Climate Change Risk and Adaptation Assessment

Tarakan

Sectoral Report
Water

June 2012

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Climate Risk and Adaptation Assessment for the Water Sector – Tarakan

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Climate Risk and Adaptation Assessment for the Water Sector – Tarakan

Draft Final Report

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I. INTRODUCTION

1.1 Background

Based on the results of some recent studies from the official government of Indonesia concerning climate change impact, it is believed that Indonesia would be strongly exposed to climate change. These studies, for instance, are: *Climate Risk and Adaptation Assessment of Lombok Island, West Nusa Tenggara Province* (KLH-GTZ-WWF-*Pemerintah Provinsi* Nusa Tenggara Barat, 2009) and *Indonesia Climate Change Sectoral Roadmap (ICCSR)* by Bappenas-GTZ, launched in 2010. Another useful study is *Adaptation Science and Policy Study* (ASPS) by DNPI-DFID done in 2010.

Climate projections in the ICCSR study indicate that the mean wet-season rainfall will increase across most of Indonesian regions, especially in regions located south of the equator, such as Java and Bali. At the same time, the length of the dry season is also expected to increase. The Lombok study clearly had identified the increase of temperature and shifting of wet-season rainfall in Lombok Island. Moreover, an increase in the intensity and frequency of extreme events, like El Nino and La Nina, are already noticeable in Indonesia. The risk of floods, during the rainy season, and drought, even fires, in the dry season, is therefore likely to increase. This will particularly impact water resources, agriculture, and forestry, fishery as well as health and infrastructure.

Adaptive measures can reduce these impacts of climate change. Therefore, the necessity for adaptation measures at national and local levels is rapidly emerging as central issue in the debate around policy responses to climate change. In order to prioritize, design, and implement interventions to adapt to climate change, it is essential to adopt a coherent set of approach, framework, and methodologies for climate risk and adaptation assessment (CRAA). This CRAA including examining hazard, vulnerability, and risk to impact of climate change and adaptation strategy to face the risk.

Among the sectors that need prioritize, design, and implementation of intervention to adapt impacts of climate change is water sector, which includes surface water and groundwater. Therefore, a study of micro level on the impact of climate change to water sector is a must to be carried out as basis for adaptation measures. The study has to involve the coherent set of approach, framework, and methodologies for examining hazard, vulnerability, risk and the adaptation strategy to minimize the impact of climate change to water sector in CRAA.

Micro level studies concerning aspects of climate change in Indonesia, including water sector, are very limited. Even micro level study in the area of vulnerability, risk, and adaptation strategy or micro level study of vulnerability assessment in facing impacts of climate change is still yet to be done.

Based on the background mentioned above, a micro level study on vulnerability assessment to climate change on water sector is carried out. The Tarakan city, East Kalimantan Province, has been taken as the location of the study. Geographically, Tarakan is an island that represents the condition of small to medium sized island that lies around the equator line in the centre part of Indonesia.

1.2 Problem Statement

The problem in this CRAA can be presented in three main areas as follow: 1) current hazards and vulnerabilities, 2) future vulnerabilities and risk; and 3) adaptation strategy for reducing the impact of climate change on water sector. These three main areas of problems are elaborated below:

(1) **Current hazards and vulnerabilities**. These problems appear from some basic questions as follows: How are the existing conditions of water resources in Tarakan? Is there any water stress that might become hazards for water sector right now? What is the history of these hazards in the past? Actually, what are the hazards of water sector in Tarakan and what are the vulnerability to that hazards and how they are related to the climate and climate change issues? What are the important issues that have to be considered in the water sector in facing hazard, vulnerability, and risk due to climate change in the Tarakan region?

(2) **Future vulnerabilities and risks**. In these problems we want to know the trend on water sector in the near future, as well as in the future, in its relation to the trend of climate change or climate variability in the Tarakan region. Problems in this area also emerge from the following questions: What are the assumptions and methodological approaches used for predicting future hazard, vulnerability, and risk on water sector due to climate change or climate variability in the Tarakan region? Other problems that are important to be answered in this area: What kind of hazards, vulnerabilities, and risks on water sector due to climate change in Tarakan in the future? Where are they distributed and how are its frequency and intensity, respectively? (How are the spatial and temporal distribution of the hazards, vulnerabilities, and risks will be likely?)

(3) **Adaptation strategies**. Here, the results of analysis in answering the previous problems are followed up. The problems appear as in the following questions: What

are the appropriate strategies to adapt climate change risk on water sector in the Tarakan region? How are the strategies developed from strategic issues related to hazards, vulnerabilities, and risks on water sector? And, what are the steps needed to integrate conductively these adaptation strategies into the existing development policy, strategy, and planning of water sector?

Furthermore, other problems emerge in correlation with the new Indonesian environmental law. The law, which was signed by the President on October 2009, outlines the framework for climate change mitigation and adaptation issues. However, the technical and operational guidelines for the law are still to be developed. Therefore, this project is challenged in producing an assessment that can be a source for developing strategy and action to be implemented in water sector as a model for the technical and operational guideline development.

1.3 Objectives

The objectives of this assessment are as follows:

- to determine the methods of vulnerability and risk assessment to climate change in water sector in accordance to the micro-level assessment approach.
- to produce the vulnerability map and analysis of risk to climate change in the Tarakan Island, as well as in the design of adaptation strategy in water sector.
- to build the capacity of stakeholders related to the vulnerability and adaptation issues in water sector, especially on the local level.
- to contribute to the database of climate change adaptation and vulnerability for the governments and stakeholders of Tarakan.
- to contribute to the guideline of mainstreaming risk analysis and adaptation options into Tarakan's current and next RPJM (2015-2019).
- as lessons learned for the national VA Guideline.

This assessment also serves as a pilot project of risk assessment in the water sector conducted in a small island, which methods, tools, and concepts can potentially be used in other islands in Indonesia with similar characteristic to the Tarakan Island.

1.4 Scope of the Assessment

The scope of this study includes activities as follow:

1. develop the conceptual framework and step by step easy to use methods for assessing climate risk on water sector and identification of data needs, based on the above methods, to be completed for the Tarakan City;
2. collection, analysis, and synthesis of the data for the water sector, which cover surface water and groundwater for Tarakan, according to the methods mentioned above;
3. analysis of climate hazards and vulnerability of the water sector for the Tarakan City, in collaboration with other experts within the scientific team;
4. synthesize climate risk for the water sector (in collaboration with the other experts within the scientific team) of the Tarakan City;
5. formulation of adaptation strategies on water sector in response to climate change for Tarakan, in collaboration with the local parliament, government and administration, and other relevant stakeholders or institutions;
6. facilitation of the mainstreaming process of the adaptation strategies into the Local Development Policies for the Tarakan City;
7. provide inputs for water sector into the climate change adaptation and vulnerability database to be used by local governments and stakeholders of the Tarakan City.

***

II. GENERAL DESCRIPTION, WATER SECTOR AND CLIMATE CHANGE ISSUES OF TARAKAN

2.1 Regional Descriptions

This section emphasizes on the general description of Tarakan, as an island and also as a city (municipal region). Here, the description consists of data and information including its location, administrative areas, and population; climate, geology, and landuse; and development, which further stresses on spatial planning. These general descriptions would be used in the analysis of assessment especially in considering its vulnerability to hazards of climate change.

2.1.1 Location, Administrative, and Population

Tarakan City is entirely an island which lies on the east of the Kalimantan mainland (Figure 2.1). Geographically, Tarakan lies between 3^{o}14'23"-3^{o}26'37" north and 117^{o}30'50"-117^{o}40'12" east. The physical boundaries of Tarakan are the coastal region of Tana Tidung district in the north and the east, the Sulawesi Sea in the east, and the coastal region of Bulungan district in the south and the west.

Tarakan City is located on an island that belongs to the small to medium-sized islands in Indonesia. It has a total area of around 657.33 km^2, which comprises of land and sea. The area for land is 250.80 km^2 (25,080 ha) or about 38.2% from its total area, and the area for sea is 406.53 km^2 (40,653 ha) or about 61.8%.

Administratively, Tarakan is divided into four sub-districts (*kecamatan*) as follows: Kecamatan (Kec.) Tarakan Utara, Kec. Tarakan Barat, Kec. Tarakan Tengah, and Kec. Tarakan Timur (Figure 2.2, *left*). The total of villages, the smallest unit of administrative, in Tarakan city is 20 villages or *kelurahan* (Table 2.1).

Table 2. 1 The distribution of villages in each district of Tarakan City

No	Sub-district	Total and names of villages or *kelurahan (Kel.*)
1.	Tarakan Utara	3 villages: Kel. Juata Laut, Kel. Juata Kerikil, and Kel. Juata Permai
2.	Tarakan Tengah	5 villages: Kel. Kampung Satu Skip, Kel. Pamusian, Kel. Selumit, Kel. Sebengkok, and Kel. Selumit Pantai
3.	Tarakan Timur	7 villages: Kel. Pantai Timur, Kel. Kampung Enam, Kel. Kampung Empat, Kel. Mamburungan, Kel. Karungan, Kel. Lingkas Ujung, and Kel. Gunung Lingkas,
4.	Tarakan Barat	5 villages: Kel. Karang Anyar, Kel. Karang Anyar Pantai, Kel. Karang Balik, Kel. Karang Rejo, and Kel. Karang Harapan

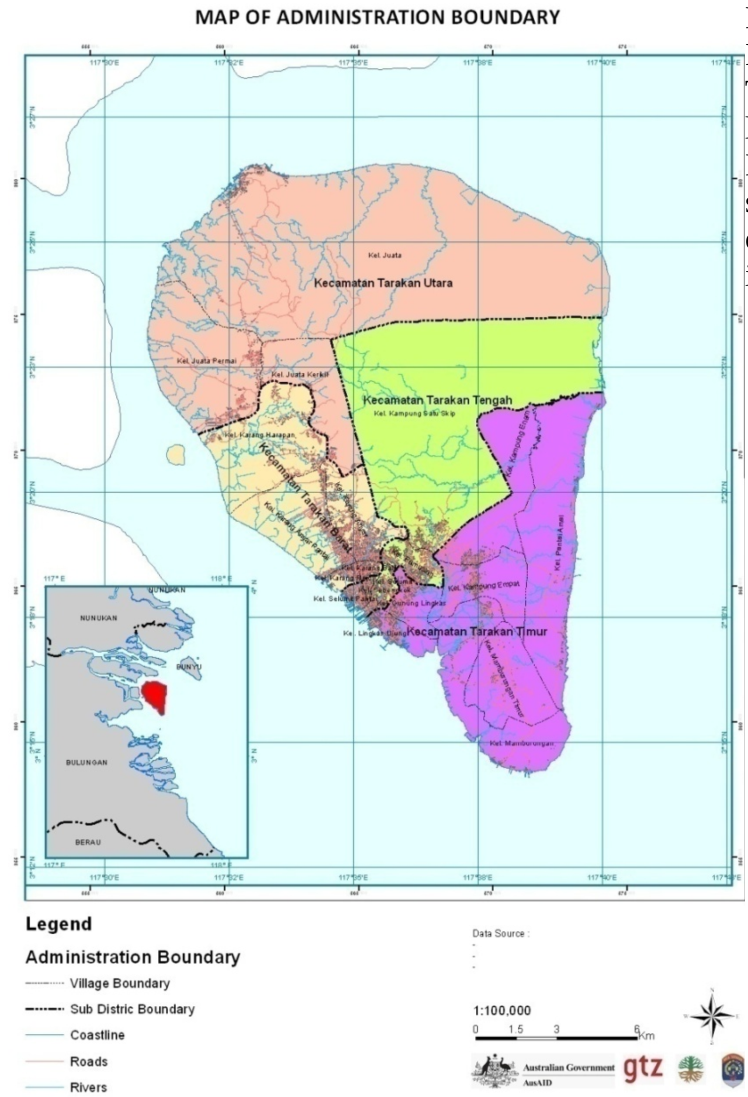

Figure 2. 1 Map of Tarakan Island (*Pulau Tarakan*), where Tarakan City (*Kota Tarakan*) is located.
Indec map (*left-lower corner*) show position of Tarakan as part of its mainland, Kalimantan island.

The total population and its distribution, density, and growth are among the important parameters in the water sector assessment. Based on the BPS (*Biro Pusat Statistik,* 2010), the total population as of 2010 is 193,069 persons with population density of 770 people/km^2 (Table 2.2 and Figure 2.3). The high population is limited in the central-western part of the Tarakan Island. The rate of population growth in 2000-2010 is 6.5%/year (*Biro Pusat Statistik,* 2010).

As shown in Table 2.2, the highest population density is in *Kec*. Tarakan Barat with 2,430 people/km^2 and the second one is in *Kec*. Tarakan Tengah with 1,087 people*/km^2*. The lowest population density with 740 people*/km^2* is found in *Kec*. Tarakan Utara.

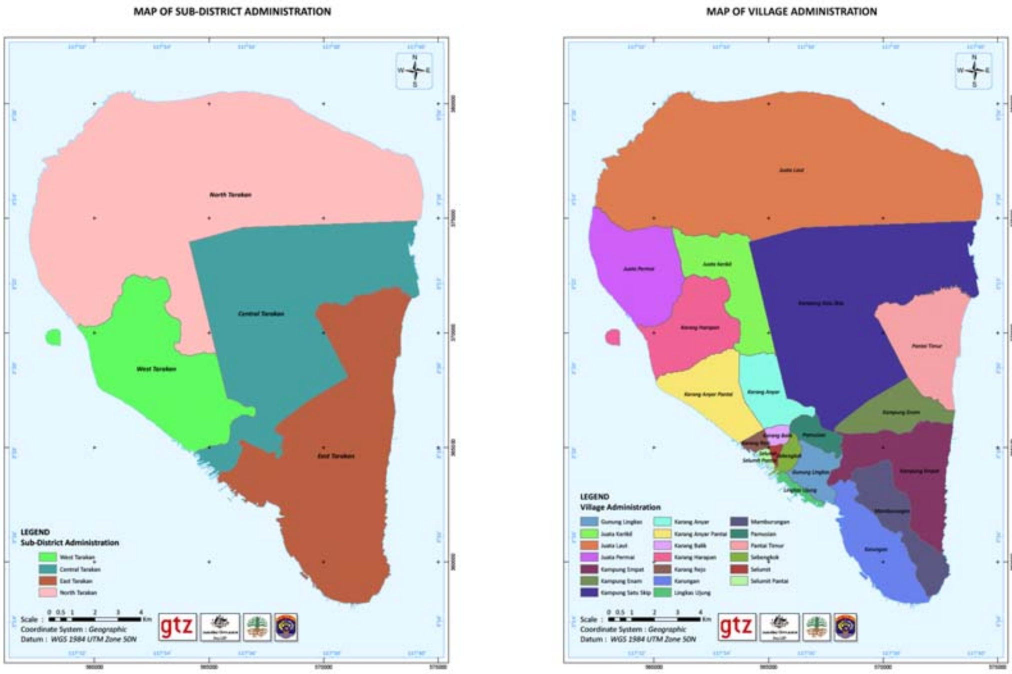

Figure 2. 2 Administrative map of Tarakan City
Devide into sub-distrcit (*kecamatan*) map (*left*), and village (*kelurahan*) map (*right*)

The pattern of population growth in Tarakan is rather different than its population density. As in Figure 2.3, the highest population growth is *Kec.* Tarakan Utara (10.81%/year in average of 2000-2010), followed by *Kec.* Tarakan Timur (average of 8.62%/year in the same periode). Meanwhile, *Kec*. Tarakan Barat and *Kec.* Tarakan Tengah are low in population growth (average of 5.24%/year and 5.36%/year, respectively, in the same periode). In total, the Tarakan City itself has higher population growth than that of national (6.50%/year vs 1.49%/year, in average, for 2000-2010 period).

The sub-district population is shown in Figure 2.4, where it shows that the highest population (> 20,000 people) in 2008 is *Kel.* Karang Anyar, while high populated areas (15,000 to 20,000 people) are *Kel.* Karang Anyar Pantai and Kel. Selumit Pantai. The lowest population (< 5000 people) is seen in *Kel.* Karungan. The others villages have population between 5,000 to 10,000 people and between 10,000-15,000 people.

Concerning the population density, the GIS team has calculated the "real" distribution. The results have been mapped and named "corrected map of population density", as shown in Figure 2.4 *(*right). Based on this map, the density is grouped into the following 5 classes: 1) low density, or ranged from 0 to 300 people/ km^2 (green colored), 2) moderately low density, or ranged from 300 to 500 people/km^2 (bright green colored) 3) moderate, density or ranged from 500 to 2000 people/ km^2 (yellow colored), 4) high density, or ranged from 2,000 to

10,000 people/km^2 (light orange colored), and 5) very high density, or ranged from 10,000 to 35,000 people/km^2 (red colored).

Table 2. 2 Population distribution & density

Kecamatan	Jumlah Penduduk	Luas Wilayah (km^2)*	Kepadatan Penduduk (jiwa/km^2)	Persebaran Penduduk
Tarakan Timur	42,909	58.01	740	22%
Tarakan Tengah	60,397	55.54	1,087	31%
Tarakan Barat	67,780	27.89	2,430	35%
Tarakan Utara	21,983	109.36	201	11%
Kota Tarakan	193,069	250.80	770	100%

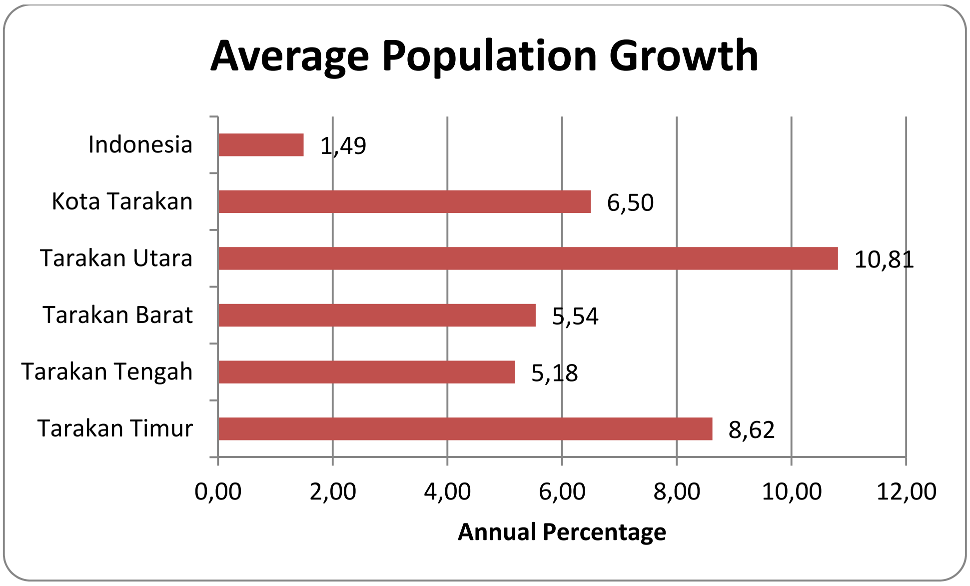

Figure 2. 3 Average population growth of 2000–2010 in each district of Tarakan City

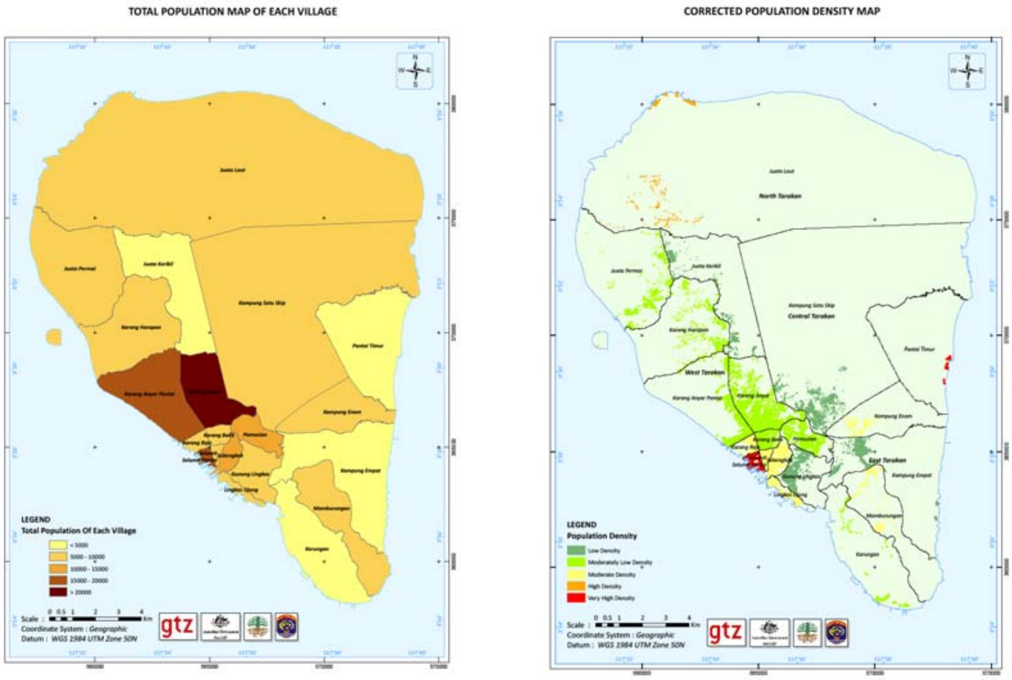

Figure 2. 4 Population map of Tarakan City
Left: total population in each village; right: population density in each village (corrected map)

2.1.2 Climate

Water sector team uses climate data from the scientific basis (SB) team. These data consist of temperature (surface temperature) data and rainfall data (Appendix 2.1). To generate such data, the SB team collected various raw climate data from at least eight sources which cover from 1900 to 2009, or more than 30 years. Hence, these climate data are reliable. By taking such data, as recommended by the SB team, water sector team uses the merged GHCN (Global Historical Climatology Network)-BMKG (*Badan Meteorologi, Klimatologi, dan Geofisika*) data for the time series of monthly rainfall data and the interpolated UDEL (University of Delaware) data for the monthly mean temperature data.

The water sector team, as the SB team does, takes the period of 1969-2009 as the baseline period. Hence, the analysis of hazards on water sector follows two climate hazards. The climate hazards are current climate hazards, as generated by the SB team as baseline climate, and future climate hazards, as outputs from their projection of rainfall and temperature changes. Below are what the SB team produced from their analysis of climate pattern and hazards in Tarakan (Hadi et al, 2010), with some additional explanations taken from the same reference:

1) Annual rainfall pattern over Tarakan has two peaks around April (338 mm monthly mean temperature or mmt) and November, with higher value of rainfall amount in

November (360 mm mmt), while February (252 mm mmt) is the driest, as well as coolest, month in a year (Figure 2.5);

2) On interannual time scale, strong El Nino events are correlated with drought, as indicated by the correlations between SPI (Standard Precipitation Index) and MEI (Multivariate ENSO Index), but the role of IOD (Indian Ocean Dipole phenomena) is likely minor or not important. However, it is interesting to note that the wettest climate in Tarakan tends to occur when both ENSO (El Nino Southern Oscillations) and IOD activities are weak. In other word, it can be said that the climate over Tarakan is the wettest during neutral phase, i.e. when both ENSO and IOD are not very active (indicated by the most positive SPI and near zero values of the indices);
3) The interdecadal variations of rainfall indicate a potential climate hazard as illustrated by data of 1960s when the decadal mean of monthly rainfall during April-August decrease by about 100 mm compared to its long-term average. Data from other places near Tarakan confirm such finding;
4) Surface monthly mean temperature, which is analyzed from the UDEL gridded data, indicates that there is an increasing trend with the rate of about 0.3 degree C throughout 1900 to 2008. The estimated rate is higher, about 0.5 degree C/100 years if calculated from 1940s. These results are comparable to the temperature trend in Indonesia from our previous studies;
5) In which flood and land-slide analyses are needed, model scenarios with extreme rainfall intensity up to 100 mm/hour can be developed. The duration of extreme rainfall events will not likely sustain for more than 2 hours.

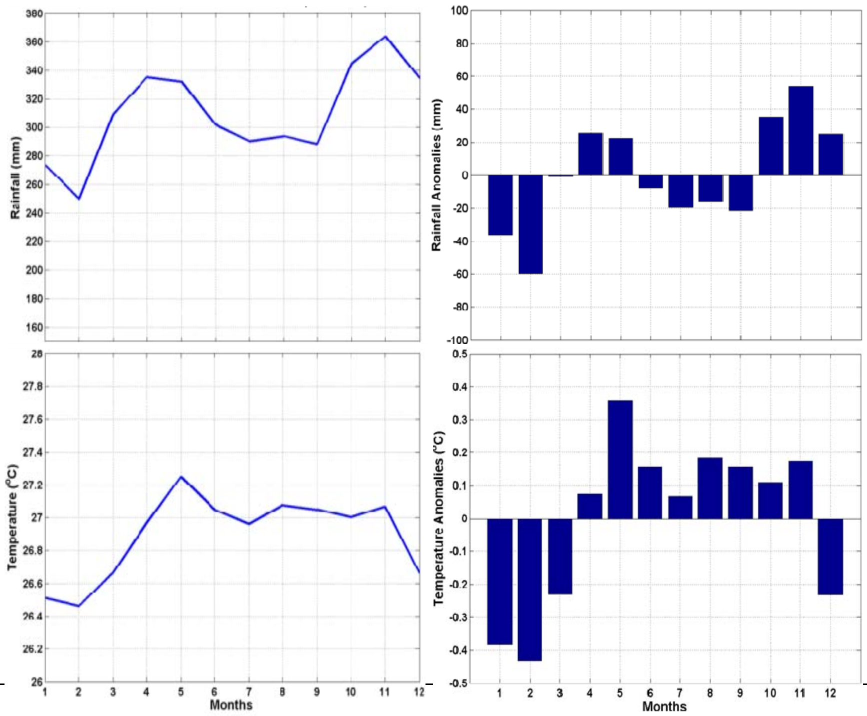

Figure 2. 5 (A) and (B) are annual patterns of rainfall and composite rainfall anomalies, while (C) and (D) are annual patterns of temperature and composite temperature anomalies, at Tarakan
(*Source*: Hadi et al, 2010).

2.1.3 Geology

Prior to the geological condition, it is important to identify the morphological condition of the site, since morphology is very closely related to geological condition. The morphology, which is the qualitative description of land form, is accompanied with quantitative description of its slopes (Figure 2.6). Furthermore, all these physical conditions will lead to the predictive condition of the hydrogeology, such as knowledge to figure the groundwater condition. The slopes condition itself would be one of the vulnerability components that are related with the climate hazards on water sector.

In general, the Tarakan Island consists of flatland or plain that surround the coastal areas and highlands, distributed from the north to the east around the middle of the island. The morphology of the site is divided into 3 (three) units as follow:

1) *Flatland or plain*. This plain is formed by coastal alluvial sediments (mud, silt, sand, gravel, and coral) located mostly in coastal areas. This morphology is relatively flat with fine relief (1-2 m), low elevation or 0-10 m above sea level (m.asl), and slope less than 5%;
2) *Wavy terrain.* This unit is formed by the Sajau Formation (quartz sandstone, claystone, siltstone, coal, lignite, and conglomerate), distributed in the western, southern, and eastern areas of the island. It is relatively flat with a rough relief between 1-5 m, medium elevation (10-25 m asl), and 5 to 10% slope;
3) *Hills*. This unit has fine to coarse relief (5-50 m) at elevation of 25-100 m asl and slope of 5% to more than 15%. It is characterized by rocks of the Sajau Formation lithologies and river flow of sub-dendritic and sub-parallel pattern and partly seasonal flow.

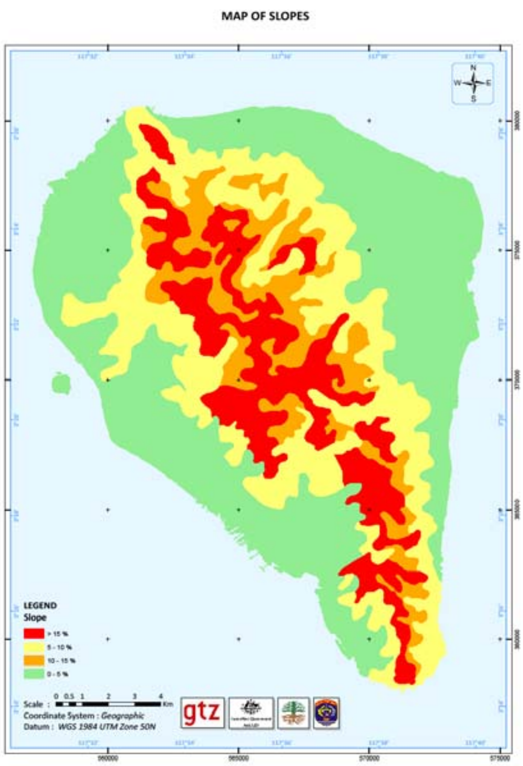

Figure 2. 6 Slope map of the Tarakan City.

In this quantitative and spatial distribution map, the slopes are divided into four groups: 1) slopes more than 15%, red-colored, 2) slopes between 10-15%, brown-colored, 3) slopes between 5-10%, yellow color, and 4) slopes less than 5%, light green-colored.

In general, the geology of the site (Figure 2.7) consists of Sajau Formation, which is older and consolidated rocks, and Alluvial unit, which is younger and mostly unconsolidated rock.

1) **Alluvium unit**. This unit consists of mud, silt, sand, gravel, and coral. The rocks are of sediment products. Over time, the coastal, rivers, and swamps depositional environment are distributed over the western and eastern of Tarakan island;

2) **Sajau Formation**. This formation consists of quartz sandstone, clay stone, silt stone, coal, lignite, and conglomerate. It is a Plio-Pleistocene-old sediment and deposited in fluvial to delta environment with a thickness of 600 - 2000 meters. It is distributed in the north, central, and southern regions of Tarakan.

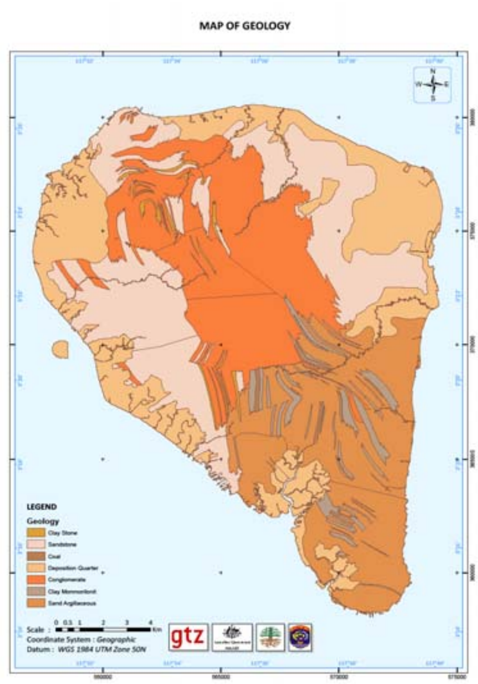

Figure 2. 7 Geology map of Tarakan.

From this map, it can be seen that the geology of Tarakan City consists of: (1) claystone, Sajau Formation (light brown-colored), (2) candstone, Sajau Formation (very light brown-colored), (3) coal, Sajau Formation (darker brown-colored), (4) quarter deposites or Alluvial units (darker orange-colored), (5) conglomerate, Sajau Formation (orange colored), (6) monmorilonite clay, Sajau Formation (darker tan-colored), and (7) Argilaceous sand, Sajau Formation (brown colored).

The geological structures of the site are bedding, faults, folds or anticline, and rock joints. In general, it consists of fault trend of the west – east dip cut anticline axis and faulted lithology of Sajau Formation. The structures of older rocks are anticline and syncline, elongated by the north to south axis direction. The rocks are strongly folded. Considering its geology, it can be predicted that alluvium rocks unit and Sajau formation can act as a productive water bearing layers (aquifers) in the Tarakan Island.

2.1.4 Land Use

Physically, changes in land use from natural area into man-made area, which often found in urban region, will reduce the infiltration capacity of surface water into the ground. These changes in land use will also be accompanied with increase in water demand, and the balance of water budget becomes greater in the demand side. Such change of land use will also increase the risk of flood events and extent the present of degraded area caused by erosion, which resulted in increasing river sedimentation. Hence, the existing land use and the prediction of its change in the future have to be considered in the assessment.

