstream part of the River Basin consists of rivers starting in a series of volcanoes, from an elevation of approximately 1000 m+Mean Sea Level, with peaks to 2451m+MSL. This area consists mostly of forest at the volcanoes artd, more to the north, in a fiat, deforested area. The downstream area of the River Basin consists of the outwash of the vulcanoes and slopes gentiy from approx. 100m+MSL (approx. 20m+MSL in city centre Kota Medan) to the Strait of Malacca

2.2.3.1 Deli - Babura River System

As mentioned in the previous chapter that the River basin will be consider and study area is Deli – Babura R i e r system comprises the following subsystem;

1. Sikambing subsystem which consist of the following tributaries
   - Batuan Riier which intersect Asam Kumbang area.
   - Selayang River which squeze the Padang Bulan area, and,
   - Putih River
2. Babura subsystem which consist of the following tributaries;
   - Bekala River which consist of
     - Sei Siput tributary
     - Lau Durian tributary
     - Lau Bamabu tributary
     - Lau Bamban tributaries
   - Babura main river.
3. Deli subsystem which consist of the following tributaries;
   - Mendiang and Pamah Riier in Deli Tua
   - Batuan River intersect with Mariendal area and,
   - Deli main river.

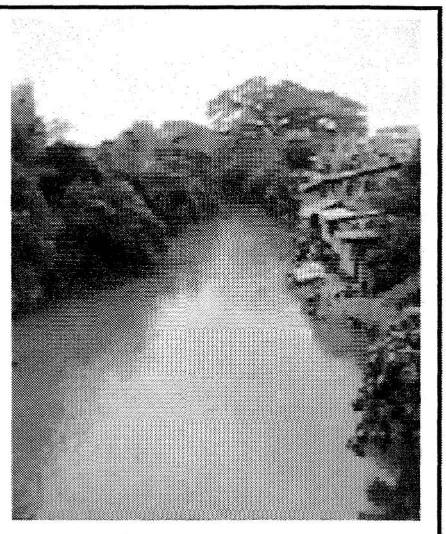


Figure 2.3 Deli river

2.2.3.2 Type of the River

Type of the river in Indonesia, mostly is a combination of a spring river and rain river, including of the project area, the Deli – Babura River is a combination of both of type of the river. In normal condition the water in the river is flow from upstream (mountainous area) which come from Sibayak mountain, Sinabung Mountain and with a safe carrying capacity to accommodate by the river system without inundation.

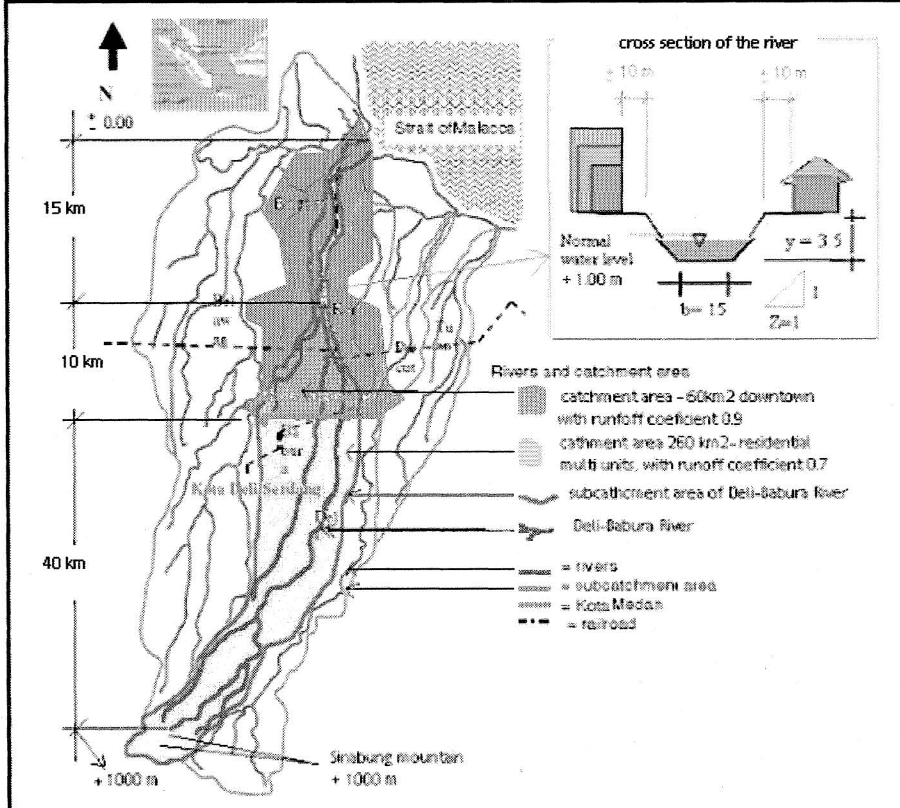


Figure 2.4. Catchments area Deli – Babura River Basin

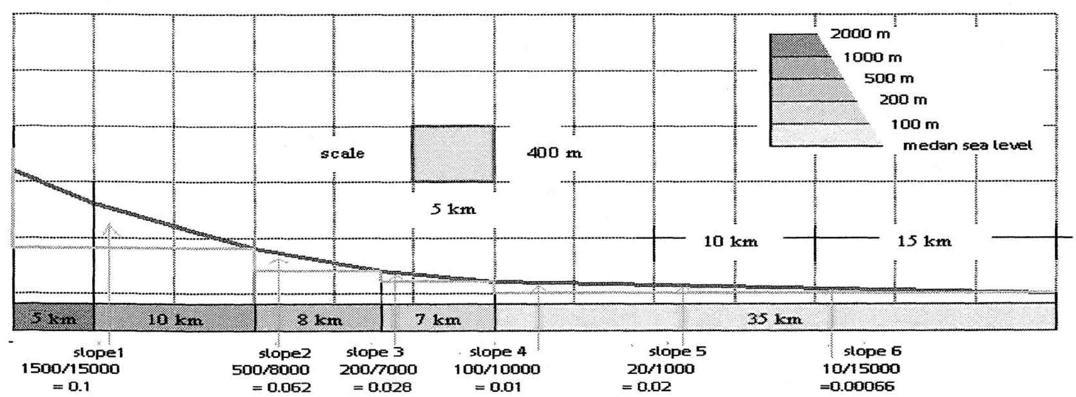


Figure 2.5. Elevation map of Deli –Babura river with various slope

Chapter 3

FLOOD PROBLEMS ANALYSIS

3.1 Flood Problem Identification

3.1.1 Flooding in Medan City

The **flood** problem **could** be defined beause of ***in the some period of time (rainy season), the amount of water by the large volumes of rain water flow to Deli River ande create a high peak of discharge which cannot be accomodate by the river basin and overflow to the surronding area.***

In **specific** what cause **high** peak of discharge and **inundation occurs because** of;

1. Rainfall

The **average** annual rainfall in **Medan** city **according** to **Polonia** station is 2500 **mm/year** with the **characteristic** and **frequency similar** in the different area of **Medan.** The annual **rainfall** in some **period** of time **could extremely** rise (example on year 2002 **with annual rainfall** 3400 **mm/year).** During **periods** of **continuous** rainfall in **the** project area which had create **high** discharge and **cannot** be **accommodate** by **existing** river **system** and cause overflow to **the** surrounding area.

2. Changes Use of Land

- The changes of land **use** and **rapid development** in the **catchments** area of **each** river (Macro ûrains) passing through the city of **Medan**
- Deforested, some of the area that **used** to be agricultural **old forest,** now have become residential or **industrial areas.** And what make it worst is because of **illegally** logging **for example** in **Leuser** Mountain which **caused** flash **floods** on November, 2003.

The **flooding** of river embankments is **less** frequent (1/25 **years)** and is more **wide** spread. Major **floods occurred** in **1956,** 1990 and **also recently** in 2002 and 2004. In **1956** 8,000 ha was inundated, in 1990 4,600 ha. **Flooding** occurs more **localised but** still **large areas** upstream of **the Sikambing** – Deli **confluence** as well as in a vast band **along the** Deli river **downstream** of this **confluence,** and **along** the **downstream** parts of the Kera, **Belawan** and **Percut** rivers. **Flooding** problems **also occur where people** have **settled** in the **streambeds** and flood **plains** of **rivers,** as in the case in quite a few places in the **centre** of **Medan.** In **figure** 3.1 the **locations** of the **"riverflooding"** are **presented** and of **the flooding** of the river **Badera** on **September** 26th 2004.. In figure, 3.2 examples are given of **the** living of **people** on the embankment.

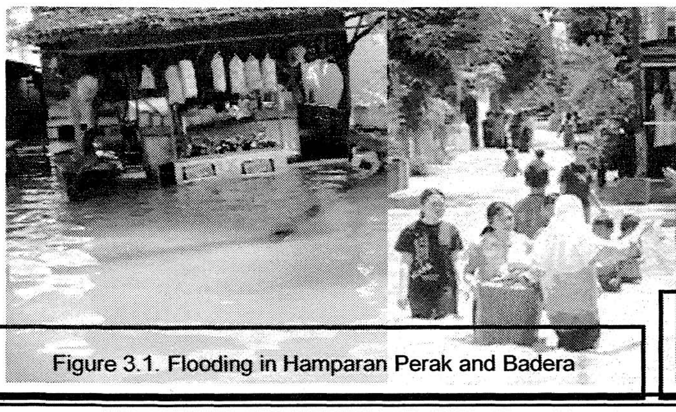


Figure 3.1. Flooding in Hamparan Perak and Badera

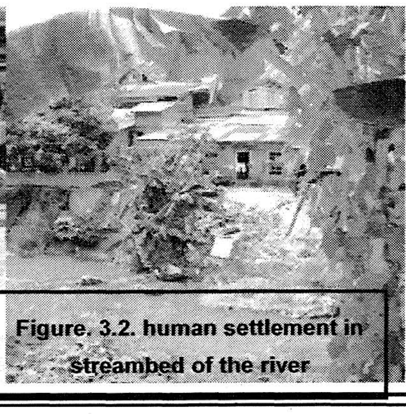


Figure. 3.2. human settlement in streambed of the river

3.1.2 Return Period

Normally the return period in Indonesia **including Medan** City **(see table** 3.1) is 5 **every 100** years, or 20-25 years, but **according** to **the** record and **interviewing** the Roods occurs 3-4 times a years. **Because the** leak of accurate, **the** author **only can** define the return period in **some quantity** of rainfall. And **for** the **calculation purpose mostly** in designing a dike the author take the vafue of flood discharge **from** the **recorded** previous flood which is 470 **m³/s,** with **rainfall intensity** 170 mmlday (maximum rainfall **intensity with** 0.6 **events/year** (see appendix)

Table 3.1. General Flood Standard - Design Flood Returns Period (years)*

Commercial	Industrial	Residential	Rural	Agriculture
5-100	5-100	5-100	5-50	5-25

* Resources; Manual ESCAP

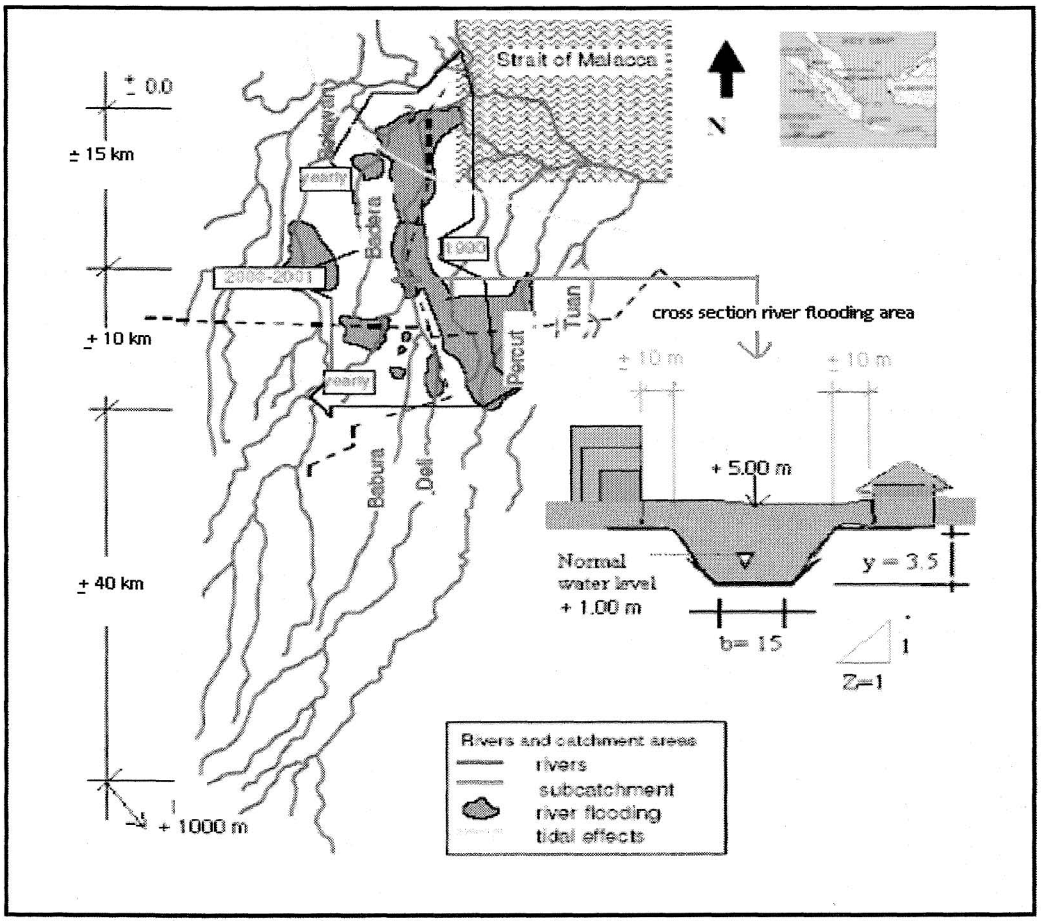


Figure 3.3. River Flooding with occurrence period in Medan City

3.2 FLOOD PROBLEM ANALYSIS

To get the a solution to prevent flooding we have to analyse the flood problem, the author denves a analysis problem which undertaken according to book of *"Twice A Rivers"* [2] as a references and the idea of the analyses were taken from Witteveen+Bos proposal idea of flood management in Kota Medan and. Focus of this analyses is on high water level and inundation.