Map of land use, shown in Figure 2.8, is produced by the GIS (geographic information system) team of this study, based on data from the Bappeda of Tarakan City, 2009. In this map, the land use of Tarakan City is divided into 23 groups. Twelve of widely distributed areas of these 23 groups of land are (see Figure 2.8): 1) dense forest (dark green colored),

2) bushes (light-green colored); 3) vacant land/moore (light-pink colored), 4) fish pond (sky blue colored); 5) dry land agriculture (dark pink colored), 6) mangrove (lime colored), 7) plantation (dark red colored), 8) built up area or settlement (rose colored), 9) mixed farm (dark aqua colored), 10) swamps (blue colored), 11) water body (light blue colored), and 12) beach (light yellow colored). The rest is water dam, air port, cementary, final disposal area, navy complex, pool, port/harbor, refinery, road, and sport field.

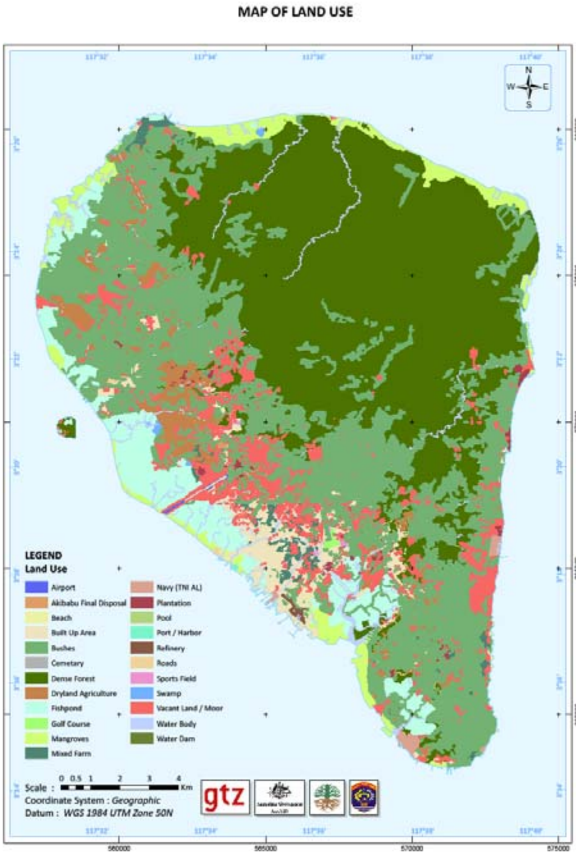

Figure 2. 8 Land use map of Tarakan City, 2010
(*Source*: GIS team)

2.1.5 Economy, Development, and Spatial Plan

Tarakan is a fast-growing region in the East Kalimantan province. This is shown in the economic profile of Tarakan City, year 2009, as follows:

- Economic structure is dominated by trade sector, which had contributed 42% of added value to gross regional domestic product (GRDP) in 2001
- Natural resources that have big contribution to the economy are fishery, oil. and natural gas, which contributed added values of 8% and 7%, respectively, to the GRDP in 2001

- Economical mean growth during the last 5 years (1997-2001) reached 5.2%, except in 1998 which had 2.2% of minus growth. Economic growths are strongly influenced by three dominant sectors; trade, fishery, and mining.
- Trade balance during the last 5 years (1997-2001) is highly in surplus. As an illustration, in 2002, export value reached US$ 67,729,218.07, while import value was only US$ 2,787,490, which means that overseas export was bigger than its foreign import. In other words, Tarakan City is one of the devisa contributors in Indonesia.

The gross regional domestic product (GRDP) of Tarakan City in 2005 was from nine income sectors, reaching Indonesia Rupiah (IDR) of 3,079,867 millions (Table 2.3).These nine sectors are: (1) Agriculture, (2) Mining, (3) Manufacture; (4) Electric, Gas, and Freshwater; (5) Construction, (6) Trades, Hotels, and Restaurants; (7) Transportations and Communications; (8) Finances, Rents, Company services; and (9) Others services. Three sectors that contribute the biggest GRDP consistently from 2002-2005 are Trades, Hotels, and Restaurant; Manufactures; and Agricultures; where, in 2005, the value of their GRDP are IDR 1,295,666.00 millions, IDR 425,341.00 millions, and IDR 305,219.00 millions, respectively.

As can be calculated from the data in Table 2.3, the growth index (GI) from these nine income sectors increased up to 420% annually in average from 2002 to 2005. Hence, it is reasonable that the regional budget of income and expenditure (RBIE or *APBD* or *anggaran pendapatan dan belanja daerah*) of Tarakan City increases year to year. For example, the RBIE in 2001 reached IDR 260,343,568,627.33 and increased up to 670% from the RBIE in 2000 (IDR 33,815,403,935.44); and in 2003 and 2004, the RBIE increased 14.18% and 22.88% from previous year, respectively. This restates that Tarakan is a fast-growing region in the East Kalimantan province.

The service and industry sectors in Tarakan play a very important role because of its contribution to high regional incomes. These are shown by trades, hotels, and restaurants and manufactures as two of the greatest contributors to the GRDP. Also, finances, rents, and company services, as well as mining sector, which are the second greatest contributor to the GRDP, confirm that service and industry sectors are the most important sector of economy in Tarakan City.

Table 2. 3 Gross regional domestic product (GRDP) and growth index (GI) based on price in the field sector incomes of Tarakan City 2003-2005

(*Source*: Tarakan in numbers, 2009)

Year / Income sector	2002		2003		2004		2005	
	GRDP*	GI (%)	GRDP*	GI (%)	GRDP*	GI (%)	GRDP*	GI (%)
Agricul.	193,361	145	219,969	165	233,553	175	305,219	229
Mining	107,792	115	108,919	116	105,667	113	218,916	234
Manufac	252,863	155	309,263	190	372,873	229	425,341	261
EGF	32,079	179	34,809	194	41,732	233	55,642	311
Constr.	80,610	337	105,054	439	125,952	527	136,046	569
Trades, Hotel & Rest.	794,603	142	932,617	167	1,008,267	180	1,295,666	232
Trans. & Commu.	161,245	155	185,285	178	208,695	201	260,410	251
Finances, Rent, Comp. services	147,131	114	156,045	121	192,115	148	221,277	171
Others services	64,509	230	80,993	289	102,765	366	161,350	575
Total	1,834,193	1,573	2,132,954	1,860	2,391,619	2,173	3,079,867	2,832

Notes:

- ** in million IDR*
- *number for GI is integered; Agricul. = agricultures; Manufac. = manufactures; EGF = Electricity, Gas and Freshwater; Constr. = construction; Rest. = restaurants; Trans. = transportation; Commu. = communication; Comp. = company*

According to the development plan of Tarakan City, service and industry sector have been targeted to be the main sectors of Tarakan's development. These developments, besides absorbing many labors and contribute high income, increase the utilization of space as well as consuming a significant amount of water resources in Tarakan City. To anticipate the uncontrolled land use in the developments, the government of Tarakan City has arranged a new spatial pattern plan (Figure 2.9) for the 2009 to 2029 period. As shown in Figure 2.9, the allocated space for industrial sector in the 2009-2029 period is high and become the second largest allocation after the allocated space for conservation areas.

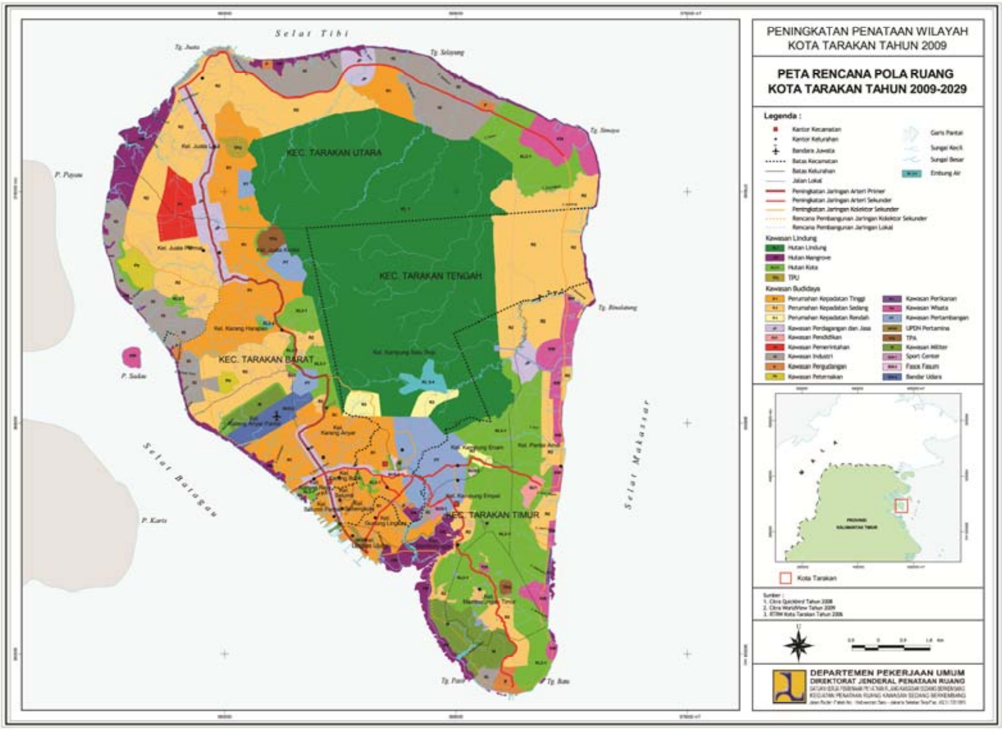

Figure 2. 9 Map of 2009-2029 spatial pattern plan of Tarakan City.
It is shown in the map that industrial areas (*kawasan industri*, dark violet colored with “IG” symbol) together with mining areas (*kawasan pertambangan*, grey colored with “KP” symbol) are the second largest of allocated space after conservation areas (*kawasan hutan lindung* & *kawasan hutan kota*, dark green colored with “KL 1” symbol and light green colored with “KL 3-1” symbol respectively) in the 2009-2029 period

2.2 General Description of Water Sector

Description of water sector is important for providing information on current water resources including its quantity and quality, spatial and temporal distribution, and utilization; problem on water resources, including current hazards and vulnerability; and strategic issues on water sector in Tarakan city. This water sector description is produced on the basis of field observation data and results of previous studies (secondary data). The data from field observation are used to update the secondary data. The previous studies concerning water sector of Tarakan city are:

1) Hydrogeological mapping of Indonesia, 1:250,000 scale, sheet 1919-1920, Tarakan and Sebatik, P. Borneo, by Center for Environmental Geology (CEG), Geological Agency (GA), 2009;
2) Environmental status report, year of 2009 by Environmental Management Agency, Tarakan City, 2009;
3) Compilation of data and information on ground water basin Tarakan City by Office of Forestry, Mining, and Energy, Tarakan City, 2010;

4) The final report of water conservation study in Tarakan City, East Kalimantan by Agency of Environmental and Natural Resources, Tarakan City, 2008;
5) The final report preparation of the master plan study of drinking water resources 2007-2027 by Bappeda Tarakan City, 2008;
6) Inventory of environmental geology of urban region in Tarakan, East Kalimantan Province by Center of Geological Environment (CGE), Geology Agency (GA), Ministry of Energy and Mineral Resource (MEMR), 2005;
7) Investigation of geological engineering to support development of city by Office for Forestry, Mining and Energy, Tarakan City, 2010.

The water sector team has conducted twice field surveys, the first survey (1) was conducted between September 26 to September 28, 2010 and the second survey (2) was conducted between October 26 and October 28, 2010. The purpose of this survey was to confirm and collect the available data of water resource, for both surface water and groundwater of Tarakan City, by updating the secondary data directly from the field. Activities conducted during this survey were field checks, focus group discussion, and interviews.

The work scope of this field survey are pointing the location of water resources including spring, dug well, bore hole, reservoirs (*embung*) and dam; and observation of flood locations, river sedimentation, and water supply facilities. The field work also included observation of water table in dug wells and bore holes; and water sampling for chemical and physical analysis of groundwater. Based on data from previous study and the updated data from field observation, the description of water sector of Tarakan city includes surface water, groundwater, and utilization of water resources.

2.2.1 Surface Water

In general, the type of rivers in Tarakan is intermittent rivers, which means dry or low flow in the dry season; and abundant flow to flood in wet season. While the pattern of river flows mostly are semi-radial in the northern center of the island and parallel for some regions in the east, south-east, and west (Figure 2.10). Several big rivers (*sungai*) in Tarakan are correlated with dense forests, i.e. *sungai* (S.) Binalatung, S. Pamusian, S. Kuli, S. Bengawan, S. Raja Alam, and S. Kampung Bugis. The river discharge ranges from 19 to 290 liters/second or 0.019 to 0.29 m^3/second.

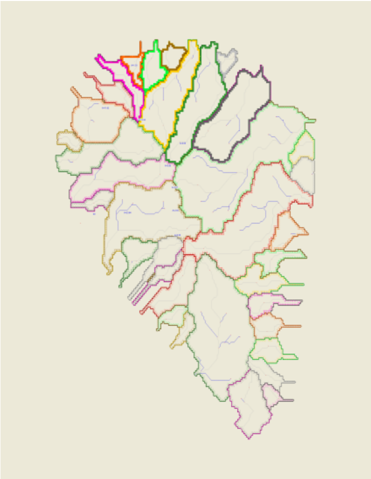

Figure 2. 10 **Map of surface water and watershed in Tarakan (Source: GIS Team, 2010).**

In some rivers, reservoir or *embung* is developed as reservoir of source for water supply of Tarakan City. The source of water in the reservoir is from river flow and rainfall. The capacity of the reservoir varies from 0.155 m^3/second at the nursery area, 0.006 m^3/second in Kampung Bugis, and 0.030 m^3/second in Juata Laut.

High rainfall and physical properties of soil of many vacant lands make these lands easily eroded, causing high sedimentation in some rivers. The quality of the water from the rivers is good enough and can be consumed after treated using activated carbon and filtering. Swamps located in low lands store a noticeable quantity of water. The water of these swamps is acid so it is not suitable for the source of drinking water.

2.2.2 Groundwater

Groundwater fills pores or fissures inside rock. Rock layers or rock formations that are able to store and drain water (groundwater) in valuable amount is called “aquifer”. The aquifer system of Tarakan City is divided into two groups:

- aquifer system which flows through spaces between its grains (pores). This aquifer system is found in rock formation which lithologically consists of alluvial deposits or loose sediments of coarse material such as coarse sand or gravel to fine material. The permeability of this aquifer system ranges from 0.092 to 0.225 m/day. These aquifer systems are distributed on lowlands with an elevation of less than 50 meters above mean seal level (m.asl).
- aquifer system which flows through spaces between it grains (pores) and fractures. This aquifer system is from the Sajau Formation, with its main constituent materials are quartz sand and conglomerate. The permeability of this aquifer ranges from 10 to 102 m/day and it is distributed over the hills undulating in the middle of Tarakan City.

These aquifers systems consist of unconfined aquifer and confined aquifer, and spring as appearance of groundwater flow at surface. Below are resumes of these three points of view of groundwater in Tarakan City:

1) **unconfined aquifers** are characterized by the position of water table that is observed through the measurement of shallow groundwater in dug wells. Its position nearly follows the local topography. Groundwater position in this morphology varies between 2 to 20 m.bls (meters below local ground surface) with static groundwater level stands at 0.15 to 14 m.blg. Meanwhile, the position of static groundwater level in undulating hills could reach 14 m.bls. Water table of groundwater deepens in areas with higher elevation and shallower in areas with lower elevation. In the lowlands, the groundwater is generally found in the swamp environment that lithologically consists of loose materials of mud, peat, clay, and fine sand. The quality of groundwater is generally poor, reddish yellow, acidic with pH less than 5 and in some location contains relatively high Fe^{+3}. In plains morphology, groundwater is extracted through dug wells.

2) **confined aquifers** are characterized by the water table position (piezometric) of groundwater that is quite shallow. In limited areas, there is self-flowing groundwater from artesian wells. The depth of this aquifers ranges from 19.16 to 25.98 m.bls. Groundwater pressure is greater than atmospheric pressure and the boundary of aquifer, both at the top and the bottom, is impermeable layers of rock. The distribution of groundwater is quite extensive over plateau in the central part of Tarakan Island in a compact rock of Sajau formation, and lies beneath alluvium layers. Groundwater positions from borehole are generally shallow and in some areas are above local ground level (self-flowing). It’s possible to find groundwater in the depth of high elevation of undulating hills.

3) **springs** are produced from the intersection between an aquifer and ground surface. Springs are found at an elevation of 25-50 meters above mean sea level (m.asl) in undulating terrains where the lithology is dominantly consists of pebbly sand of Sajau formation. The type of springs is mostly depression spring in the form of seepage with a small discharge of 0.01 to 0.25 liters/second (l/sec).

Figure 2. 11 Map of Potential Groundwater of Tarakan (Source: CEG, GA, 2009).

Map of potential groundwater in Tarakan is presented in Figure 2.11. Based on Figure 2.11, there are only two types of potential groundwater in the Tarakan Island. The first is low potential groundwater, which is distributed mostly in high topography. The second is moderate potential groundwater, which is distributed over plain areas. No high potential groundwater in the Tarakan Island.

2.2.3 Water Availability

The primary sources to fulfill daily water demand in Tarakan City are surface water, groundwater, and a small portion supplied from rain water that is used directly. Some engineering treatments and processes are applied to develop these primary resources to gain suitable water sources, especially for drinking water (secondary resources), such as tap water or piping water (in *bahasa*: *air ledeng*), and bottled water (in *bahasa*: *air dalam kemasan*). Hence, water for all daily use in Tarakan City is in fact in the form of surface water (river, swamp, pond), groundwater (dug well, drilled hole, tapped spring), tap water, bottled water, and rain water (direct use).

Furthermore, this report will present results on general water availability (water quantity) of surface water and groundwater using water balance method and compare it to similar water availability gained from secondary data (previous related study from Tarakan City officials). As an important secondary source of water supply, especially fresh water supply, this report will also present short review on water tap or piping water produced by the local government company (*PDAM* of Tarakan City). Meanwhile, other secondary resources, including rain water, tap water, and bottled water, will be elaborated more completely in Sub-chapter 2.2.5.

Surface water and groundwater availability

Based on the water balance analysis, using climate data as in Appendix 1, it is calculated that the total water availability in Tarakan Island reached 711.04 x 10^6 m^3 every year in 1951-2009 period. This water comprises of 219.5 x 10^6 m^3 per year of groundwater and 491.9 x 10^6 m^3 per year of surface water in the same period (see: Appendix 2). This is the result on the water availability based on the water balance method in this study.

Based on the water balance analysis from secondary data of available reference (the final report preparation of the master plan study of drinking water resources 2007-2027 by Bappeda of Tarakan City, 2008), the total groundwater in Tarakan City is 1,491,022.08 m^3 (1,5 x 10^6 m^3) per year. There is no data on the quantity of surface water calculated using water balance method in the report.

Compared to preliminary result of annual groundwater availability of this study (219.5 x 10^6 m^3), it is clearly seen that annual groundwater availability from the secondary data (1,5 x 10^6 m^3) is too small. By looking into precipitation data that was used in the secondary data of water availability, it can be seen that these precipitations are too small and look like monthly precipitation data. Therefore, the 1,5 x 10^6 m^3 of total groundwater is perhaps monthly–and not annual–available groundwater of Tarakan City.

Fresh water supply of PDAM

Fresh water supply for Tarakan City is managed by the Regional Water Company (PDAM). Raw water or water sources used by the PDAM are surface water, spring, and groundwater. The surface water is taken from four rivers, Semunti river, Persemaian river, Kampung Bugis River, and Binalatung River (Table 2.4). The total springs and dug wells, which are extracted from shallow groundwater, reaches up to 378 locations, where 162 locations among them are extracted by hand pumps.

Table 2. 4 Rivers as sources of water and the capacity of water treatment plants of PDAM

Watershed/River	Water Treatment Plant (WTP)	Watershed Area (Km^2)	Discharge (m^3/second)	WTP Capacity (m^3/second)
1. **Semunti**	Juata Laut	8,976	0.784	0.035
2. **Persemaian**	Persemaian	14,779	1.290	0.155
3. **Kampung Bugis**	Kampung Bugis	5,641	0.493	0.120
4. **Binalatung**	Kampung Satu	22,591	1.973	0.090
Total	4 WTP's	51,987	4.530	0.400

Note: m^3/sec = m^3/second, ltrs/sec = litres/second
Source: modified from PDAM of Tarakan, 2007.

The total capacity of water supply (discharge) of the PDAM in 2007 reached 4.530 m^3/second (see Table 2.4) or 391,392 m^3/day. In the same year, the available capacity of WTP (water treatment plant) of PDAM, as shown in Table 2.4, was 0,400 m3/second or 400 litres/second or 1,440 m^3/day; while production capacity was 305 liters/second (not listed on the table). Hence, 95 liters/second (24% of the capacity) was not used.

2.2.4 Groundwater Quality

Based on result of the study of groundwater conservation, 2008, the physical properties of groundwater generally fulfilled the drinking criterion, which are tasteless, odorless, normal color, and normal clearness. The chemical properties of groundwater include pH, salinity, total dissolved solids (TDS), and electrical conductivity (EC). The pH value is varied and generally doesn't fulfill the drinking criterion (pH < 6.5). The EC value generally fulfills the criterion and the TDS value also fulfills the normal limit to be consumed (<1500 mg/L).

In general, the condition of groundwater in Tarakan can be classified as Bicarbonate (HCO^3) Magnesium (Mg) class, based on laboratory analysis with the Kurlov method. The Bicarbonate Calcium class is found around the sea shore. The Sulfate Magnesium class is found in springs on Tarakan Utara. The Chloride Calcium class is found in springs on Tarakan Timur. The Bicarbonate Nitrate class is found in Mamburungan, Tarakan Timur. The dominant proportion of cation shows that the aquifer is formed by ground materials with varied composition of magnesium. Analysis through the groundwater piper trilinier diagram shows three groundwater groups of origin in Tarakan:

- the Ca+Mg, $Cl+SO_4$ group, which shows that the springs are originated from ground origin material with sea sedimentation environment, but no sea water intrusion. This group is found in various springs relative to the center of Tarakan, while on dug wells, it is found in places near the coast.
- the Ca+Mg, HCO_3 group, which shows that the springs are originated from ground origin material with fluvial sedimentation environment, but no sea water intrusion. This group can be found in various springs on northern and southern Tarakan, while the dug wells can be found on the central Tarakan.
- the Na+K, $Cl+SO_4$group, which shows that the groundwater has been replaced by sea water, meaning that sea water intrusion is taking place. This group is found in drilled wells on the sea shore of Tarakan Timur.

Ten groundwater and surface water samples were taken from the field (Tarakan island) in this study. Field data of the samples are presented in Table 2.5 and pictures of some locations of the sample are shown in Figure 2.12.

Table 2. 5 Coordinate and others field data of groundwater/surface water samples

No	Code [1)]	Type [2)]	Coordinate		Elev (m) [3)]	Water Table (cm) [4)]	Remarks
			X	Y			
1.	115	Dugwell	572965	366571	4	50	-
2.	118	Dugwell	573663	371310	9	64	-
3.	123	Dugwell	566116	367457	16	125	-
4.	125	Dugwell	565981	367329	28	77	-
5.	128	Pond	562964	371033	20	80	60 m depth,PDAM's source
6.	131	Flowing well	561216	368609	7	-	Debit: 800 liters/second
7.	132	Dugwell	562242	369305	8	280	-
8.	135	Dugwell	570114	358511	4	-	-
9.	143	Borehole	571455	358088	18	-	22 m depth, coastal region
10.	144	Borehole	571360	358431	10	-	30 m depth, coastal region

Notes:
1) Code = sample code for laboratorium analysis; 2) Type = types of water samples; 3) Elev = elevation in meter above mean sea level; 4) Water table = depth of water table in centimeter (cm) from ground surface.

Figure 2. 12 Location pictures of some water samples:
Sample code 118 (*above left*), sample code 125 (*above right*), sample code 131 (*below left*), and code 128 (*below right*).

Those ten samples then tested in Water Laboratory of Environmental Engineering of ITB, Bandung and the results are showed in Piper diagram as presented in Figure 2.13. Based on the Piper diagram (Figure 2.12), it shows that most of the groundawater samples have HCO^{-3} and Cl^{-} as the dominant anion which is correlated with the water flow from upper zones to lower zones in the Chebotarev sequence. Ranging from 5 to 127.6, HCO^{-3} has indicated that water in the upper zones is where the most important acid produced. Ranging from 4.14 to 85.99, higher Cl-, with higher total dissolved solids, indicated that water in the lower zones is close to seawater.

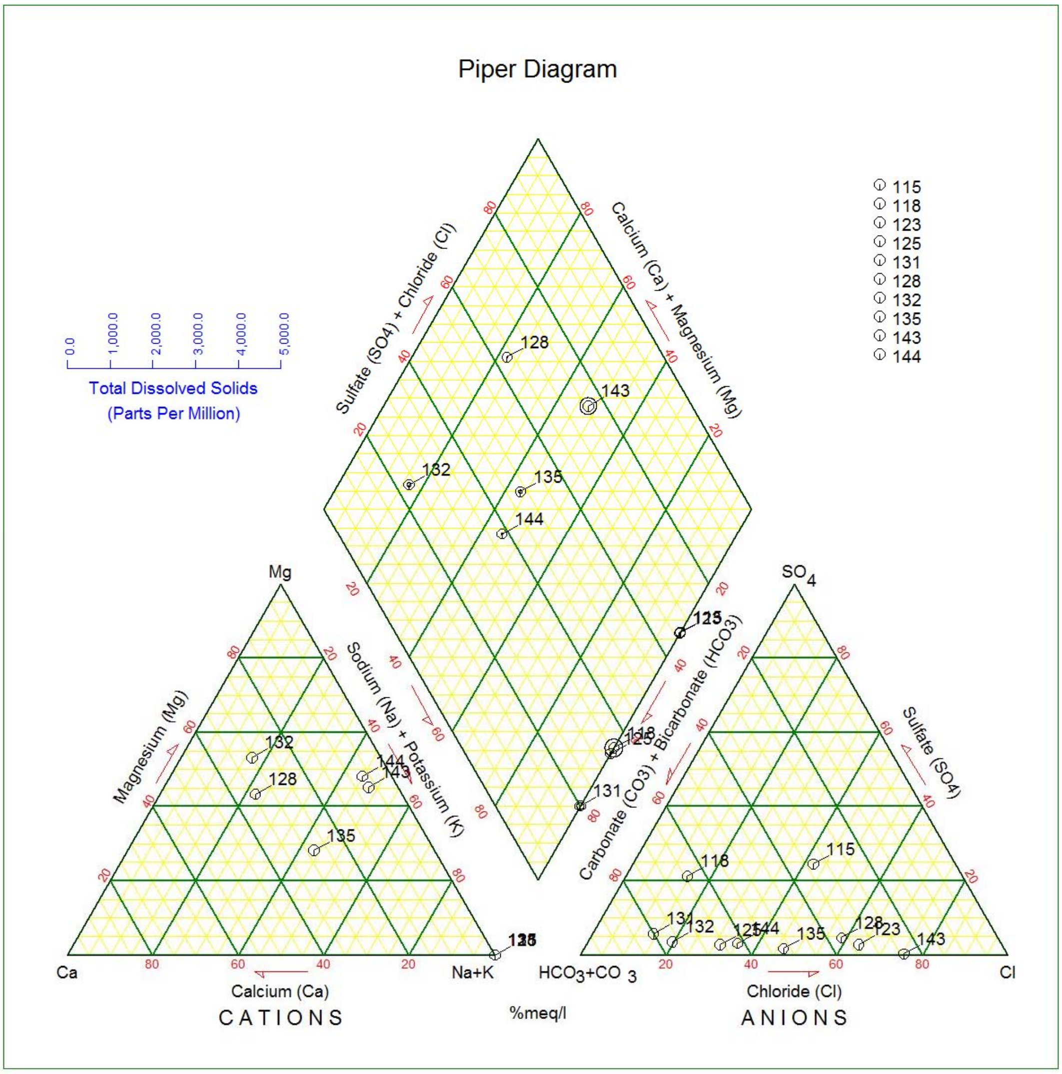

Figure 2. 13 Piper diagram for 10 groundwater samples of Tarakan, which were tested in this study, shows the majority of groundwater contain high chloride.

2.2.5 Water Utilization, Water Need, and Water Budget

Water Utilization

The water utilization in Tarakan can generally be divided into three sectors: domestic, non-domestic and industry. No existing references (secondary data) directly calculate the annual total water used by the three sectors. However, there is secondary data from the officials of Tarakan City that calculated the water need in year 2008 using different user of sector components, which are domestic, non-domestic, and industry. This water utilization calculation is shown below (Table 2.6).

Table 2. 6 Tarakan City water need, 2008

Sub-district	Water need in 2008 (m^3/year)			
	Domestic	Non-domestic	industry	Total
Tarakan Timur	254,923.00	4,995,207.50	5,740,100.96	
Tarakan Tengah	389,489.00			
Tarakan Barat	387,873.00			
Tarakan Utara	124,094.00			
TARAKAN	1,156,379.00	4,995,207.50	5,740,100.96	11,891,688.00

Source: Bappeda Tarakan, 2008

Based on the above table, in 2008, the Tarakan City used water as much as 11,891,688.00 m^3/year, which consists of domestic, non-domestic, and industry usage of 1,156,379.00 m^3/year; 4,995,207.50 m^3/year, and 5,740,100.96 m^3/year, respectively. Data from the above table also shows that the water usage of domestic sector is the highest in *kecamatan* Tarakan Tengah (389,489.00 m^3/year) and Tarakan Barat (387,873.00 m^3/year).

To learn about the annual water usage from domestic and industry sectors, and also as early steps of calculating the water usage or water need, this study calculates the water need based on population, non-domestic, and industrial data from 2008, or assumes that the data still valid in 2008 for each sectors (population, land type and area, and industry). The results are then compared to the water usage per *kecamatan* of 2008, obtained from the secondary data.

Assumptions used in this study for calculating the total water used in Tarakan, 2008, are:

- for domestic usage: (1) data of total inhabitants (water users), uses data from BPS, 2006, where, according to the reference, the total inhabitants as water users is 176,009 person; (2) inhabitants as water users in Tarakan are then divided into two groups: 70% from urban and 30% from rural; (3) standard use of water are 125 litres/day/person, minimum, and 150 litres/day/person, maximum, for city inhabitants and 40 litres/day/person, minimum, and 60 litres/day/person, maximum, for village inhabitants; (4) 30% of the total domestic users, or 2,370,577.22 m3/year, is addressed as major public water usage system that added to the domestic usage;
- for non-domestic usage: (1) There is only two commodities considered, which are corn and mix farming; (2) the standard water use for corn is, 2.5 mm/day, minimum, and 3.2 mm/day, maximum; and the standard water use for mix farming is 2.5 mm/day, minimum and 3.0 mm/day, maximum (*Source*: Dr. Ruminta, agriculture expert in this study); (3) in one year, 180 days is used for the corn farming and mix farming;

- for industry: (1) The data used are for 7 large industries, 61 medium industries, and 1,505 small industries (BPS, 2006); (2) the standard water consumptions are: a) 225 m3/day/unit industry, minimum, and 1,350 m^3/day/unit industry, maximum, for large industry; b) 12 m3/day/unit industry, minimum, and 97 m^3/day/unit, maximum, for medium industry; and c) 1.6 m3/day/unit industry, minimum, and 57.6 m^3/day/unit industry, maximum, for small industry; and (3) there is 365 days in one year of operational for each industry.

Based on the 2008 data in the assumption mentioned above, the total amount of water usage in Tarakan in 2008 was supposedly reach 18,135,525.58 m^3 per year in minimum and 57,819,643.46 m^3 per year in maximum or 37,977,585.52 m^3 per year in average (see Table 2.7). The total water usage comprises of (minimum-maximum) 8,017,550.58 to 10,272,488.48 m^3/year for domestic use; 8,397,000.00 to 10,297,080.00 m^3/year for non-domestic use; and 1,720,975.00 to 37,250,075.00 m^3/year for industry use (Tabel 2.8, Table 2.9, and Table 2.10).