Below is diagram of chart the problem analysis[1]

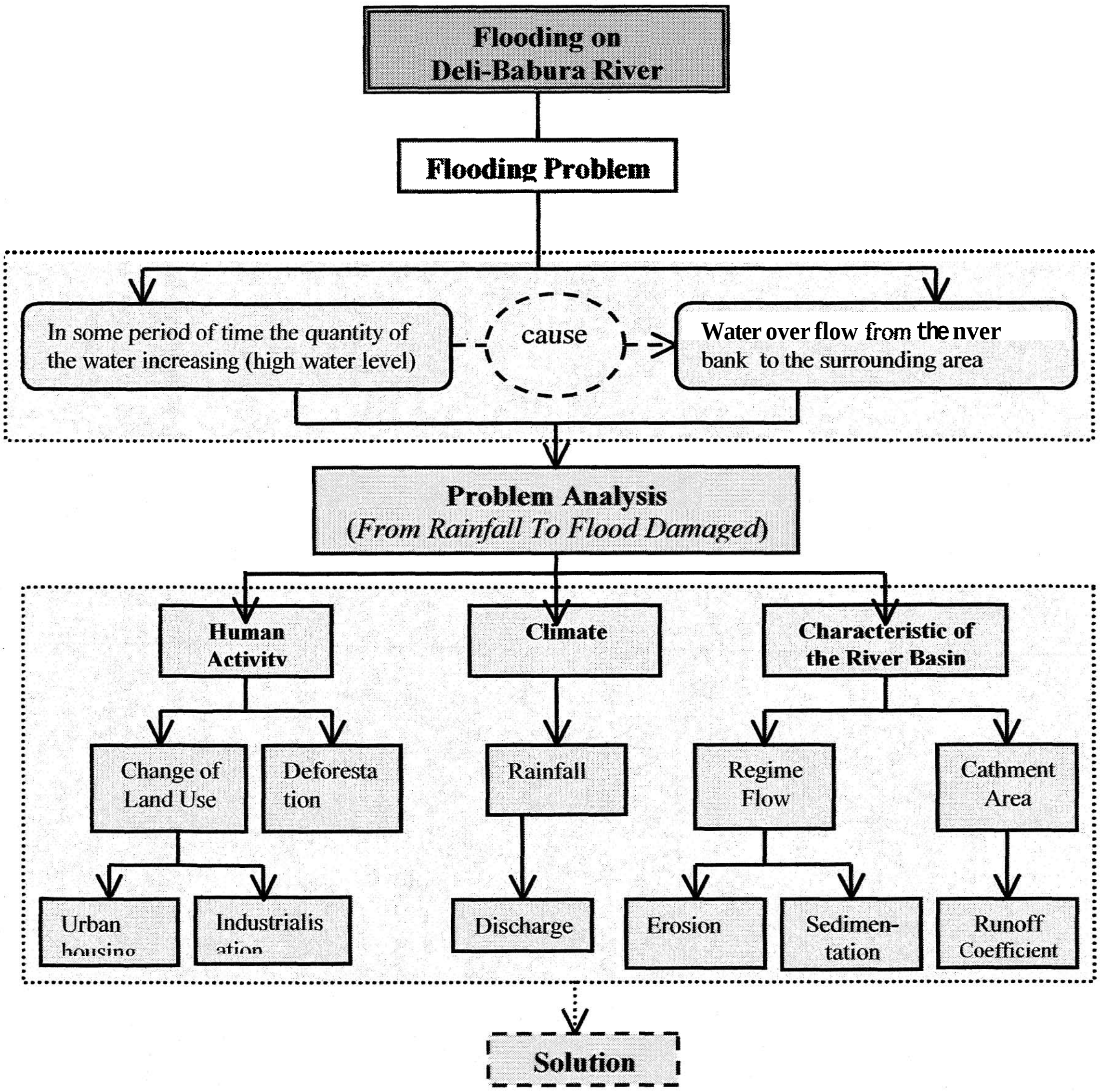


Figure. 3. 4. Table of Diagram Flood Problem Analysis

[1] Floods, Twice a River – Rhine and Meuse in the Netherlands. page 33-36

3.2.1 From Rainfall to Floods to Damage

The flooding it self cannot be define in the flooding area but its more over in what happen in the up stream through downstream, so it is important to have a good understanding of the chain of events that lies between rainfall in the mountains upstream and the actual suffering of damage due to floods downstream.

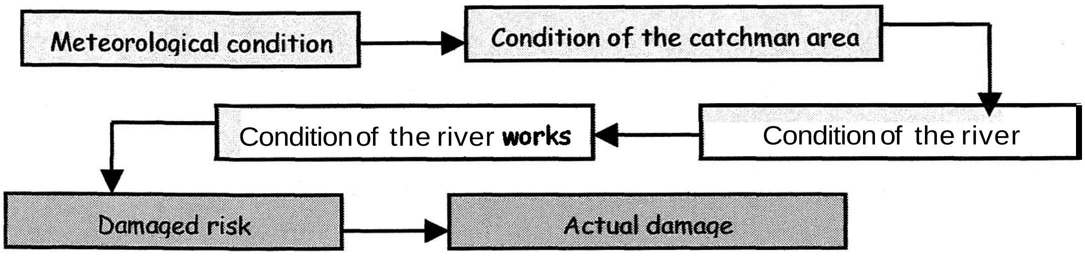


Figure 3.5. Diagram from rainfall to floods damage

A good understanding of this logical chain makes it easier to formulate the necessary actions and to intervene in the most efficient way. A very brief description of the different links of this chain is given below (see figure 3.3)[2]. Looking of this chain it will also be clear that the floods and flood damage are not only 'natural events'. The human factor plays a decisive role, both in causing and solving the problems.

3.2.1.1 Meteorological Condition

The river store the water from spring and rainfall and what cause effect of it is the rainfall, thus meteorological conditions form the basis for the amount of rainfall in the basin will be consider as a main subject to be analyse. The location and natural conditions of the river basin also play a role (for instance mountainous areas).

Annual rainfall of this project Location is average *2500* mm/year (maximum annual rainfall is 3400 mm / year on year *2002* which caused flooding in surrounding area with big damage), the rest of the analysis could be seen in the graphics below.

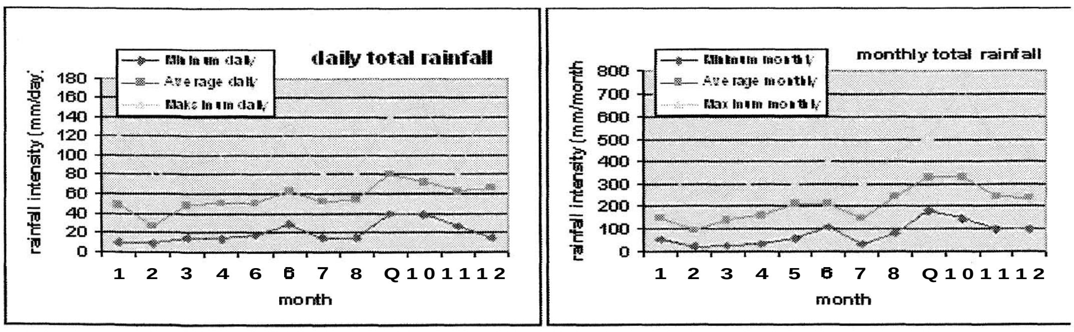


Figure 3.6. Distribution monthly and maximum daily rainfall over the year

[2] Starting points & boundary conditions, Preparation IAP, Flood Management of Medan City, Witteveen+Bos, 2004

A **quick** analysis of rainfall regime in Kota **Medan,** using a 13-year record (1991-2003) of **daily** rainfall Pobnia station (earlier data **and** long-term data **for** other **stations were** not available **digitally) confirm** that;

- the **highest** rainfall events occur in the **wettest** part of **the** year (September-October, Figure **1**)[3].
- Rainfall events over 70 **mm/d can** occur in any **month** of the year
- The maximum day rainfall is **170mm/day** with **0.6** eventslyear
- **Average** rainfall is 2500 **mm/year**
- The previous **flooding were recorded** is 470 **m³/s.**

3.2.1.2 The condition of the catchments area

The condition of the catchments area is a **deceive** factor for the **run-off** of the rainwater and the time needed for the water to **reach the** river. A green, forested area **will** have a **high natural** retentiin **capacity** and **will** retained the water for a long time, thus subduing sudden discharge peaks. **Areas which** have been **affected** by **uncontrolled** land-use do **not** have such **retention** capacity. A direct **correlation between** the **increasing use** of the watershed and the time needed for **the** water to **reach** the river exists is **could** be seen **on figure** 3.7. (**for detailedinformation see** appendix – chapter water shed area and run off **coefficient**

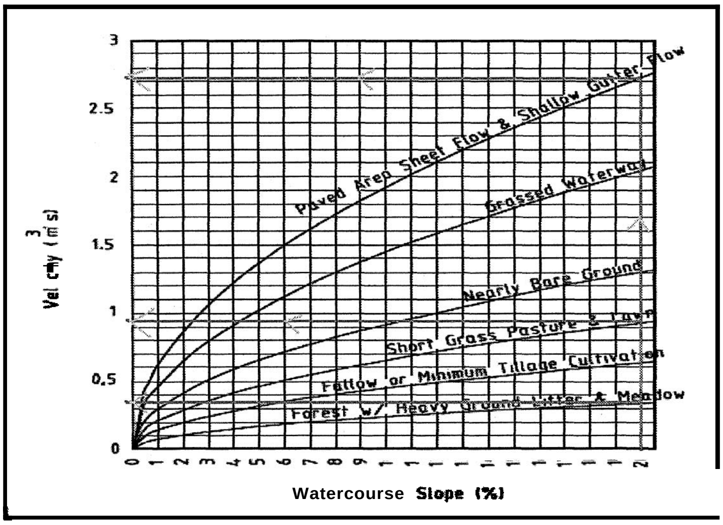


Figure 3.7. Velocities for Upland Method of Estimating Time of Concentration--Metric
(Adapted from the National Engineering Handbook Volume 4)

Assume the slope is 20% than we get different **Velocity** with **various** watershed area, for **example** on forest area with 20% **slope** we get **velocity** 0.25 **m3/s**, and **for** paved area we get **velocity** approximately 2,7 **m3/s**. More high the value of **velocity** than **the time** of concentration become lower or the time **needed** for the water to **reach** the river become less.

[3] **Quick Scan Rainfall Analysis, IAP Flood Management of Kota Medan,** Witteveen+Bos, 2004

3.2.1.2.1 Changes of Land Use

In the development city and increasing population make the needed of housing is increasing, and to provide a place for living or either for industrial. More of civilian built their houses near the river or either in the streambed of the river which suppose to be an area to resist the flooding. From the picture below we can see that how people build their house in the river area or in the flood plain area because lack of land needed, and in the period of high rainfall will flood the river including the houses, could cause flash flood.

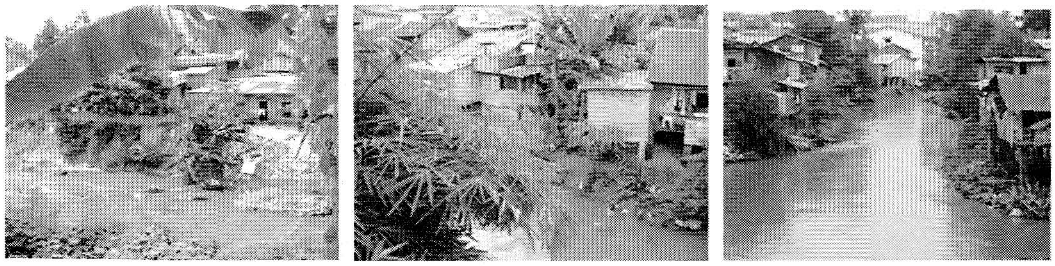


Figure 3.8. Human Settlement in streambed of the river

Concluded that land use and infrastructure were the most important factors responsible for the increase in peak water levels and frequency of high runoff peaks. With the catchments area 360 km^2 and mostly is urban housing (building and houses) with the pavement and concrete, it makes the rainfall directly flow to the river with less runoff coefficient (cannot fully be absorb to the ground, which cause the higher run-off coefficient).

3.2.1.2.2 Deforestation

Forest is one of the important factor to in flooding aspect. deforestation is said to have caused higher surface runoff, consequential soil erosion and therefore reduced water storage capacity Without forest the soil in upstream will easily wash out to the river. The disforest or either illegal logging in surround the river which should act as absorption area and reduce the floods had been replaced into logging area (like in Leuser Mountain or Bukit Lawang mountainous area) which caused flash flood (flood in upstream) on November 2003.

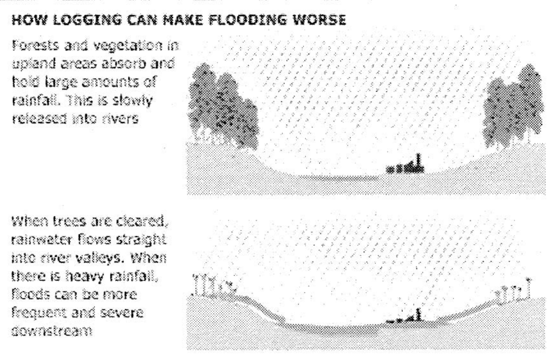


Figure 3.9. Deforestation make the flooding worse

- In the upstream area deforestation is continuing. This will result in less capacity of retention of rainfall upstream and therefore a faster and higher discharge of water to the downstream area.
- Deforest is assume the main factor of flash Roods which act as a broken dam which cause a large avolume of water flow in short time and cause inundation in downstream area.
- The level of quantii and quality in sedimentation, erosian, absorbtion as result from deforest could not be defined M accurate (such a study is recommended).

3.2.1.3 The condition of the river

The condition of the river is determining the time needed for the water to reach the downstream areas and the water levels (see chapter 3.3.1. for relation between velocity, discharge and water levels). In this context many factors play a role, for instance; canalisation (making the river shorter), dredging, obstacles, encroachment, etc.

3.2.1.3.1 Regime Flow

A channel is said to be in regime when , over a hydrological cycle , the channels shows no appreciable change in its width, depth or gradient (L.S Blake, Civil Engineer Reference Book)

According local civilian, the channel parameters of width, depth, gradient and flow on the Deli river system in this previous years naturally is change (cause by flood with different characteristicand frequency, 3-4 times year), thus the regime condition is established.

3.2.1.3.2 Erosion and Sedimentation analysis

Erosion and sedimentation is part of the regime flow of the river characteristic, from the previous flooding had caused several probiem like;

- Erosian, because of big flooding with high velocity (water flow) it had cause the energy of the velocity make erosion in the nver bed. (discussion about velocity is define in chapter 3.3.1.1
- Sedimentation, from the fiow of the river and small flooding (less velocity) had caused sedimentation along the river bank.
- From the picture below shown that not all the river bank were developed very well, erosion and sedimentation could be easily establish since no retaining wall or lining in the river bank.

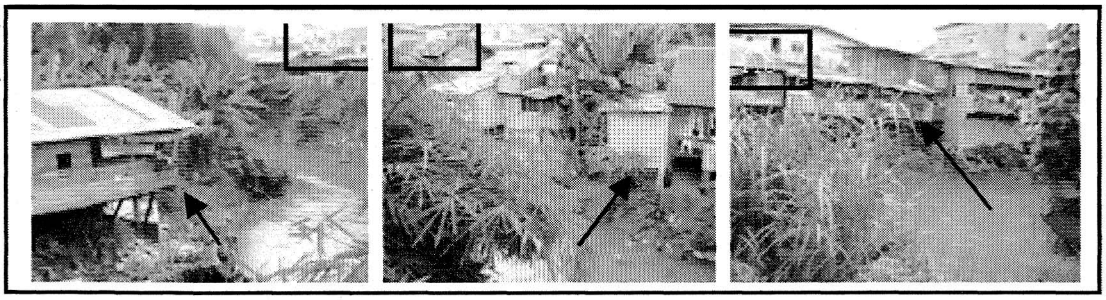


Figure. 3.10 Picture of condition of the Deli river

From the picture in above, between the urban housing and transportation road and the river bank is one level and without ernbankment As we know embankments are needed provided along river channels to prevent flooding, so without embankment, inundation easily occurs.

3.2.1.4 The Damage Risk

The damage risk is defined by the situation in the 'receiving area'. It is obvious that the position of the area in relation to the river is a first relevant factor (nearby, far away, low high). Furthermore the damage will be defined by the character of activities in the Rood area. In other word the potential damage will be higher in industrialised or urbanized areas than in agricultural areas.

3.3 High Water Level Analysis

Simply method assumption for flooding in downstream is with the increasing of the peak discharge more than the capability of the river to accommodate with the result of inundation r in other word with high volume of water which increasing the water level in the river which over limit than the capability of the maximum storage water level during normal flow which the result of inundation to the surrounding area. In this analysis we find maximum storage water level of Deli River for flow it properly without inundation and the probability of the increasing peak discharge / volume of water with result increasing of water level during the flood. (Due the limited data, assumption will be taken for the measurement).

3.3.1 Relation of Discharge (Q) and Water level (h)

This analysis is to defne the maximum storage water level without inundation for normal flow and the probability different water level with the incoming different discharge.