Table 2. 7 Tarakan City water need for 2008, results are from the approach of this study

No	Sector	Total water usage (m^3/year)		
		Minimum	Maximum	Average
1.	Domestic / Municipal	8,602,163.05	10,272,488.46	9,437,325.76
2.	Non-domestic	8,397,000.00	20,297,080.00	9,347,040.00
3.	Industry	1,720,975.00	37,250,075.00	19,485,525.00
Total water usage (m^3/year)		18,720,138.05	57,819,643.46	38,269,890.76

Table 2. 8 Tarakan City water usage for domestic sector, 2008, results of this study

No	Domestic type	Total (person)	Standard Water Need (ltrs/day/person)		Total water usage (m^3/year)	
			Min	Max	Minimum	Maximum
1.	City (30%)*)	123,206	130	150	5,846,124.70	6,745,528.50
2.	Sub-district (70%)*)	52,803	40	60	770,923.80	1,156,385.70
3.	Major public water use system (30%)**)	-	-	-	1,985,114.55	10,272,488.46
Total water usage of domestic (m3/year)					8,602,163.05	10,272,488.46

Note:
*) % is percentage of total water user (total inhabitant)
**) percentage of total domestic use (= 30% x (total no 1 + no 2)

Table 2. 9 Tarakan City water usage for non domestic sector, 2008, results are from the approach of this study

No	Non-domestic use	Total Area (ha)	Standard Water Need (mm/day)		Total water usage (m^3/year)	
			Min	Max	Minimum	Maximum
1.	Corn	613	2,5	3.2	2,758,500.00	3,530,880.00
2.	Mix farm	1,253	2,5	3.0	5,638,500.00	6,766,200.00
Total water usage of agriculture (m3/year)					8,397,000.00	10,297,080.00

Note: 1 year = 180 day

Table 2. 10 Tarakan City water usage for industry sector, 2008, results are from the approach of this study

No	Type of Industry	Total (unit)	Standard Water Need (m^3/unit/day)		Total water usage (m^3/year)	
			Min	Max	Minimum	Maximum
1.	Large industry	7	225.0	1,350,0	574,875.00	3,449,250.00
2.	Medium industry	61	12.0	97,0	267,180.00	2,159,705.00
3.	Small industry	1,505	1.6	57.6	878,920.00	31,641,120.00
Total water usage of industry (m^3/year)					1,720,975.00	37,250,075.00

Note: 1 year = 365 day

It is interesting to compare the data of water usage in Tarakan City in 2008 between the results from the secondary data (Table 2.6) and the calculation results from this study (Table 2.7, 2.8, 2.9 and 2.10). By ignoring the parameter of the different water users (in the secondary data, the three water users are domestic, non-domestic, and industry; while this study uses domestic, agriculture, and industry), a few aspects can be compared:

- the total water used is significantly different, 38,269,890.76 m^3/year (the average value from this study) and 11,891,688.00 m3/year, from secondary data. Closer values are obtained when the minimum value from this study is used instead, resulting in an average of 18,720,138.05 m^3/year, compared to the secondary data of 11,891,688.00 m^3/year;

- the water usage for domestic sector differs quite more significantly, which is 8,602,163.05 m^3/year, minimum, or only 6,617,048,50 m^3/year if the calculation only includes water usage from the population of cities and villages, compared to 1,156,379.00 m^3/year from the secondary data. The difference becomes larger when the calculation uses the maximum values of usage;

- the water usage for industry sector are also differs largely, especially when the secondary data (5,740,100.96 m^3/year) is compared to the maximum value of calculation (37,250,075.00 m^3/year). However, the usage from the secondary data is still inside the range of minimum-maximum values of this study (1,720,975.00 m^3/year to 37,250,075.00 m^3/year). In other words, the secondary data can be used to obtain the standard water usage approach for industry in Tarakan City.

In this Sub-sub-chapter, it is useful to look into the profile on how the people in Tarakan fulfills their daily water need; or how the profile of water sources used by households (Tabel 2.11 and Figure 2.14). Based on Table 2.11, the profile includes: 1) bottled water, 2) drinking water companies, 3) water pumps, 4) protected wells, 5) unprotected wells, 6) protected springs, 7) unprotected springs, 8) rivers, and 9) rain water.

Bottled water is purified water which is them inserted into bottles in various sizes. It is primarily used as drinking water, also known as (in bahasa) "*Air Minum dalam Kemasan* (AMDK)". For household needs, *galon*-sized bottled water is commonly more used (in bahasa: "*air galon*"). Based on the field surveys, the primary resource in water treatment for bottled water is groundwater, extracted by pump wells.

Table 2. 11 Sources of water used by households, 2008

(*Source*: Bappeda, 2008 with modification)

No	Source of used water	Number of households	%
	Bottled water	989	3.6%
	Drinking water company	6,984	25.3%
	Pump	61	0.2%
	Protected well	1,349	4.9%
	Unprotected well	743	2.7%
	Protected spring	490	1.8%
	Unprotected spring	184	0.7%
	River	123	0.4%
	Rain water	16,659	60.4%
Total		27,582	100.0%

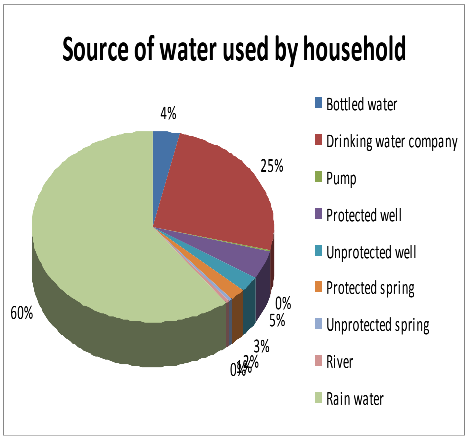

Figure 2. 14 Sources of water used by households
(*Source*: Master Plan of Drinking Water, Bappeda of Tarakan, 2008)

Note:

- *No notes in the reference for total people or persons in each household. In practice, there are generally 5 people in each household*
- *Based on the field surveys, the primary resources for bottled water are groundwater, which is extracted by pump well*
- *Drinking water company = PDAM*
- *Protected wells and unprotected wells are dug well*
- *Protected spring is tapped spring*

Based on Table 2.11, the greatest source used by households in Tarakan is rain water (60.4% of 27,582 inhabitants surveyed). Next is from the drinking water company (25.3% of 27,582 people). From the table, also noticeable that bottled water is almost as important as protected wells, as the source used by households in Tarakan, and exceed the use of unprotected wells, since bottled water are used by 3,6%; protected wells used by 4,9%; and unprotected wells used by 2,7%; of 27,582 people, respectively.

Water Need

Based on the 2007-2027 final report preparation of the master plan study of drinking water resources by Bappeda of Tarakan City (2008), the water needs of Tarakan was projected until 2013, 2018, and 2033. There are four assumptions used on that calculation, which are population growth, water demand for domestic, non-domestic, and industry. The value of population growth assumed on that calculation was 7.35%. Basically, each person needs water around 80 liter per day. Water demand for non-domestic was about 30% from the domestic, and water demand for industry is about 35% from the domestic.

The following Table 2.12 to Table 2.14 are the scenarios or projections of water need for Tarakan City in 2013, 2018, and 2033, based on the study of Bappeda (2008) using the assumptions mentioned above:

Table 2. 12 Projections of water need for Tarakan City in 2013

Sub-district	Water need in 2013 (m^3/year)			
	domestic	non-domestic	Industry	Total
Tarakan Timur	1,701,199.30	510,359.79	425,299.83	2,636,858.92
Tarakan Tengah	2,466,667.45	740,000.27	616,666.77	3,823,334.49
Tarakan Barat	2,748,517.53	824,555.08	687,129.29	4,260,201.89
Tarakan Utara	1,007,634.70	302,290.45	251,908.77	1,561,833.91
TARAKAN	7,924,018.97	2,377,205.58	1,981,004.65	12,282,229.20

Source: Bappeda of Tarakan, 2008

Table 2. 13 Projections of water need for Tarakan City in 2018

Sub-district	Water need in 2018 (m^3/year)			
	domestic	non-domestic	industry	Total
Tarakan Timur	2,425,299.81	727,589.91	423,824.86	3,576,714.57
Tarakan Tengah	3,516,583.01	1,054,974.83	879,145.57	5,450,703.41
Tarakan Barat	3,918,399.83	1,175,520.10	979,600.14	6,073,520.07
Tarakan Utara	1,436,525.76	430,957.69	359,131.53	2,226,614.98
TARAKAN	11,296,808.40	3,389,042.52	2,641,702.10	17,327,553.02

Source: Bappeda of Tarakan, 2008

Table 2. 14 Projections of water need for Tarakan City in 2033

Sub-district	Water need in 2033 (m^3/year)			
	domestic	non-domestic	industry	Total
Tarakan Timur	7,027,424.21	1,756,855.96	1,756,855.96	10,541,136.13
Tarakan Tengah	10,189,469.94	2,547,367.49	2,547,367.49	15,284,204.91
Tarakan Barat	11,353,753.88	2,838,438.56	2,838,438.56	17,030,631.00
Tarakan Utara	4,162,403.06	1,040,600.77	1,040,600.77	6,243,604.59
TARAKAN	32,733,051.08	8,183,262.77	8,183,262.77	49,099,576.62

Source: Bappeda of Tarakan, 2008

From the secondary data, it can be seen that the projections of water need until 2033 (49,099,576.62 m^3/year) doesn't exceed the calculation result of this study on the maximum water usage of 2008 (57,819,643.46 m^3/year).

In this report, water needs projections are not calculated yet. The early identification of water usage in 2008 and the projections of water need from the secondary data will be used as inputs to calculate the projections of water need.

Water Budget

Based on the water usage and water need data, also from the water availability data of Tarakan City, the early identification of water need and availability can be presented. By taking the 2008 data and the projections for 2013 and 2018 from the secondary data, and also from the water availability data calculated, it can then be compared between water need and water availability, as shown in Table 2.15 below.

Table 2. 15 Projections of water need in Tarakan City for 2033

No	Sub-district	Water Utilization/Water Need (m^3/year) [1)			Water Availability (m^3/year) [3)
		2008	2013	2018	
1.	Tarakan Timur	- [2)	2,636,858,92	3,576,714.57	[4)
2.	Tarakan Tengah	- [2)	3,823,334.49	5,450,703.41	[4)
3.	Tarakan Barat	- [2)	4,260,201.89	6,073,520.07	[4)
4.	Tarakan Utara	- [2)	1,561,833.91	2,226,614.98	[4)
	Total Tarakan City	11,891,688.00	12,282,229.20	17,327,553.02	711,040,000 [5)

Note:
1) Source:
2) Data unavailable
3) Availability distribution is not yet calculated, will be included later in the final report
4) Source: calculation from this study
5) Calculation results for 2008-2009 consist of 219,500,000.00 m^3/year of ground water and 491,000,000.00 m^3/year of surface water; projections for 2013, 2018, and 2033 are not yet calculated

2.3 Current Hazards and Vulnerabilities of Water Sector

Current hazards on water sector that are presented here cover any significant problem that has been experienced or likely will be experienced in the period of current time by Tarakan City without considering it as climate change impact. With that coverage, it means that current climate hazards identified by the scientific basis (SB) team are not yet followed up as stimuli to gain related current hazard on water sector. The climate hazards produced by the SB team will be further analyzed as inputs for identifying hazards of water sector due to climate change (chapter 4).

The information of current hazards will be useful in proofing the identified climate change hazard on water sector in the baseline period. Meanwhile, current vulnerabilities here, are: population, land use, nature – especially forest – conservation, water demand, water quality, infrastructure of water resources, etc.

2.3.1 Hazard on Water Availability

In general, there is no indicator of existing hazard on water availability or water shortage. As shown in Sub-sub-chapter 2.2.5, the water availability in the current period is still greater than water needs even for the 2033 period (17,327,553.02 m^3/year vs 711,040,000 m^3/year). Moreover, if the maximum needs (57,819,643.46 m^3/year) is used, the current water availability (711,040,000 m^3/year) is still very much larger, assuming that the projection of water needs, based on the secondary data, is valid and that the water availability calculation from this study is constant or very little changed from current condition until 2033. Even so, the water availability, if seen from its spatial distribution in several places, has shown a shortage, compared to the needs.

If the performance of PDAM service is considered, there is an indication of clean water supply problem, since the coverage of PDAM service in 2009 is only reaching 38.00% of the total population (2009) since 2007. The total capacity of water supply (discharge) of the PDAM in 2007 reached 4.54 m^3/second or 392,256 m^3/day (see Table 2.4). Meanwhile, the number of household customers of the PDAM in 2007 reached 10,045 or 32,115 people. With 175,009 of total population, the coverage of PDAM in 2007 reached only 18.35% of the total population. In 2009, the number of people is 186,298, while PDAM services only covered 71,238 people. Hence, the coverage service of PDAM reached only 38% of total inhabitants.

With the total population of 193,069 people (BPS, 2010) and standard domestic water utilization of 130 liters/person/day, the total demand of fresh water for domestic use in Tarakan City in 2010 is up to 25,098,970 litres/day or 25,098.97 m^3/day. It is important to consider this problem of low coverage of PDAM services which only reaches 38% of total population, while water demand is lower than PDAM production (25,098.97 m^3/day vs 26,352.00 m3/day or 290.50 litres/sec vs 305 litres/sec, see Table 2.4). The demand is much lower than the discharge intake of PDAM (25,098.97 m^3/day vs 391,392 m3/day). These problems are likely caused by other factors, such as lack of water supply facility or the lost of water treatment and water distribution of PDAM.

The problems of clean water processing and supply, as identified by the PDAM of Kota Tarakan (2009), are as follows:

- the source or raw water supply of Tarakan PDAM from Kampung Bugis river is disturbed by high sedimentation from and other activities which impacted the low capacity of clean water production, in both quality and quantity;
- pipe maintenances for water distribution need to be conducted intensively, such as by cleaning from waste and plant regularly. Meanwhile, the existing pipes used for water distribution are dominantly in old or broken condition;
- the lose of water while in distribution is more than 40%. This case is a significant cause for the low coverage of PDAM service.

This problem of low service coverage of PDAM could become a hazard of water availability, along with the increasing water needs due to increasing population and other water user sectors (industry and agriculture).

The direct use of rain water as source of water for households is also important to be noticed. The proportion of households that use rain water is 60,4% of 27,582 households surveyed, it is the largest proportion in the survey. This number states that the rain water is the important primary source of water in Tarakan City. Thus, in this case, the long dry season can be a hazard to water sector for rain water users, as indicated by the analysis conducted by the science basis team that in the 1960s there were significant decrease of monthly rainfall down to 100 mm compared to long term average.

Other conditions from the water availability points of view are the type of drinking water and the water quality of water resources that are dominantly consumed or used by people. There is a trend that packed water (*air minum dalam kemasan* or *AMDK*) is highly used in Tarakan Island as source of fulfilling water needs (3,6% of total 27,582 households surveyed in 2008), especially in urban areas. The standard water source used by AMDK is groundwater, extracted by pump wells. Other users of groundwater using pump wells including households, PDAM, and industries. If the usage of groundwater is not well managed, then in the future, the over extraction of groundwater from a certain aquifer might happen. Although generally, groundwater extracted by pump wells is from deep aquifers (deep groundwater or confined aquifer), but in the condition of decreased water availability, AMDK companies might extract groundwater from shallow wells. This will become problems because households fulfill their water needs by using dug wells, both protected wells (wells with infrastructure built to protect it) and unprotected wells (wells with no infrastructure built to protect it), which calculated to have contributed to the water usage by 4.9% and 2.7%, respectively, from total 27,582 households surveyed. This condition could become a potential hazard today and in the next future, especially in low rainfall periods.

Meanwhile, people in rural areas mostly consume water with physically poor quality because of its high turbidity and acidity. This also potentially become water sector hazard, due to not potable water consumed by people, especially in the rural areas.

Other hazard that might be found in Tarakan is salt water intrusion. Although no report of impact of salt water intrusion in Tarakan, but it is expected to become a problem as impact of sea level rise due to the position of Tarakan as an island, aquifer properties, and the increasing water needs.

Further analysis resulted from this study will be presented in the final report of this study, which will study the current hazard potential of water sector and its possibilities in the future (next period).

Due to expanding problems of water availability, several components of environment become more vulnerable to the hazards. These problems include: 1) unavailable water supply caused by uneven water distribution, 2) low PDAM service compared to the needs of clean water, especially in urban areas, 3) decreased rain water availability as direct source of water in the rural areas, 4) decreased groundwater caused by poorly managed groundwater usage, 5) and lack of potable water to be the primary source of water needs for people in the rural areas.

Thus, the current potential vulnerabilities are population density along with its water consumption pattern; clean water infrastructures, which are water reservoir (in *bahasa*, *embung*) facilities and distribution of water pipes; river conditions, including sedimentation and river flow stability which PDAM's standard water come from; and landuse plan of water catchment areas (in *bahasa*, DAS = *daerah aliran sungai*) of rivers used as water sources.

As related to rainfall as the primary source of river water and springs, which are used as water sources, the potential vulnerabilities are the condition of soil and rocks, also the status of land cover or land use and the distribution of aquifer. Springs and groundwater are among the important water sources used by people especially in rural area.

As in for potential hazard, the results of the next analysis will be presented in the final report of this study. It will consist of further study on potential water sector vulnerability of current condition and its possibilities in the future (for the next period).

2.3.2 Flood

Flood, as stated by many reports and newspapers, is the problem for water sector in Tarakan. However, a limited historical data of flood events in Tarakan are summarized from Data Information Office of Public Works, detailed bellow:

1) August 2002: Flood areas are Karanganyar, Sebengkok, Karang Harapan, Pamusian, Kampung Empat (Islamic Center), Karanganyar Pantai, Selumit, Kampung Satu, and Bandara. After this flood, in April 2003, Public Works office started to construct new drainage system to reduce the flooding areas;
2) February 2005: Flood areas are Karanganyar, Karanganyar Pantai, Sebengkok, Karang Harapan, and Selumit. No flood at Pamusian due to finished drainage system in this area.
3) June and July 2008: Flood areas are Kampung Bugis and Karanganyar Pantai, and several areas at Sebengkok and Karanganyar. Until this year, the construction progress of new drainage system is not yet finished;
4) October 2009: Flood areas are Sebengkok and a part of Karanganyar. Based on field check during field surveys of this assessment (September 2010), it seemed that there are insufficient drainage systems. Also observed in the field surveys, were high sedimentation on some channels.

Based on the secondary data, the map of existing flood has been produced as shown in Figure 2.15. The map in Figure 2.15 presents information concerning current locations that are susceptible or sensitive to puddle-generated flood (“puddle flood” or in *bahasa*: *banjir genangan*). The map is also accompanied with information of swamp areas, dam locations, and tides-susceptible areas; and measurement of infiltration rate (in m/day) for 2005, 2008, and 2010.

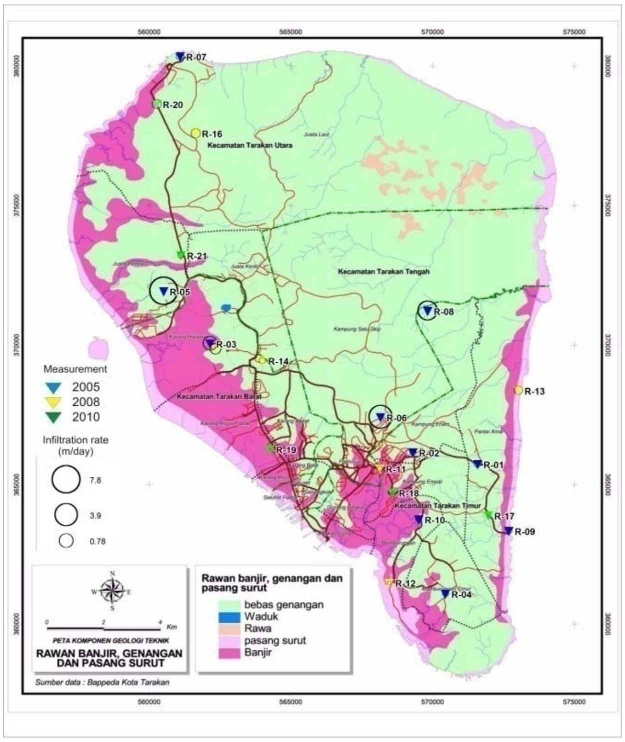

Figure 2. 15 Map of Geological Engineering Components: Susceptibility to Flood Generated by puddles and Tides (in bahasa: *Peta Komponen Geologi Teknik: Rawan Banjir Genangan dan Pasang Surut*) (*Source*: Bappeda Tarakan, 2008)

Figure 2.15 shows areas that are susceptible to puddle flood (*pink colored*), areas which are not susceptible to puddle flood (*light green colored*), areas that are susceptible to tide (*light rose colored*), swamp area (*tan colored*), and dam location (*light blue colored*).

As shown from the map, susceptibility to puddle flood are correlated with high number of infiltration rate. Many floods are accompanied by mud, or called mud flood. Here, mud is the product of erosion from open land in the upstream or caused by the characteristics of local soil.

The vulnerability components identified include: population density (distribution of settlement on flood susceptible areas), landuse or land cover, water infrastructure conditions, land characteristics (slopes, land type, and rocks), and the behavior of society towards the environment.

2.3.3 Landslide and Erosion

Landslides and erosions are related to geological engineering properties, including the water property of soil. Hence, landslides and erosions are among the aspects that related to the problem of water managements. Landslides and erosions often occur in Tarakan, shown in Table 2.16 and Figure 2.16. As listed in Table 2.16, at least 18 locations in Tarakan have geological engineering problem related to landslides and erosions.

Table 2. 16 Locations which have geological engineering problems related to landslides and erosions (modified from Geological Engineering Report, 2010)

No	Location	Coordinate	Remarks from Observation

		X	Y	
1.	Kel. Mamburungan Kec. Tarakan Timur	568524	362208	Soil improvement due to landslide problem
2.	Kel. Mamburungan Kec. Tarakan Timur	568611	361593	Mass movement and potential landslide
3.	Kel. Mamburungan Timur Kec. Tarakan Timur	570051	361852	Mass movement, historical landslide at this area
4.	Kel. Karanganyar (RT-64) (*Jalan Gunung Selatan*) Kec. Tarakan Barat	565250	369133	Erosion at remaining mining area. Water infrastructure problem as impact of erosion
5.	Kel. Kampung Satu Skip (*Jalan Gunung Selatan*) Kec. Tarakan Tengah	565395	368921	Erosion problem
6.	Kel. Kampung Satu Skip (*Jalan Gunung Selatan*) Kec. Tarakan Tengah	565476	368841	Drainage, erosion, and landslide problem.
7.	Kel. Kampung Satu Skip (*Jalan Gunung Selatan*) Kec. Tarakan Tengah	567464	367203	Landslide problem
8.	Kel. Kampung Satu Skip (*Jalan Gunung Selatan*) Kec. Tarakan Tengah	566915	367240	Landslide problem
9.	Kel. Kampung Satu Skip (*Jalan Gunung Selatan*) Kec. Tarakan Tengah	565962	368624	Drainage and erosion problem
10.	Kel. Juata Laut Kec.Tarakan Utara	560604	375537	Erosion and landslide problem
11.	Kel. Juata Laut Kec.Tarakan Utara	560547	375774	Erosion and landslide problem
12.	Kel. Juata Laut Kec.Tarakan Utara	560556	375941	Landslide problem
13.	Kel. Juata Laut, Kec.Tarakan Utara	560556	375941	Erosion problem
14.	Kel. Juata Laut Kec.Tarakan Utara	560970	377981	Landslide problem
15.	Kel. Juata Laut Kec.Tarakan Utara	561022	380228	Landslide problem
16.	Kel. Juata Kerikil Kec. Tarakan Utara	562445	372411	Landslide problem
17.	Kel. Juata Laut Kec.Tarakan Utara	560677	374971	Landslide problem
18.	Kel. Karang Anyar Kec.Tarakan Barat	564822	366656	Landslide problem

Figure 2. 16 Landslide and erosion position, geometry, and related slope condition.

The color indicates slope condition which are green (0 to 8%), light green (8 to 15%), yellow (15 to 25%), orange (25 to 45%), and red (more than 45%); while arrow sign from the smallest to the biggest size indicates direction and length of land slide that ranges from 0 to 1 m^2, 2 to 3 m^2, 4 to 6 m^2, 7-10 m^2, and 11 to 20 m^2, respectively (Source: modified from Geological Engineering Report, 2010).

Based on Table 2.16 and Figure 2.16, also from other related supporting data (interview, local newspapers archive, etc.), several landslide and erosion related identification can be presented as follows:

- the majority of landslide and erosion happened in the southwestern areas of Tarakan. The landslide and erosion positions are in accordance with high population areas, or areas with high development;
- the landslide areas mentioned above are in correlation with the changed slope condition, from high inclination (15% to 25%) to low inclination (8% to 15%) or very low (0% to 8%). Landslides did not happen on high inclination areas (> 25%), probably because the areas are still dominantly covered by forest or dense vegetation;
- the direction of the landslide is generally pointing to the same direction, southwest. This is caused by the direction of the hills where landslides happen is in accordance with the flow of the rivers in the southwestern areas of Tarakan;
- several landslides caused significant impacts such as lose of lives and materials.

Next, this study will detail the type of landslides, the correlation of landslides with rocks type and structure, its relation with landuse, and climate. Other potential hazards which will be more investigated are the relation of erosion and the level of sedimentation on the surface flow, especially in the rivers and reservoirs where PDAM extracts standard water and other water sources used by society. The results will be presented in the final report of this study.

Based on the identification of the potential hazard of landslide and erosion mentioned above, several potential aspects to be the vulnerability components can be identified. These vulnerability components include: population density, landuse or land cover, and slopes. Other potential aspects as the vulnerability to landslide and erosion hazards are: type of rocks and soil and geological structures.

2.4 Strategic Issues of Water Sector, Climate Change, and Development

The strategic issues of water sector identified here are issues related to water sector in its relation with current and future periods of climate change in Tarakan. These strategic issues could hamper Tarakan's development if not handled correctly, both physically and socially.

Based on the ICCSR study and science basis climate study of this work, Tarakan has suffered increase of temperature with an average of 0.5^{o}C/100 years, which will continue in the future. From the same study, Tarakan in 1961-1970 suffered a sharp interdecadal rainfall decrease, from normal condition of 300 mm/month of annual average, to around 230 mm/month of annual average. This condition needs to be significantly considered due to its possibility to reoccur in the future, which will cause great impact to water sector, considering the results of several climate study around Tarakan Island shows relatively same phenomenon of decreasing interdecadal rainfall pattern (Figure 2.17).

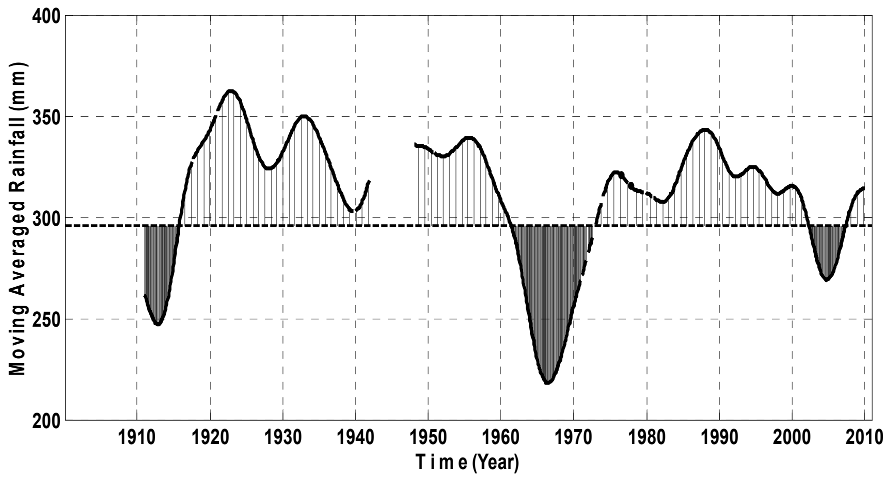

Figure 2. 17 Time series of monthly rainfall observed over Tarakan from 1911 to 2009, Smoothed with 24-point moving average applied 12 times iteratively (courtesy of Wahyu Hadi, 2010, science basis of this study). The figure shows indications of decreasing interdecadal rainfall in 1960-1970 with the probability of repeating in the next future period.

The results of science basis in the aspect of sea surface dynamics from this study shows that the seas around Tarakan experience sea level rise about 0.6 cm/year and is predicted to increase until 60-100 cm in the next 100 years. From the ICCSR study, Tarakan, as any other areas in Indonesia, also experiences La Nina and El Nino, which repeated in certain period of time.

The following identification of strategic issues of water sector will be the next main focus of this study. These strategic issues are derived based on the results of general condition identification, and current hazard and vulnerability of water sector as discussed on previous sub-chapters, also from secondary data, especially on the issues of water availability in Tarakan.

Table 2. 17 Issues, existing condition, and problems of water availability

No.	Issues	Existing Condition	Problems
1	Service area and product capacity	• Total inhabitants: 186.298; coverage of PDAM services: 71.238 inhabitants (38%) • Available capacity: 400 l/sec; product capacity: 305 l/sec; unused: 95 l/sec (24%)	• Annual growth of PDAM services: 2,5%; population growth: 7%/year • Limited water supply in WTP (water treatment plant) in Kampung Bugis • Insufficient of distribution pipes (secondary and tertiary distribution)
2	Water losses	Water losses: 38.4%	• Distribution pipes are leaky due to old age • Water meters are broken/inaccurate • Late in handling leaks • Illegal pumping • No measuring instrument in several distribution zones
3	Pressure and water continuity	• Water flow not reaching houses or settlements • No water flow	• Limited capacity or charge of freshwater production • Pipe sizes not suitable with distribution charge • No pressure regulation accompanied with valve instrument for water control • Available water capacity unbalance with costumers demand • Water pump disfunction caused by power outages • No immediate handling of leakage • Illegal pumping • Unstable water flow, especially in hill areas
4	Water quality	• Water contain sediment • Water smell of caporite	• Water contamination due to leaky pipes • Chemical overdose in treatment process • Decreasing quality of water due to high rainfall
5	Reliability of system	• WTP Kampung Bugis not optimum (only 50% of capacity used) • Water losses in the distribution network • Not all installations between	• Decreasing water sources in Kampung Bugis river for supplying Kampung Bugis WTP • Old distribution pipes • Zoning service for all installations

		Kampung Bugis and Persemaian are connected	
6	Electricity and chemical material	High consumption of electricity and chemical (30,9%)	• Manual treatment process in some WTPs while water fluctuation is undetected • Some measurement equipments need reparation or substitution • Electricity tariff in Tarakan is among the highest over Kalimantan
7	Water sources	Decreasing water quality and quantity	• Decreasing forests as recharge areas • Increasing erosion in upstream • Low awareness of environmental conservation, especially along flood plains
8	Health and Safety	Negative impact to health and safety of operational staffs in laboratories, WTPs, or fields	• Manual equipments • Official's lack of knowledge and understanding to work risk

Other than local issues mentioned above, water sector and its relation with climate change in Tarakan City are connected with national water sector strategic issues, as identified in the ICCSR study. In the ICCSR study, there are 7 strategic issues:

- maintaining balance between water availability and demand (water balance);
- sufficient water infrastructure and provision of alternative water sources in certain areas;
- availability of data, technology, and research as basis for water resource management;
- reduction of vulnerability and risk from water shortage, flood, and drought;
- finding synergistic solutions for cross-sectoral issues with agriculture, forestry, health, energy, and industry sectors;
- integrated water resources management and flood control;
- water conservation based on innovation, community participation, and local wisdom.

Based on the above statements, the major hazards are (1) flood, (2) water availability, and (3) landslide, erosion, and sedimentation. The scope of strategic issues, and the adaptation issues, to reduce risk, can be detailed as following:

Flood

Flood in the Tarakan Island is usually triggered by puddle. Several floods are even followed by mud flow. This makes Tarakan to be vulnerable to flood risk. The flood issue includes type, intensity, frequency, future condition, location, and area of flood. Current and future climate information must be able to be derived into information of flood hazard, both spatial and temporal. Furthermore, flood issue is related to other water sector hazards such as erosion, sedimentation, water availability.

Water availability

Based on data, water availability problem concerns surface water, groundwater, and rain water. Due to climate change, water availability problem would also cause: decreasing quantity and quality for PDAM’s intake, groundwater stresses, etc.

The clean water issue is related to other water sector issues such as landslide, erosion, and sedimentation issues. Low PDAM’s water service and infrastructures also worsen the clean water issue. It is predicted that climate change will further complicate this clean water problem.

Furthermore, the use of groundwater in urban areas also needs to be supervised. The main issue here is the tendency of using groundwater by various sectors or society's activities. The data of water used by households, industries, and PDAM shows that the percentage of groundwater use in Tarakan, especially in urban areas, is high. Although no conflict of groundwater use has been reported, the probability of such conflict in the future will be high, along with the increasing intensity of development in Tarakan City. Climate change influence, such as temperature rise, interdecadal dry season variability, and El Nino, will affect water usage pattern and water needs, ultimately increasing the intensity and frequency of the problems.

The use of surface water, groundwater, and rain water directly is usually practiced in rural areas. The quantity of surface water and groundwater are affected by the condition of rain, water catchment, and water usage in the upstream. Rain water quantity is directly influenced by the climate condition. Groundwater quality is generally influenced by the level of sedimentation and floods. Rain water quality is improper to be used directly as drinking water.