From the equation, Q = V x A, in general the factors that effect the varying water level are;

- Velocity of the water in the river (detail explanation see chapter calculation and measurement)
- Cross section of the river (detail explanation see chapter calculation and measurement)

By assuming a cross-sectiin (height-width-slopes, see picture below) of the river at the specific spot , not for the river as a whole (the location is where the river enters the urban area where the inundation occurs), and assuming varying velocity with the result of various discharge (Q) with varying water levels (Q-H curve). Below is the assumption of the river system from upstream to Medan City and we assuming a specific spot to analyse the overflow water (see appendix A-I to A-4 for detailed information about this).

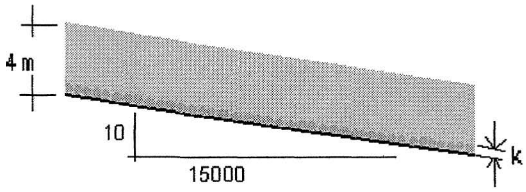
3.3.1.1 Average flow velocity

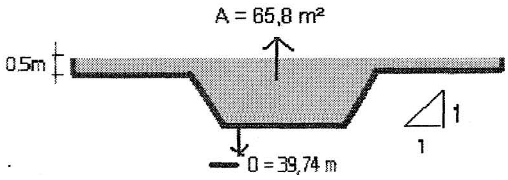
The optimal velocity could be reach if the water flow properly through river system . There are some factors which effect the average flow velocity of the river, and in this thesis the main factor value of the velocity is the slope of the river and the river bed (assumption with open channel flow and the material of the river 0.001, 0.01, 0.05 calculation purpose we defined the watershed area based on the different slope on Deli River (Figure 3.11 shown the elevation map with different watershed area)

From figure 3.11 we get the different slope (assumption stay constant) which will effect the result of different velocity;

Slope 1 = 0.06
Slope 2 = 0.008
Slope 3 = 0.001
Slope 4 = 0.00066

More high the value of **the slope** than it **will** effect the **velocity result** get higher, in this thesis **the** assumption **will** take on **calculation** of the downstream area (area **get flooded)**. For this **purpose we will use** ***chezy*** **equations**; (Bed ,Bank and Shore Protection, Gerrit J Schierek)

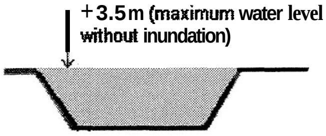




- For **(for Slope4)** = 10115000 = 0.00066, and cross **sectional** area (F)

in this part there **will** assumption with different water level and **material** of the **river** bed **to** get **average** of the flow **velocity** of the **river** in downstream to get **the average** of **possibility height** water level **related** to inundation in the downstream area;

+>h_3 = 3.5 m → A = 67.2 m²



O = 25.9 m

R = AIO = **67.2 / 25.9 =** 2.59

>> ***For*** ■ h = ***3.5m and k*** = ***0.005*** , ***C*** = 18 log **(12R/k)** = 18 log [(12 x 2.59) **/** 0.0051 = 68.28

and V = C [R I] $^{0.5}$ = **68.28** [2.59 x **0.00066]** $^{0.5}$ = 2.82 **m/s**

>> For ■ h = ***3.5m andk*** = ***0.01*** , ***C*** = 18 log **(12R/k)** = 18 log [(12 x **2.59) / 0.01]** = 62.86

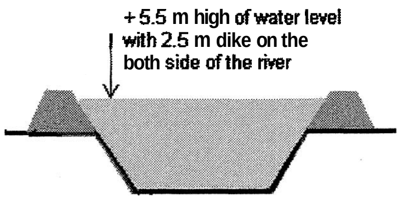
and V = C **[** R I **]** $^{0.5}$ = **62.86** x [**2.59** x **0.00066]** $^{0.5}$ = 2.57 **m/s**

>> *For* ■ ***h*** = ***3.5 m and k*** = ***0.05*** , ***C*** = 18 **log (12R/k)** = 18 log [(12 x 2.59) 10.051 = 49.3

and V = C **[R** I] $^{0.5}$ = 49.3 x [2.59 x 0.000661 $^{0.5}$ = 2.0 rnls

>h_3 = 5.5 m → A = 118 m²

(assumption with 2.5 m height dike in the nver **side**)



O = **32.18** m

R = A/O = 118 / 32.18 = 3.66

>> For ■ h = ***5.5 m and k*** = ***0.005*** , ***C*** = 18 log **(12R/k)** = 18 log **[** (12 x 3.66) **/ 0.005]** = 70.98

and V = C [R I] $^{0.5}$ = 70.98 **[3.66** x **0.00066]** $^{0.5}$ **= 3.4 m/s**

>> ***For*** ■ ***h*** = ***5.5 m and k*** = ***0.01*** , ***C*** = 18 log **(12R/k)** = 18 log **[** (12 x 3.66) **/ 0.01]** = 65.56

and V = C **[** R I **]** $^{0.5}$ = 65.56 x [3.66 x **0.00066]** $^{0.5}$ = 3.2 mls

>> *For* ■ ***h*** = ***5.5 m and k*** = ***0.05*** , ***C*** = 18 log **(12R/k) =** 18 log [**(12** x **3.66)** 10.051 = 52.98

and V = C **[R** I] $^{0.5}$ = 49.3 x [**3.66** x **0.00066]** $^{0.5}$ = 2.5 ***m/s***

> **h_4 =** **4 m** → A = **88.9 m²**

O = **46.9** m

R = AIO = **88.9 / 46.9** = **1.89**

>> *For* → h = 4 m and k = ***0.005*** , C = 18 log **(12R/k)** = 18 **log** [(12 x 1.89 **/ 0.005]** = 65.8

and V = C [R ▮] $^{0.5}$ = 65.8 [1.89 x 0.000661 $^{0.5}$ = <u>2.3 **m/s**</u>

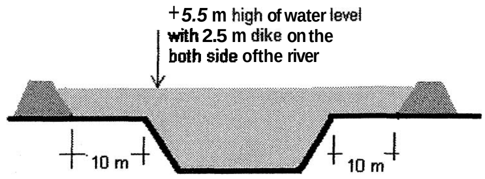
>> *For → h = 4 m and k = 0.01* , **C = 18 log (12R/k) = 18 log [(12 x 1.89) / 0.01] =** 60.40

and V = **C [R I] $^{0.5}$ = 60.40 x [1.89 x 0.00066]** $^{0.5}$ **=** <u>**2.1** mls</u>

>> *For → h = 4 m and k = 0.05* , C = **18 log (12R/k) = 18 log [(12 x 1.89) / 0.05] = 47.8**

and V = C [R **I**] $^{0.5}$ = 47.8 x [1.89 x 0.00066] $^{0.5}$ = <u>1.6 m/s</u>

>h_6 = 6 m ■ (consider with dike – 2,5 m height and **settlement approximately** 0.5 m **which** the **effective** of **the** dike **become** 2.0 m height)



A = **158.8 m²**

O = 44.94 m

R = AIO = 158.8 **/ 44.94 = 3.53**

>> For → h = 6 m and k = ***0.005*** , C = 18 log **(12R/k)** = 18 log **[** (12 x 3.53) **/ 0.005]** = 70.44

and V = C **[R I]** $^{0.5}$ = 70.44 **[** 3.53 x **0.00066]** $^{0.5}$ = <u>3.31 mis</u>

>> *For → h = 6 m and k = 0.01* , **C = 18 log (12R/k) = 18 log [(12 x 3.53) / 0.01] =** 63.03

and V = C [R ▮] $^{0.5}$ = 63.03 x [3.53 x 0.000661 $^{0.5}$ = <u>3.0 **m/s**</u>

>> For ■ h = 6 m and ***k = 0.05*** , C = 18 log **(12R/k)** = 18 log [(12 x 3.53) ▮ 0.051 = 52.44

and V = C **[R I]** $^{0.5}$ = 52.44 x **[3.53** x **0.00066]** $^{0.5}$ = <u>2.46</u> mis

in fact that in the **Deli** river, many factor effect the **value flow velocity** of the river, **likes**[4];

1. **Condition** of **the river**

The condition of **the** Deii River is effecting the value of the **velocity cannot reach** the **optimal velocity mostly** in **downstream** area (downtown city) **building**, houses and other **structures** in the **flood plane** of the **rivers obstruct** the free flow of water and the river itself **its not alignment which reduce** the flow **velocity** induding in **upstream** area.

2. **Sediment transport**

Consider the **mechanism** of **it** is transport, **the** sediment transport **were categories** as the wash **loads, comprises** relatively fine **material** and, **but** during the **floods it** more than fine material.

---

[4] **Civil engineer's references book, L.S Blake, page 30/15-30/16** ***(2000)***

There **were** many **sediments** transport equations, none of **which can claim** high degree of **predictive** accurate., the more **simple** Enguland and **Hansen equations yields similar** levels of **accuracy. From** the data **assumption** condition of **Deli River (previous** chapter),

- In **downstream** where Channel Flowing at **2.5m/s** at a depth of 4 m with **slope** of 0.00066 and a median sediment **size** of 1 mm, the sediment concentration **approximately** about;

  $X = [16000 \times 2.65 \times 2.5 \times (4)^{0.5} \times (0.00066)^{1.5}] / (2.65 - 1)^2 \times 0.001 = \underline{134.47 \ p.p.m}$

- In middle stream where Channel Flowing at 3.0 **m/s** at a depth of 4 m with **slope** of **0.001** and a median sediment **size** of 1 mm, sediment **concentration approximately** about;

  $X = [16000 \times 2.65 \times 3 \times (4)^{0.5} \times (0.001)^{1.5}] / (2.65 - 1)^2 \times 0.001 = \underline{300 \ p.p.m}$

- In **Middle** city where Channel Flowing at 5.0 mls at a **depth** of 2 m **with slope** of 0.008 and a median sediment **size** of 1 mm, we get the sediment **concentration approximately about**;

  $X = [16000 \times 2.65 \times 5.0 \times (2)^{0.5} \times (0.008)^{1.5}] / (2.65 - 1)^2 \times 0.001 = \underline{8226 \ p.p.m}$

- In **upstream** where Channel Flowing at **8.0** mls at a depth of 1 m with **slope** of 0.06 and a median sediment site of 1 mm, we get the sediment **concentration approximately** about;

  $X = [16000 \times 2.65 \times 8 \times (1)^{0.5} \times (0.06)^{1.5}] / (2.65 - 1)^2 \times 0.001 = \underline{184637 \ p.p.m}$

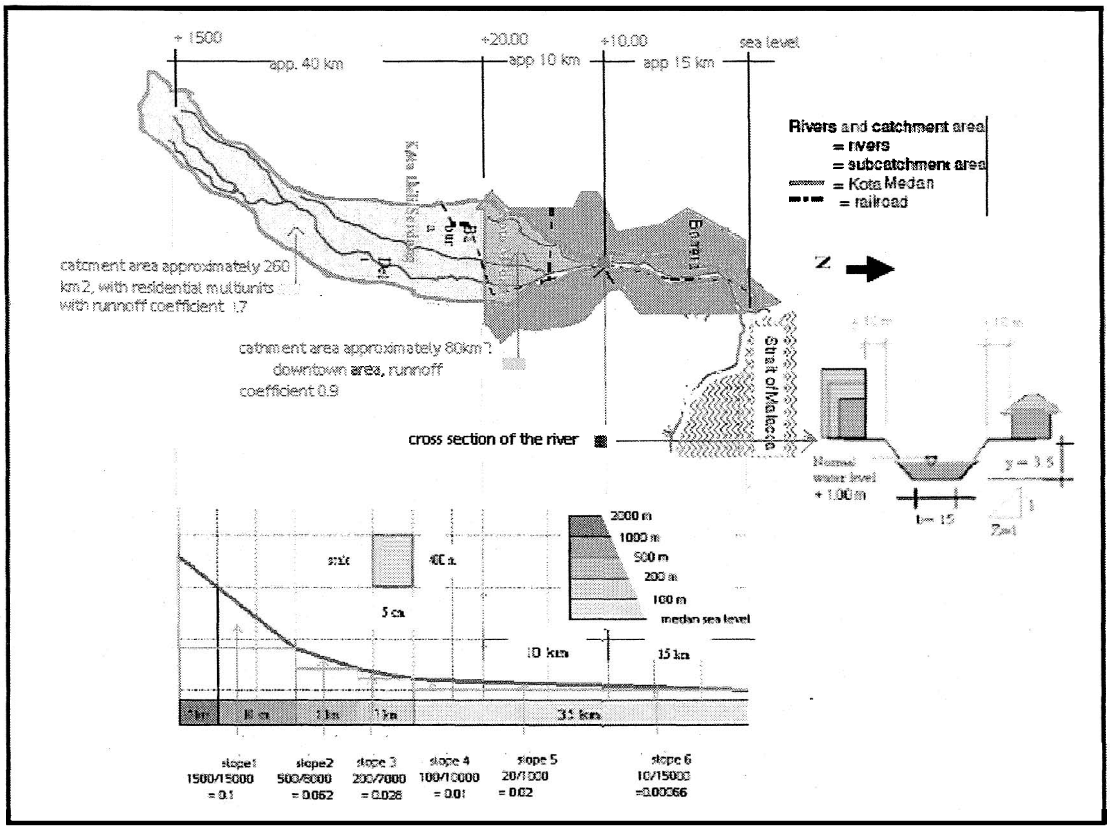


Figure.3.11 Topographical of the river with assumption slope

3.3.1.2 Cross sectional area of the river

Due the limited information so **its difficult** to do measurement **for** the whole river system, so in this thesis the assumption **will be** undertaken by analysis on **one** spot of **the river which assume** on the river area **which** enter the **urban** city (Area E and F - **downstream)** and the cross section **will stay constant including the velocity**.

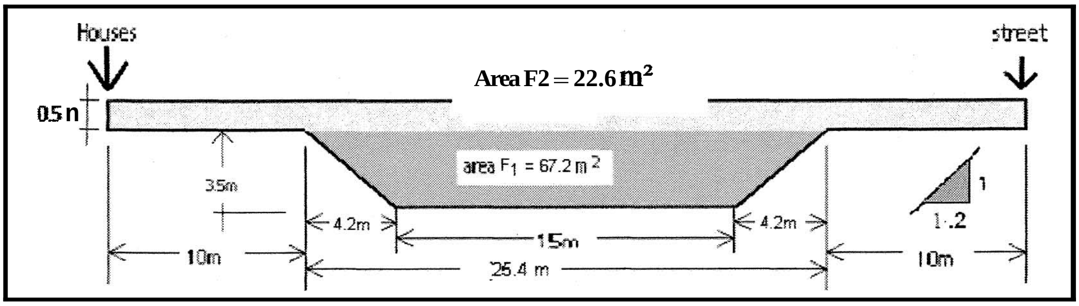


Figure 3.12. Cross section of the river assumption when totally flooded

Table 3.2. Cross sectional area with slope 1:1,2 and bottom width 15 m

Height (water level)	0.5	1	1.5	2	2.5	3	3.5	4
Area (m2)	7.8	16.2	25.2	34.8	45	55.8	67.2	89.8
Wetted perimeter (m)	16.56	18.12	19.68	21.2	22.8	24.37	25.9	29.7
Hydraulic Radius (m)	0.47	0.89	1.28	1.63	1.97	2.28	2.59	2.96

From the **calculation** of the cross sectional area of the river **(see chapter** measurement and **calculation), with** 4 meter high is **85,8 m²** and **for** the 3.5 **mete** is 67.2 m² (assumption for the maximum water level without inundation the houses and building).