A number of further issues includes water availability (quantity) and quality, both surface and ground water; water needs; distribution of water resources; identification of factors which affect the quality and quantity of water sources (temperature rise and rainfall variation).

Landslide, erosion, and sedimentation

Currently, Tarakan experiences many landslides, erosions, and sedimentations in its river ways and other ground water bodies. Several landslides have caused lost of properties and even lives. Generally, landslides, erosions, and sedimentations are very closely related to the condition of surface water flow and water behavior inside the ground, where high quantity of groundwater could cause landslides; also, heavy flow of surface water on relatively open lands is causing erosion and sedimentation. Thus, landslide, erosion, and sedimentation problems in Tarakan are important to be considered as strategic issues in water sector and climate change.

Recent landslides, erosions, and sedimentations in Tarakan, based on the temporary identification, were related to the condition of rainfall, type and characteristic of rocks, landcover condition, and the condition of water bodies. For sedimentation, the condition of river ways and the quantity of river flow are one of the main causes of high level sedimentation.

Obviously, landslide, erosion, and sedimentation do not occur solely because of water factor. However, the condition of water flow and water quantity holds an important role in triggering landslide, erosion, and sedimentation. With the prediction of climate such as temperature rise, rainfall variability, and extreme climate event (La Nina and El Nino), the occurrences of landslide, erosion, and sedimentation can be anticipated. Dry climate or lack of rainfall, such as caused by El Nino, is giving great impact to drier atmosphere condition, ground surface, and water, which trigger erosion in the wet season.

Sea water intrusion and drought

Sea water intrusion and drought are the minor issues in Tarakan. Meaning, that in current period, the hazard of sea water intrusion and drought have not been seen yet in the Tarakan region. However, considering the results of climate predictions, which identified the possibility of interdecadal dry period and sea level rise, then these two hazards will need attention in the near future.

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III. METHODOLOGY OF ASSESSMENT

3.1 Framework of the Assessment

In this sub-chapter, we express in short the context of methodology and general framework used in the Climate Risk and Adaptation Assessment for Water Sector, in Tarakan Municipality. However, apart from the explanation of methodology and general framework below, there are also assumptions and problem simplification.

For the analysis of water shortage, GIS analysis has been done since the beginning of this study. The main framework of this study is shown in Figure 3.1.

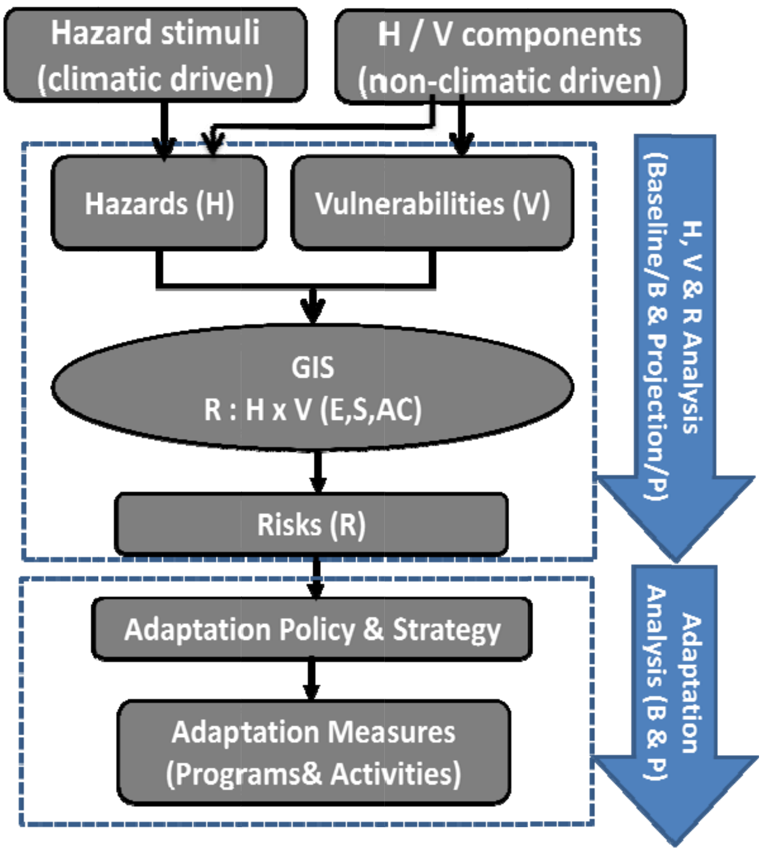


Figure 3. 1 Main framework in the climate risk and adaptation assessment of this study.

Note: Main hazard stimuli (climatic drivers) are temperature increase and precipitation variability. H or V (H/V) is components of non-climatic drivers, i.e population, and land-use. R is risk, H is hazard, V is vulnerability, E is exposure, S is sensitivity, AC is adaptive capacity; GIS is geographic information system. R is function of H and V; while V is function of E and S where E and S multiple the vulnerabilty, while AC decreases the vulnerability. Weighting is used to rank the value of H, V and R.

Assumptions about future trends are needed to show how the driving force on water sector is assumed to happen on the projection period. Thus, there are two assumptions, climatic drivers and non-climatic drivers. Assumptions about future trends in climatic driver are needed to limit the main stimuli from the climatic components affecting future water sector. As stated in the AR4, assumptions about future trends in non-climatic drivers are necessary in order to assess the vulnerability of freshwater systems to climate change, and to compare the relative importance of climate change impacts and impacts due to changes in non-climatic drivers.

3.2 Assumptions about future trends

3.2.1 Climatic drivers

As stated in the AR4, the most dominant climatic drivers for water availability are precipitation, temperature, and evaporative demand. The three drivers are also valid for the water condition of Tarakan. Precipitation involved in the climate change impact projection to water sector in Tarakan is the monthly precipitation. But, for several cases, if the data is available, daily precipitation is also used.

The temperature stimulus is also assumed important in determining the future water condition on Tarakan. The temperature data is obtained from the climate sector study; in this context it is also assumed to include sea level rise impact. The evaporative demand, due to the unavailability of ground level solar radiation data, atmospheric humidity, and wind speed, is assumed could be approached by only using temperature data. Another assumption is that for all of Tarakan Island, there is only one climatic data (Temperature T; and Precipitation CH) which comes from one observational station located on the island. In other words, it is assumed that there is no spatial variation in the temperature and precipitation of Tarakan Island.

This study takes SRA1B as the scenario of climate change due to global warming. The next climate data and information used in this discussion are the T and CH from climate analysis results of scenario SRA1B.

Geographically, the projection of increasing surface temperature (T) of 0.5ºC is assumed equal for Tarakan because the available climate data comes from only one climate observational station. Temperature increase of 0.5ºC is lower than the global temperature rise projection where by the end of the 21st century, the most likely increases are 3 to 4ºC for the A2 emissions scenario and around 2ºC for B1 (AR4, 2009). However, temperature rise of 0.5ºC in 2030 is higher from the trend of temperature rise during the 20th century in the region.

It is assumed that evaporative demand will increase on Tarakan during the projection condition. In this study, evaporative demand is calculated by using Tornwhite formula in the water balance analysis.

The decreasing interdecadal condition from 1990-2010 to 2010-2030 is smaller than the decreasing interdecadal in 1961-1970 to 1951-1960. But, the projection model may result in higher decreasing precipitation as in the 1961-1970. The precipitation variability in the projection period is in accordance with one of the results of global climate projection. The increasing temperature and decreasing precipitation are further assumed to cause decreases of total runoff (TRO), which causes decreasing water availability.

3.2.2 Non-climatic drivers

As stated by the IPCC in AR4, water resources, both in quantity and quality, are influenced by land-use change, the construction and management of reservoirs, pollutant emissions, and water and wastewater treatment. Also, as stated in the AR4, water use is driven by changes in population, food consumption, economic policy (including water pricing), technology, lifestyle, and society's views of the value of freshwater ecosystems. In short, the availability and functions of water are very influenced by non-climatic drivers.

For Tarakan, based on the consideration of temporal and spatial data availability, thereare nine non-climatic drivers involved on the water sector in this vulnerability analysis: *population density, land-use, water demandor water sources; water quality; PDAM services (*PDAM : Perusahaan Daerah Air Minum*) or regional company for drinking water; role of infrastructures, governmental program, and society's welfare*. All those non-climatic drivers are especially involved in the analysis of vulnerability to water sector hazards, in baseline and projection periods, except for water demand and land-use where both are used in the hazard analysis as well as in the vulnerability analysis.The nine non-climatic drivers are described shortly as follows:

(1) Population

Data of total population, population density, and population growth per district in Tarakan Municipality is assumed as data from the 2010 survey. Furthermore, it is important to calculate the population of each house to gain the spatial population density distribution in a more reliable condition in the baseline period. In this assessment, the population of each house is obtained based on the following assumptions: 1) population of each house is the same in a village; and 2) a house is a building with an area less than 500 m^2.

In the projection condition (2030), the general assumption is that population distribution will be distributed following the development of regions. The development can be indicated by road planning and is limited by the settlement planning. The development assumptions are: 1) population growth only happened in regions of settlement planning; 2) the existence of roads shows that the settlement is ready to be developed; and 3) population growth level is determined by the current population density. Using these assumptions on the simulation, the population density in 2030 is obtained.

(2) Land-use

Land-use type strongly influences the level of risk. Current land-use as a baseline is based on the 2008 land-use from the BAPPEDA of Tarakan Municipality. Meanwhile, the 2030 land-use condition is assumed as the 2030 Spatial Planning of Tarakan Municipality.

(3) Water demand

The performance of water supply gets worse by higher water demand. The higher water demand can lead to shortage of water supply. Hence, water demand is an indicator which will be used to analyze the vulnerability and hazard of water shortage.

Water demand is analyzed from two components, they are population or domestic water needs and industrial' water needs. Based on the standard of WHO, domestic water needs is 144 liter/person/day and industrial water needs is around 0.3-0.8 liter/second/ha or 25.92-69.12 m^3/day/ha (*Kementrian PU*, Ministry of Public Works). This standard is used in the baseline or current water needs because no others standard is available for the Tarakan water needs.

It is also difficult to predict the water demand in 2030 because of, among others, difficulty in establishing the projection of future industries built in Tarakan Municipality. But based on the 2030 Spatial Planning of Tarakan Municipality, the location of industries has been clearly depicted. The areas of industries in the 2030 Spatial Planning are assumed to be the areas of industries in 2030.

To project the water demand in 2030 period, we also need the standard of water needs both for domestic and industrial. In this study, standard of domestic water needs is relatively unchanged from the current condition. Meanwhile, the standard of other water needs in the 2030 period are grouped based on land-use. This last standard assumed as a reliable approach in determining the water need in projection period.

(4) Water resources

The impact of climate change to water availability will be felt by people according to the amount of water sources utilized. The higher the dependence of the water sources to climate, the bigger the impact of climate change felt. Water source, especially surface water and shallow groundwater of unconfined aquifer are sensitive to temperature rise and precipitation variability.

Water sources information used by the local people is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Based on the data, there are 10 water sources utilized by the population of Tarakan: *1) rain water, 2) river water, 3) unprotected spring, 4)* *protected spring, 5) unprotected well, 6) protected well, 7) drilled well, 8) retailed piped water, 9) piped water (PDAM services), and 10) bottled water.* Those water sources are assumed as the signifinact water sources for Tarakan Municipality in the baseline or current period.

In the projection condition, it is assumed that 90% of Tarakan Municipality will be served by PDAM network. This assumption is based on the Masterplan of PDAM. Thus, it is assumed that in the period of 2030, the Masterplan of PDAM is achieved so the assumption that 90% of Tarakan Municipality will be served by PDAM network is valid.

(5) Water quality

Water availability is expressed in two main factors, water quantity and quality. Large quantity of water does not mean that it can be used directly if the water quality is poor. Thus, the quality factor determines the actual water availability.

Water quality is sensitive to fluctuation of water flow or supply. Decreasing water flow in a river which has been affected by pollutants, will increase the level of its pollution. Also, exploiting groundwater from an aquifer in coastal region that exceed the limit of its recovery will trigger salt water intrusion to the aquifer and decreases its water quality. Another component that influences water quality is the nature of water source. For instant, surface water and shallow groundwater or unconfined aquifer in swamp areas surely have bad quality for drinking water because of high concentration of acid or iron in its water.

In this study, only natural quality of water in the form of swamp water is involved as parameter of water quality. This is based on the availability of the data needed in the analysis. Another reason is that the quality of shallow groundwater mostly still in good condition or still under the standard condition.

Based on field surveys to several areas on Tarakan Island, a large number of swamp areas or formerly swamp areas contain very high iron. This iron is due to the nature of swamps as long inundation from surrounding rivers and discharged only through evaporation. Waters with such quality is not suitable especially for drinking water. So, water bodies in swamp areas or formerly swamps area are assumed as bad quality and cannot be utilized.

The existence of swamps can be observed by using 2030 Landsat images. The projection condition (2030) uses the assumption that 90% of population is served by PDAM, meaning that the water quality condition is guaranteed, so the vulnerability level due to water quality can be ignored.

(6) PDAM services

One of the role of government or government program is to minimize the impacts of disasters. PDAM, as one of government institutions, also has a role in handling the impacts of fluctuation of water availability or water supply. Also, the existence of PDAM will play a very important role in controlling water usage in such a way that contributes to water conservation. The important aspect of PDAM services for this study is the coverage area or population in each sub-district or district of PDAM services.

To obtain data of population serviced by PDAM in each sub-district or district, it is assumed that the area of PDAM services is represented by the distribution of PDAM network both in number of services as well as map of the network. Based on the 2007 Masterplan of PDAM of Tarakan Municipality, it is known that the area of PDAM services covers 33% of the total population of Tarakan Municipality. PDAM services in 2010 reached 60% of the population and in 2030 are projected to reach 90% of the population. This assumption is based on the area of PDAM services, and it will also used in the analysis of water availability or water supply.

(7) Role of infrastructures

Natural disasters or impact of climate change often cause great collateral damage. This happened if there are important infrastructures. The amount of this damage is difficult to measure but very real. As an example, if a landslide occurred on a road, then every activity on the road, such as public transportation and economy, cannot be continued.

Current infrastructure distribution can be seen from the current infrastructure data of PDAM. Future infrastructure condition is difficult to calculate, but can be assumed based on the 2030 Spatial Planning. The infrastructure classes are uniformed by using the type of infrastructures in the 2030 Spatial Planning.

(8) Government programs

The role or involvement of government in handling disasters is very expected. But generally, this involvement is passive, meaning there will be actions only after disasters occured. If there are landslides, government involvement is based only on the landslide occurred on roads (based on studies), while if there are floods, government involvement will be focused in recovering or rehabilitating government facilities and other important infrastructures.

Currently, areas which will receive special treatment from the government are roads blocked by landslides, government facilities and important infrastructures. Meanwhile, for the projection condition, it is assumed that the government has special services in treating the disasters or the impacts; meaning that government role in treating disasters or climate change impact is in the maximum condition. This assumption means that government program in anticipating flood and landslide will cover all areas of Tarakan Municipality.

(9) Social welfare

Other than government programs, society also plays a role in minimizing the impact of disasters or impact of climate change. This is what we address as adaptive capacity that will reduce the vulnerability. But the involvement of adaptive capacity of society is very depended on the ability or capacity of society itself. This ability or capacity of society is assumed could be approached from analysis of the social welfare condition.

In this study, assumption for social welfare is that its value can be considered from two sides, house types and society's income. With this assumption, the social welfare can be counted temporally (baseline and projection conditions) and drawn spatially. Currently, house types and society's income are based on the existing data. In the projection, social welfare is not included due to government program that assumed has the performance of maximum condition.

3.3 Method of Hazard Analysis

In general, method for identifying climate change hazards on water sector is conducted by analyzing the direct hazards or climatic potential of hazards with physical potential hazards using a suitable approach or analytical method for each related hazard, respectively. Based on the strategic issues of water sector, climate change, and development in Tarakan (see Chapter 2, sub-chapter 2.4 of this report), there are 3 hazards of climate change to water sector. These hazards, from the less important to the most important are water shortage, floods, and landslides. The direct hazards involved in the analysis are the results of climate projection of temperature and precipitation. Meanwhile, the physical potential hazards are any non-climatic drivers that is decreasing water availability or increasing the probability of floods or landslides, such as land-use change.

In more specific, hazards in this research are the result of hydrology modeling within the framework as shown in Figure 3.2. The hydrology models are derived to determine water availability, floods, and landslides. Climate data, baseline and projection, is used as an input in the hydrology model, i.e. precipitation and temperature data.

Here, we also mention sea level rise in the flood modeling. Hydrology model using secondary data is needed to verify the result of the model by fitting the hydrology condition, both in baseline and projection. Similar framework can be drawn for the groundwater modeling to identify climate change impacts to groundwater sources or groundwater recharge, especially groundwater in unconfined aquifer or shallow aquifer.

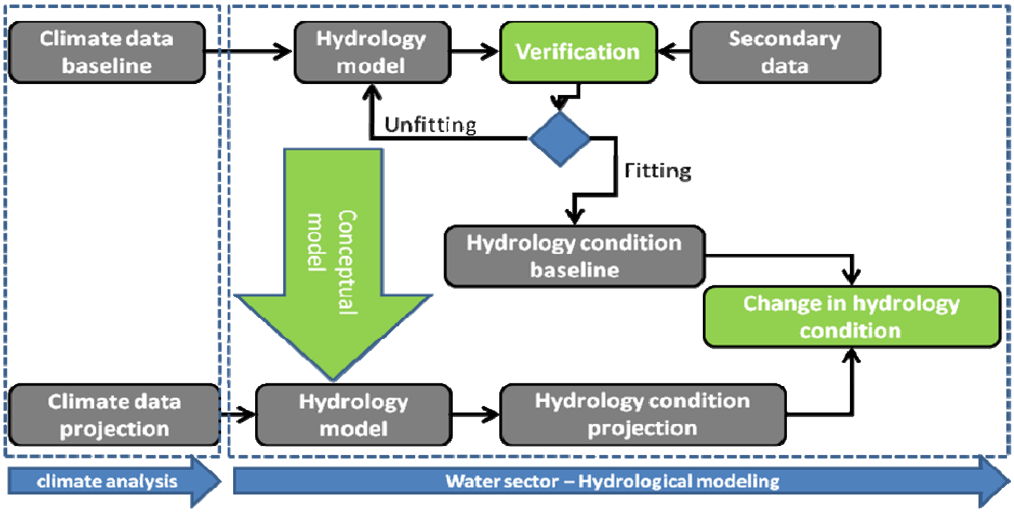


Figure 3. 2 Framework to determine climate change impacts to water sources (surface water). Similar framework can be implemented to groundwater.

Using the framework in Figure 3.2, all these hazards are modeled and fitted to both baseline and projection by following the hydrology and groundwater modeling. The names and/or processes of these modeling are explained in Figure 3.3.

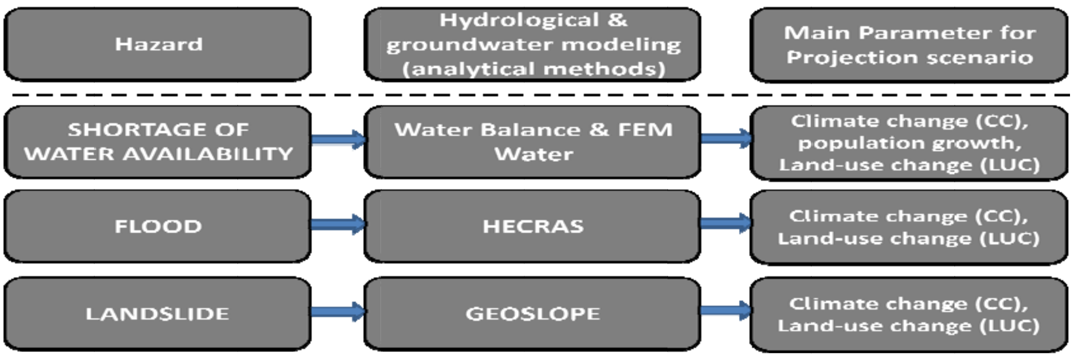


Figure 3. 3 Processes of modeling water sector into projection scenarios in climate change model.

General data availability used in hazard analysis on water sector is presented in Table 3.1

Table 3. 1 List of data used, sources, and user or related analysis

No.	Data Used	Data Sources	User (Analysis Tool)
1	Rainfall (mm/hour)	Climate Science Basis (CSB) analysis	HEC-RAS (WMS)

2	Rainfall (mm/month)	CSB analysis	Water balance,FEM Water
3	Temperature	CSB analysis	HEC-RAS, Water Balance
4	Land-use	Bappeda, GIS assistants	HEC-RAS, FEM Water, Water Balance
5	Soil/rock type	BPLHD (Study of GW Conservation)	GeoSlope, FEM Water
6	Geology/geological cross-section	- Center of Geological Survey (Geological Agency) - Energy & Mining Agency, Tarakan	HEC-RAS, Water balance, FEM Water
7	Recharge areas	GIS Assistants (Land-use and Geologic Analysis)	HEC-RAS, Water balance, FEM Water
8	Water usage areas	GIS Assistants (Land-use)	FEM Water
9	Water table (groundwater)	DinasPertambangan (Mining Agency of Tarakan)	FEM Water
10	DEM	RBI SRTM Other sources	HEC-RAS, GeoSlope, Water balance, FEM Water
11	Debit (river, groundwater)	Dinas PU (Public Works) BWS	HEC-RAS, Water balance

3.3.1 Method of water shortage hazard analysis

The hazard of shortage of water availability, or in simply, water shortage hazard (WS hazard) is analyzed based on direct climate change impact and physical potential hazard. The direct impact is the analysis results of climate scientific basis. The results consist of projection of temperature and precipitation. The physical potential hazards are water demand and quantity of water in watershed unit.

Water availability is the amount of available water that can be utilized. Water availability in nature is affected by climate variability and climate change. On the other hand, water availability in nature is also affected by human activities. Even sometimes, human activities have a great deal in the decreasing water availability. Based on these facts, water shortage can be interpreted as "the decreasing amount of water both naturally or due to human utilization".

Water potential can be approached by using the method from F.J. Mock. This method is developed based on hydrological cycle with the concept of water balance. The general form of water balance equation is: **$P = Ea + \Delta GS + TRO$**

Precipitation (P) will be used for evapotranspiration (Ea), surface run off (TRO), and then stored in the ground (**ΔGS).** The amount of water utilized directly by society is the surface run off or often called total runoff (TRO). Total runoff consists of Direct Runoff (DRO) which is directly flowed on the surface when raining, base flow which becomes the run off of river bed through springs and storm run off which is a run off on the unsaturated zone.

The evapotranspiration in the formula mentioned above is calculated using Thornwhite formula with modification. The formula based only on temperature (T) data. The formula with modification is taken because of the available data, for calculating evapotranspiration, spatially and temporally, is only temperature data.

Water balance calculation is best used in the watershed unit and monthly time series. The hazard analysis is based on the water availability data in a watershed. The surface water availability in a watershed is seen from the total runoff (TRO) value. Meanwhile, the current water shortage can be seen based on the changing value of TRO cumulative probability 50 % in current period ($TRO_{CDF50\%,\ current}$) to the condition of TRO cumulative probability 50 % in the baseline period ($TRO_{CDF50\%,\ baseline}$). Meanwhile, the value of water shortage in the projection is the decreasing total runoff cumulative probability 50 % in the projection ($TRO_{CDF50\%,\ projection}$) to the value of $TRO_{CDF50\%,\ baseline}$. The baseline condition is defined as the condition of 1960 – 1990, current condition 1990 – 2020, and projection condition is the condition of 2000 – 2030.

In this study, WS hazard is defined as decreasing water availability (DoWA) plus the value of water demand (WD) and divided by total water availability in baseline condition ($Q_{Baseline}$ or $Q_{1960\text{-}1990}$) in watershed unit as expressed in the following formulation:

$$Water\ Shortage\ Hazard\ (WS\ Hazard) = \frac{(DoWA + WD)}{Q_{Baseline}}$$

The DoWA (decreasing water availability) and total water availability in baseline condition ($Q_{Baseline}$) are calculated using the method of water balance analysis. The TRO here is an important tool for calculating the DoWA and $Q_{Baseline}$. Cumulative distribution frequency (CDF) analysis, as illustrated in Figure 3.5, is used to further calculate the total runoff (TRO) data which is obtained from the water balance analysis. By application of the CDF methode it is possible to determine value of TRO which can generate the water shortage as the TRO below 50% on CDF graphic (see sample on Figure 3.5) denote the value.

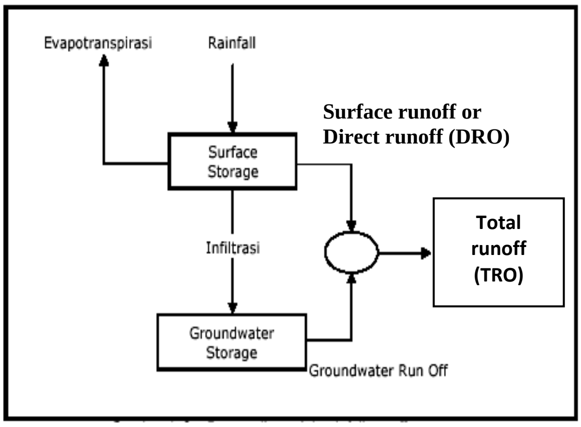


Figure 3. 4 Conceptual framework of water balance analysis. The total run off or TRO = direct run off (DRO or surface run off + groundwater run off

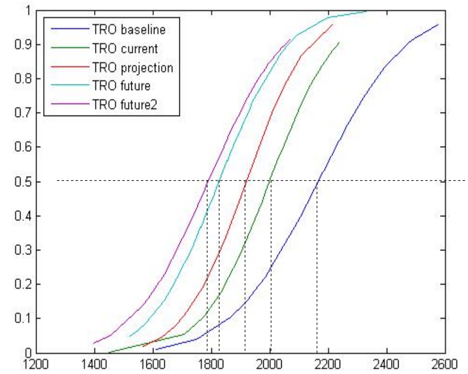


Figure 3. 5 Illustration of CDF 50% for TRO in baseline (1960-1990), current (1991-2020), projection (2010-2030), future1 (2031-2060) & future2 (2061-2090)

Furthermore, the DoWA (decreasing of water availability) is formulated as the probability of water decrease compared to normal condition (baseline condition, or 1960-1990). The value of 50% TRO is taken as reference, while the value below 50% TRO indicates decreasing water availability. Hence, the DoWA in the formula mentioned above are :

(1) the difference between TRO of baseline condition ($TRO_{Baseline}$) and TRO of current condition ($TRO_{current}$), or $DoWA_{current} = TRO_{Baseline} – TRO_{current}$ for current condition; and

(2) the difference between TRO of baseline condition ($TRO_{Baseline}$) and TRO of projection condition, or $DoWA_{projection} = TRO_{Baseline} – TRO_{projection}$ for projection condition.

Finally, the DoWA is also influenced by water demand (WD). The higher the water demand, the bigger the magnitude of the hazard. The WD is calculated spatially based on the total population and industry for the baseline period; and based on population and type of land-use for the projection period. WD analysis uses standard water demand for each component of water user and assumptions as mentioned in section 3.1 and presented in Table 3.2 and Table 3.3 below. From the formula of WS hazard, it is clear that the unit of WS hazard is watershed or water catchment area.

Table 3. 2 Standard of water need for domestic use

Total population (household)	Connection to House	Connection to Public Facility	Water Demand in Average (m^3/day/person)
>1000	0.21	0.30	0.174

500 – 1000	0.17	0.30	0.170
100 – 500	0.15	0.30	0.126
20 – 100	0.90	0.30	0.78
0 – 20	0.60	0.30	0.54

Table 3. 3 Standard water needs in 2030 based on land-use

Land-use Types	Water Demand (m^3/day/ha)
Industries	50
Trades and services	40
Airports	40
Hospitals	30
Governmental offices	25
Religious places	25

3.3.2 Method of flood hazard analysis

Flooding is a natural and recurring event for a river or stream. Statistically, streams will equal or exceed the mean annual flood once every 2.33 years (Leopold et al., 1964). Flooding is a result of heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams, and coastal areas. This causes a watercourse to overflow its banks onto adjacent lands. Floodplains are, in general, those lands most subject to recurring floods, situated adjacent to rivers and streams. Floodplains are therefore "flood-prone" and are hazardous to development activities if the vulnerability of those activities exceeds an acceptable level.

Floodplains can be looked at from several different perspectives: "To define a floodplain depends somewhat on the goals in mind. As a topographic category it is quite flat and lies adjacent to a stream; geomorphologically, it is a landform composed primarily of unconsolidated depositional material derived from sediments being transported by the related stream; hydrologically, it is best defined as a landform subject to periodic flooding by a main stream. A combination of these [characteristics] perhaps comprises the essential criteria for defining the floodplain" (Schmudde, 1968). Most simply, a flood-plain is defined as "a strip of relatively smooth land bordering a stream and overflowed [sic] at a time of high water" (Leopold et al, 1964).

Frequency of inundation depends on the climate, the material that makes up the banks of the stream, and the channel slope. Where substantial rainfall occurs in a particular season each year, the floodplain may be inundated nearly every year, even along large streams with very small channel slopes.

In the baseline condition, the hazard model used the data of discharge in extreme condition (*Kajian Sumber Daya Air*, 2008) the result only shows the area of flooding without the depth of flood and ponding time. In the projection of flood hazard, the model is using the discharge data derived from the rainfall projection data which used scenario 3 (SRA1B) as shown in Figure 3.6. The projection shows the accumulation of extreme event, La Nina, and storm surge that are tend to increase about 188.38 % in the future.

The projection flood model also mention the inundation caused by sea level rise regarding to scientific basis of oceanography (Sofian, 2010) and accomplished by Latif (2011) as shown in Table 3.4.

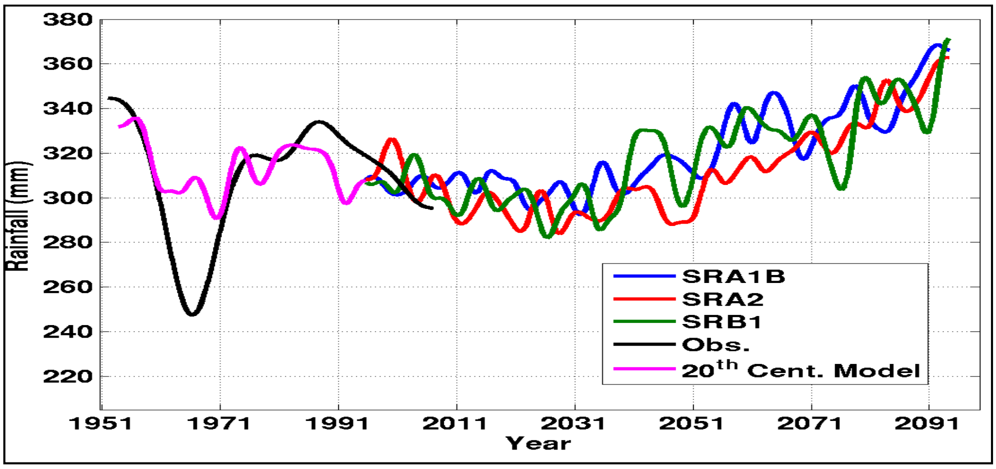


Figure 3. 6 The smoothed GCM out based projected monthly rainfall of Tarakan for the 21st century (Hadi, 2011).

Table 3. 4 Elements of Hazards Related to Sea Level Changes for SRES A1B

Item/Year	2030	2050	2080	2100
Tidal Range	3.1m/3.5m	3.1m/3.5m	3.1m/3.5m	3.1m/3.5m
Sea Level Rise	14.7 ± 6.25cm	26.0 ±11.0cm	48.0 ±22.0cm	65.5 ±28.5cm
La Nina	15cm	15cm	15cm	15cm
Surges	30 cm	30 cm	30 cm	30 cm
Wind wave	1.3m (estimation)	1.2m	1m	1.m

Note: The wind waves are based on the annual daily maximum wave height, due to the IPCC wind projection that only available for daily.

Flood hazard modeling uses land-use data, rainfall data, discharge data, and digital elevation map (DEM) and sea level rise impact (in projection only) as shown in Figure 3.6 and more detailed as in Figure 3.7 below. Flood hazard is modeled in two conditions or period, baseline and projection conditions or period.

Flood hazard model is using WMS-HECRAS (Watershed Modeling System – HECRAS) method. Flood hazard is modeled in two conditions or period, baseline and projection conditions or period. The first step to creating an HEC-RAS model is to create a conceptual model which defines the river reaches (layout and attributes), the position of cross sections on those reaches (orientation and station values), bank locations, and material zones. The conceptual model will be used to create a network schematic inside the River module. The conceptual model created from a digital elevation map as well as scattered bathymetric (elevation) data in the form of a TIN. The core of conceptual model of HECRAS is centerline coverage for reaches and cross section coverage for cross sections.

The second is a numeric model stored as a schematic of cross sections organized into reaches. The centerline will consist of reaches in the main channel (divided by the tributary). Bank arcs are used to define the locations of the banks and the over-bank distances. Bank arcs create along both sides of each centerline arc. One of the properties HEC-RAS uses is roughness values. The roughness value will be assigned base on land use types as material zones. The material zones are stored in WMS (Watershed Modeling System) as Area Property coverage. The roughness values for the materials found in the cross section database. The roughness values are stored as part of the 1D model in the River module. HEC-RAS associates most of its model data with cross sections and generates solutions or output at the cross sections. Therefore, cross sections are the most important part of the map. HEC-RAS requires at least two cross sections on each reach. In the cross section coverage, all arcs are cross section arcs. The position and orientation define the location of the cross sections in the system, but as of yet, they do not have any data assigned. The data are elevation data, materials, and point property locations to the cross sections. This information will be extracted from the TIN, the area property coverage, and the centerline coverage.

WMS interacts with HEC-RAS using a HEC-GeoRAS geometry file. This file contains the cross sectional data used by HEC-RAS in addition to three dimensional georeferencing data. To create this geometry file, the conceptual model must be converted to a network schematic diagram in the River module.

The next step, The HECRAS simulation will be setup and running and then export the results for post-processing in WMS. The setup will include entering junction lengths, specifying flow values, and assigning river boundary conditions.

The HEC-RAS has computed water surface elevations. The result of HECRAS can be read the solution into WMS. The water surface elevations are read in as 2D Scatter Points and can be used to perform floodplain delineation. WMS has a tool that interpolates scatter points along centerline and cross section arcs which achieves more accurate floodplain delineation.

3.3.3 Method of landslides hazard analysis

Landslide is one of the water resource problems that need to be taken into consideration of planning for measures against the impacts of climate change. There are two analyses that considered as the causes of landslide as follows:

- Increasing of groundwater table
- Decreasing of soil strength

Precipitation is a key factor in determining groundwater recharge and changes in the amount, frequency, duration, and intensity of rainfall events, which will thus have a significant impact to groundwater sources. Groundwater responses to rainfall events have a longer lag time than the corresponding hydrological response in surface water systems.

Landslide happens when mean rainfall is above normal and occurred beyond the infiltration capacity time due to the recharge of ground table. The prolonged rainfall infiltration reduces the matric suction of soil which in turn decreases the soil shear strength, and subsequently triggers the slope failure. The development of landslide modeling uses the estimation of water table elevation and decreasing soil strength. The monthly rainfall data as output of GCM as shown in Figure 3.7 is used to estimate the changing of water table elevation.

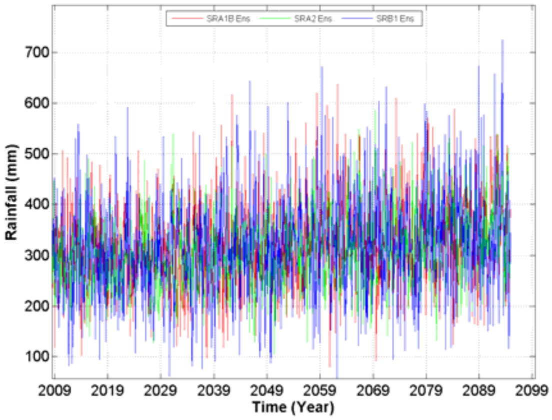


Figure 3. 7 The GCM out based projected monthly rainfall of Tarakan for the 21st century (Hadi, 2011)

Methods that have great potential to forecast recharge are those that have establish relationships between rainfall, abstraction, and water level fluctuations, such as the CRD (Cumulative Rainfall Distribution), EARTH, Auto Regression Moving Averages, and empirical methods.

Various applied techniques for estimating ground water recharge are described for local, hillslope, catchment, regional, and national scales. It is clear that the scale of the problem investigated must determine the method used. Recharge estimates are generally performed assuming a vertical profile. However, it is also evident that the hillslope and lateral processes inherent in generating event and low flow discharges must be defined and quantified so that the proper stream flow generating source, whether ground water aquifer or hill slope vadose zone, is identified.

3.3.3.1 Modelling GWT Recharge Using CRD Method

Since the possible method to apply is the cummulative rainfall departure CRD method, based on the premise that water level fluctuations are caused by rainfall events. Bredenkamp et al. (1995) applied the method extensively with success in South Africa. Recently, the method was revised to accommodate for trends in rainfall time series (Xu and Van Tonder, 2001). Recharge is calculated as (Xu and Van Tonder, 2001):

$$ {}_{av}^{1}CRD_i = \sum_{n=1}^{i} R_n - \kappa \sum_{n=1}^{i} R_{av} \qquad (i = 0,1,2,3,4, . . .) \qquad (1)$$

where R is rainfall amount with subscript "i" indicating the i-th month, "av" the average and k = 1+(Qp+Qout)/(ARav). k = 1 indicates that pumping does not occur and k > 1 if pumping and/or natural outflow takes place. It is assumed that a CRD has a linear relationship with a monthly water level change. Bredenkamp et al. (1995) derived.

$$\Delta h_i = \left(\frac{r}{S}\right) . \left({}_{av}^{i}CRD_i\right) \qquad (i = 0,1,2,3,4, \ldots)$$

(2)

where r is a percentage of the CRD which results in recharge from rainfall. Eq. (2) may be used to estimate the ratio of recharge to aquifer storativity through simple regression between CRDi and Dhi (Bredenkamp et al., 1995).

Groundwater table recharge estimation, using CRD method, is based on existing rainfall data of 2001-2010 and projection (2011-2030). The projection condition is divided into two parts, 2011-2020 and 2021-2030. CRD method needs infiltration and pumping data, there are 11 different locations to estimate the changing of groundwater elevation.

Table 3. 5 Infiltration and pumping data

Code	Coordinate		village	permeability	aquifer
	X	Y		k (m/day)	boundary (S)
R11	568135	365576	KampungEnam	0,0310	0,000202
R12	568469	361480	Mamburungan	0,0111	0,000202
R13	573029	368373	PantaiAmal	0,1414	0,000147
R14	563987	369439	KarangAnyarPantai	0,0478	0,000104
R15	562346	369854	KarangHarapan	0,3090	0,000147
R16	561645	377558	JuataLaut	0,1863	0,000147
R17	571966	363894	PantaiAmal	0,0014	0,000202
R18	568593	364710	KampungEmpat	0,0031	0,000202
R19	564263	366265	KarangAnyarPantai	0,0047	0,000202
R20	560270	378637	JuataLaut	0,2170	0,000147
R21	561122	373218	JuataPermai	0,0620	0,000104

The landslide model is developed by utilizing the concept of extreme rainfall and unique relationships between rainfall characteristics, hydraulic conductivity, suction, and water content of unsaturated soil to evaluate the minimum suction distribution and factor of safety of soil slope as shown in Figure 3.8.

Part of the rain water that falls on the ground is infiltrated into the soil. A part of this infiltrated water fill the soil moisture deficiency and others part of it is percolated down reaching the water table of groundwater and known as the recharge from rainfall to the aquifer. Recharge due to rainfall depends on various hydrometeorological and topographic factors, soil characteristics, and depth of water.

Statistical prediction of rainfall as an impact of climate change has extremely played an integral role in the water sector where landslide is one of the impacts. The prediction from the statistical of scientific basic sector show that the extreme rainfall consideredabout 100 mm/^{3}hours. Ground water table (GWT) recharge estimation is using Cummulative Rainfall Distribution(CRD) method, based on rainfall data existing 2001-2010 and projection condition 2011-2030. Then projection conditions are divided into two parts, yet are 2011-2020 and 2021-2030.

The water level series is simulated using the computer program Microsoft Office EXCEL. Comparison of simulated water levels with the generated ones is shown in Figure 4.35 for baseline condition, while Figure 4.36 and 4.37 for projection condition, where dh(crd) are water levels calculated using Bredenkamp et al. (1995) approach.

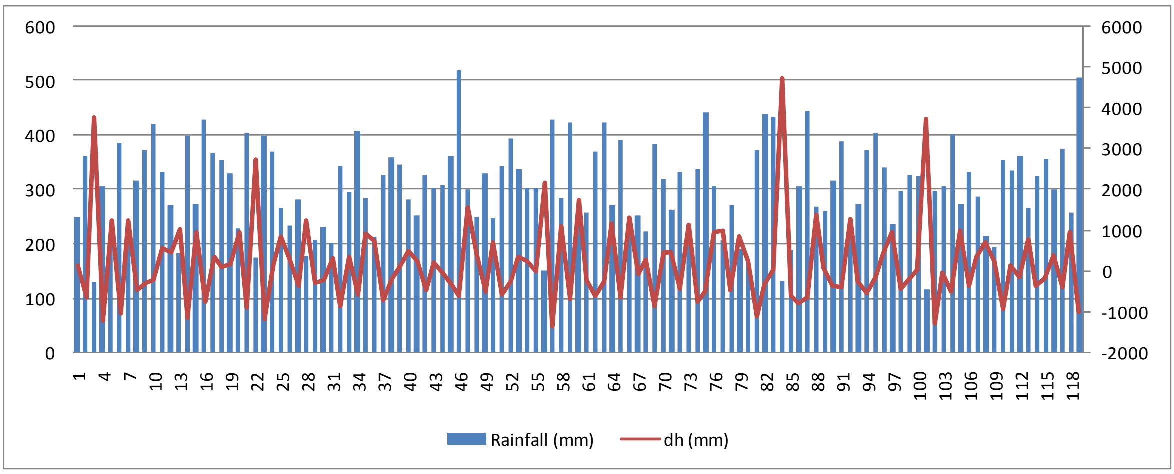


Figure 3. 8 Simulation of GWT recharge on baseline condition

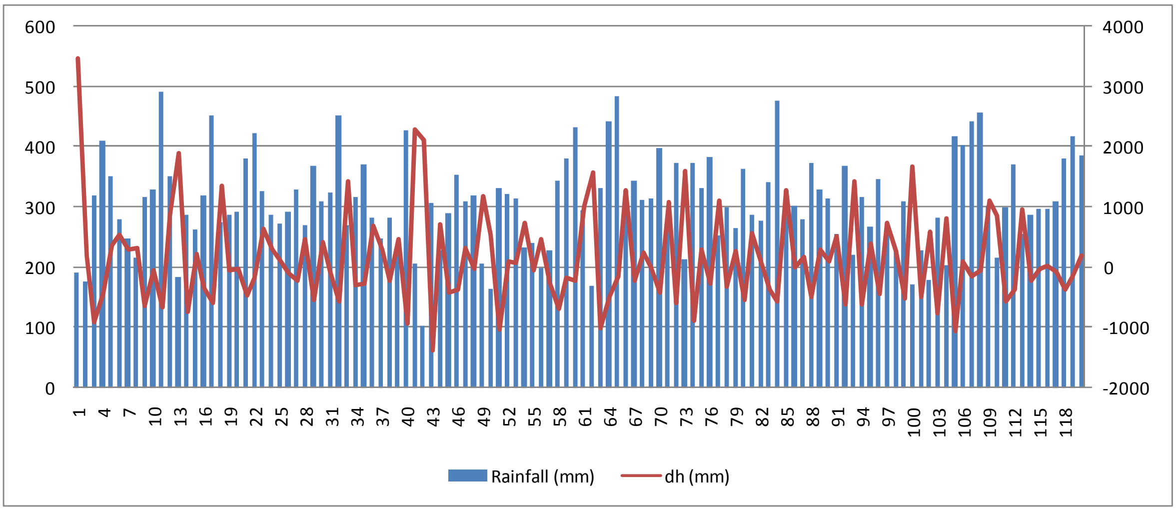


Figure 3. 9 Simulation of GWT recharge on projection condition 2011-2020

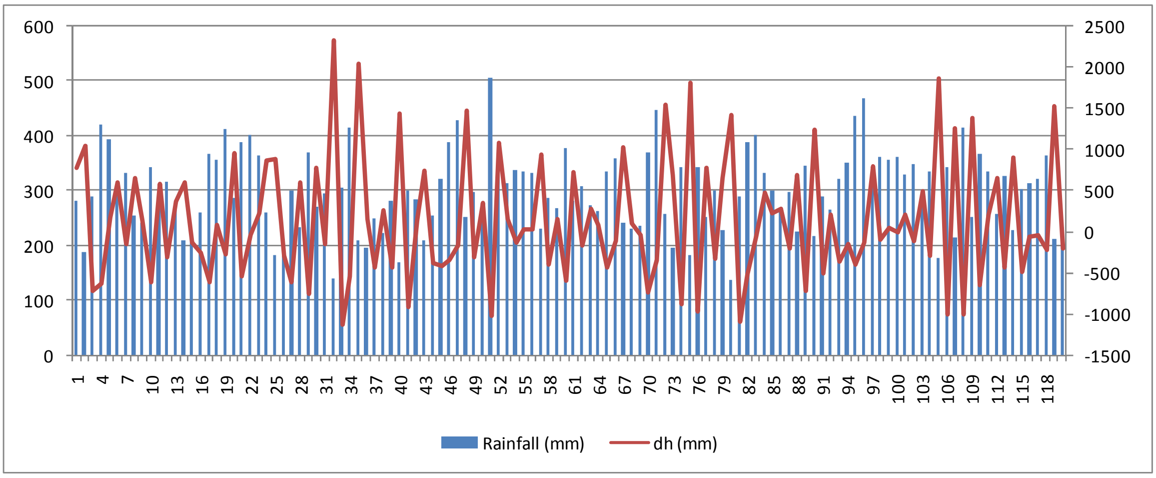


Figure 3. 10 Simulation of GWT recharge on projection condition 2021-2030

From the three figure above, seen that rainfall on last month will significantly affected to the recharge on next month. The recharge will be higher at dry month as an impact of cumulative rainfall from some rainy months. As seen in figure 4.35, at 84th-month the recharge is higher than last month, due to cumulative rainfall from last rainy months. The fluctuation are varied, the highest Ground water table recharge at baseline condition (2001-2010) are show in 84th-month for about 4000 mm in baseline condition, while in projection condition (2011-2020) in 1th-month for about 3500mm and in projection condition (2021-2030) in 21th-month for about 2400mm, that consider ground water table recharge is generally as a cause of landslide.

There are 11 CRD was made. Based on pumping and infiltration test data as a simulation input. 11 different locations of pumping and infiltration test as shown in Table 3.5. The simulation of ground water table fluctuation are different from a location to another location. Figure below show 11 location with it own water level fluctuation. Figure 4.38 for baseline condition, while Figure 4.39 and 4.40 show projection condition for 2011-2020 and 2021 - 2030.

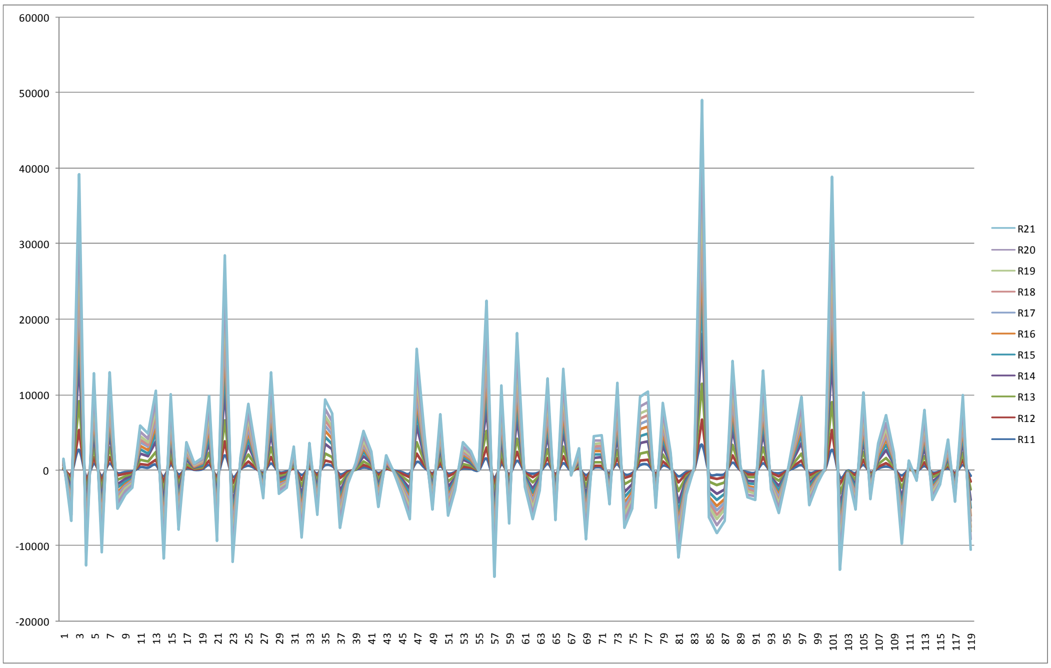


Figure 3. 11 GWT fluctuation of 11 condition on baseline

Simulation models show the fluctuation of water table is increasing rapidly to 4,8 meter for projection 2011-2020, and to 3,2 meter for projection 2021-2030. The fluctuations data are used for slope stability modeling. The mechanism of GWT recharge is impacting to change soil condition from unsaturated to saturated soil and soil strength will decrease.

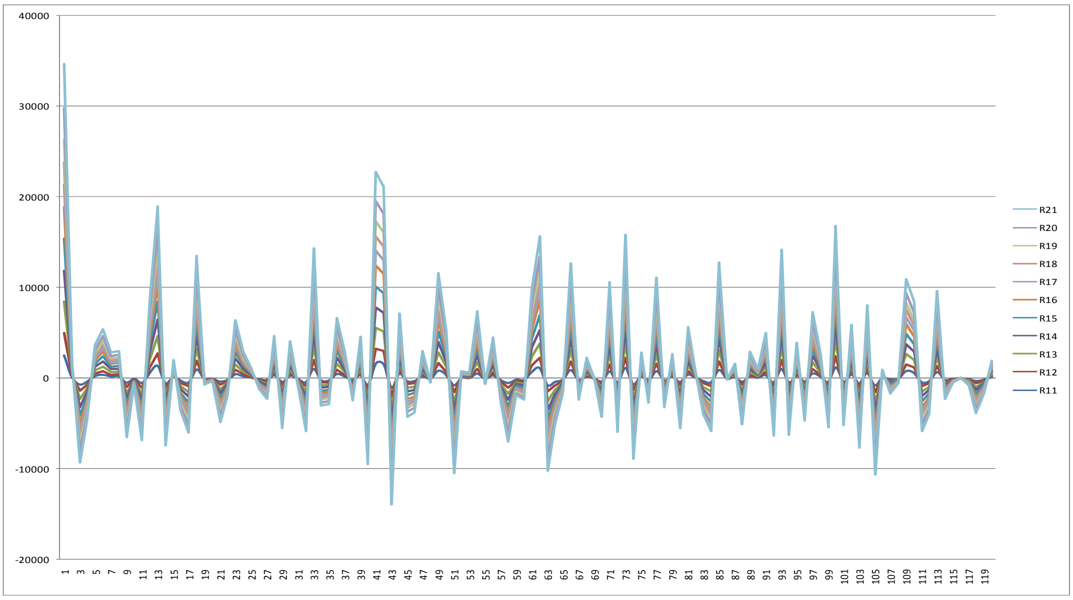


Figure 3. 12 GWT fluctuation of 11 condition based on projection 2011-2020

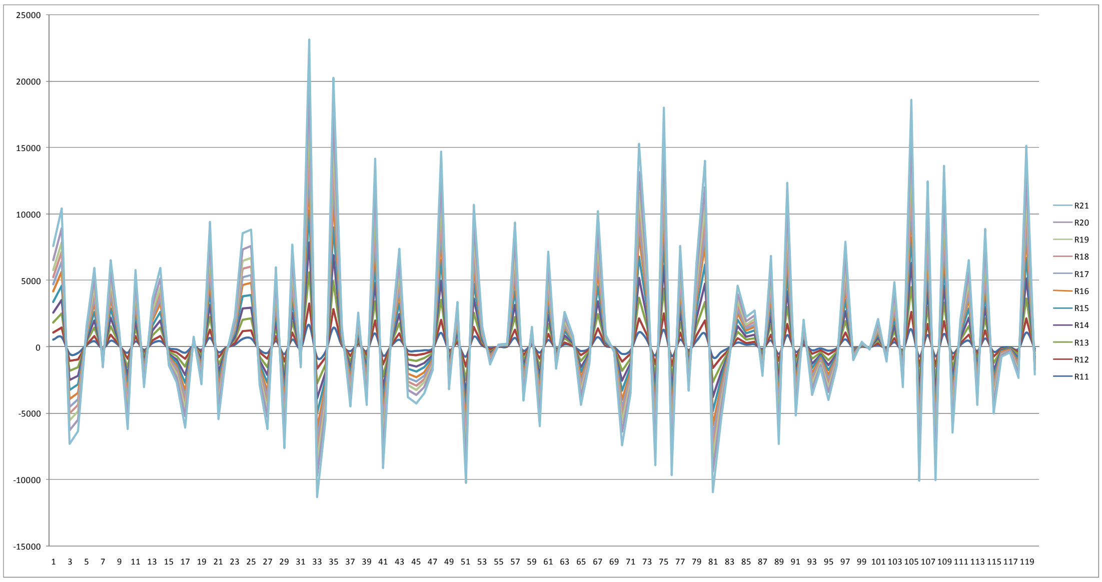
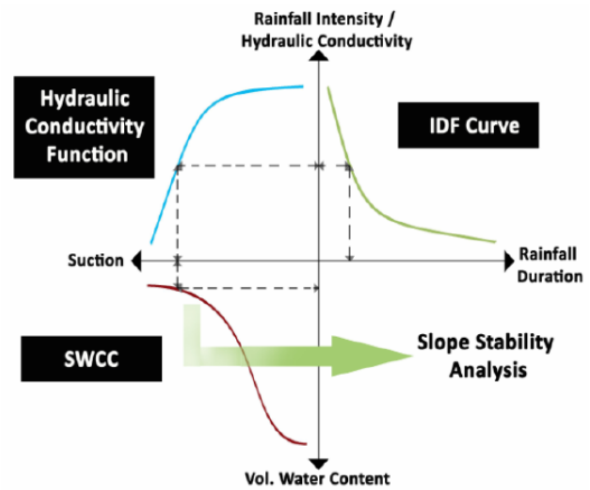


Figure 3. 13 GWT fluctuation of 11 condition based on projection 2021-2030

As shown in figure above, seen that location R21 at Juata Permai, as it conditions then ground water table fluctuation at this location are used for input of slope stability modelling as climatic drive factor of an climate change drive changes, with ground water table recharge analysis by using Cumulative Rainfall Departure (CRD) method. Rainfall induced to the soil, and infiltrated to zone of unsaturated and saturated, this change cause soil strength decrease as the trigger of landslide.

3.3.3.2 Estimating Soil Strength Decrease



Besides, the slope geometry and shear strength properties of soil were also taken into account in the analysis since these parameters are the essential contributing factors in any slope stability analysis. The development of landslide modeling by decreasing the value of cohesion from existing values to the last possible values. Hence the decreasing indicates that extreme rainfalls that

Figure 3. 14 Unique relationships between IDF (Intensity Duration Function) curve, hydraulic conductivity function, and SWCC (soil water character curve) that used in analysis landslide hazard.

infiltrated to the ground change unsaturated soil to saturated soil.

In the practice, soil parameters of c' and ϕ' are evaluated from direct shear tests on unsaturated samples. Those values which are obtained from the direct shear tests are not saturated soil parameters. In other words, those values are over-evaluated compared to the critical values. As a result the factor of safety is over-evaluated. It is therefore important to develop a simple approach for predicting the saturated shear strength parameters c' and ϕ' using the direct shear test results. Additionally, for many geotechnical problems involving slope stability concerns, knowledge on pore water pressures is of primary interest.

Usually unsaturated residual soils experience high matric suction during dry periods, which contributes to the shear strength of the residual soil. During prolonged wet periods when there is sufficient infiltration into the slope, the matric suction of the soil decreases, and this in turn results in an increase in the soil water content. As a result, the additional shear strength provided by the matric suction can be reduced enough to trigger a shallow landslide (Fredlund and Rahardjo 1993).

The minimum suction and water content in soil under extreme rainfall of any duration can be predicted through this correlation. The minimum suction is an important input parameter in the computation of unsaturated soil shear strength, while the water content is essential for the estimation of wetting front depth based on the water balance theory.

The hydraulic properties of unsaturated soil can be attributed to water retention characteristic (soil water characteristic curve) and water coefficient of permeability (hydraulic conductivity function). In addition, engineering characteristics of unsaturated soil involve the determination of an unsaturated friction angle which represents the additional strength due to the matric suction in soil.

Soil water characteristic curve (SWCC) is a fundamental hydraulic property of unsaturated soil relating the volumetric water content (θ) to matric suction (ψ). Many properties of unsaturated soil can be estimated from the SWCC (Fredlund and Xing, 1994). For instance, it has been an acceptable procedure to predict the hydraulic conductivity function of unsaturated soil empirically by using the saturated coefficient of permeability and the SWCC (Fredlund et. al., 1994).

3.4 Method of Vulnerability Analysis

Vulnerability is defined as a function of the character, magnitude, and rate of climate change as well as the degree of variation to which a system is exposed, its sensitivity, and its adaptive capacity (Affeltranger, et al, 2006 as quoted in Suroso, D.S, 2008). Thus, the components of vulnerability consist of exposure (E), sensitivity (S), and adaptive capacity (AC). The function initially is a multiplication between E with S factors and divided by AC factor as in the following formula: V = (E x S)/AC. The formula means vulnerability to a certain hazard is strengthened by its exposure and its sensitivity and decreased by its adaptive capacity. In this assessment, the function of V = (E x S)/AC is *pseudo* multiplication, because, in practice, the vulnerability (V) is gained from addition between the exposure (E) component with the sensitivity (S) component and reduced by adaptive capacity (AC) component.

Several sub-sections below explain the method of vulnerability assessment in facing hazard used in this study. The hazard which has been identified in previous chapter are water shortage, floods, and landslides. Hence, there are three type of vulnerabilities: vulnerability to water shortage hazard, vulnerability to flood hazard, and vulnerability to landslide hazard. The scopes of the explanation including method of identification and selection of vulnerability components as well as indicator of each components, method of assessment of water shortage vulnerability as well as method of flood vulnerability assessment and landslide vulnerability assessment; and method of analyzing and weighting each component of vulnerability.

In this study, we also implement dynamic vulnerability. Meaning, indicators of each vulnerability components are dynamic. To obtain the vulnerability results in a more reliable projection condition, an analysis of change of vulnerability indicators from baseline condition to projection condition is needed, both its number and distribution. Several analysis methods are needed to approach this dynamic vulnerability.

3.4.1 Method of vulnerability components identification and selection

In this step, we identify the vulnerability components E, S, and AC through each of its indicators for every hazard. Sources of identification are some related IPCC's publications, and previous study results in Indonesia, and discussions between experts in this VA Tarakan study, also the results of focus group discussions with stakeholders from the government of Tarakan Municipality.

Next, we select from the identification results based on certain criterions to determine final vulnerability indicators and components. The criterions are:

(1) The level of significant relation between indictors and hazards reviewed where the strongest significance will be chosen;

(2) Indicators have enough availability or its data can be calculated, both temporal (baseline and projection) and spatial, based on its available data parts; and

(3) Indicators are not yet involved in the analysis of hazard.

The next step is to map the indicators into one of the components of vulnerability: exposure, sensitivity, and adaptive capacity. Then followed by calculating the quantity, mapping the distribution, and weighting the vulnerability components based on its indicators in the baseline and projection period.

3.4.2 Method of assessment of water shortage vulnerability

Based on the benchmarking to literature studies (AR4 IPCC, ICCSR, VA Lombok, etc.) we obtained that indicators with strongest relation with the water shortage hazard are water availability, water demand, water sources as a part of water availability, water quality, population welfare, PDAM network as community's access to clean water source, local government's policies and programs on water management, initiatives and role of local community on water conservation, landslides, water sources damages, etc.

Based on the three criterions that have been mentioned above, we identify the vulnerability indicators for water shortage hazard, which are: water demand, water sources used by inhabitant people, water quality, network of PDAM service, and social welfare. These indicators wil be fixed in Chapter V of this study with each data sources presented in Table 3.6 below.

Table 3. 6 Indicators and sources of their data for water shortage vulnerability

Indicators	Data
Water Demand	• Population Census of Tarakan Municipality , 2010 • Landuse 2008 • *Rencana Tata Ruang* Tarakan Municipality, 2030
Water sources	• National Census, 2007
Water Quality	• Field Survey

PDAM network	• PDAM Network, 2008
Population Welfare	• House type, Capital Income (Field survey, National Census, 2007)

Based on Table 3.6, methods used in the assessment of water shortage vulnerability are:

1) Calculating and mapping of water demand

Water demand (WD) is calculated based on the water needs of every water user, they are society, industries, etc. The difference of WD used as vulnerability components with WD in the hazard analysis is that the WD in the vulnerability is calculated per grid or distribution per grid with grid area = 100 m x 100 m or 1 hectare; while the WD in the hazard analysis is calculated per watershed unit.

Society's WD is calculated based on current population for the baseline and based on 2030 population for the projection condition. At first, water needs standard used is 144 liter/person/day for the baseline condition. After processed based on the classification of total households, the standard is modified into as in Table 3.2. For the projection condition, society's WD is calculated based on the projection of 2030 population. Population growth here uses values from BPS. Meanwhile, the water needs standard of the projection is assumed the same with the standard of baseline period (Table 3.2).

Society's WD calculation per grid with grid area of 1 hectare or 10.000 m^2, needs an approach to estimate the distribution of population density more reliably for both baseline and projection period. For the baseline period, we need the calculation of population distribution per every household in each village and the number of houses per grid area. In the projection period, we need data on 2030 spatial plan to calculate population development and its distribution in the same grid area. Thus, we use assumptions as discussed in sub-section 3.1.2 1) above, for both baseline and projection period. Findings of this population density distribution per grid method and its results are one of the results of this climate risk and adaptation study on Tarakan Municipality which will be further discussed in Chapter 5.

Calculation and mapping of industries' and other's WD is based on the approach of land=use condition and standard water needs for every land-use. In the baseline condition, the number and distribution of land-use is obtained from the land-use map of Tarakan Municipality of 2008, while the standard water needs per land-use unit is as shown in Table 3.3.

In the projection period, the land-use condition is determined by 2030 land-use approach derived from 2030 Spatial Planning of Tarakan. The standard of water needs per land-use unit for the projection period is assumed the same with the standard water needs for every type of land-use in the baseline period (Table 3.3).

2) Calculating and mapping of water sources

Water sources are various sources of water that are used by population in Tarakan Municipality for the baseline and projection periods. For the baseline, the calculation and mapping of water sources data is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Report of the survey consists of the data of each source of water used by people and its distribution in village as unit of distribution.

In the projection condition, based on the assumption that 90% of Tarakan Municipality will be served by PDAM network, it is clear that 90% of water sources in every village are taken from PDAM service. Hence, map of this water source will follow the map of PDAM service networking. Here, the contribution of the others sources, which are 10% of total water source in the projection are neglected.

3) Calculating and mapping of water quality

Based on literature studies, swamp water on Kalimantan and its surrounding has a bad quality because possibly it contains iron or has a high acidity. Based on the data of water sources used by public, in Tarakan, there are still people using river water, wells, and springs for its daily use. In the regions near swamps or regions which are previously swamps there are possibilities that the water quality from those three sources is contaminated by low quality swamp water. Meanwhile, in the projection period where there will be a decrease of water supply, swamp water may likely used by the public as a source of water.

The next method of this water quality vulnerability indicators study begins with extracting samples or checking other secondary sources of water. These water samples then tested at a laboratory to ensure its level of quality. The next step after the quality of water is obtained, is determining the source of water which fulfills the criterions to be a vulnerability component indicator.

The final step is to calculate the spatial distribution of these selected sources of water. To determine the distribution of swamp area, for instance, we can use an observational method with the help of Landsat ETM7 images of 2003 with the assumptions that has been mentioned in previous sub chapter. Other significant sources to water quality may also be calculated and mapped based on its distribution. In the projection period we assume that water quality is not significant as a vulnerability indicator because in 2030 it is assumed that PDAM's water service with a quality fulfilling the standard drinking water has reach 90% of the total population, and the 10% left can be ignored.

4) Calculating and mapping of PDAM's service network

Based on data availability, the reliable method to calculate and map PDAM's service network is by using the approach of population served by PDAM. Thus, we calculate the population percentage served by PDAM with its service network map in the baseline or current condition (2010) and projection period (2030).