3.3.1.3 River Flow (Q) [m3/s]

From the cross sectional area of the nver **it** shown **that** the maximum water level **allowable** without inundation **with** high **damage** is 3.5 meter with **velocity 2m/s – 2.82m/s** and 4 meter and the **velocity** of **the** river is **average 1.8m/s – 2.4m/s (the maximum velocity will** be taken), from this **information** we **get** the **allowable discharge** (safe **carrying** of the river) **to prevent** inundation which are; (Discharge is **amount** of water **flowing** past a point in a given unit of **time)**

The equation to determine discharge is ;

Q = V A

Where:
Q = Discharge (m^3/s)
V = Velocity (m/s)
A = Cross section area (m^2)

- **In** Downstream, with **slope** 0.00066

> **3,5** m high is **the** maximum water level without overflow from the river

$h_{3.5}$ = 3.5 m, A = 67.2 m² → $Q_{0.005}$ = **67.2m** ^{2} x 2.3 **m/s** = 155.25 m^3/s

$Q_{0.01}$ = 67.2 m^2 x **1.95 m/s = 131.0** m^3/s

$Q_{0.05}$ = 67.2 m^2 x 1.54 **m/s** = **103.48** m^3/s

> With **dikes** (2.5 meter height) and located beside the river **side**

$h_{5.5}$ = 5.5 m, **A = 118 m² → $Q_{0.005}$ = 118m ^{2} x 3.4 m/s = 401.2 m^3/s**

$Q_{0.01}$ = **118** m^2 x **3.2 m/s = 377.6** m^3/s

$Q_{0.05}$ = 118 m^2 x **2.5 m/s = 295** m^3/s

> **for** dike (2.5 meter height) located in 10 meter **from** river **side**

h_4 = 4 m, A = 88.9 m² → $Q_{0.005}$ = 88.9 m^2 x 2.3 **m/s** = 204.47 m^3/s

$Q_{0.01}$ = 88.9 m^2 x 2.1 **m/s** = 186.7 m^3/s

$Q_{0.05}$ = 88.9 m^2 x 1.6m/s = 142.24 m^3/s

h6 = 6 m, A = 186.2 → $Q_{0.005}$ = **186.2m** ^{2} x 3.31 **m/s** = 616.32 m^3/s

$Q_{0.01}$ = 186.2 m^2 x 3.0 **m/s** = **558.6** m^3/s

$Q_{0.05}$ = 186.2 m^2 x 2.46 **m/s** = 458 m^3/s

3.3.1.4 W Curve

From the equation of Q = VA, and **with varying velocity** we can define **the** Q-H curve , which a graphic of **relation between** high water level and discharge which **will accommodate** by the **Deli** River (maximum water level without inundation)

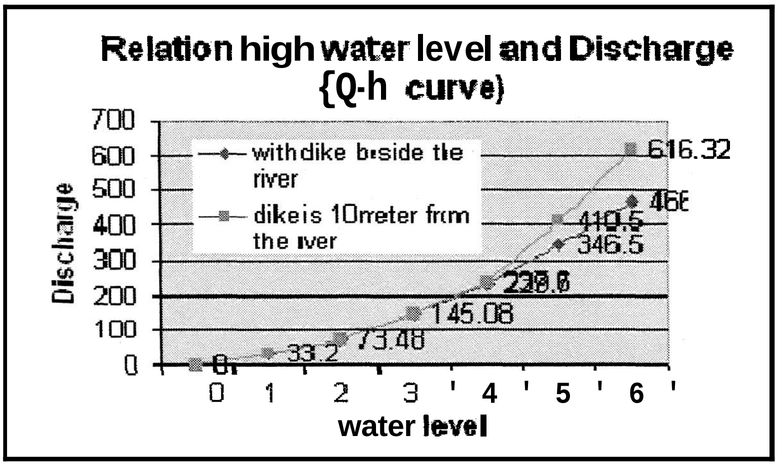


Figure 3.13. Diagram of Relation Q-H

From the figure 3.13 (above) there is **some** assumption **summary** we can get related to the high water level (H), which are;

1. **Discharge** and **velocity will effect** the water level **to** safe **carrying capacity** of the river

2. **By** decreasing value of H, we **will** decrease the value of H, or in other words more the value of discharge increase it **will** effect the high of the water level to increase.
3. **velocity will** effect the discharge and the water level, **for** example on the **same** water level **3.5m** with **different velocity** could resutt the different value of q (discharge);
   - with **velocity** 1.54 **m/s only** can accommodate q with 104 **m^3/s** without **inundation**
   - with **velocity 2.3** mls could **accommodate** q with 155 m^3/s without inundation
4. For example the **max** water level is 4 meter, so **If** we get the value of Q higher than 142 m^3/s (v=1.6m/s) or 205 **m^3/s** (v = 2.3 **m/s**) and the **consequence** is we **will** faced the **problem** with high water level which could cause inundation so **to prevent** inundation;
   a. we have to decrease the **value** of Q **(see figure above)**.
   b. increase the **velocity** without cause **erosion** (low **velocity will** cause sedimentation which **will** decrease the **capability** of the river to accommodate the water).

If item "a" and "**b**" could be establish than to deal with **increasing** Q and V and we have **to** increase the **capacity** of the river **until** the limit safe **carrying capacity** of the **river**.

3.3.1.5 Flood Discharge

The method of the analysis is using **rational** method and **rational equation** for Rood **discharge** : **according** to **I.S.Blake** (Civil engineer's **refferences book**),

The equation is $Q_{50} = C.\ I_{50}\ .\ A,$

where;

Q_{50} = Peak Discharge, (m^3/s) for 50 years return period
A = watershed area, (m^3)
i_{50} = Rainfall intensity, mmlhour (The Rainfall intensity (i)is taken from Intensity/Duration/Frequency curves for rainfall events (Haskoning Data, see appendix B) in the geographical region of interest for 50 years return period

With the various **condition** of the catchments area which approximately 360 km^2, the **calculation were divided into** the catchments area **condition**. By **assuming one** intensity rainfall which are **170mm/day** (assume the rainfall **intensity similar** in the **characteristic** and quantii) , than the peak discharge in the **Deli-Babura River Basin**.

Table 3.5. Various peak discharge with diirent condition of the watershed

Name of the watershed area	Condition of the watershed area	Area (km2)	Runoff coefficient	rainfall intensity (mm/day)	Peak Discharge . x10³ (m³/d)
R	multi units residential	100	0.6	*170*	10200
V	multi units residential	50	0.6	*170*	5100
W	multi units residential	50	0.6	*170*	5100
X	neighborhood district	70	0.7	*170*	8330
Y	Downtown (city)	60	0.9	*170*	9180
Z	Industrial	30	0.6	*170*	3060
				total peak discharge	40970

From table 3.5, with rainfall intensity 170 **mm/d** and **total** peak discharge **(from** the **total** contribute area of the **watershed)** is 40970 **x10³** m³/d **(total** volume of water is 40970 **x10³** meter **cubic** in flooding day) or approximately 475 **m³/s,** this **value** is **reasonable since according** to data **recorded,** the orevious **flood** is **approximately** 470 **m³/s.**

According to **the calculation** above **in possibility** of the river to **accommodate the** discharge with water **level 3,5** m without inundation is maximum **approximately** 155 **m³/s** and 4 m without inundatii is **maximum approximately** 205 **m³/s** (in **downstream). Based** on the inforrnation the river is **cannot accommodate** the **flood** discharge**, except** we increase **the capability** of **the** river (**see figure 3.14**).

If we put the **rainfall** intensity based on **daily** and monthly rainfall **intensity** in on 12 month **(quick** scan rainfall **analysis)** than we **get various** peak discharge **which could** be **seen on table** 9.2. **(calculation will** be **assume** sirnilar with the **rational method** in above **- assumption the velocity will stay** constant and with **the similar characteristic).**

Table 3.6. Various monthly-daily peak discharge in **Deli-Babura** river **basin**

month	1	2	3	4	5	6	7	8	9	10	11	12
Daily Peak ›charge	28290	18178	21690	27168	16388	31812	19762	19762	33256	37114	19280	40970
Monthly ak Discharge	81940	62660	62660	77120	74710	96400	74710	103630	122910	175930	113270	108450

With The use of **dikes** 2,5 meter high **beside the** river **side** (which mean to **increase the capability** of **the** river in nver **flow) the possibility** of **maximum discharge** is **approximately** 466 **m³/s (velocity** 3.4 **m/s),** and the use of **dikes** 2,5 meter (10 meter from river **side)** the **possibility** of maximum diicharge is **approximately** 540 m³/s **(velocity** 3.3 m/s) and 616 **m³/s** with **velocity** 3.3 **m/s, and the material** of **the** river bed is **k=0.01**).

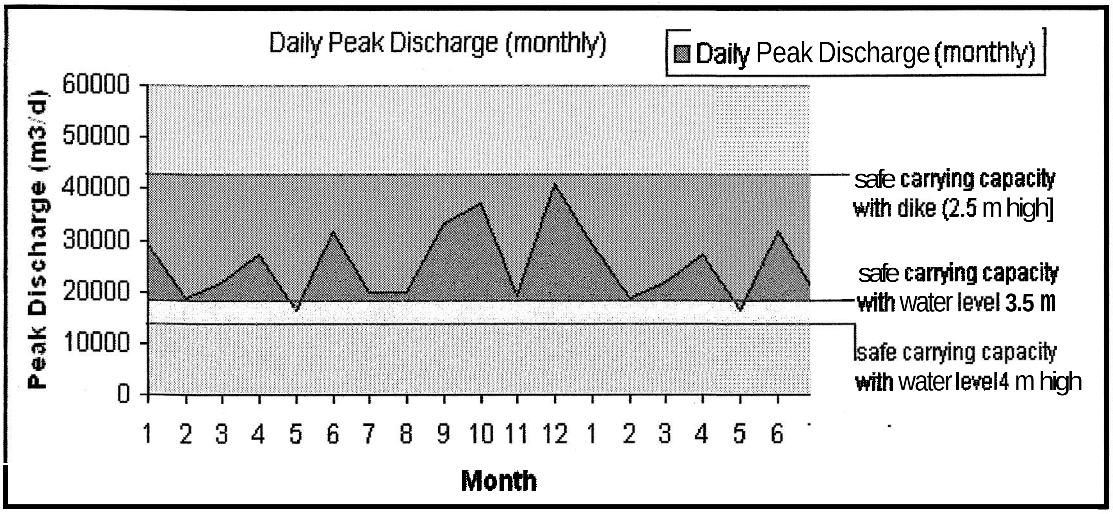


Figure **3.14. probability** of **various** discharge and water level

Chapter 4

FLOOD PREVENTION- SOLUTION DESIGN

4.1 FLOOD PREVENTION –Solution Design

In order to fulfil the aims of the dissertation, which "to explore the ways in which the implementation of the water management can solve or reduce the problems cause by flooding, and the main focus of this solution design is to prevent river flooding or inundation.

From The book of Principles of River Engineering – The non-tidal alluvial river by P.Ph. Jansen (ed)[5], it was proposed on possibility solution design to prevent flood or flood control, like

- Flood control by dikes
- Retarded flood plain storage
- Storage of flood Volume in reservoirs diversion of Flood water
- Increase of Discharge Capacity

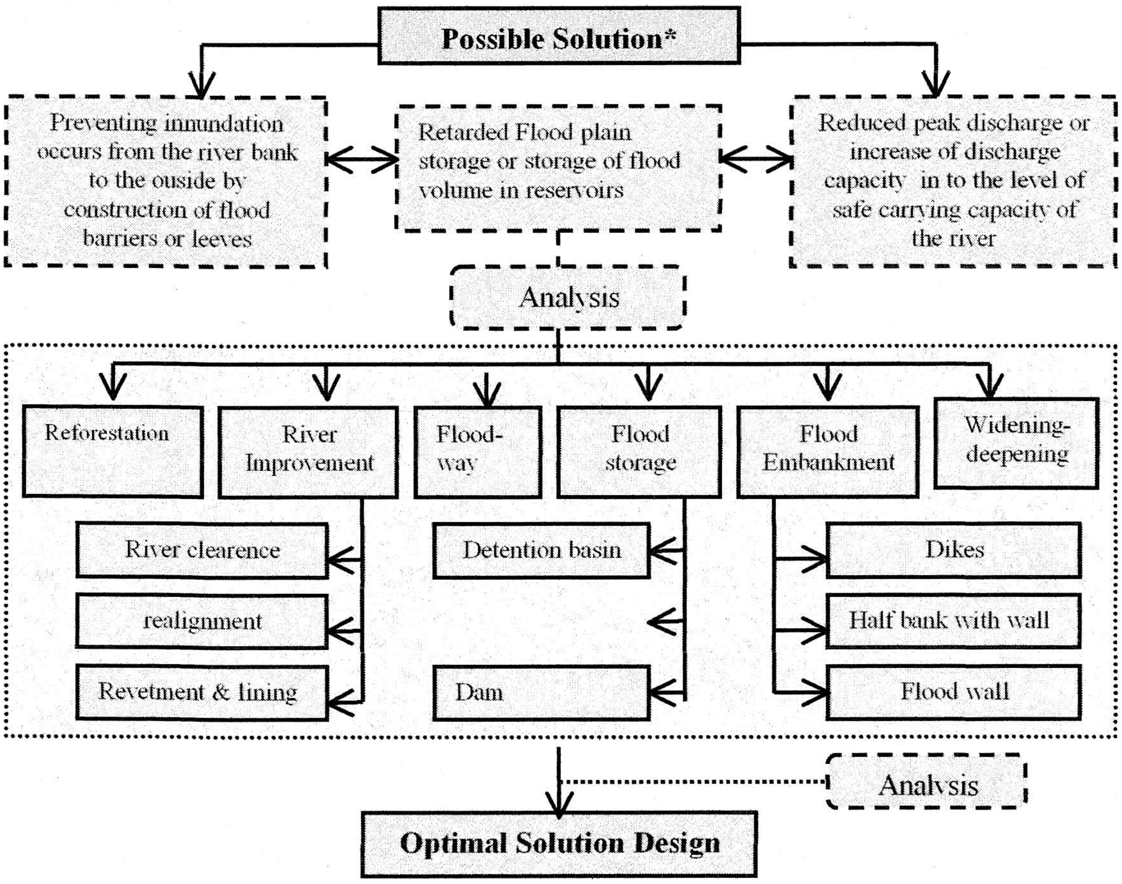


Figure 4.1. Structural Diagram of the solution design

[5] Principles of River Engineering – The non-tidal alluvial river by P.Ph. Jansen (ed), Delfte Uitgevers Maatsschappij page 394 - 412

4.2 Possibility Implementation Solution Design

From figure 4.1(Flood Prevention in Medan City), it was mentioned the possibility solution design which could be implemented to prevent flooding in Medan City. The possible solution will be analysis in its possibility to be implemented or execute in Medan city related to major aspect like environment , financial, etc. From the analysis which lead to optimal solution design according to the writer and it will be discuss in specific about its execution and design to be irnplemented.

4.2.1 Reforestation

Reforestation or catchments conservation by simple measure as re-greening, water harvesting, so at upstream area, the peak flow of river discharge could be reduced. It is also effect the time required to permit flow from entire tributary area to reach the point under consideration, and effect the peak discharge (decrease the runoff coefficient will decrease peak of dischargef.