5) Calculating and mapping of social welfare

As assumed before, social welfare is stated by two sub-indicators, they are type of house and population income. Hence, the calculation method of house type is based on the house type in every village through field surveys. Meanwhile, the calculation method of population income is done by analyzing data from the 2007 National Census. With these two methods, house type and population income can be calculated and mapped for each village unit. The two methods are calculation and mapping of social welfare for the baseline period (2010).

For the projection period, this social welfare is assumed not contributing to reducing the vulnerability. It is because of the government program to mitigate water shotage is assumed in maximum condition that is 90% PDAM service target is achieved.

3.4.3 Method of flood vulnerability assessment

Based on the existing literature references, we obtain a number of alternative indicators with strong relation to floods hazard. These indicators are: population density, land-use, watershed degradation, slope, rock type and its ability to absorb water, role of infrastructure, population welfare, and government program.

Based on the same criterions that have been applied in selecting the indicators of water shortage vulnerability, we can identify vulnerability indicators to floods hazard: population, density, land-use, role of infrastructure, population welfare, and government program as shown in Table 3.7. These will be fixed in Chapter V.

Table 3. 7 Indicators and sources of their data for flood vulnerability

Indicators	Data

Population Density	Population Census of Govt. of Tarakan City 2010
Land-use	Land-use 2008 (Tarakan City with modification)
Role of Infrastructure	PDAM Tarakan 2005 and Landuse 2008
Population Welfare	House type, Capital Income (Field survey; National census, 2007)
Government Program	Infrastructures (Public Work Agency, Tarakan Municipality, 2008)

Based on Table 3.7, two of the indicators are the same with the indicators previously used in the assessment of water shortage vulnerability, such as: population density (used in the calculation of water needs), and population welfare. Below are the assessment methods in detail for the floods hazard indicators.

1) Calculating and mapping of population density

The population density data used as the indicator of floods vulnerability is the same with the population density data calculated in the analysis of water needs in the assessment of water shortage vulnerability. In principal, the method of this population density study is calculating and mapping the population distribution as realistic as possible. The method has been discussed in the explanation of water demand indicator.

2) Calculating and mapping of land-use

To calculate and map the land-use type, we acquire sufficient data from the local government. The data includes: the 2008 land-use from the BAPPEDA of Tarakan Municipality for the baseline period and 2030 land-use of the Spatial Planning of Tarakan Municipality for 2030 with the assumption that have been mentioned in sub-sub chapter. The next needed study is to assess the data further to group the land-use based on the uniform land-use unit between baseline and projection period. This step is needed considering the difference of grouping between 2008 land-use and 2030 land-use.

3) Calculating and mapping of role of infrastructure

Role of infrastructure here, as mentioned in the assumptions, is infrastructures useful in preventing floods or overcoming impacts of floods. An example of this role is reservoirs used as floods reducer besides its function as water storage, and which is useful as clean water supplies for society suffered from the flood. Assessment in this case is in the form of calculating and mapping infrastructures useful to prevent floods and accelerate recovery from floods impacts. Data used include: current infrastructure data of PDAM's service and 2008 land-use map for the baseline period. For the projection period the same assessment will be done using the 2030 Spatial Planning. With the assumptions, the infrastructure classes can be assessed by its roles to floods.

4) Calculating and mapping of government program

As stated in the assumption about future trends, the government programs are any treatment from the government to handle landslides to government facilities and important infrastructures which suffered from floods. Those government programs are for the baseline period. Hence, the methods that will be done here are assessing the location of government program related to floods that has been implemented or planned to be acted in the next couple of years and drawing their magnitude and distribution on the map.

Meanwhile, for the projection period, it is assumed that the role of government program in the projection is in the maximum condition. It means that government program in anticipating flood in the projection period will cover all areas of Tarakan Municipality. Being in this assumption, the method for calculating and mapping the government program for the projection period can easily be done by tracing the location of the landslide in the projection period.

5) Calculating and mapping of social welfare

The social welfare indicator for floods is as the social welfare indicator for the water shortage vulnerability. Hence, the method used to calculate and map the social welfare in this floods vulnerability is the same with the method of study of the social welfare in the water shortage vulnerability.

3.4.4 Method of landslide vulnerability assessment

Using the same method as in benchmarking the alternative indicators to water shortage and flood vulnerability, for vulnerability to landslides, there are several vulnerability indicator options: population, density, land-use, watershed's critical level, slope, rock type and its ability to filtrate water, ground water surface, roads position to hills, role of infrastructure, settlement distribution, population welfare, government program, etc.

Based on the criterions used, we can identify indicators for landslides vulnerability as population, density, land-use, role of infrastructure, population welfare, and government program (Table 3.8). These temporary indicators will be fixed in Chapter V.

Table 3. 8 Indicator and sources of their data for landslide vulnerability

Indicator	Data
Population Density	Population Census Govt.Tarakan City 2010
Landuse	Landuse 2008 (Government of Tarakan, with modification)
Role of Infrastructure	PDAM Tarakan 2005 and Landuse 2008
Population Welfare	House type; Capital Income (Field survey, National census, 2007)
Government Program	Roads (Public Work Agency, Tarakan City, 2008)

Vulnerability indicators to landslides and its sources (Table 3.8) are the same with the indicators and its sources used in the assessment method of flood vulnerability as in Table 3.8. This is due to data availability which prevents landslides vulnerability indicators to acquire more complete data.

Based on the comparison of Table 3.7 and Table 3.8, methods used in the vulnerability assessment to landslides are the same as the calculation and mapping methods of vulnerability to floods. In this case, we don't need another discussion on the assessment of vulnerability to landslides.

3.4.5 Method of vulnerability weighting

As in hazards, vulnerability in this study needs to be weighted to determine its level as factors of risk in the next study. The indicator weighting method in this study uses AHP (Analytic Hierarchy Process), that is a method founded by Saaty in 1980 and became a popular and widely used method for multi-criteria decision making.

1) The Basic Principal of AHP Method

As often stated in many references of the AHP, this method was designed for formalizing decision making where there are a limited number of choices but each has a number of attributes and it is difficult to formalize some of those attributes. This method allows the use of qualitative, as well as quantitative criteria in evaluation.

The basic principle in AHP is to develop a hierarchy of decision criteria and define the alternative courses of actions. Shortly, it is said that AHP algorithm is basically composed of two steps: 1) determine the relative weights of the decision criteria; 2) determine the relative rankings (priority) of alternatives. Both qualitative and quantitative information can be compared using informed judgments to derive weights and priorities.

2) Method of AHP implementation in the assessment

This study use AHP method by ignoring several weaknesses of the method such as the rather arbitrary aspects of the procedure. Implementation of AHP in this study is to give relative weighting to every vulnerability component to each other. In this case, there are 5 indicators of landslide vulnerability where the indicators of floods are the same as the indicators of landslides. All of these indicators for AHP application is presented in Appendix 3.

Based on the number of hazard identified and indicators for each vulnerability to the hazards, there are 3 sets of questions for the experts to answer as inputs in the AHP; 3 sets, as much as the number of hazards. Each question has 15 pairs of pair wise comparison to be filled by the experts with reference to the pair wise comparison scale matrix as in Appendix 3.

3.5 Method of Risk Analysis

Following the definition of Risk (R) as function of Hazard (H) and Vulnerability (V) or R = f (H,V), risk analysis conducted after hazards and vulnerability have been identified by using GIS method. In this study, the function (f) is addition rather than multiplication or R = H + V. Using weighting method and GIS analysis, risk map of every hazard and vulnerability to the related hazard is produced.

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IV. ANALYSIS OF HAZARD DUE TO CLIMATE CHANGE

4.1 Direct impact of climate change related to water sector

The increasing temperature and precipitation variability are among the direct impacts of climate change. In water problems, temperature and precipitation are the main agent that determines natural water supply. Two important results of climate team are: the projection of temperature (T) with an increase as much as 0.5ºC and variability of precipitation with the possibility of repeating 1951-1970 decadal patterns in the 2010-2030.

We obtain the temperature data of 1951-1970 until 2091 projection (Appendix) from the climate modeling resulted by the scientific basis (SB) team. This data is complemented with observational data, then plotted the temperature rise vs time (1951-2091) as shown in Figure 4.1 (Hadi et al, 2011).

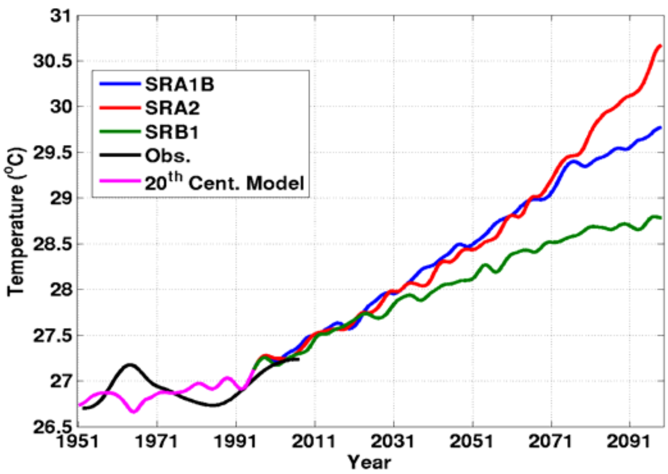


Figure 4. 1 Average surface temperature increase pattern on Tarakan in 1951–2010. Observation (black) and 20th century model (pink); SRA1B (2011-2091) scenario (blue), SRA2 (red), and SRB1 (green) from climate analysis (Hadi et al, 2011). Temperature T during the projection period experiences an increase in all scenarios. Climate projection results until 2030s show tendency of increasing average temperature as high as 0.5ºC for all scenarios (B1, A1B, and A2). *Source*: Hadi et all, 2011)

Based on the climate study of the , the projection of monthly average surface temperature (T) on Tarakan in 2011-2030 is 27.7005°C. During the period, maximum temperature T is 28.6479°C which is projected to happen on September 2017, and minimum T of 26.7794°C projected to happen on January 2019. In this study, evaporative demand is calculated by using Thornwaite formula in water balance analysis. The significant temperature rise will trigger significant evapotranspiration rise. This rise will be followed by decreasing TRO – caused by non climatic factor – which will cause water shortage hazard.

Meanwhile, the porjection monthly average precipitation (MAP) is varying but in general it shows trend of decreasing trend in the period 2011-2030. As in the result of scientific basis analysis, the MAP in the projection period of 2011-2030 actually experiences variability or up and down in the period of 5 to 10 years, but the general trend of the MAP in the projection period of 2011-2030 is decreasing.

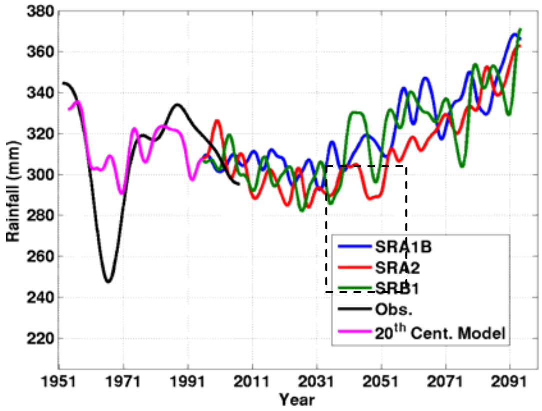


Figure 4. 2 Average rainfall increase pattern on Tarakan in 1951–2010.

Observation (black) and 20th century model (pink); SRA1B (2011-2091) scenario (blue), SRA2 (red), and SRB1 (green) from climate analysis (Hadi et al, 2011). In the box, 2011–2030 projection shows precipitation variability with general trend of decrease, consistent for all scenarios with the lowest decrease in scenario SRB1 of 2021-2030 period. There is a trend of interdecadal decrease in 2011-2020 and 2021-2030 although the decrease is not as low as the 1961-1970 period.

The maximum projection monthly average precipitation (MAP) on 2011-2030 period is 507.1287 mm/month which is expected to happen on March 2023, and minimum MAP in that period is 102.3027 mm/month on June 2014. While the average of MAP in 2011-2030 period is 304.6937 mm/month. Based on the 10 years (decadal) for 2010-2030 projection period, the MAP for 2011-2020 period is 308.5426 mm/month and 2021-2030 is 303.3431 mm/month. The maximum MAP in 2011-2020 is 492 mm/month on November 2011; in 2021-2030 period is 507.1287 mm/month March 2025; while the minimum MAP in 2011-2020 projection period is 102.3027 mm/month on June 2014 and in 2021-2030 period is 138.1239 mm/month on August 2027.

Meanwhile, on the baseline condition (1960-1990), average monthly average of precipitation (MAP) in the 1961-1970 decade is 250.0108 mm/month and average MAP in 1971-1980 is 318.2700 mm/month, and average of MAP in 1981-1990 is 329.2120 mm/month. While the average MAP of the current period is 318.3158 mm/month in 1991-2000 and 305.6542 mm/month in 2000-2009.

The average of monthly average precipitation (MAP) before the baseline, which is 1951-1960, is 338.0283 mm/month. Thus, the average of monthly average precipitation (MAP) decadal is assumed experiences repeating decrease in 2011-2030 (MAP = 305.9429 mm/month) compared to current condition (1990-2020; MAP = 311.9850 mm/month) with average maximum decrease happened in 2030s. The possibility of repeating decadal precipitation decreases is a potential threat to water availability. Data trend of 2010-2030 precipitation also validate this potential hazard.

4.2 Water Shortage Hazard

Water shortage has been indicated in the previous chapters as a hazard faced by Tarakan in the baseline period and projection period. Based on the framework of the assessment method, water shortage hazard is formulated as the probability of decreasing of water availability (DoWA) or decreasing water supply in the normal condition multiplied by the condition of water demand (WD) and compared to the water availability or water supply of normal condition ($Q_{baseline}$). The normal condition is assumed as 1960-1990 (Baseline).

The main indication of water shortage hazard is the tendency of decreasing precipitation as stated by the results of climate analysis, where 1960-2030 precipitation fluctuated, but had a decreasing trend (see Figure 4.2). The consistent temperature rise since the baseline period is predicted to increase potential evapotranpiration (ET) ensuring the threat of natural water supply.

The next indication is the increasing population and industry in Tarakan, and the change of landuse which increases water demand (WD). This is the contributing factor which is not driven by climate change impact. Increasing water demand will stress the hazard.

Next we study the hazard components influenced by non climatic drivers, which are water needs per watershed and water supply in the baseline condition as comparison of the water shortage hazard. The last part of this chapter will discuss the calculation results and mapping distribution of water shortage hazard in Tarakan along with its weight.

4.2.1 Climatic drivers of water shortage hazard

Based on the climate data in the Appendix, we analyze Potential Evapotranspiration (ET) and water balance which produced Total Runoff (or Total Run Off or TRO), Base Flow (BF), Direct Run Off (or Direct Runoff or DRO) and Storm Run Off (or Storm Run Off or SRO) data in mm/year from 1960-2080. The analysis results of ET, water balance, and infiltration value (IF) from the rock type infiltration characteristic of Tarakan, are plotted. The results are shown in Figure 4.3 and 4.4.

From Figure 4.3 we can see that the decreasing trend is greater along with time (year) for the following variables: Total Runoff (TRO, green), infiltration (IF, tosca green), Direct Runoff (DRO, yellow green), and Base Flow (BF, purple) from 1960 to 2080. The decreasing variables of TRO, IF, DRO, and BF are the indicators of water availability shortage. These curves are the proves of future water shortage hazard, beside the decreasing precipitation trend and temperature rise.

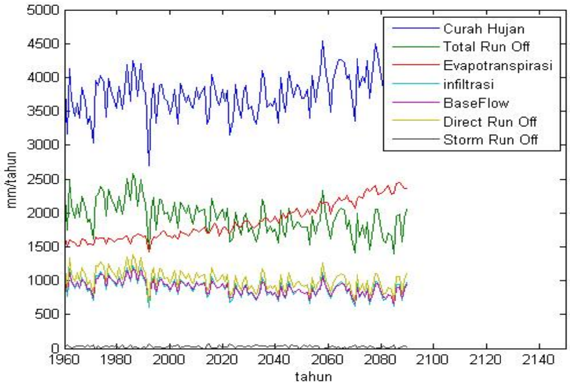


Figure 4. 3 Plot of rainfall, Total Run Off (TRO), potential Evapotranspiration (ET), Infiltration (IF), Base Flow, Direct Run Off, and Storm Run Off. In 1960-2030 all parameters are decreasing except ET.

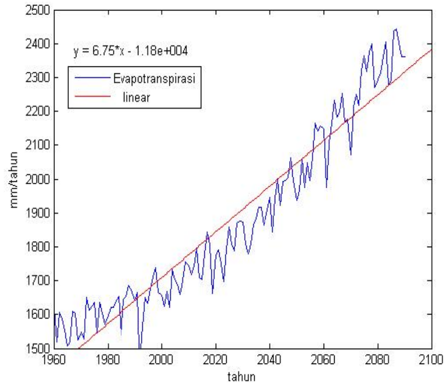


Figure 4. 4 Blue: magnification of ET (mm/year) vs time (1960-2090). Red: linier regression of ET vs year, with equation y = 6.75x + 1.18 * 10^4

Figure 4.4 shows an enlarged evapotranspiration (ET) trend to show the increasing ET from year to year. The linier line formulation, y = 6.75*x + 1.18e+004 or y = 6.75x + 1.18 * 10^4 is the linier regression from the evapotranspiration (ET) curve where y is the evapotranspiration in mm/year and x is year, from 1960 to 2090. Evapotraspiration is the amount of water evaporates from Tarakan from 1960 to 2090, and increasing trend means decreasing water supply.

To obtain the cross section estimation of increasing evapotranspiration with decreasing TRO, Figure 4.3 is enlarged. The result in Figure 4.5 shows two curves of total runoff (TRO, green) and evapotranspiration (ET, red) from 1960 to 2080 (inside the red elipsoid). It can be seen that 2030 is the critical moment, where the amount of water evaporated is 1750 mm/year. After 2030, the TRO will be smaller than the potencial amount evaporated (ET), meaning, there will be a deficit of water if water supply depend only on precipitation.

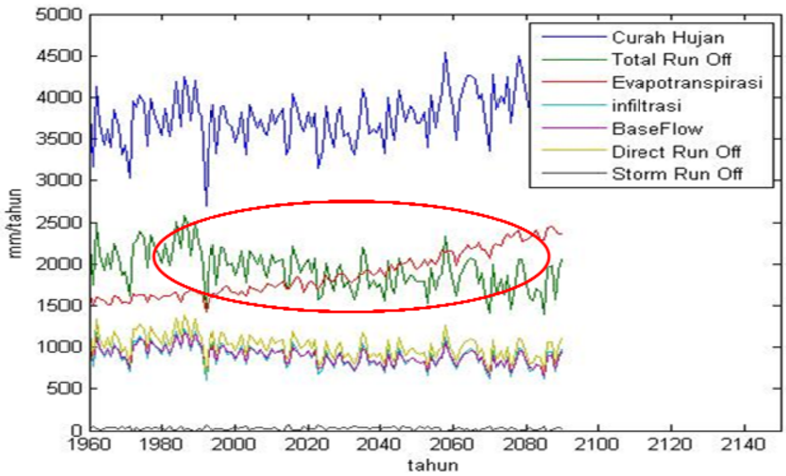


Figure 4. 5 Enlargement of ET-TRO curve, vs time period of 1980-2080 (red ellipsoid), shows the critical water supply due to evaporation exceeding total surface run off, if not followed by good water management

Note: *Curah Hujan* = Precipitation; Total Run Off = TRO; *Evapotranspirasi* = Evapotranspiration; *Infiltrasi* = Infiltration

The last analysis to show the direct impact of climatic drivers to water shortage is the analysis of CDF to TRO. CDF (cumulative distribution function) analysis as a tool is used to correlate TRO value to certain numbers from the cumulative percentage which assumed show a certain condition. The certain condition being water shortage, while the assumption is 50% of CDF as the normal level. TRO value below 50% of CDF means water shortage. TRO is acquired from the analysis of water balance. Thus, this study calculate TRO from 5 different periods, which are Baseline (1960-1990), current period (1991-2020), Projection (2010-2030), Future (2031-2060), and Future 2 (2061-2090); and analyze each with the CDF method. CDF analyses for the future and future 2 TRO are included here to see further trend supported by available data from climate projection result up to 2090. The results are then plotted and shown in Figure 4.6, with x axis is TRO and y axis is CDF.

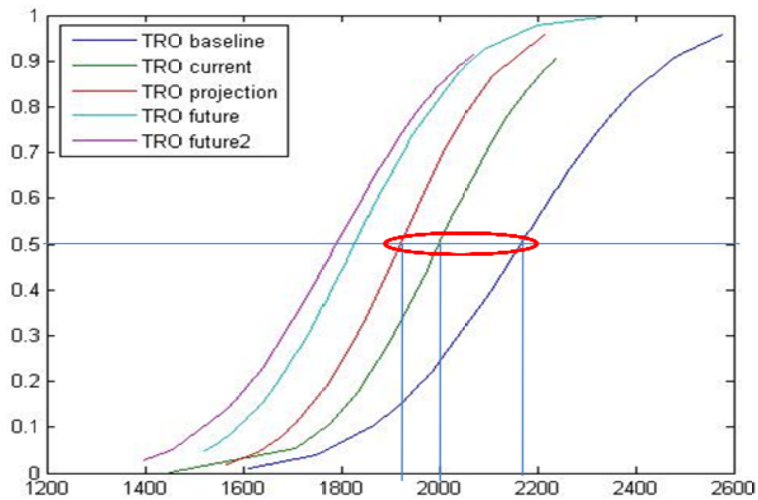


Figure 4. 6 CDF (Y axis, maximum = 1 or 100%) vs TRO (X axis, mm/year). Drastic decrease occurred in 1960-1990 (Baseline) to 2010-2030 (projection) where TRO drops from 2164 mm/year in the Baseline (1960-1990) to 1992 mm/year in 1991-2020 (current period), and decrease again to 1911 mm/year in 2010-2030 (Projection period).

Based on results of the CDF analysis (Appendix and Figure 4.6), we can see a consistent prove that the decreasing water supply is the decrease of TRO from normal condition in 1960-1990 (Baseline) of 2,164 mm/year, to 1,992 mm/year in 1991-2020, and again to 1,911 in 2010-2030. This TRO drop even continues to further future as shown in the graph. It is clearly pictured in Figure 4.6 that although precipitation tends to increase in 2020, the annual TRO condition tends to decrease due to temperature rise affecting the increasing evapotranspiration. We can formulate that: **(1) Decreasing baseline TRO (1960-1990) to**

current TRO (1991-2020) is the baseline hazard; and (2) Decreasing baseline TRO (1991-2020) to projection TRO (2010-2030) is the projection hazard.

The decreasing TRO between baseline and current periode and between baseline and projection gives water shortage values of 180 mm/year or 8% decrease from 1960-1990 to 1991-2020 and 267 mm/year or decreases 12% from 1991-2020 to 2010-2030. The decreasing water supply for every watershed is shown in Table 4.1.

Table 4. 1 Water shortage per watershed in baseline (current) & projection period

No	Watershed	Decreasing of Water Availability (DoWA) (m^3/year)	
		baseline/current (1990-2020)	Projection (2010-2030)
1	Amal Baru	597,393	159,504
2	Bengawan	2,356,801	629,266
3	Binalatung	3,499,427	934,347
4	Kampung Bugis	1,441,799	384,960
5	Karungan	1,569,111	418,953
6	Kuli	1,353,754	361,452
7	Mangantai	2,699,028	720,641
8	Maya	1,884,820	503,247
9	Pamusian	3,840,604	1,025,441
10	Persemaian	3,705,257	989,304
11	Semunti	2,818,620	752,572
12	Sesanip	1,875,597	500,784

Based on the CDF-TRO analysis, the trend of increasing evapotranspiration, and the comparison of evapotranspiration with 2030 TRO, it seems that water shortage hazard is very important to anticipate. This analysis hasn't consider the decreasing precipitation based on the results of climate analysis (Figure 4.2). There are also the influence of non-climatic drivers which will decrease the amount of water in the watershed unit.

4.2.2 Non-climatic drivers of water shortage hazard

The non-climatic drivers affecting water shortage hazard are water demand per watershed unit; and water quantity in the baseline condition (1960-1990), calculated based on the value of precipitation infiltration value per watershed area. But the water quantity of baseline is a constant factor, thus making water demand (WD) the important part.

Actually, many factors of non-climatic drivers which could worsen the condition of water shortage, such as: land-use, critical level of land, vegetation cover, water source condition, water user behavior. But further study shows that these factors are better positioned as vulnerability components to water shortage hazard. Hence, only water demand indicator, which is used as a non-climatic driver of hazard analysis.

As assumed before, water demand is calculated based on domestic, industries, and other water needs. For domestic, the amount of water needs is calculated based on the population in each watershed, approached using the number of households in each watershed with the classification stated in Table 3.2 in sub-chapter 3.2.1. Based on these assumptions and standards, the number of households and water needs for every classification are: > 1000 hh (0.174 m^3/day/person); 500-1000 hh (0.170 m^3/day/person), 100-500 hh (0.126 m^3/day/person), 20-100 hh (0.178 m^3/day/person), and 0-20 hh (0.54 m^3/day/person). The number of households per watershed itself is calculated based on the assumption and method of population calculation and distribution which almost realistic, as stated in Chapter 3.

For industrial and other needs, each water needs are calculated by using the approach of land-use type and standard water needs per land-use as in Table 3.3 sub-chapter 3.2.1: Industries (50 m^3/day/hectare), Trades and Services (40 m^3/day/hectare), Airports (40 m^3/day/hectare), Hospitals (30 m^3/day/hectare), Governmental Offices (25 m^3/day/hectare), and Religious Places (25 m^3/day/hectare). Hence, we can construct the water needs table for each watershed, shown in Table 4.2. Based on the total water needs per watershed (Table 4.2) we produce the map of water needs for baseline and projection periods as in Figure 4.7.

Table 4. 2 Water needs per watershed in baseline (current) & projection periods

No.	Watershed	Water Demand (WD) in m^3/day					
		Domestic		Industry & others		Total	
		Baseline	Projection	Baseline	Projection	Baseline	Projection
1	Amal Baru	147	319	0	482	147	801
2	Bengawan	1,544	5,501	0	14,069	1,544	19,570
3	Binalatung	154	1,665	0	2,925	154	4,591
4	Kampung Bugis	12,271	14,358	427	5,286	12,699	19,643
5	Karungan	592	4,389	0	10,594	592	14,983
6	Kuli	169	1,030	0	1,367	169	2,397
7	Mangantai	0	213	0	20,766	0	20,979
8	Maya	0	1075	0	4,961	0	6,036
9	Pamusian	13,495	16,010	198	5,037	13,693	21,048
10	Persemaian	2,195	8,320	2	16,432	2,197	24,752
11	Semunti	113	5,476	0	11,084	113	16,560
12	Sesanip	1,999	4,107	1451	15,550	3,450	19,658

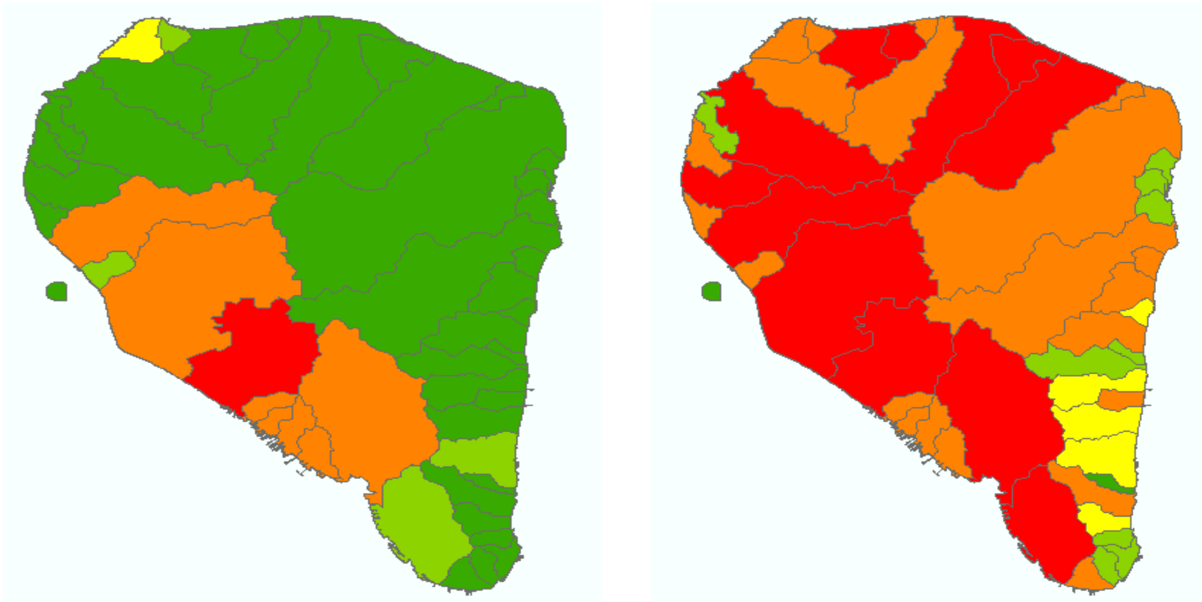


Figure 4. 7 Water demand per watershed unit, for the baseline/current period (left), and projection period (right). Water needs level is divided into 5 classes with a unit of m^3/day. Water needs in the projection period increases significantly compared to current needs. In both periods, the water needs in the western is always higher than the eastern and northern Tarakan.

4.2.3 Figure of water shortage hazard

As in Chapter 3, water shortage hazard or hazard of decreasing water supply in this study is formulated as the probability of decreasing water amount from the normal condition which will be worsen by the water demand condition. The probability is approached by the analysis of CDF to TRO in the 50% CDF. The analysis of CDF has shown that the TRO 50% CDF tendency to decrease consistently from the baseline (1960-1990), current (1991-2010), and projection (2010-2030), even continued to future (2090, see Figure 4.6).

In its implementation, the amount of water shortage and water demand per watershed as hazard indicators are then compared to the water amount of normal condition, the baseline condition of 1960-1990. So, the form of water shortage hazard (WSH) is obtained from overlaying the decreasing of water availability (DoWA) with the water demand (WD) and compared to the water amount in the baseline condition ($Q_{Baseline,1960-1990}$). Mathematically, it can be approached with WSH = [(DoWA + WD)/ $Q_{Baseline,1960-1990}$] with watershed unit. From this approach, and the temporary results of sub-chapter 4.2.1 on decreasing water availability and sub-chapter on water demand (Figure 4.7), we can create the map of water shortage hazard below.

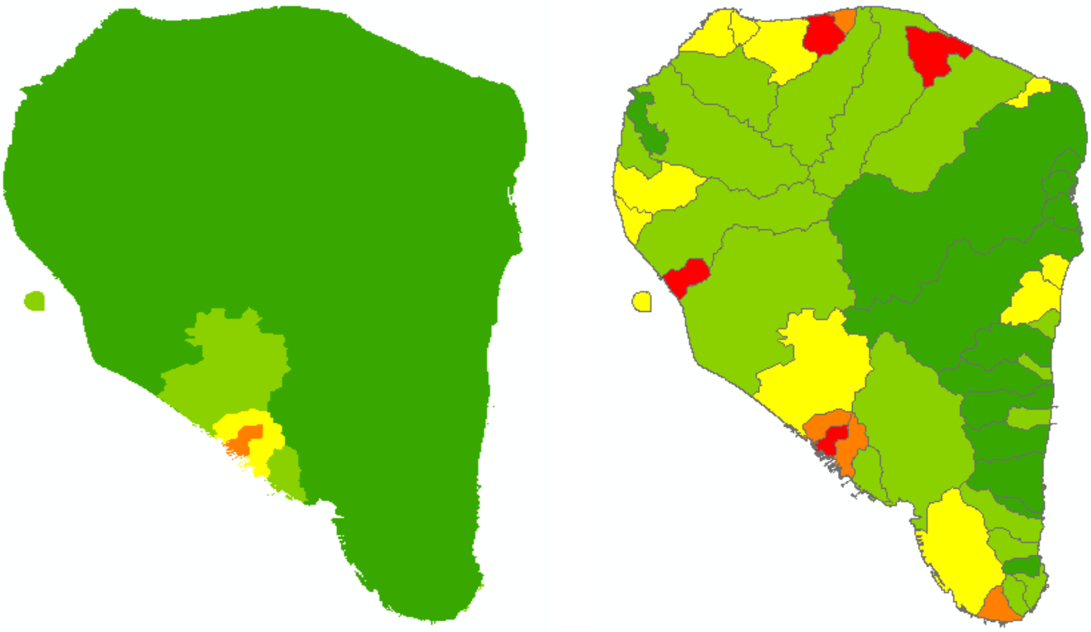


Figure 4. 8 Map of water shortage hazard for baseline period, 1990-2020 (left) and projection period (2010-2030) condition (right).
The overlay result between map of decreasing water availability with map of water needs for every watershed with 5 hazard classes: very high (red), high (orange), moderate (yellow), low (light green), and very low (green).