For example; - the value of C (runoff coefficient) for residential is 0.6

- the value of C (runoff coefficient) for forest is 0. 1

from chapter AIO we get the peak of discharge with existing condition like on table 12. 1, approximately 40970 x10³ m³/d

Table 4.1. peak discharge without reforestation (with **rainfall intensity 170 mm/d**)

Name of the watershed area	Condition of the watershed area	Area (km2)	Runoff coefficient	rainfall intensity (mm/day)	Peak Discharge . x10³ (m³/d)
R	multi units residential	100	0.6	170	10200
V	multi units residential	50	0.6	170	5100
W	multi units residential	50	0.6	170	5100
X	neighborhood district	70	0.7	170	8330
Y	Downtown (city)	60	0.9	170	9180
Z	Industrial	30	0.6	170	3060
				total peak discharge	40970

But if we the reforestation (C = 0.1) approximately 50% were establish from total area "R", "V", "W" so the runoff coefficient become 0.3.5 (0.6 + 0.1 x 50%), than we get the value of peak discharge with reforestation approximately 32470 x10³ m³/d, as shown on table 12.2

Table 4.2.2. peak discharge with reforestation (with rainfall intensity 170 mmld)

Name of the watershed area	Condition of the watershed area	Area (km2)	Runoff coefficient	rainfall intensity (mm/day)	Peak Discharge . x10³ (m³/d)
R	multi units residential	100	0.35	170	5950
V	multi units residential	50	0.35	170	2975
W	multi units residential	50	0.35	170	2975
X	neighborhood district	70	0.7	170	8330
Y	Downtown (city)	60	0.9	170	9180
Z	Industrial	30	0.6	170	3060
				total peak discharge	32470

If we put the rainfall intensity based on monthly rainfall intensity in on i 2 month (quick scan rainfall analysis) than we get various peak discharge every month of the year where the using od reforestation could decrease the peak discharge approximately 20 %.

Table 10.2. Various monthly peak discharge (x1000 m3/m) with and without reforestation

month	1	2	3	4	5	6	7	8	9	10	11	12
ıonthly Peak Discharge without eforestation	81940	62660	62660	77120	74710	96400	74710	103630	122910	175930	113270	108450
lonthly peak ischarge with eforestation	64940	49660	49660	61120	59210	76400	59210	82130	97410	139430	89770	85950

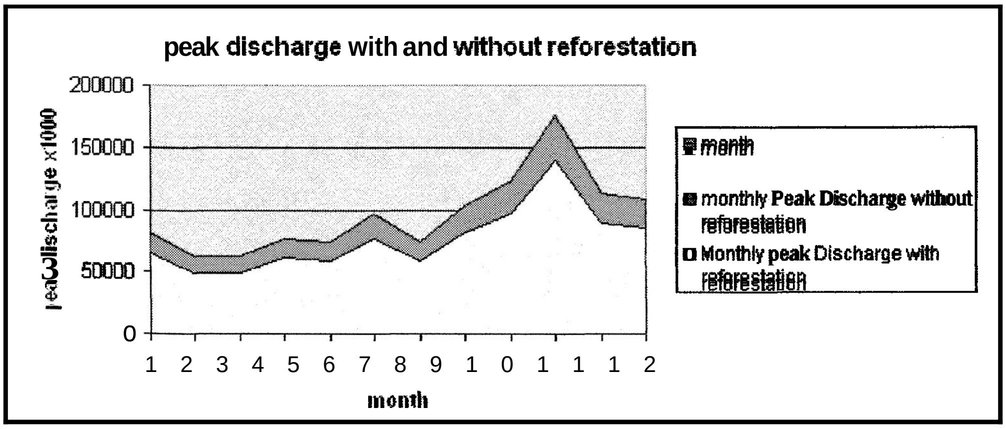


Figure 4.2. Peak Discharge with and without reforestation

4.2.2 River Improvement

The idea of improvement of existing river system with flood prevention is to bring back the discharge capacity of the river system to its original value and to give a free flow of water. By rehabilitating the rivers, the risk on flooding assume could be reduced to once every 20 or 50 years. This assumes that the quality of the rivers remains perfect with ability to accomodate the water from storm rain without causing overflow. in figure below shown with same water level and different velocity we get a different value of discharge.

And for reducing the roughness of the low-water bed depends mainly on the bed form and cannot be influenced by man. For that reason improvements are restricted to clearing the banks and the fiood plains from bushes, hedges, and other obstacles which destruct the river flow

As we know already that the equation of discharge is Q = VA, and the idea of river improvement is to increase the capability of the river to flow the water properly (like increase the value of velocity and cross sectional area of the river to accomodate the water (see the corelation in chapter A Calculation and measurement).

4.2.2.1 River Clearance

In northern Europe the clearance of trees, brushwood and weed offers greater improvement in reduced flood levels in relation to cost than any other form of channel improvement. Such works could be apply and executed with a sympathetic approach since Medan rivers are an asset for Medan city and alot of people live in the surrounding area and well used for living. The aim is to retain the appearance which is as natural possible.

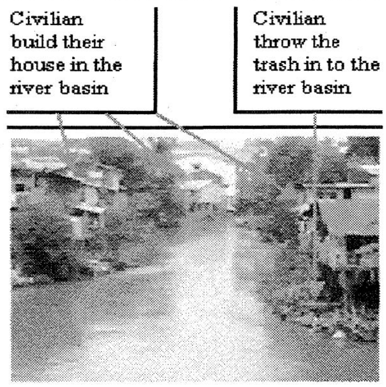


Figure.3.3. Urban housing in the river basin

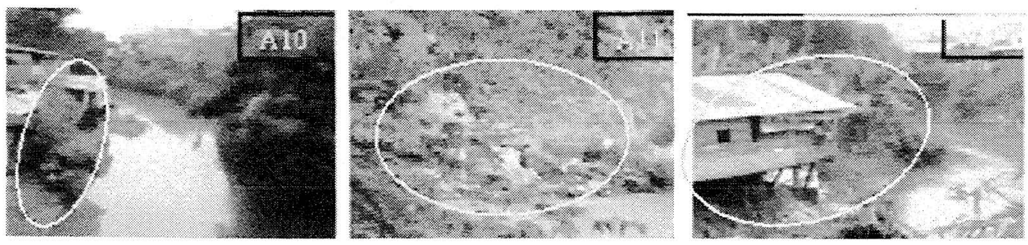
4.2.2.2 Realignment

Natural rivers and streams often follow a meandering course, and natural floods levels in a particular area can be obtained by straightening the course downstream by diversions across meander or by completely new channel. Consider the location of the river in downtown area, where the land acquisition is mostly not possible to establish.

4.2.2.3 Revetments, Lining and Retaining walls

Revetment is any means of protecting a channel bank from erosion or under timing. Channel lining is used where both bed and bank scour are to be prevented or where it is necessary to streamline the river. The riverside retaining wall is used to support the river bank in Medan river, where a sloping revetments is inappropriate. For this condition sheet piling for wall height in excess of 3 meter (is very common in river works).

From the analyses of the river bank, the river require an revetments and lining near the river side to protect erosion which cause sedimentation.



The yellow mark is an example of river area which are require a reveatments and lining or retaining walls

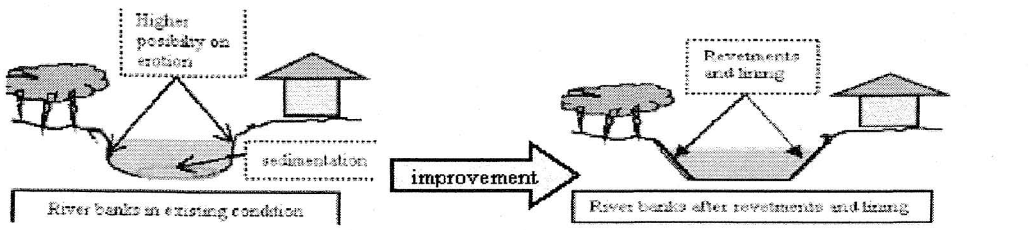


Figure 4.8. Condition and Possibility to Revetments, Lining, Retaining walls on Putih River

River Clearance	Realignment	Revetments, Linings
Could forming a bypass channel which leaves a sensitive reach of river untouched.	Since the river system mostly curve and an development of urban housing in the area make difficulty to execute the project in fully	since the river system mostly curve and an development of urban housing in the area make difficulty to execute the project.
Without following the human resources the execution could be establish in continuous period of time	Could make the rivers like a canal (for this case a course with sweeping curves is preferable)	could make the rivers like a canal (for this case a course with sweeping curves is preferable) Realignment will eliminate sharp bends where erosion takes place
Form a natural environment neighbourhood.	Shortened the flow of the river	shortened the flow of the river
Could not be execute totally because of civilian still live near the riverside	Form the freely flow velocity	Avoid erosion and sedimentation
Length of the river approximately 65 km will take alot of cost	Cost a lot of financial problem mostly in ensure land acquisition	Length of the river approximately 65 km will take alot of cost

4.2.3 Deepening and Widening

The main idea Enlarging the conveying cross section (A) could be established by deepening or widening the river, which could increase the capacity/ discharge of the river (figure 4.2.). Deepening the low-water bed by dredging will result in a temporary improvement at high cost. The entarged cross section will gradually fill up until the original bed and slope have been restored, obviously, since the sediment load from upstream during flood approximately i7000 p.p.m, deepening or permanent improvement will be achieved by continuous dredging with the result in high cost. More over the solution of widening and deepening in Medan City (downstream area) mostly with urban city where the land area is difficult to occupy and consider the cost also the operation cost and maintenance cost, the idea is not fully can be execute in Deli-Babura River.

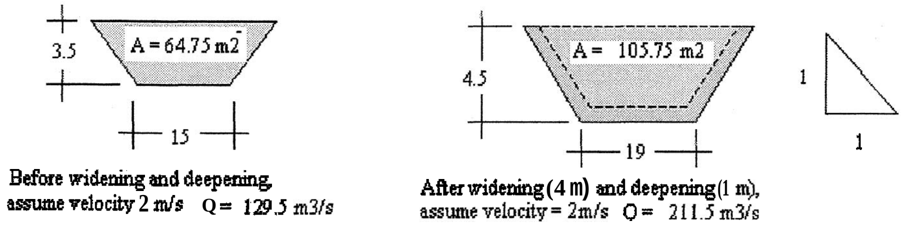


Figure 4.2. Enlarging the conveying cross section will increase the discharge

4.2.4 Storage of Flood Volume in Reservoirs

4.2.4.1 Retention Basins

The most direct method of flood control is the storage of runoff in the upstream part of the catchments area. The most simple form , only serving flood-control purpose, is the detention basin. Design and implement measures that prevent water from running off too quickly. The peak discharge in the river or stream of Medan city can be reduced by storing storm of the flow in a Retention basin temporarily.

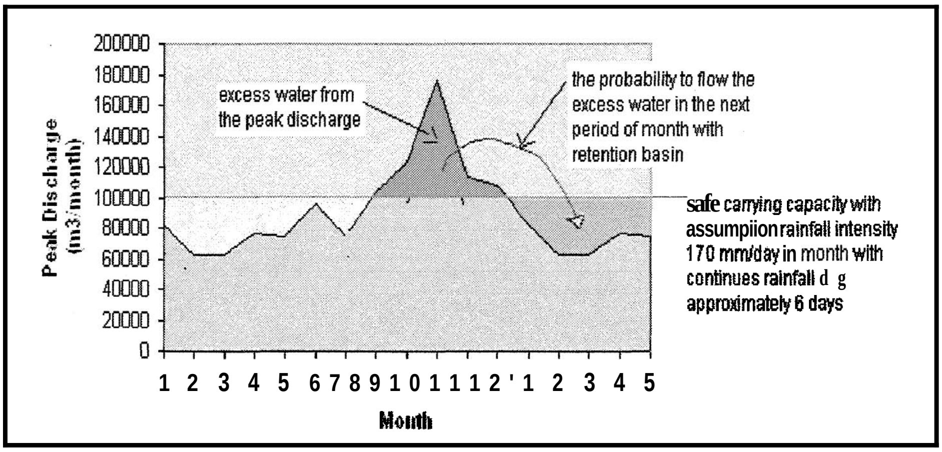


Figure 4.6. Storage the excess volume of the water into detention basin and flow in the next month into safe level for the river to carrying the discharge.

The flow into the Medan river basin should be controlled by banks and weirs so that flow up to the bank-full capacity can pass down the stream leaving the basin empty. In flood the excess flow can then be spilled into the basin over a weir or through a sluice so that flow down the river is still the restricted to a safe value (figure 4.6.). To implemented retention basin mostly could easily to execute in outside of Medan City since the use of this solution need to occupy land area which difficult in downtown area which land is difficult and expensive.

4.2.4.2 Dams

Dams are separate into two main types by the choice of material used for their construction; (1) embankment; and (2) concrete dams. The principle of to prevent the flood is shown in figure 4-6 (above). The role of this structure construction is to storage irrigation water to provide water for industry and larges city and either hydro-electric city. Related to the flood problems in Medan city which in unpredictable period of time the water level in the river get higher and overflow unto the city, for that reason the idea of dams is proposed the unpredictable large amount of water from irrigation or storm rain in mountainous are and flow it properly to the river through water system.

The proposed area for build a dam with high slope was proposed in Nomobatang within catchments area approximately 100 km2 and runoff coefficient 0.6. With a quick scan rational method calculation and rainfall intensity 125 mm/day (50-years return period), the excess water will be store in Nomobatang dam is approximately with peak discharge 86.8 mm/s.

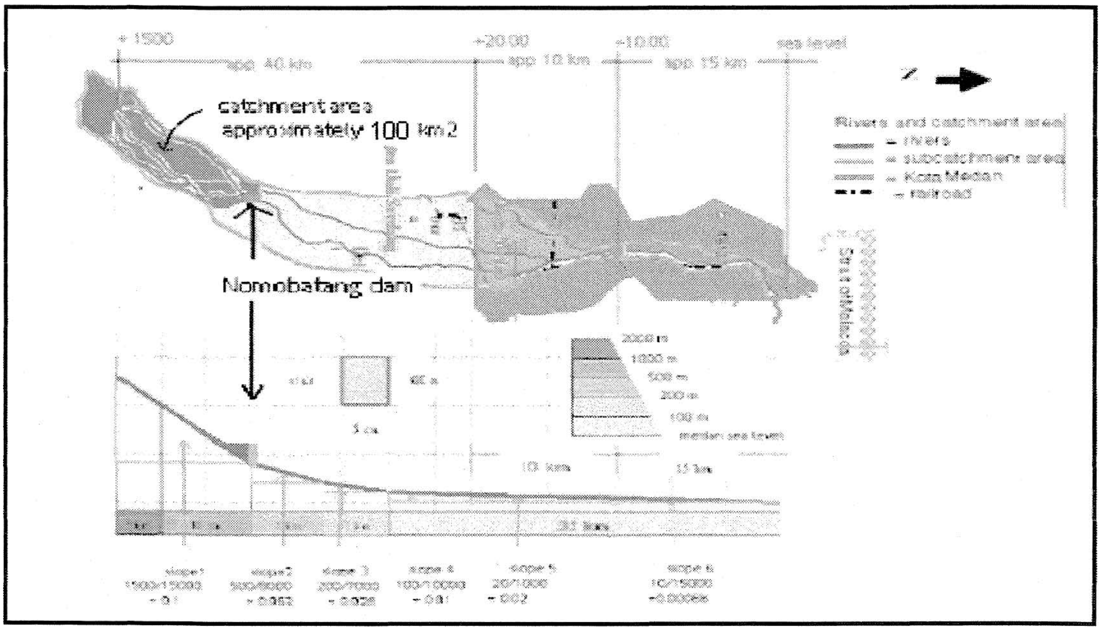


Figure 4.7. Implementation Dams in Nomobotang (resources Witteveen +Bos)

The Nomobatang Dam in the Deli river, will have a muiti-purpose, both reducing the peak discharges from upstream (en therefore reducing the risk on flooding downstream) and having a reservoir for irrigation water. Nobobatang dam are long term plans (>2010) related to large financial due to execute the project. Environmental Impact Analysis (ERA) were executed and resulted in positive advises. First priority was the downstream flooding of the river.