Figure 4.8 shows the temporal water shortage hazard for 1990-2020 and projection period (2010-2030); and spatial. It can be seen quite clearly from the above figure that the hazard increases from current to projection condition.

The regions of current period with very high threat are the regions bordering with the western coast in the middle south are, especially Kampung Bugis watershed and its surrounding including villages of Selumit, Selumit Pantai, and Sebengkok (West Tarakan sub-district); Karangbalik, Karang Rejo and Selumit (Central Tarakan district). The hazard level in those regions is high to moderate. Surrounding those high to moderate level of water shortage hazard is low level of the hazard. This low level of water shortage hazard covers area of Sesanip watershed which belongs to part of Karang Anyar villages and Karang Anyar Pantai village in West Tarakan sub-district; and Pamusian watershed which belong to Lingkas

Ujung village and Gunung Lingkas villages, East Tarakan sub district. The others regions are belong to very low level of water shortage hazard.

The hazard level in the projection period will increase along with the decreasing natural water supply due to decreasing precipitation and increasing evapotranspiration, and increasing water demand. Most regions in Tarakan City will experience increasing hazard level in the projection period. The main cause of the hazard is water demand.

The highest level of the hazard in projection period is very high. Watersheds that its level water shortage hazard is very high are Kampung Bugis, Persemaian, watershed located western Mangantai and eastern Maya. In Kampung Bugis watershed this very high level of the hazard was distributed in part of Selumit village, Selumit Pantai village and Sebengkok village (Central Tarakan district). In Persemaian watershed, the very high level of the hazard was located in part of Karang Harapan village. Meanwhile in western Mangantai and easteren Maya watershed this very high water shortage hazard was belonging to Juata Laut village, North Tarakan district.

Next to very high level of water shortage hazard is high level of water shortage hazard. This hazard level is distributed Kampung Bugis, northern Kampung Bagus, southern Kampung Bugis, Pamusian, southern Karungan, and eastern Maya watershed. In Kampung Bugis watershed this high level of the hazard was distributed in part of Selumit village, Selumit Pantai village and Sebengkok village (Central Tarakan district). In Northern Kampug Bugis watershed, region with high level of the hazard was located in part of Karang Balik and Karang Rejo (West Tarakan district); while in watershed southern Kampung Bugis this high level of the hazard was distributed in parst of Sebengkok village (Central Tarakan district). This high level of water shortage hazard also was distributed in Pamusian village, Central Tarakan district at Pamusian watershed. It was distributed in southern part of Karungan village also, which located in East Tarakan district in southern Karungan watershed. Meanwhile in eastern Maya watershed, this high level of water shortage hazard was distributed in Juata Laut village, North Tarakan district.

The others level of water shortage hazard are moderate, low and very low level. Those level are still the most dominant level of water shortage hazard in Tarakan City in projection period. The moderate level of the hazard is located in Sesanip, Karungan, Bengawan, northern Bengawan, southern Binalatung, and eastern Maya watersheds which cover several villages that belong to west Tarakan, east Tarakan, and North Tarakan, such as: Karungan village (Karungan watershed, East Tarakan), part of Karang Anyar Pantai village and Karang Anyar village (Sesanip watershed, West Tarakan district); Juata Permai village (Bengawan watershed, North Tarakan district). The others region have low to very low level of water shortage hazard. Table 4.3 and Table 4.4 below summarizes each level of water shortage hazard and value of decreasing of water availability and water demand; and its distribution spatially in the baseline period and projection.

The hazard component of decreasing of water availability in the risk assessment will be filtered again, thus the risk map is still has not represent the hazard map.

Table 4. 3 Water shortage hazard and its distribution in the watershed for current period and projection period

Level of WS[1)] Hazard	Current (baseline), 1991-2020			Projection, 1991-2020		
	DoWA[2)]	WD[3)]	Watershed	DoWA[1)]	WD[2)]	Watershed
Very High	-	>2,500,001	Kampung Bugis	629,266	>2,500,00 1	Persemaian Kampung Bugis Western Mangantai Eastern Maya
High	-	500,001-2,500,000	Kampung Bugis, Pamusian	384,960-1,025,441	500,001-2,500,000	Kampung Bugis, Northern & Soutern of Kampung Bugis Pamusian Southern Karungan Eastern Maya
Moderate	1,441,799-3,840,604	250,001-500,000	Kampung Bugis, Pamusian	418,953-500,784	250,001-500,000	Sesanip, Karungan Bengawan Northern Bengawan Southern Binalatung Eastern Maya
Low	1,875,597-3,840,604	50,000-250,000	Sesanip, Pamusian	159,504-1,025,441	50,000-250,000	Semunti, Bengawan, Kampung Bugis, Pamusian, Amal Baru, Kuli, Binalatung, Mangantai, Southern Mangantai Maya Eastern Maya
Very Low	597,392.8-3,840,604	0-50,000	Semunti, Bengawan, Sesanip, Kampung Bugis, Pamusian, Karungan, Amal Baru, Kuli,	159,504-934,347	0-50,000	Semunti, Amal Baru, Kuli, Binalatung Northern Binalatung Northern & Southern Mangantai

			Binalatung, Mangantai, Maya			

Note:
1)WS : water shortage
2)DoWa : decreasing water availability or supply, m^3/year
3)WD : water demand in m^3/year

Table 4. 4 Water shortage hazard and its distribution in the watershed and administrative region for current period and projection period

Level of WS[1)] Hazard	Current (baseline), 1991-2020			Projection, 1991-2020		
	Watershed	District	Village	Watershed	District	Village
Very High	Kampung Bugis	-	-	Persemaian Kampung Bugis Western Mangantai Eastern Maya	West Tarakan, East Tarakan	Parts of Karang Balik, Karang Rejo; Parts of Selumit, Selumit Pantai and Sebengkok
High	Kampung Bugis, Pamusian	West Tarakan Central Tarakan	Parts of Karang Balik, Karang Rejo; Parts of Selumit, Selumit Pantai and Sebengkok	Kampung Bugis, Northern & Soutern of Kampung Bugis Pamusian Southern Karungan Eastern Maya	West Tarakan, Central Tarakan, East Tarakan, North Tarakan	Parts of Karang Balik, Karang Rejo; Parts of Selumit, Selumit Pantai and Sebengkok Parts of Pamusian South of Karungan, West part of Juata Laut
Moderate	Kampung Bugis, Pamusian	West Tarakan, Central Tarakan	Parts of Karang Balik, Karang Rejo; Parts of Selumit, Selumit Pantai and Sebengkok Parts of Pamusian	Karungan Sesanip, Bengawan Northern Bengawan Southern Binalatung Eastern Maya	East Tarakan, West Tarakan, North Tarakan Central Tarakan	South part of Karungan , part of Karang Anyar Pantai, part of Karang Anyar, center-north part of Juata Permai, west part of Pantai Timur, west part of Kampung 1 Skip
Low	Sesanip, Pamusian	West Tarakan, Central Tarakan, East Tarakan	Karang Anyar, Karang Anyar Pantai; parts of Pamusian and parts of Lingkas Ujung and Gunung Lingkas	Semunti, Bengawan, Kampung Bugis, Pamusian, Amal Baru, Kuli, Binalatung, Mangantai, Southern Mangantai	North Tarakan West Tarakan, Central Tarakan, East Tarakan,	Parts of Juata Laut, Jauata Permai, Juata Kerikil Karang Harapan,Karang Anyar, Karang Anyar Pantai, Part of Karungan, Mamburungan,

				Maya Eastern Maya		Kampung Empat
Very Low	Semunti, Bengawan, Sesanip, Kampung Bugis, Pamusian, Karungan, Amal Baru, Kuli, Binalatung, Mangantai, Maya	West Tarakan, Central Tarakan, East Tarakan, North Tarakan	All village in Tarakan City except Karang Balik, Karang Rejo; Selumit, Selumit Pantai, Sebengkok, Pamusian, Karang Anyar, Karang Anyar Pantai;Lingkas Ujung and Gunung Lingkas	Semunti, Amal Baru, Kuli, Binalatung Northern Binalatung Northern & Southern Mangantai	All except West Tarakan	East of Juata Laut, most parts of Kampung satu Skip Kampung Enam and Kampung Empat; parts of Pantai Timur

4.3 Flood Hazard

Based on the data availability, flood modeling, using WMS, is applied to 12 watersheds from 20 watersheds as shown in Figure 4.9 and two scenarios that are baseline condition and projection condition. The result only shows floodplain area without depth and duration of flood due to availability of rainfall data.

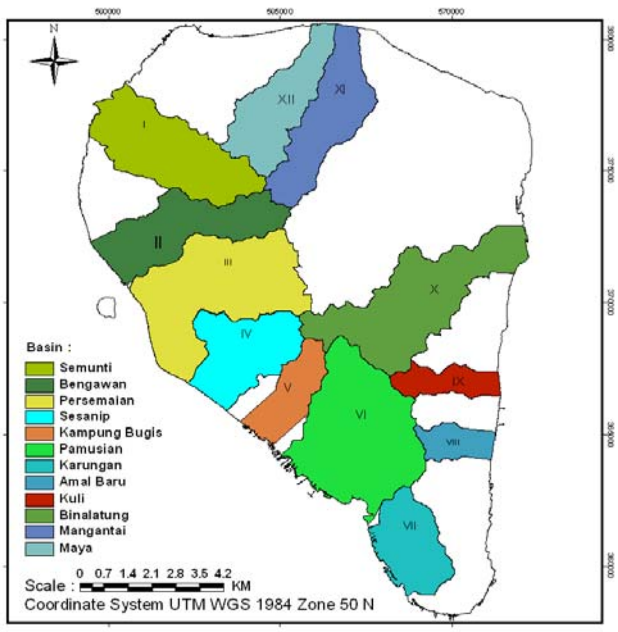


Figure 4. 9 Watershed for flood modeling

The map of flood is shown in Figure 4.10 both in baseline condition (left) and projection condition (right) and the area of flood in each watershed is figured out in Table 4.1. The flooding area is significantly increasing especially in Karungan, Pamusian, Persemaian, Semunti and Sesanip watershed. Flooding area is controlled by basins topographic, due to runoff flows to downstream and mostly occurred in the western area of Tarakan Island.

BASELINE PROJECTION

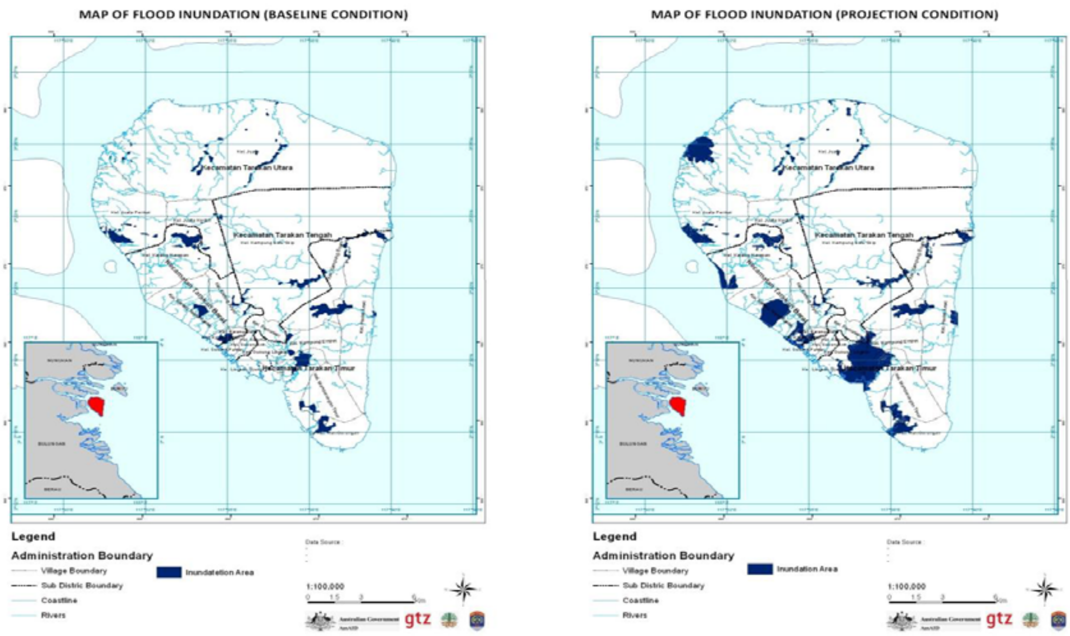


Figure 4. 10 Flood of map in baseline condition (*left*) and projection condition (*right*)

Table 4. 5 Flood Hazard Area of Tarakan Island

No.	Rivers/Basins	Flood Hazard Baseline Area (KM^2)	Flood Hazard Projection 2030 Area (KM^2)
1	Semunti	0,164	2,139
2	Bengawan	1,231	1,549
3	Persemaian	0,962	1,82
4	Sesanip	0,425	2,051
5	KampungBugis	0,789	1,605
6	Pamusian	1,154	5,974
7	Karungan	0,997	1,806
8	AmalBaru	0.154	0.461
9	Kuli	1,207	1,486
10	Binalatung	1,145	1,802
11	Mangantai	0,516	0,713
12	Maya	3,083	3,618

Administratively, Juata village has the largest inundation area that comes from 3 watersheds of Semunti, Maya, and Mangantai followed by Kampung Enam village that comes from 2 watershed, Binalatung and Kuli. In projection condition, Juata village has the largest flooding area about 3.313 km^2. The next is Mamburungan village about 2.648 km^2. In projection condition, the flood hazard will inundate 18 villages, as shown in Table 4.5.

Table 4. 6 Floodplain Area in Projection Hazard of Tarakan Island

District	Village	Floodplain Area (km^2)
Utara	JuataKerikil	0.123
	JuataPermai	0.952
	Juata	3.313
Tengah	SelumitPantai	0.072
	Pamusian	0.111
	KampungSatuSekip	0.964
Barat	KarangAnyar	0.163
	KarangAnyarPantai	0.32
	karangBalik	0.012
	KarangHarapan	0.964
	KarangRejo	0.423
Timur	KampungEmpat	0.992
	KampungEnam	0.897
	PantaiAmal	2.165
	Mamburungan	2.648
	MamburunganTimur	0.693
	GunungLingkas	1.311
	Lingkas Ujung	0.928

The detailed explanation in each watershed are as follows.

4.3.1 Semunti

Semunti River is located in Juata village, Tarakan Utara district. The catchment area is 15.21 km^2 and the length of the main river is 0.772 km. Majority shrubs (semak belukar) and agriculture land (pertanian lahan kering) has located in this catchment.The extreme discharge of this river occurred in 1995, about 1.971m^3/s.

In the baseline condition, flood hazard inundated about 0.1646 km^2 of Juata village. It floods mostly ponds with 0.0875 km^2 (Figure 4.12, left). Therefore, in the projection condition, the area of flooding is more extensive, about 2.139 km^2. It floods mostly ponds 0.7325 km^2 (Figure 4.12, right).

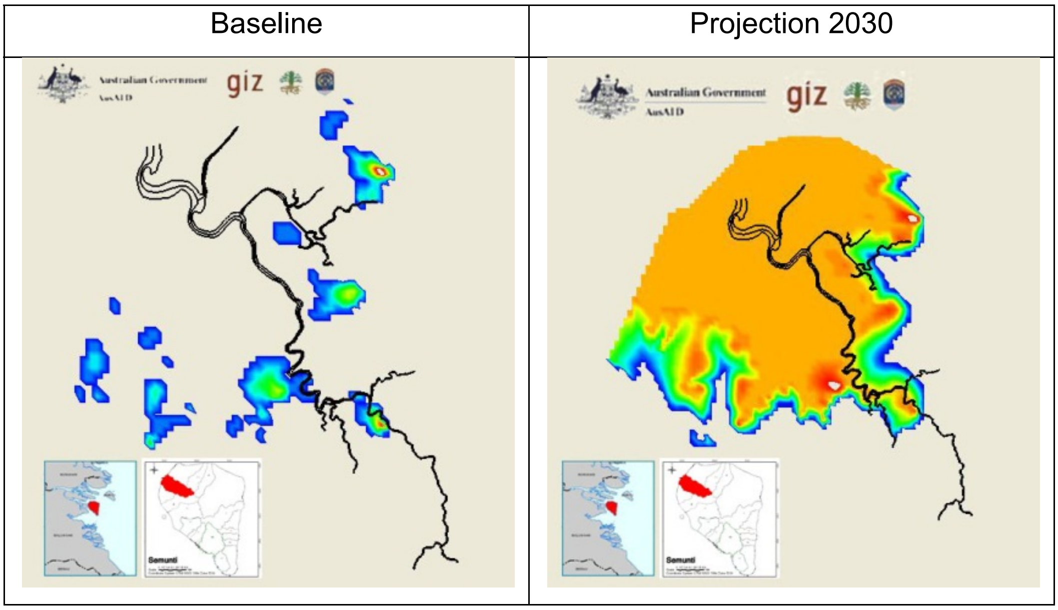


Figure 4. 11 Floodplain Area of Semunti Watershed

4.3.2 Bengawan

Bengawan River crosses trough 3 villages, Juata Permai, Juata Kerikil, and Karang Harapan village. The area of catchment is 12.65 km^2 and the length of the main river is 1.063 km. The Bengawan Watershed covers mostly agriculture lands with 4.955 km^2 and shrubs with 2.965 km^2. The extreme discharge occurred in March 1995 of about 2.714 m^3/s.

In the baseline condition, due to delineation of floodplain as results of modeling, the area of inundation is about 1.231 km^2. It floods most of ponds and shrubs areas (Table) as shown in Figure 4.14 in the left side. Otherwise, for the projection condition, the extreme discharge increased to 5.1126 m^3/s or increasing 1.88 percentage compared to the baseline condition as impact climate change. The flooding area is inundated most of industrial area (Figure 4.14, right side).

Table 4. 7 Flood Hazard to Land Use Type of Bengawan Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area (km2)	Land Use	Area (km2)
Hutan Lebat	0.0225	Hutan Kota	0.0755
Jalan	< 0.001	Hutan Lindung	0.2628
Kawasan Terbangun	0.0025	Hutan Mangrove	0.0838
Kebun Campuran	0.02	Kawasan Industri	0.8201
Mangrove	0.125	Kawasan Pertambangan	0.0115
Pertanian Lahan Kering	0.075	Kawasan Peternakan	0.0444
Rawa	0.045	Perumahan Kepadatan Sedang	0.1556
Semak Belukar	0.2875	Perumahan Kepadatan Tinggi	0.0008

Tambak	0.5425		
Tanah Kosong/Tegalan	0.0075		
Tubuh Air	0.0275		

In baseline condition, flood hazard has submerged one of main infrastructure that is road that should connect districts in Tarakan Island.

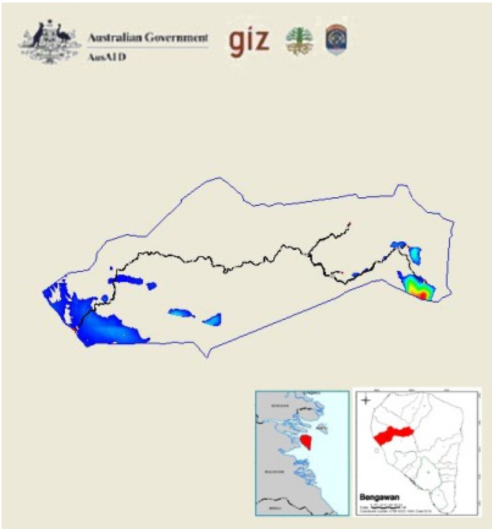
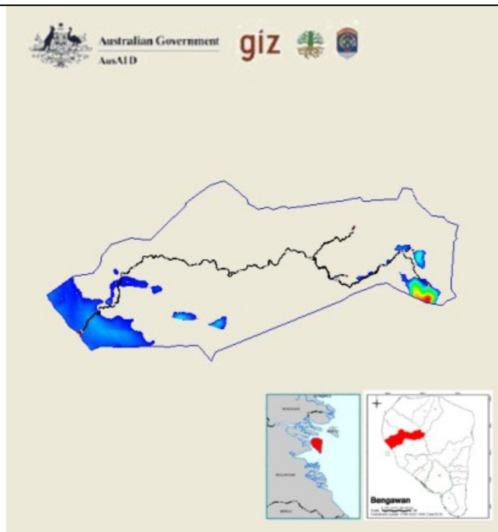
Baseline	Projection 2030
	

Figure 4. 12 Flood Area of Bengawan Watershed

4.3.3 Persemaian

Persemaian River is located in 2 villages that the upstream is positioned in Juata Kerikil village, while the downstream is positioned in Karang Harapan village. The catchment of Persemaian watershed is about 20.64 km^2 and the length of the river is about 1.271 km. Persemaian watershed covers by forests, roads, residential areas, crops, ponds, mangrove, agriculture lands, swamp areas, and shrubs. The extreme discharge occurred in March 1995 with about 3.245 m^3/s of discharge

In the baseline condition, flood hazard inundate about 0.962 km^2 and located in most of Karang Harapan village. It flooded most of agriculture lands and shrubs areas. In the projection condition, the flooding area is more spreading to about 1.820 km^2 and inundates most of high density residential area in Tarakan city.

Table 4. 8 Flood Hazard to Land Use Type of Persemaian Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	**Area (km^2)**	**Land Use**	**Area (km^2)**
Embung Air	0.0175	Embung Air	0.02
Hutan Lebat	0.01	Hutan Kota	0.09
Jalan	0.01	Hutan Mangrove	0.11
Kawasan Terbangun	0.055	Kawasan Industri	0.54
Kebun Campuran	0.055	Kawasan Pergudangan	0.02
Kolam	0.0025	Perumahan Kepadatan Sedang	0.09
Mangrove	0.0075	Perumahan Kepadatan Tinggi	0.83
Pertanian Lahan Kering	0.54		
Semak Belukar	0.1775		
Tambak	<0.001		
Tanah Kosong/Tegalan	0.045		
Tubuh Air	<0.001		

In baseline condition, flood hazard has submerged one of main infrastructure that is road that should connect districts in Tarakan Island. In projection condition, flood hazard will be submerged industrial area that one of the sectors that provides the source of local revenue.

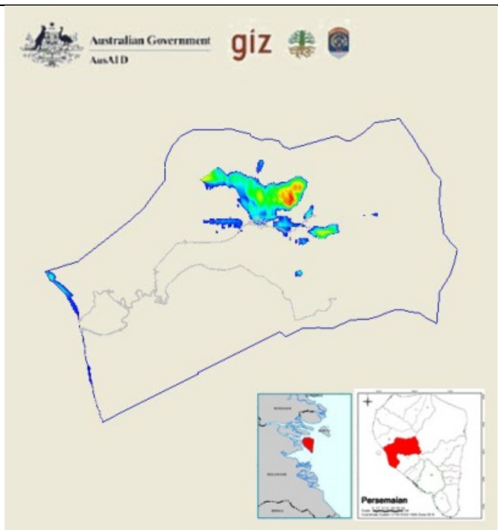
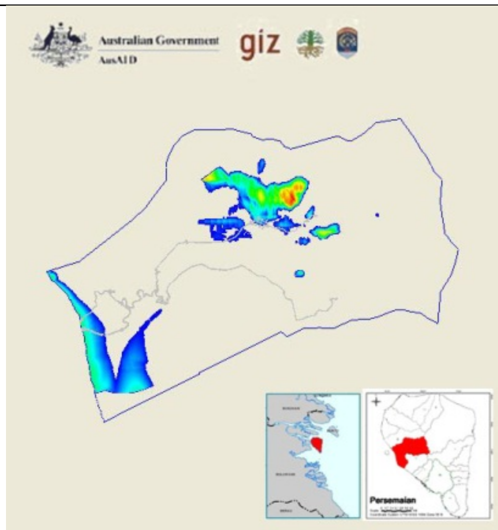
Baseline	Projection 2030
	

Figure 4. 13 Floodplain Area of Persemaian Watershed

4.3.4 Sesanip

Sesanip River is located in Karang Anyar Pantai village with 0.574 km of main river length. It has 6.68 km^2 of catchment area which covered area of airport, forests, roads, residential lands, crops and pasture, ponds, mangrove, agriculture lands, and shrubs. Based on the Report of Water Source Master Plan (*Kajian Sumber Daya Air, 2008*), the occurrence of extreme discharge was about 1.467 m^3/s in March 1995, as shown in Figure 4.17.

In the baseline condition, flood hazard inundates Karang Anyar Pantai village which consists of 0.425 km^2 and floods most of ponds. Meanwhile, in the projection condition, flood hazard inundates 2.051 km^2 total area which consists of 0.205 km^2 mangrove, 1.2225 km^2 ponds, 0.0725 km^2 residential lands, 0.0625 km^2 roads, 0.09 km^2 croplands, 0.035 km^2 agriculture lands, and 0.0575 km^2 shrubs areas.

Table 4. 9 Flood Hazard to Land Use Type of Sesanip Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Jalan	<0.001	Bandar Udara	0.59
Kawasan Terbangun	0.05	Hutan Mangrove	0.17
Kebun Campuran	0.05	Perumahan Kepadatan Tinggi	1.13
Kolam	0.005	others	0.11
Mangrove	0.0025		
Semak Belukar	0.025		
Tambak	0.2875		
Tubuh Air	0.0025		

The difference of inundation area between baseline and projection increases significantly. It is caused by the influence from sea level rise that is included in the projection scenario. The inundation is located in elevation 0 – 1 m of mean sea level. Based on flood hazard model in projrction condition, flood will be inundating most of airport area that one of main infrastructure to connect to other cities.

Baseline	Projection 2030

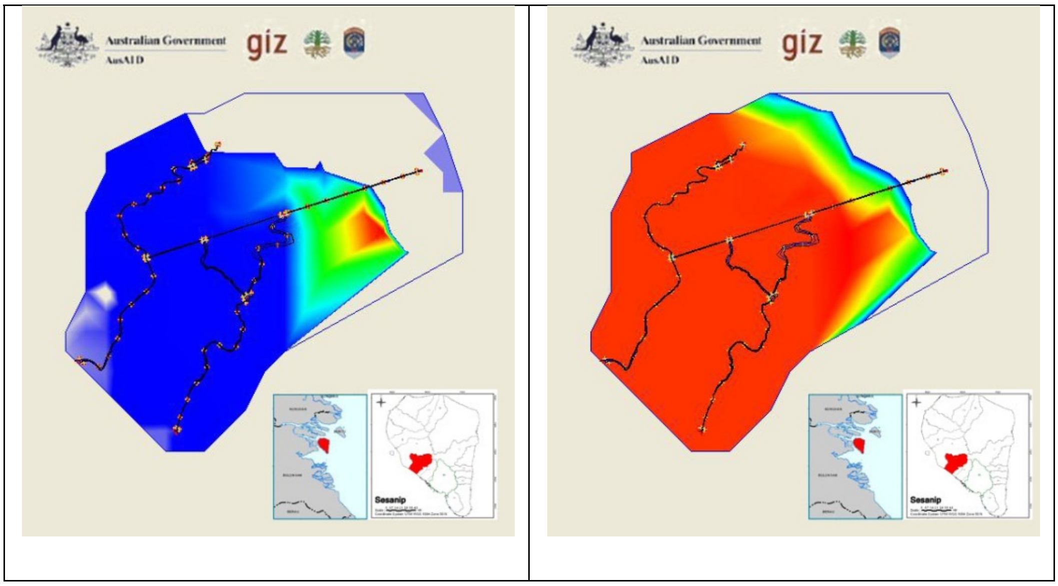


Figure 4. 14 Floodplain Area of SesanipWatershed

4.3.5 Kampung Bugis

Kampung Bugis River crosses over Kampung Satu Sekip village in the upstream and Karang Anyar village in the downstream, and also this river is the boundary between Karang Anyar Pantai village and Karang Rejo village. The catchment area of Kampung Bugis River is 5.64 km^2 and the length of the main river is 0.485 km.

Kampung Bugis basin covers roads, residential areas, crops and pasture, mangroves, ponds, port, swamp areas, and shrubs. The extreme discharge of this river was about 1.238 m^3/s on March 1995. The detailed discharge from 1982 to 2007 is shown in Figure 4.19.

In the baseline condition, modeling of flood hazard uses the extreme discharge (1.238 m^3/s). The result shows floodplain area of about 0.789 km^2. The inundation area covers most of residential areas. The flooded villages are Kampung Satu Sekip, Karang Anyar, and Karang Rejo village (Figure 4.20 left side).

In the projection condition, the extreme discharge increased by 1.88 than the baseline condition. It would be a more extensive flooding of about 1.605 km^2 submerged area. It would be inundate most of high density housing. Therefore, the floodplain area of projection is in 5 villages: Kampung Satu Skip, Karanganyar, Karang Anyar Pantai, Karang Rejo, and Karang Balik village (see Figure 4.20, right side).

Table 4. 10 Flood Hazard to Land Use Type of Kampung Bugis Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area

Jalan	0.0175	Hutan Kota	0.17
Kawasan Terbangun	0.3	Hutan Mangrove	0.03
Kebun Campuran	0.0725	Kawasan Perdagangan dan jasa	0.23
Kolam	0.01	Perumahan Kepadatan Rendah	0.11
Mangrove	0.0125	Perumahan Kepadatan Tinggi	0.80
Pertanian Lahan Kering	0.0675		
Semak Belukar	0.175		
Tambak	0.11		
Tanah Kosong/Tegalan	0.005		
Tubuh Air	0.0175		

Based on flood hazard model, inundation area floods road and commercial and services area that influence economic of Tarakan City.

Baseline	Projection 2030

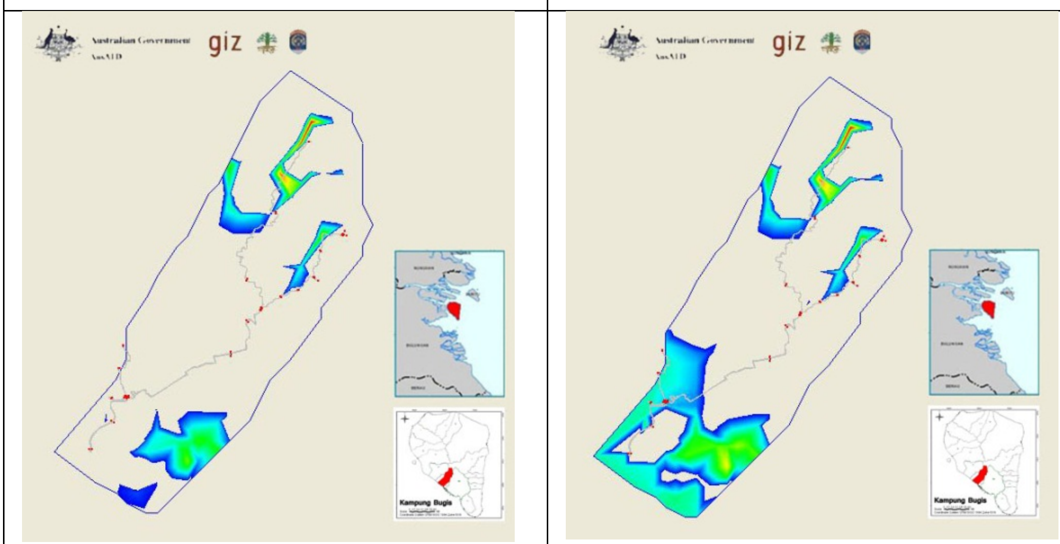


Figure 4. 15 Floodplain Area of KampungBugis Basin.

4.3.6 Pamusian

Pamusian River is located through 8 villages: Mamburungan, Lingkas Ujung, Gunung Lingkas, Kampung Empat, Kampung Enam, Sebengkok, Kampung Satu Sekip, and Pamusian village. Pamusian Watershed has 20.55 km^2 of catchment area and 1.467 km length of main river. Pamusian Watershed covers forests, roads, residential areas, crops, refinery, ponds, cemetery, mangrove, agriculture lands, swamp areas, and shrubs. The occurrence of extreme discharge was about 4.512 m^3/s on March 1995 and the detailed discharge from 1982 to 2007 is shown in Figure 4.21.

In the baseline condition, the flood hazard inundates about 1.154 km^2 that covers 0most of pond areas. The flood is located in Mamburungan village, as shown in Figure 4.22, left side. Meanwhile, in the projection condition, flood hazard inundates about 5.974 km^2 that covers most of mangrove and high density housing. It flooded 5 villages: Pamusian, Kampung Empat, Mamburungan, Lingkas Ujung, and Gunung Lingkas villages. The Floodplain area in the projection condition is shown is Figure 4.22, right side.