4.2.5 Dikes or Levee

Dikes or Levee on the river side, provide the necessary increase in the water way section by providing both extra width and depth without overflow. For hundred of years river dikes or levees have been used as a primary means for the protection of man and his property against flooding yet it is still the most expedient method for flood control. More over this method had been very well develop in The Netherlands, and proof successfully to prevent flooding and protecting the dry land from the water to entry in to the land.

Where a high safety requirement in the downstream area to be protected, the function of the modern levees is needed as a protection against floods with the return period, the choice of their limit depending on economic consideration. As from the previous floods (1990) where the inundation occurs with high water approximately level 1.50 – 2.00 m. solution with dike may keep peak discharges in the safe carrying valuable, but due to the low frequency of the high water levels, people might start living on the embankments. This requires special attention, as the prime objective gets lost when this type of settlement occurs.

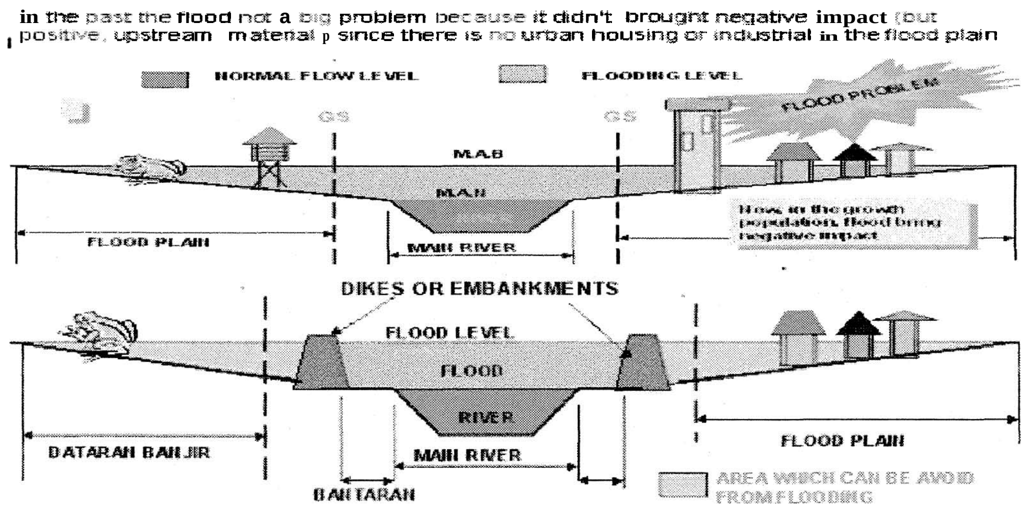


Figure 4 4 From Flood Problem unto Solution Design with Dikes

4.2.6 Diversion of Flood Water – Flood Way

The idea of this method is to reduce the top of a flood by diverting some or all of the flood water away from the river for example diversion into the a topographic depression near the river where the water sinks into the ground or evaporates, or into the lake or the river not belonging to the river system (for example Percut river) or into the sea via a flood-way.

The objective of the proposed Floodway frorn the Deli to the Percut, is to reroute high discharges from the Deli avoiding flows through the city of Medan. The idea had been discuss in the Government Institution, the loan is granted, the design is ready, but only part of the land acquisition was successful. At this moment the govemment of North-Sumatra is pressuring land owners to ensure land acquisition, as building has to finished within the loan period (end of 2006). More over considering that Percut River is not belonging to the Deli-babura River System, but it end in the Strait Malaca which close to the Deli-babura river system and Medan City and considering the storm rain it this two main river with a high peak discharge and causing flooding in downstream.

Chapter 5

OPTIMAL SOLUTION DESIGN

5.1 Optimal Solution Design

5.1.1 Feasibility Study

Basic principle of feasibility study in determine the optimal solution is with analysing the possibility of solutions design by compare the solution design within its advantages and disadvantages, possibility in implementation of the solution related to the cost, construction, etc. (For detail description see appendix D)

5.1.1.1 Solution Comparison

The first method is by comparison of the possibilities solution (references; Maria Besteman - Water Management lecture, and its assume suitable for this case). Within its analysis, possibility, interview, study literature, and comparison within its impact to several aspect (like environment, humanity, financial, etc). Considering from the analysis mentioned in previous chapter the student will choose the optimal solution which will be investigate in deeper by planning, designing

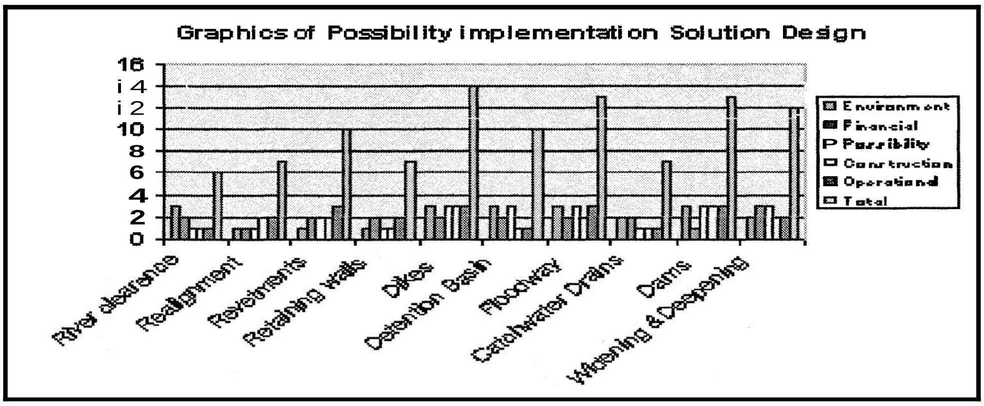
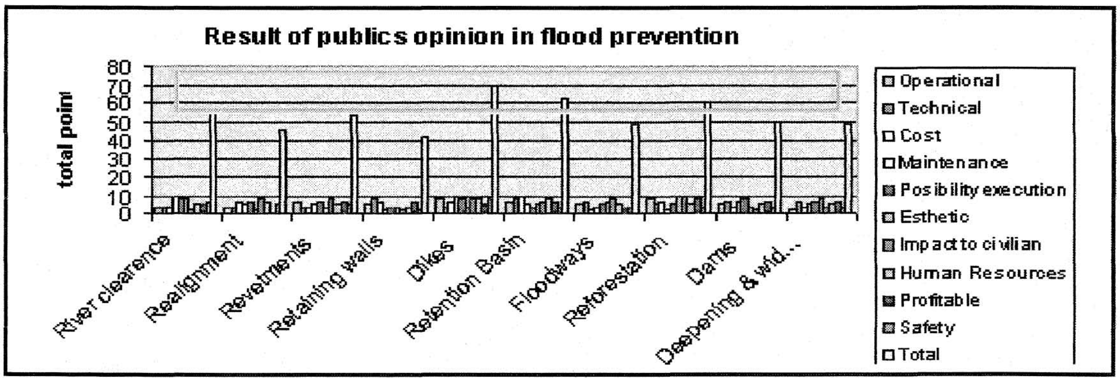


Figure 5.i. Graphics of Comparison Alternative Solution Design

From figure. 5.1 (above) we can see from the alternatives solution design and its analysis with the other aspect we get the result of the use of Dikes, Flood-ways, Dams, is the proposed solution in Flood Preventing

5.1.1.2 Publics opinion

The second method will be a Public Questioner. The method is to collect all the public opinion with the solution design (the questioner will be given to the public with several background, assume the opinion based on the background education - see appendix for the sample of the questioner). The Idea is to investigate or to do quick scan analysis about the optimal solutions design with considering other aspect like economy, politic, environment, etc. by questioner the people with different background study . From the 20 respondent, Dikes, Retention Basin, and Reforestation is the most chosen solution by publics opinion in flood preventing.



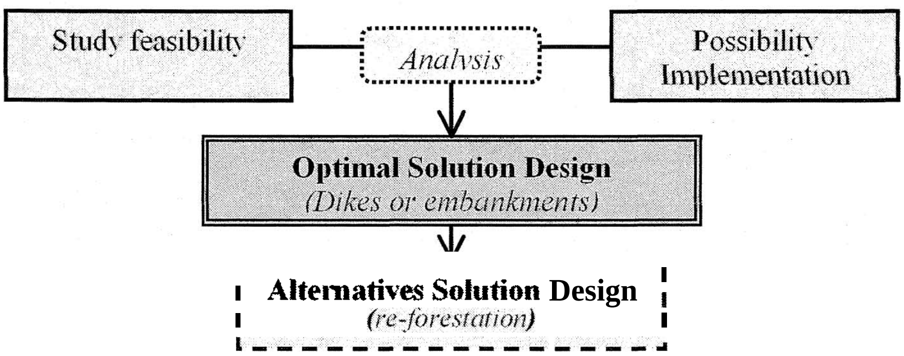
Fiiure *5.2.* Public Opinions in Flood Prevention

5.1.1.3 Chosen Solution

The proposed measures divert (as mentioned in the previous chapter within its analysis) from realigning the rivers, rehabilitation of dikes, setting back of dikes, adding a floodway and adding dams upstream. Despite of the problem like

- There is no budget for larger adjustments, like regular dredging.
- Similarly a maintenance program is not available for the more expensive actions.
- For the upstream Deli (downtown Medan), a limited part still has to be restored, there is no money available, and land reclamation is a problem (expensive, easements).
- *Floodway* from the Deii to the Percut the loan is granted, the design is ready, but only part of the land acquisition was successful. At this moment the government of North-Sumatra is pressuring land owners to ensure land acquisition, as building has to finished within the loan period (end of 2006).
- The Nomobatang Dam in the Deli river are long term plans (> 2010). First priority was the downstream flooding of the river.

Considering all what had mentioned in above yet the action should be undertaken to prevent the coming flood and within analysis from the two method and solution analysis (chapter 5.1.1) the writer suggest the embankments or dikes with limited maintenance as the solution to prevent flood in Medan city.



5.1.2 Dike or Embankments

To supplement the Flood Protection Act, A policy document entitled 'make a way for rivers' was published in 1996 by the Ministry of Transport, Public Works and Water Management and the Ministry of Housing, spatial Planning and Environment.[6] The idea intend to give the great river more room fin this case Deli River), so their flow capacity is retained and , where necessary, increased mostly in high discharge.

The idea of dikes is could be implemented as the last barrier to prevent inundation. The purpose of dikes had been prove to prevent flood in the Netherlands for century, thus this idea could be implemented in this project area consider the assumption which mentioned in above

There are 4 type embankment which could be implemented in the location due the different characteristic with the condition of the river, which are;

- Dikes I embankment
- Half bank with wall
- Flood wall

Study Feasibility of the embankments

No	Dikes	Half bank with wall	Flood wall	Flood wall on embankment
	Easy to execute	Difficulty on execute the project	Difficulty on execute the project	Difficulty on execute the project
	Cheap	expensive	expensive	very expensive
	With sandy clay dikes its easily to get the material	Need a lot of material for construction	Need a lot of material for construction mostly for concrete	Need a lot of material for construction mostly for concrete
	Could involve the civilian to execute the project	Could involve the civilian to execute the project	Could not involve the civilian to execute the project	Could not involve the civilian to execute the project
	Occupy a land area	Occupy less land area	Occupy very less land area	Occupy a land area
	Aesthetic – retain the appearance natural	Aesthetic – not fully retain the appearance natural	Un Aesthetic	Un Aesthetic
	Limited high level	Get a high level water	Get a high level water	Get a very high of water level

All this method could be implemented in the project area depend on the problems which occurs, but for most off all the writer is suggest with the method of dike, for the reason of less financial, aesthetic, and in structural it was strength enough to resist the flood.

[6] Twice a River, Rhine and Meuse in the Netherlands, page 42

The using of Dike may prevent inundation, but due to the low frequency of the high water levels, people might start living on the embankments, this requires special attention, as the prime objective gets lost when this type of settlement occurs.

The proposed high of the dike is by taken from the previous flood approximately 470 m³/s and from the rational method calculation which is 473 m³/s, fdue the increasing of the water level approximately **2 to 2.5** meter) for that reason the dikes will be design 2 .5 meters high (assumption see chapter 3 for the probability of increasing flood discharge and the capability for the river in normal flow without inundation) along the river in downstream (approximately 10 km long) fsee chapter 6)

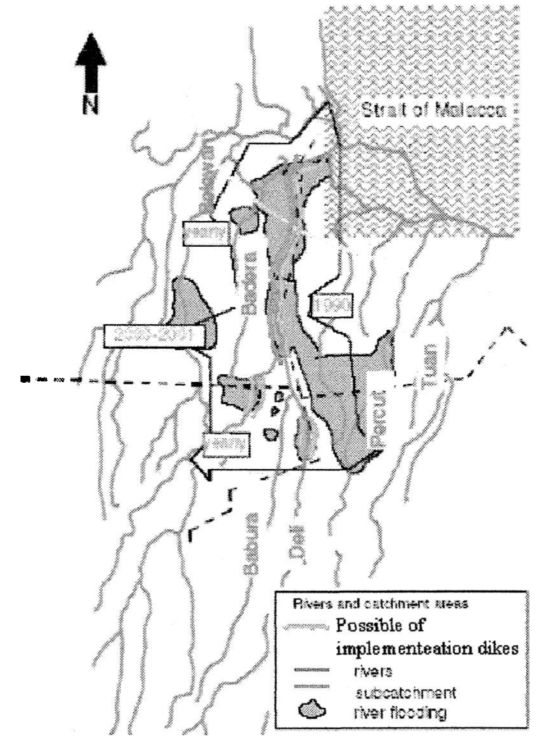


Figure 5.2. Possible Location area for the Dikes ~

5.1.3 Re-Forestation

Consider the increasing of the rainfall more than the measurement in this report or either by settlement consideration, the author proposed and alternative solution design with Reforestation or watershed conservation by simple measure as re-greening, water harvesting, so at upstream area, the peak flow of river discharge could be reduced (retention) approximately **25%.** Re-forestation is proposed by the writer as the alternative solution design in order to decrease the peak discharge (see reforestation analysis in previous chapter or Appendix A-12)

The proposed area for implemented reforestation to prevent flooding which are a long in upstream area like;

- Pancur Batu
- Bandar Baru
- Sibolangit
- Bukit kubu
- Mandailing
- Brastagi
- etc

Chapter 6

PLANNING AND CONSTRUCTION of the Dike

6.1 EMBANKMENT DESIGN FOR FLOOD PREVENTION

6.1.1 Data

The situation shown in figure I is assume to be condition of the river in downstream. The soil stratification is assumed to be like as following:

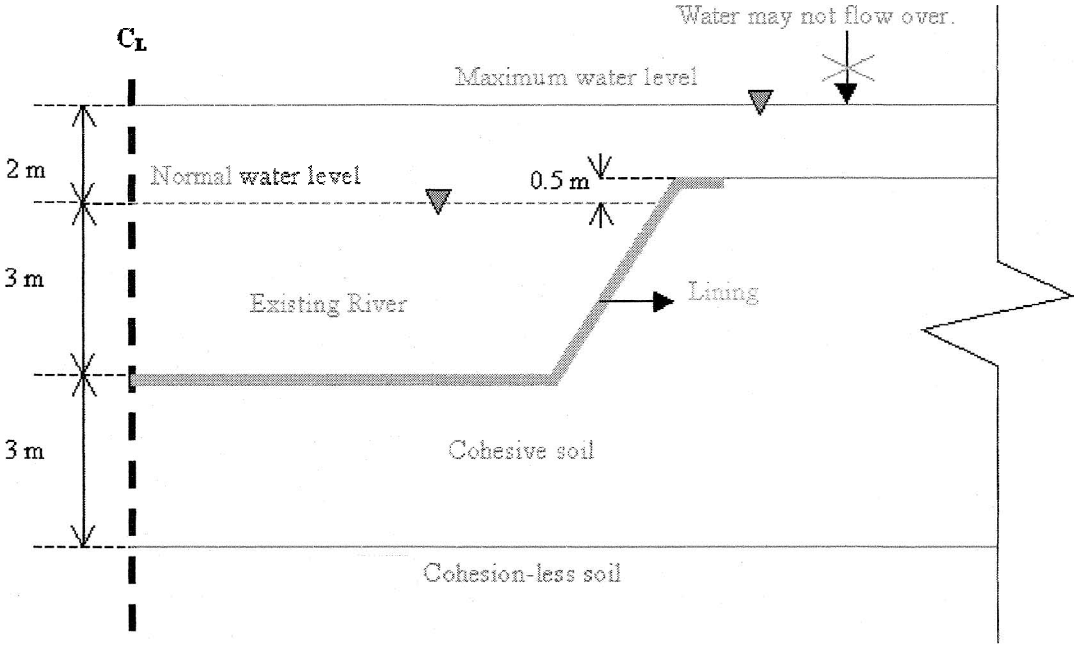
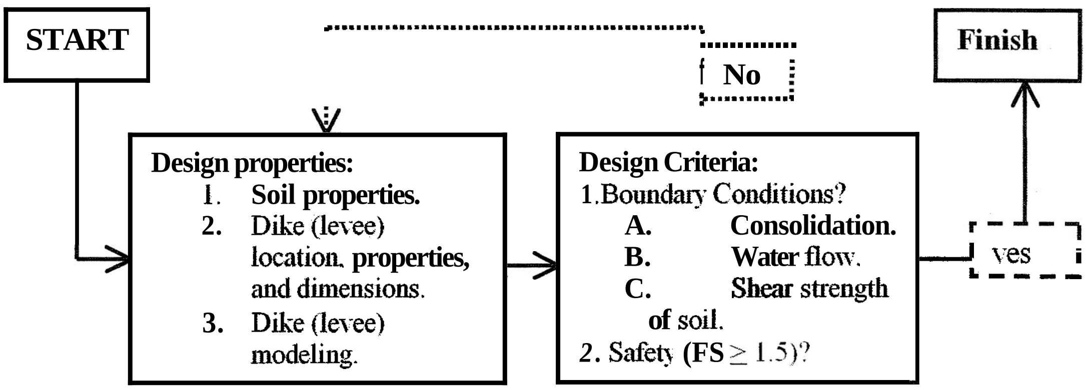


Figure 6.1: The Cross Section of the River and the Most Possible Water Level Increasing

6.1.2 FLOW CHART

In common the following flow chart may give a rough path to fulfill the safety of the embankment.



6.1.3 Design[7]

The function of natural dikes is to protect the hinterland (population and economical values)against inundation due the stom surges.

A. Design philosophy[8]

The resulting design will be regarding to *effective* and *efficient*. Effective means that the dike should be functional both for user and the environment. Efficient means that the cost of the (effective) dike should be as low as possible and that the construction period should not longer than it is necessary.

The method for this design is focus on the probability of failure due the functional in inundation prevention, and so fundamental soil mechanics theories are needed such as: stresses in soil, flow and force, capillarity in soil, slope stability, settlement (concolidation), wave and erosion protection.

B. Design Methodology [9]

Starting with identification to prevent inundation, the designing of dike structures in this thesis will following aspects to be considered like; the function of the structure, the physical environement, the construction method, and maintenance. Some of the design criteria such as;

- Dikes usually have a rather mild slope, mostly of the order of 1:2 or milder, but , but due to the low frequency of the high water levels, people might start living on the embankments, this requires special attention, for this reason the chossen dope elevation of the dike is 1;1.2 or 40° will be consider (minimum dope to stay stable). In order to prevent the dike free destruct by human and cattle.
- It is obvious that too low dikes will lead to flooding either but too hight dike also bring some aspect of problem like financial.. a safe approach is no significant overstopping is allawed which not be lower than 2% wave run-up level. More over the height of the dike is mostly depend on the water level (volume of water due the flooding), in this case the height of 2.5 m will be consider related some aspect like;
    - Water level (from the previous flooding the high of the water Bevel is recorded to 1.5 m from the top of the river, for the extract water, other solution will be consider.
    - Settlement (due the period of time and the load of the dike the settlement will occurs which effect the height of the dike, approximately 0.5 m)
    - Safety factor (± 0.5 m will be consider during design the height of the dike as a safety factor due the increasing of water level in order to prevent flood overtopping
    - Esthetic (consider the esthetic of the environment and the city itself, limited height of the dike will be consider.

7 *Dikes and Revetments*, Design safety and maintenance, Krystian W. Pilarczyyk.
8 .Introduction to Bed, Bank and Shore Protection, Gerrit J. Schierek, page 4-6.
9 Dikes and Revetments, Design *Safety* and Maintenance, Kristian W Pylarczyk, Cahpter 2 page 19-18

- Financial (more height will extract financial like material, period of construction, land needed, load of the dike, settlement, etc).

- The soil is mostly clay or other cohesive soil for both river and levee that may enable water to flow slowly and commonly have a better stability when is made for sloping ground. It is desirable to use the same kind of soil for an earth construction like dike. The inclination of river slope and levee is also important due to water level increasing and it may not fail and have FS (factor of safety) at least 1.5 at extreme condition.

- The seepage and capillarity of the water may cause some risk depend on the chosen solution. Apparently, soil mechanics consider a higher dry density value or even the same as wet density in case of clay to bet put into either hand calculation or program.

Un-drained cohesion of the levee and subsoil will gradually improve as the time becoming drained cohesion. In this case the improvement factor is not taken into account. So, we will use the same cohesion value for drained condition

Regarding to the idea to construct an embankment (levee) next to the river basin, then we come to some options where to build (see figure 6.2).

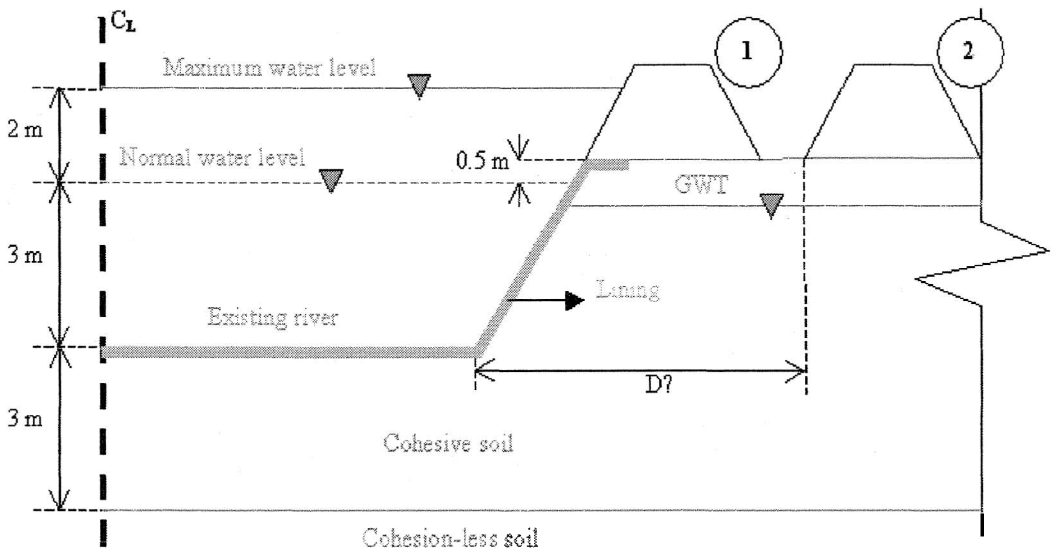


Figure 6.2. Possible Solutions for Embankment (dike) Construction

Instead of choosing 1 or 2, the other important matter is how far D to let we consider the existing river embankment or not. Some considerations must meet the safety (FS ≥ 1.5) and economic criteria.

6.1.4 Soil Properties (assumed):

All soil properties are assigned to mohr-coulomb model, but in the end of this paper we will change to soil-creep model to estimate the total settlement and time-rate primary consolidation.

1. River embankment (one soil type, normally consolidated):
   - Slope angle : 40°.
   - Undrained cohesion : 20 kPa.
   - Dry density : 18 kPa.
   - Wet density : 18 kPa.
   - Friction angle : 10° (undrained).
   - Dilatation angle : 0°.
   - Modulus elasticity : 20000 kPa (elastic).
   - Permeability : 1E-04 m/day (vertical and horizontal directions).
2. Dike (one soil type, normally consolidated):
   - Slope angle : 40°.
   - Undrained cohesion : 20°.
   - Dry density : 15 kPa.
   - Wet density : 15 kPa.
   - Friction angle : 5° (undrained).
   - Dilatation angle : 0°.
   - Modulus elasticity : 10000 kPa (elastic).
   - Permeability : IE-04 m/day (vertical and horizontal directions).
   - e_0 : 1.

6.1.5 Theories Related

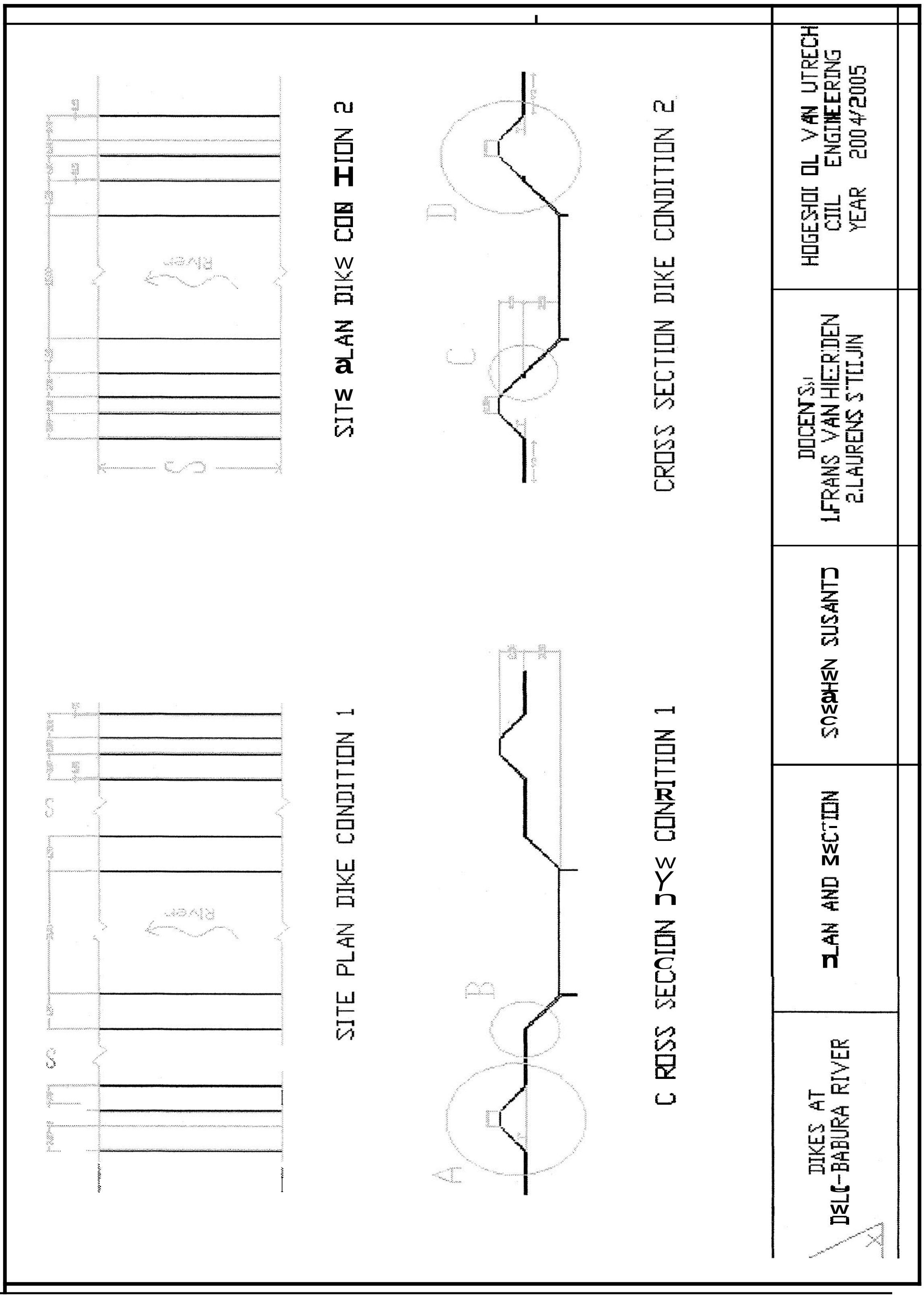
Some fundamental soil mechanics theories are needed such as:

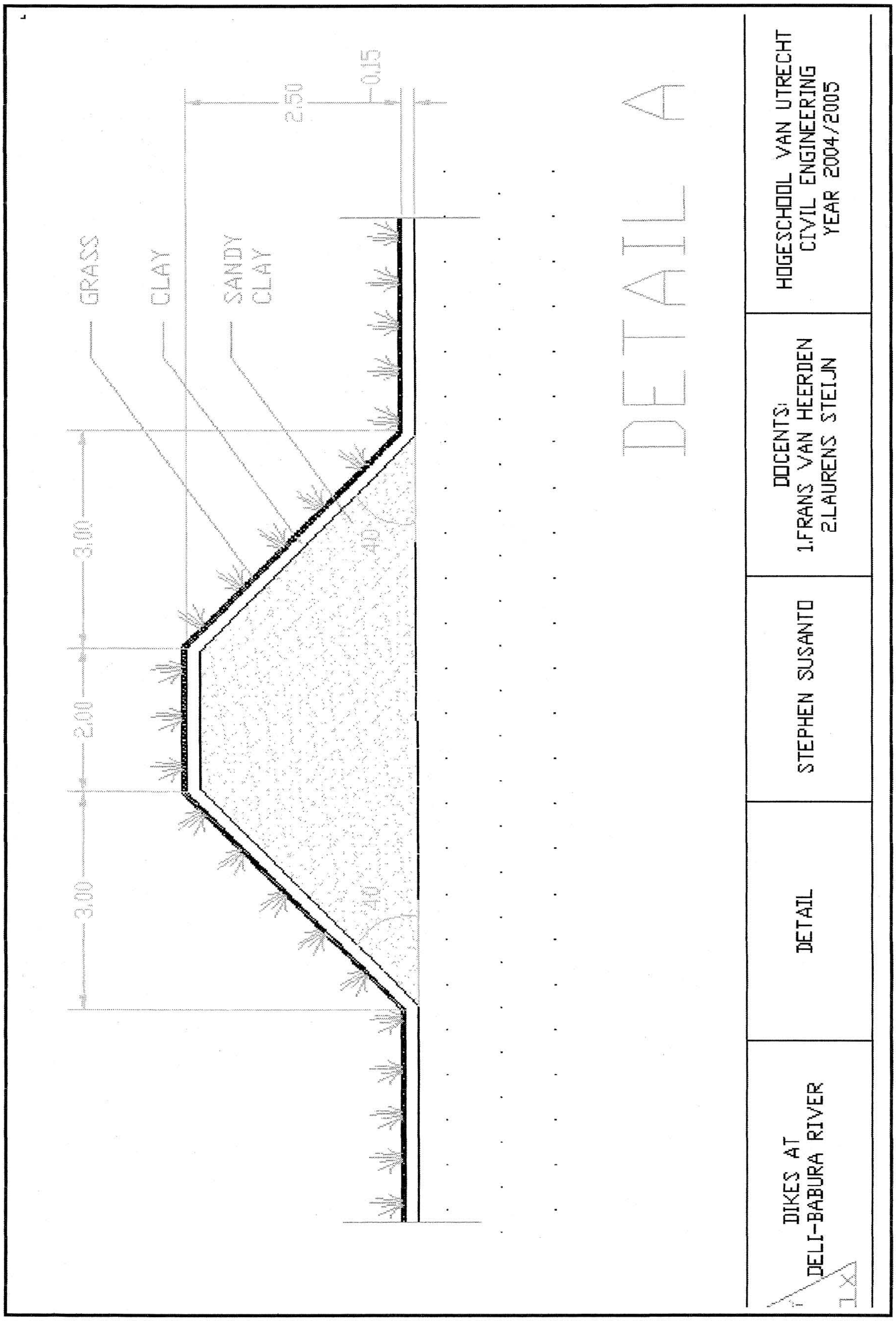
- Stresses in soil.
- Seepage (flow and force) and capillarity in soil.
- Slope stability.
- Settlement (consolidation).
- Wave

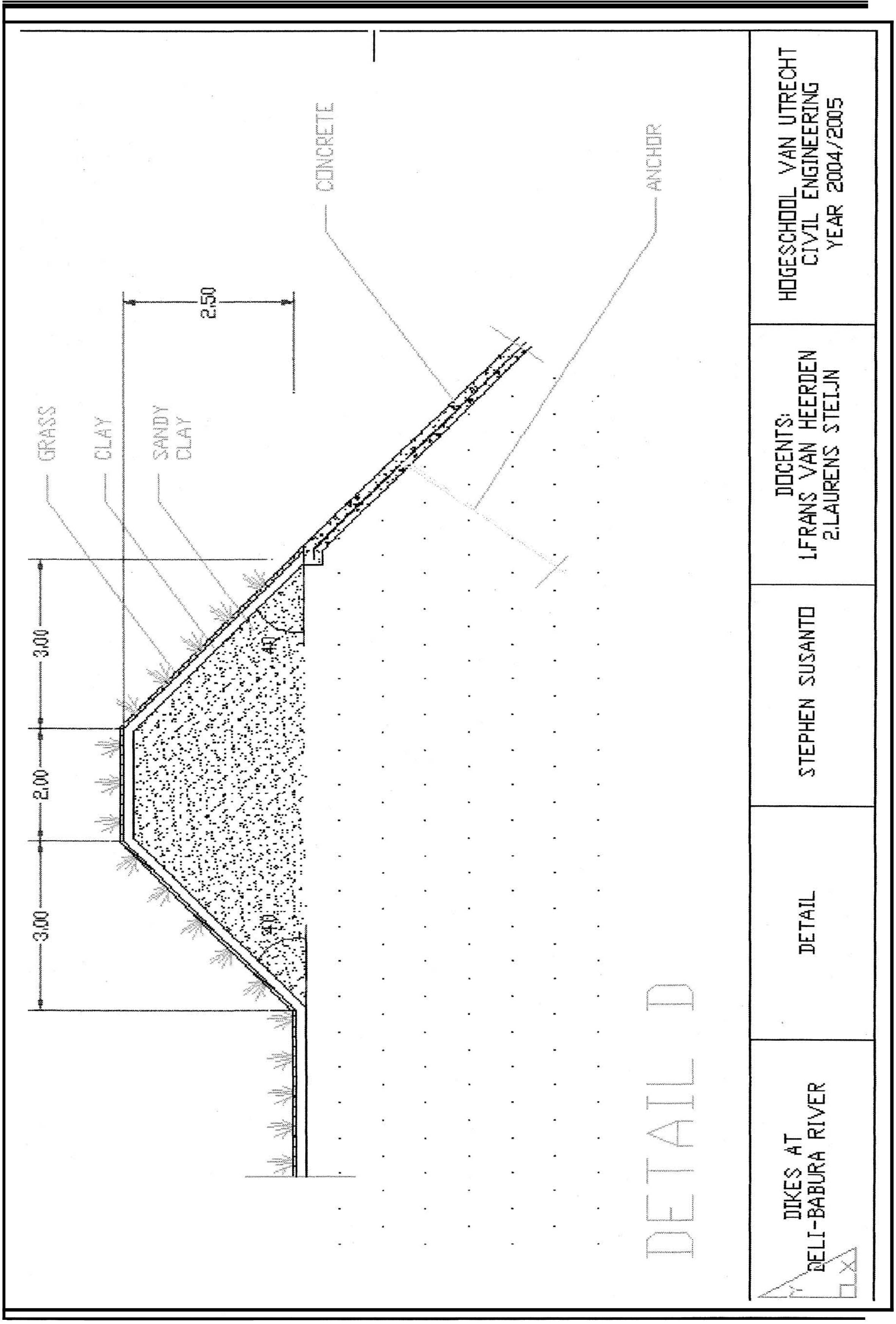
All measurement and calculation of this fundamental could be seen in the appendix chapter, including the complete analysis of the Dike or embankments.

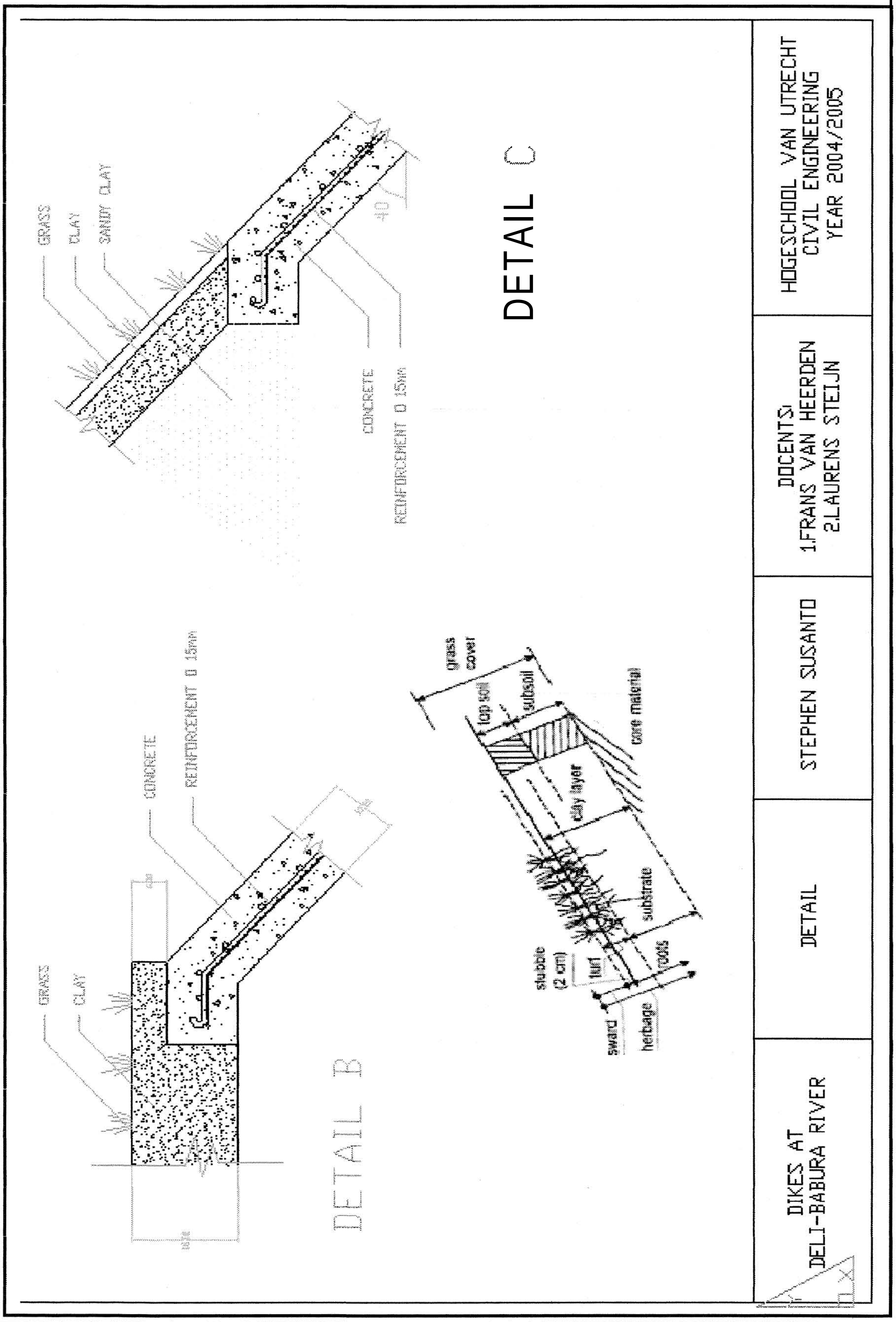
For detailed design, measurement or calculation see appendix B- Dikes or Levees

6.1.6 Drawing and Detailing




GRASS
CLAY
SANDY CLAY
2.50
0.15
3.00
2.00
3.00
DETAIL A
HOGESCHOOL VAN UTRECHT
CIVIL ENGINEERING
YEAR 2004/2005
DOCENTS:
1.FRANS VAN HEERDEN
2.LAURENS STEIJN
STEPHEN SUSANTO
DETAIL
DIKES AT
DELI-BABURA RIVER


CONCRETE
ANCHOR
GRASS
CLAY
SANDY CLAY
2.50
3.00
2.00
3.00
40
40
DETAIL D
HOGESCHOOL VAN UTRECHT
CIVIL ENGINEERING
YEAR 2004/2005
DOCENTS:
1.FRANS VAN HEERDEN
2.LAURENS STEIJN
STEPHEN SUSANTO
DETAIL
DIKES AT
DELI-BABURA RIVER


GRASS
CLAY
SANDY CLAY
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CONCRETE
REINFORCEMENT Ø 15mm
DETAIL C
GRASS
CLAY
CONCRETE
REINFORCEMENT Ø 15mm
DETAIL B
grass cover
top soil
subsoil
core material
clay layer
substrate
stubble (2 cm)
turf
roots
sward
herbage
HOGESCHOOL VAN UTRECHT
CIVIL ENGINEERING
YEAR 2004/2005
DOCENTS:
1.FRANS VAN HEERDEN
2.LAURENS STEIJN
STEPHEN SUSANTO
DETAIL
DIKES AT
DELI-BABURA RIVER

Chapter 7

CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

The Project will divided into 3 term of the project solution, which are;

1. Short-term Solution;

   From the analysis it was found the probability of erosion probability. For this reason the revetments in the river side wilt be consider to being establish before the dike execution, to prevent dike beng destruct during the needed of revetments construction.

2. Mid-term Solution;

   From the analysis its found that the discharge in the downstream river is approximately 200 m³/s and for this reason a solution with dike to increase the value and to prevent inundation by river flooding will be undertaken for mid-term solution with 50 years return period. Consider the economical and the time needed for the long term solution totally establish to reduce the water Bevel cause by peak of discharge during storm rain.

3. Long-term Solution

   Reforestation will be undertaken in upstream to decrease the peak of discharge, within assumption the project will be totally execute within period approximately 30 – 40 years from the first execution.

7.2 RECOMMENDATION

The following recommendations are proposed in order to maximise the benefits of the implernentation of optimal solution in flood preventing, which divided into 3 term solution;

1. Short-term;

   Collect all information about the funding institutional and make contact with the institutional in order to get financial to execute the project.

2. Mid-term;

   Consider reforestation keep continuing or cannot be fully established, than the solution with dam in Nomobatang will be consider to decrease peak of discharge with assumption period of the execution project fully established approximately 10-15 years.

3. Long-term;

   Ensuring involvement of other institutional like education institutional with study and research will be a good consideration in order to find a new insight in water management to prevent river flooding. Example recommendation for the further studies:

   - Analyse the impact of the solution design to the environment aspect
   - Analyse possible ways to create a room Por river or increase the capability of the river to accommodate the rain water without causing over flow and backwater.

APPENDICES

APPENDIX A. MEASUREMENT AND CALCULATION RIVER FLOW

APPENDIX B. DIKE AND EMBANKMENT

APPENDIX C. PICTURE CONDITION OF DELI RIVER

APPENDIX D. STUDY FEASIBILITY – FORM OF QUESTIONNARE

LIST OF REFERENCES

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Direktorat Jendral Sumber Daya Air, (2003).	*Unit Data* Sumber Daya Air, Departemen Permukiman dan Prasarana Wilayah. (http://sda.kimpraswil.go.id/info/uu.asp)
Eric C.L. Marteijn	*"Twice a River", Rhine and Meuse in the Netherlands,* Floods – page43, Rhine and Meuse, page 17-29, f1999)
Gerrit J. Schiereck (2001)	*"Introduction to Bed, bank, and shore protection",* The interface of soil and water (2001)
Haskoning, the Netherlands (1992)	*"Study of River Flows and Flood Control in Medan River Basins",* Final Report, Volume 1/2/3/4/7/9/10.2, Haskoning , the Netherlands (1992)
Ir . D. Broere (2002)	*'Water Management",* course material, Academie voor Bouwkunde en Civiele Techniek – Hoogeschool 's Hertogenbosch, page 12-73 (2002)
ir. H.J. Verhagen	Delft University of Technology, Royat Haskoning, Rijkswaterstaat (DWW,. BD or Limburg Directorate) and Van Oord. Section of Hydraulic Engineering, Subjects for M.Sc.-theses,
ir. I. W. Nortier Ir. P. de Koning	*Toegepaste Vloeistofmechanica", Hydraulica voor waterbouwkundingen (1996)*
Joseph E. Bowles (1997)	*' Foundation Analysis and Design:* Chapter *I*, 2, 3, International edition (1997)
Krystian w. Pilarczk (1998)	*"Dikes and Revetments",* Design , Maintenance, and Safety Assesment (1998)
Leslie Spencer Blake. (2000)	*"Civil Engineer's Reference Book",* Fourth Edition, Part B: Land Drainage and River Engineering, page 30/12 – 30/22, Concrete Construction page 37 3-3722 (2000)
MH. Thamrin and M. Wafid A. Novianto (I 99611997)	'Engineering Geological Map of Medan and its Surrounding, North, 1996/1997
Medan Local Government (2003)	*"Development Policy and Flood Control of Medan City",* Prepared For Consultation Visit To Diens Waterbeheer en Riolering (DWR), December 2003
P.Huisman, W. Cramer, G.van Ee, J.C. Hooghart, H.Salz, F.c. Zuidema	*" Water in the Netherlands",* Netherlands Hydrological Society (NHV), (1998)
Rijkswaterstaat, March 2004	*"Proposal",* Preparation Integrated ActionPlan – Flood Management Kota Medan, page 5-20 (2004)
Russell W. Faust, P.E. (2000)	*"Hydrology - a Review for Civil Engineers,"* Course Introduction, (2000)
Texas Department of Transportation (2004)	*"Hydraulic",* Hydraulic Design Manual, Texas Department of Transportation, Revised , Chapter 5 page 5/4 –5178– March (2004)

T.H.M. Rientjes, R.H.Boekelman (2001)	*"Hydrological Models", Part III; Surface Water Model,* Faculty of Civil Engineering and Geosciences, January 2001, Page 139-177
T.N.O (1985)	"Water in Urban Areas", M O Commitee on Hydrological Research, Proceding of Technical Meeting 42, April, page 5-98, 161-165 (1985)
Witteveen+Bos (2004)	*"Proposal",* Integrated Action Plan - Flood Management Kota Medan, Page 5-20 (2004)
Witteveen+Bos (2004)	*"Quick Scan Rainfall Analysis",* Integrated Action Plan - Flood Management Kota Medan, Page 1-16, (2004)
Witteveen+Bos (2004)	*"River Basin Engineering",* Integrated Action Plan - Flood Management Kota Medan, Page 1-10, (2004)
Witteveen+Bos (2004)	*"Starting points & Boundary Conditions",* Preparation Integrated Action Plan, Flood Management of Medan City (2004)