Table 4. 11 Flood Hazard to Land Use Type of Pamusian Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Jalan	0.005	Hutan Mangrove	2.27
Kawasan Terbangun	0.035	Kawasan Industri	0.27
Kebun Campuran	0.095	Kawasan Pergudangan	0.11
Kolam	0.01	Kawasan Pertambangan	0.45
Mangrove	0.16	Perumahan Kepadatan Sedang	0.15
Semak Belukar	0.065	Perumahan Kepadatan Tinggi	1.42
Tambak	0.625	Sport Center	0.12
Tanah Kosong/Tegalan	0.0525		
Tubuh Air	0.0525		

Based on flood hazard model, the flood will inundate industrial and warehousing area that influencing economic of Tarakan City.

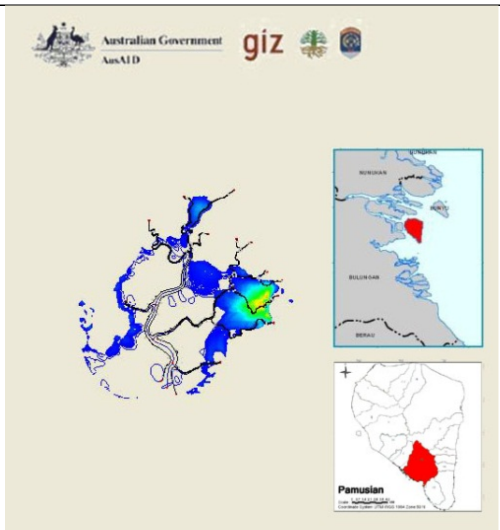
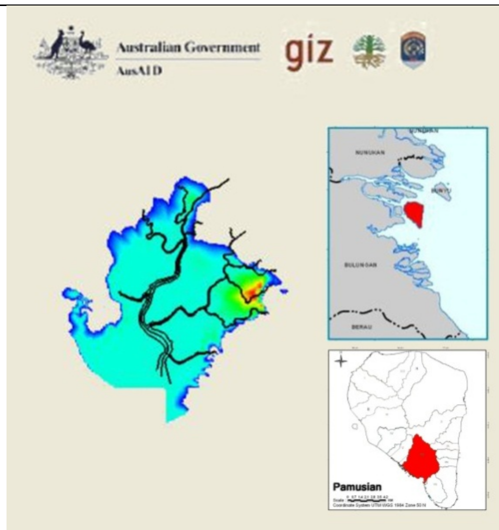
Baseline	Projection 2030
	

Figure 4. 16 Floodplain Area of Pamusian River

4.3.7 Karungan

Karungan River is located in 2 villages, the upstream of Karungan River is located in East Mamburungan village whereas the downstream is in Mamburungan village. Karungan River has 7.05 km^2 of catchment areas with 0.607 km of main river length.

Karungan Basin covers forest, road, residential areas, crops and pasture, ponds, mangrove, beach, other agriculture lands, swamp areas, and shrubs. Based on the discharge gauging in 1982 – 2007 to Karungan River, the extreme discharge occurred with a dischrage of 1.549 m3/s.

In the baseline model, the analysis of flood hazard produces 0.997 km^2 inundation areas, located in Mamburungan and East Mamburungan village that cover most of ponds. Meanwhile, in the projection model, flood hazard model uses discharge data of 1.8838 higher than the baseline model. The projection model shows 1.806 km^2 submerged area that covers city forest, mangrove, mining area and military area.

Table 4. 12 Flood Hazard to Land Use Type of Karungan Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	**Area**	**Land Use**	**Area**
Hutan Lebat	0.0225	Hutan Kota	<0.001
Kawasan Terbangun	0.0025	Hutan Mangrove	0.14
Kebun Campuran	0.0125	Kawasan Militer	1.50
Mangrove	0.0675	Kawasan Pertambangan	<0.001
Pertanian Lahan Kering	0.04	others	±0.2
Rawa	0.015		
Semak Belukar	0.035		
Tambak	0.785		
Tanah Kosong/Tegalan	0.0025		
Tubuh Air	0.0175		

In projection condition based on flood hazard model, flood area has inundated most of military area.

Baseline	Projection 2030

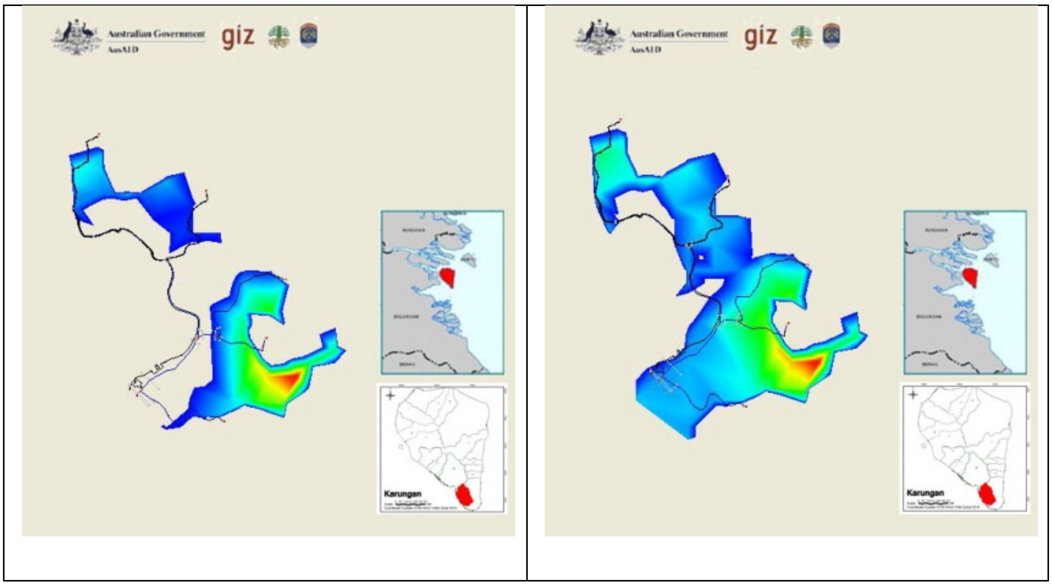


Figure 4. 17 Floodplain Area of KarunganWatershed

4.3.8 Amal Baru

Amal Baru River is located in Pantai Amal village, in southern east of Tarakan Island. The river has a catchment area of 3.47 km^2 and main river length of 303 m. The Amal Baru Basin covers forests, roads, residential areas, croplands and pasture, ponds, beach, other agriculture lands, shrubs and brush, and moor. Based on the discharge gauge data (1982 – 2003) of Master Plan of Tarakan Island, Amal Baru River had an extreme discharge of 0.761 m^3/s that occurred in 1995.

In the baseline condition, the result of flooding model shows 0.154 km^2 of submerged area. It located in coastal areas. Meanwhile, the projection model analysis is based on the rainfall projection data (SRA1B) increased percentage. Because of it, the discharge data in the projection model becomes 1.8838 higher than the baseline discharge. The result of flood projection model shows 0.461 km^2 submerged area. It covers city forest, tourism area, middle density housing and sport center.

Table 4. 13 Flood Hazard to Land Use Type of Amal Baru Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Kawasan Terbangun	<0.001	Hutan Kota	0.01
Kebun Campuran	0.005	Kawasan Wisata	0.23
Pantai	0.0075	Perumahan Kepadatan Sedang	0.20
Pertanian Lahan Kering	<0.001	Sport Center	0.02

Semak Belukar	0.0225		

In projection based on flood hazard model, the flood will inundating tourism area that is around 50 % of inundation area. Tourism sector is one of income sources of local government.

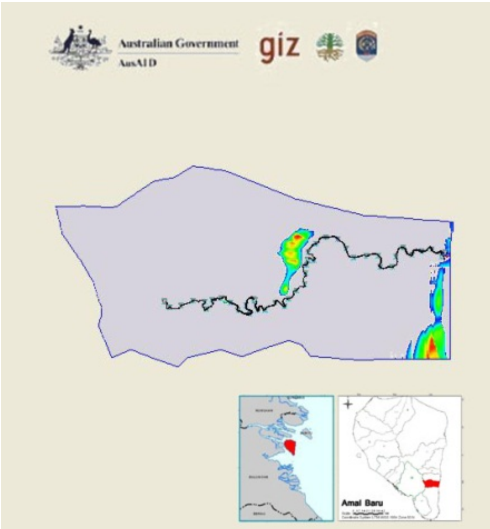
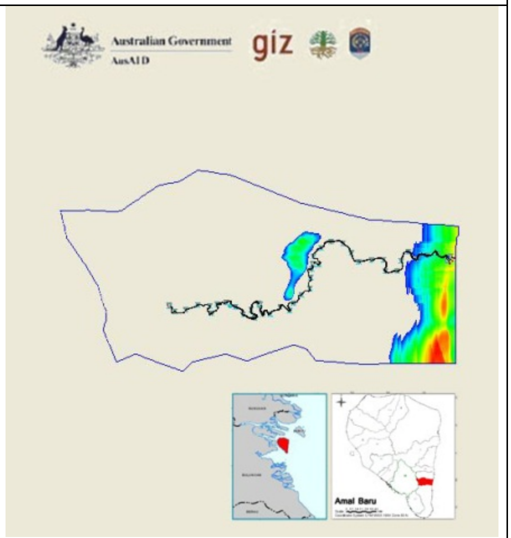
Baseline	Projection 2030
	

Figure 4. 18 Flood Area of Amal Baru Watershed

4.3.9 Kuli

Kuli River is located in 2 villages, where the upstream is located in Kampung Enam village while the downstream is located in Pantai Amal village. Kuli River has 3.82 km^2 catchment area and 0.334 km of main river length. Kuli Basin covers forests, crops and pasture, roads, residential areas, ponds, beach, other agriculture lands, and shrubs. Based on the discharge data of Water Source Master Plan of Tarakan Island, it showed an extreme discharge of 0.839 m^3/s. on March 1995.

In the baseline Model, the flood hazard shows 1.207 km^2 of submerged areas. Most of the inundation area is located in Kampung Enam village. It covers most of shrub areas. Meanwhile, in the projection model, the flood hazard covers 1.486 km^2 inundation areas that would be cover city forest, mining area, tourism area, low and middle density housing.

Table 4. 14 Flood Hazard to Land Use Type of Kuli Watershed

Flooding Area (Baseline)	Flooding Area (Projection)

Land Use	Area	Land Use	Area
Hutan Lebat	0.1075	Hutan Kota	1.05
Jalan	0.005	Kawasan Pertambangan	0.01
Kawasan Terbangun	<0.001	Kawasan Wisata	0.2
Kebun Campuran	0.02	Perumahan Kepadatan Rendah	0.07
Kolam	<0.001	Perumahan Kepadatan Sedang	0.16
Pantai	<0.001		
Pertanian Lahan Kering	0.03		
Semak Belukar	0.82		
Tanah Kosong/Tegalan	0.14		
Tubuh Air	0.0125		

Based on flood hazard model, in baseline, the flood would be inundated road which is one of main infrastructures of Tarakan City that connect rural area to urban area. In projection condition, the flood will be inundating tourism area which is one of economic sectors that has contributed to income of local government.

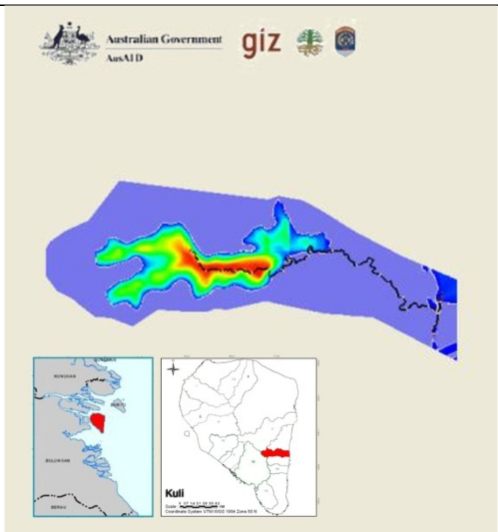
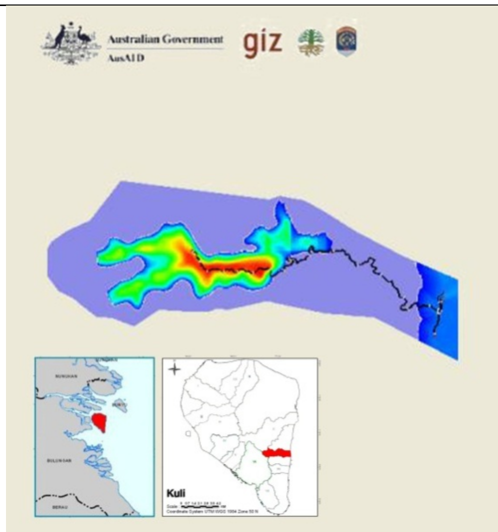
Baseline	Projection 2030
	

Figure 4. 19 Floodplain area of Kuli Watershed

4.3.10 Binalatung

Binalatung River is located in 2 districts and across 3 villages. The districts are Middle Tarakan district and East Tarakan. The upstream of Binalatung River is located in Middle Tarakan district, while the downstream is located in the district boundary between middle Tarakan and East Tarakan. Binalatung River has a catchment area of 22.59 km^2 and main river length of 1.943 km. The Binalatung Basin covers forests, roads, residential areas, crops and pasture, mangroves, other agriculture lands, and shrubs. Based on the discharge gauging in 1982 – 2007, the data showed the extreme discharge of Binalatung River was 4.960 m^3/s. The extreme discharge occurred on March, 1995.

In the baseline model, the Binalatung basin has a 1.145 km^2 of submerged area. It covers most of shrubs areas. Meanwhile, in the projection model, the Binalatung Basin has a 1.802 km^2 of submerged areas that inundate pond (embung), city forest, green forest, mangrove, commercial and services area, tourism area, low and middle density housing.

Table 4. 15 Flood Hazard to Land Use Type of Binalatung Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Hutan Lebat	0.145	Embung Air	0.28
Jalan	0.0025	Hutan Kota	0.01
Kawasan Terbangun	0.0075	Hutan Lindung	0.48
Kebun Campuran	0.0525	Hutan Mangrove	0.04
Kolam	<0.001	Kawasan Perdagangan dan jasa	0.01
Mangrove	0.0075	Kawasan Wisata	0.26
Pertanian Lahan Kering	0.1175	Perumahan Kepadatan Rendah	0.15
Semak Belukar	0.6375	Perumahan Kepadatan Sedang	0.58
Tanah Kosong/Tegalan	0.14		
Tubuh Air	0.0225		

In baseline condition, based on flood hazard model, the flood would be inundated road which is one of main infrastructures of Tarakan City that connect rural area to urban area. In projection condition, the flood will be inundating tourism area which is one of economic sectors that has contributed to income of local government, pond (Embung) that is one of water reservoir of Tarakan City.

Baseline	Projection 2030

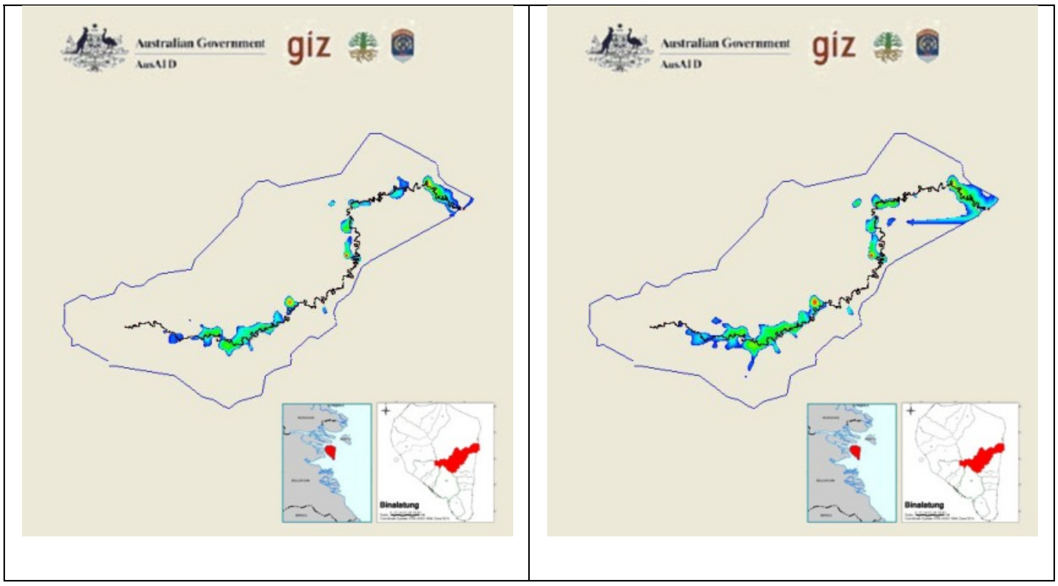


Figure 4. 20 Floodplain area of Binalatung Basin

4.3.11 Mangantai

Mangantai River is located in Juata village. The river has a 10.42 km^2 of catchment areas with a 0.896 km of main river length. The Mangantai basin covers forests, mangrove, shrubs, and crops and pasture. Based on the discharge data of Water Source Master Plan of Tarakan Island, the extreme discharge was 2.288 m^3/s, occurred on March 1995.

In the baseline model, the flood hazard model shows 0.516 km^2 of inundation areas with most of the inundation areas located in riverine area. It covers forests, mangrove, shrub, and croplands. The flood hazard model in the baseline condition uses the extreme discharge of Mangantai River that occurred in 1982 – 2007.

Meanwhile, in the projection model, the flood hazard model analysis is based on the increasing extreme discharge using rainfall projection (SRA1B) with increasing percentage, and sea level rise projection in 2030 of 2.634 m. The model shows 0.713 km^2 inundation areas that are located mostly in the riverine and coastal areas. It covers green forest, mangrove, industrial area, and high density housing.

Table 4. 16 Flood Hazard to Land Use Type of Mangantai Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Hutan Lebat	0.4375	Hutan Lindung	0.47
Mangrove	0.0375	Hutan Mangrove	0.05
Semak Belukar	0.025	Kawasan Industri	0.06

Tanah Kosong/Tegalan	0.005	Perumahan Kepadatan Tinggi	0.11
Tubuh Air	0.01		

In projection condition, the flood will be inundating industrial area that is one of supporting of economic sector of Tarakan City.

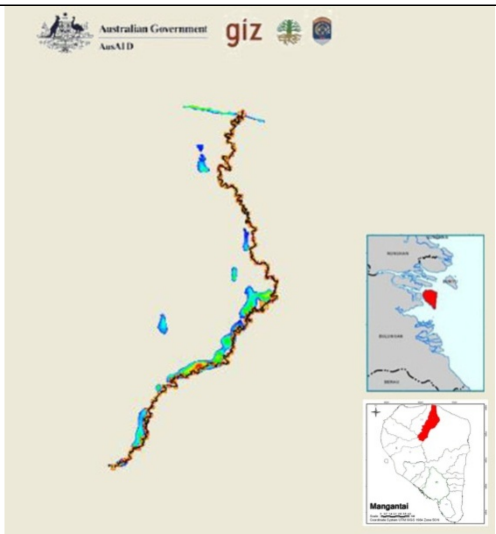
Baseline	Projection 2030
	

Figure 4. 21 Floodplain Area of Mangantai Watershed

4.3.12 Maya

Maya River is located in the northern Tarakan Island, precisely in Juata village. The river has a 15.07 km^2 catchment area and 1.256 km of main river length. The Maya Basin covers forests, mangrove, shrubs, ponds, and crops. The Water Source Master Plan of Tarakan Island shows an extreme discharge of Maya River of 3.308 m^3/s, occurred in 1995.

In the baseline model, the flood hazard shows a 0.3135 km^2 inundation area located in Juata village. It covers green forests, mangrove, ponds, and shrub areas. Meanwhile, in the projection model, the flood hazard shows 0.3734 km^2 inundation areas. It covers green forest and middle density housing.

Table 4. 17 Flood Hazard to Land Use Type of Maya Watershed

Flooding Area (Baseline)		Flooding Area (Projection)	
Land Use	Area	Land Use	Area
Hutan Lebat	0.305	Hutan Lindung	0.29

Mangrove	0.025	Perumahan Kepadatan Sedang	0.01
Semak Belukar	0.005		
Tambak	0.02		
Tubuh Air	0.015		

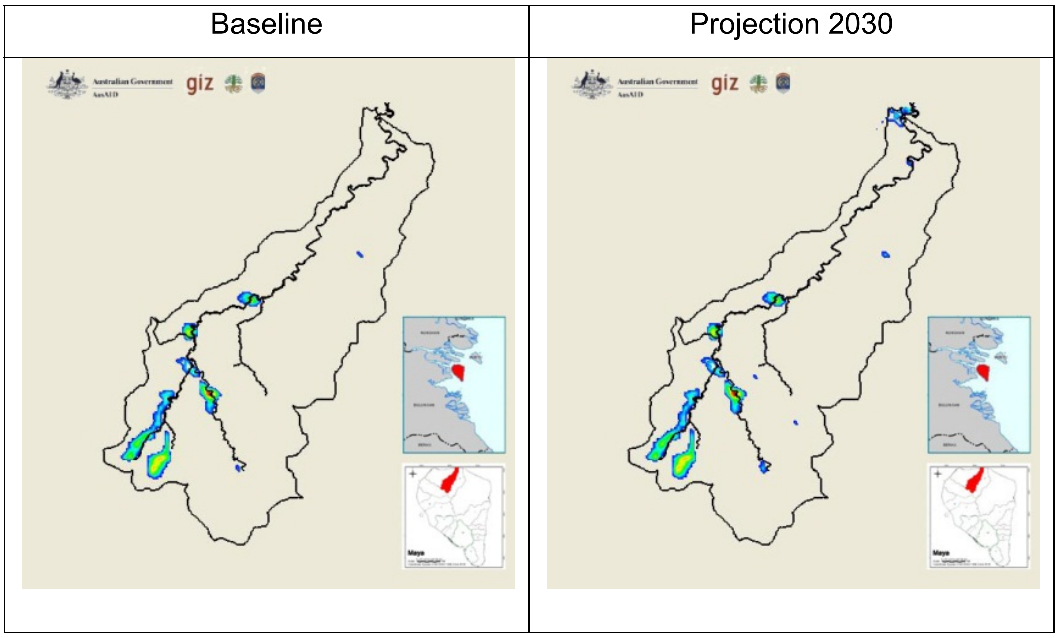


Figure 4. 22 Floodplain Area of Maya Watershed

4.4 Landslide Hazard

The model was developed by utilizing the concept of extreme rainfall and unique relationships between rainfall characteristics, hydraulic conductivity, suction, and water content of unsaturated soil to evaluate the minimum suction distribution and factor of safety of soil slope. Besides, the slope geometry and shear strength properties of soil were also taken into account in the analysis since these parameters are the essential contributing factors in any slope stability analysis. The developed of landslide modelling is done by decreasing the value of cohession from existing value to the last possible value. Where the decreasing is indicated that extreme rainfall is infiltrated to the ground water then changes unsaturated soil to saturated soil.

4.4.1 Slope Stability Analysis

The Digital Elevation Map (DEM) of Tarakan is obtained the location and geometry of landslide area. The area of each landslide are different from each other, depend on the contour and estimating type of landslide. Figure 4.41 is figured out the estimationof type of landslide and the area impact based on map elevation. The estimating of landslide integrated to this map, depend on the contour as showed, the other way of estimating is using Triangulated Irregular Network map. Landslide area is described into cross section, then modelled by using Geostudio v6.2 (Figure 4.23)

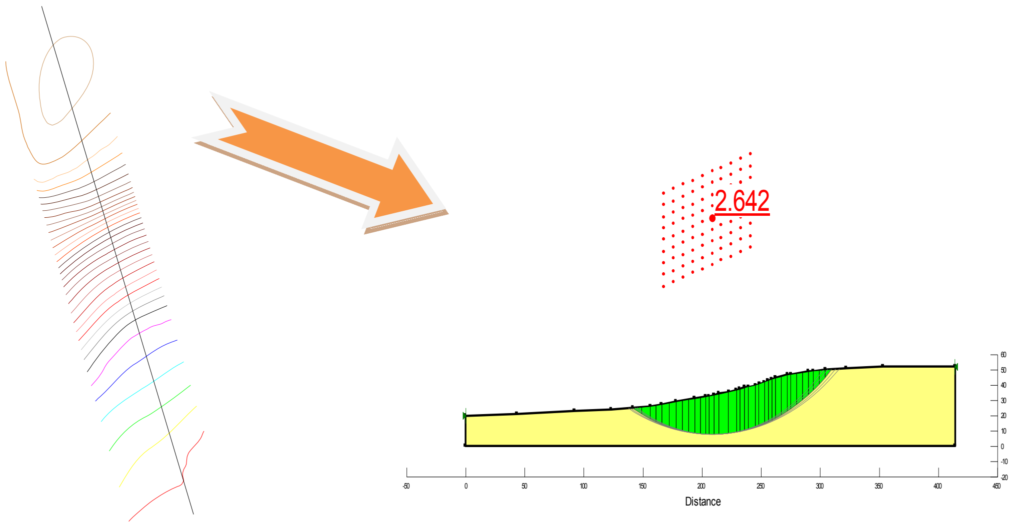
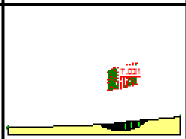
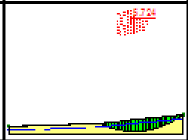
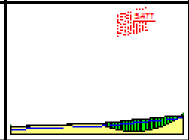
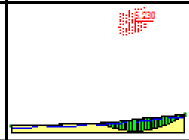
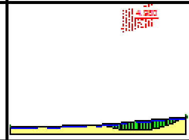
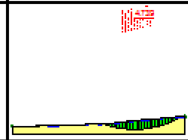
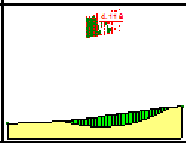
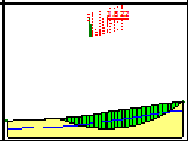
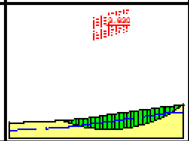
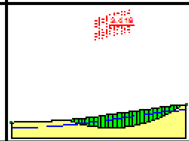
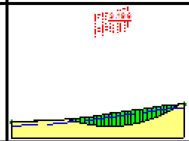
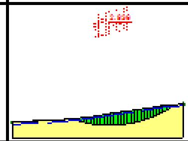
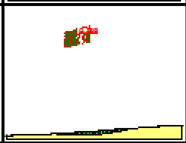
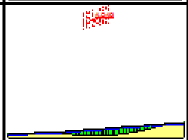
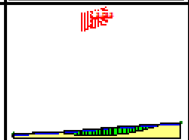
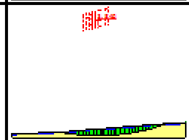
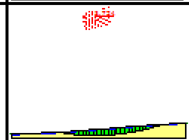
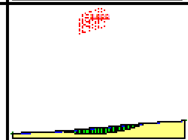
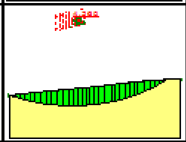
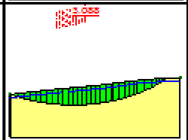
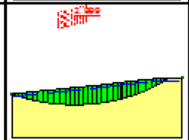
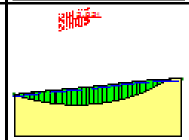
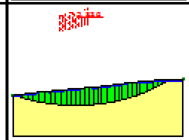
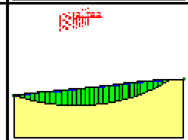
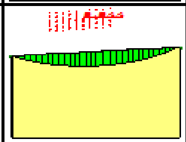
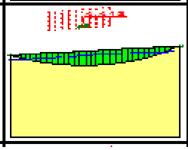
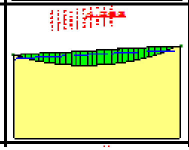
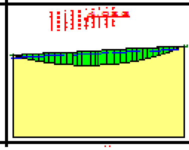
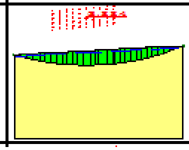
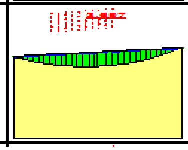


Figure 4. 23 Illustration of elevation map to cross section at Juatakerikil landslide area

Factor of safety is computed using Geostudio V6.2 and it should be noted that the software was not designed to predict the ultimate safety factor of the slope, but to compute the relative factor of safety between extreme rainfall and dry conditions. This feature is important to evaluate the stability of the slope in response to the rainfall infiltration. In case, the soil properties and rainfall characteristics data were not well documented, the input parameters of the analysis could be assigned from a range of data provided in the database of the software. Then the output that obtained is a hazard map for the baseline.

In projection condition, the model is using two analysis that has done before in previous section as the input. First, landslide is modeled by estimating GWT recharge from 1-5 m below the surface as shown in Table 4.6. Second, landslide is modeled by prediction of the amount of rainfall that infiltrates the slope is also required. Infiltration of rainfall into a residual soil slope might be impaired slope stability by changing the pore water pressure in the soil which in turn controls the water content of the soil. The prolonged rainfall infiltration reduces matric suction of soil which in turn decreases the soil shear strength, and subsequently triggers the slope failure. By decreasing the c value to the the last possible model is made as shown in Table 4.18.

Table 4. 18 landslide modelling by estimating GWT recharge

No	Location	Coordinate		[illegible]												Remarks
		X	Y	Without pore water pressure	Safety Factor	Including pore water pressure 5 m from the surface	Safety Factor	Including pore water pressure 4 m from the surface		Including pore water pressure 3 m from the surface		Including pore water pressure 2 m from the surface		Including pore water pressure 1 m from the surface		
1	Kel. Mamburungan Kec. Tarakan Timur	[illegible]	[illegible]		7,031		5,724		5,477		5,23		4,98		4,739	Soil improvement due to landslide problem
2	Kel. Mamburungan Kec. Tarakan Timur	[illegible]	[illegible]		4,118		3,822		3,63		3,416		3,196		2,936	Mass movement and potential landslide
3	Kel. Mamburungan Timur Kec. Tarakan Timur	[illegible]	[illegible]		5,386		4,049		3,933		3,845		3,724		3,6	Mass movement, historical landslide at this area
4	Kel. Karanganyar (RT-64) (Jalan Gunung Selatan) Kec. Tarakan Barat	[illegible]	[illegible]		4,26		3,088		2,999		2,921		2,835		2,752	Erosion at remaining mining area. Water infrastructure problem as impact of erosion
5	Kel. Kampung Satu Skip (Jalan Gunung Selatan) Kec. Tarakan Tengah	[illegible]	[illegible]		5,544		4,413		4,263		4,083		3,884		3,697	Erosion problem

Tabel excel terlampir, agar bisa di edit lebih bagus lagi di report ini.

In projection condition, the model is using two analysis that has done before in previous section as the input. First, landslide is modeled by estimating GWT recharge from 1-5 m below the surface. It is shown that the factor of safety is decreasing over the recharge of GWT about 1-2 value. As shown in table 4.6 at the first model Mamburungan village, East Tarakan sub-district, safety factor for baseline are 7,031, and it decrease to 5,724 when ground water table increase at 5 m from surface, and at the last it decrease to 4,739 when ground water table at 1 m below the surface. It indicates that the recharge of ground water table as an impact of climate change is caused landslide.

Table 4. 19 Landslide modelling by estimating soil strength decrease

No	Location	Coordinate		Safety factor with c value								
				Baseline condition	Projection condition							
		X	Y	Real condition	8	7	6	5	4	3	2	1
1	Kel. Mamburungan Kec. Tarakan Timur	568524	362208	7,031						6,968	6,905	6,842
2	Kel. Mamburungan Kec. Tarakan Timur	568611	361593	4,118						4,059	4,001	3,942
3	Kel. Mamburungan Timur Kec. Tarakan Timur	570051	361852	5,386						5,3428	5,31	5,272
4	Kel. Karanganyar (RT-64) (Jalan Gunung Selatan) Kec. Tarakan Barat	565250	369133	4,26							4,251	4,235
5	Kel. Kampung Satu Skip (Jalan Gunung Selatan) Kec. Tarakan Tengah	565395	368921	5,544							5,521	5,483

Table above shows that cohession value as the indicator of soil strength decrease due to the changes of soil condition from unsaturated to saturated cause the decreasing of safety factor, while cohession value decrease. As shown in table 4.7, at the first model Mamburungan village, East Tarakan sub-district, safety factor for baseline are 7,031, and it decrease to 6,968 when cohession value decrease to 3, and at the last it decrease to 6,842 when cohession value decrease to 1. It indicates that the prolonged wet periods when there is sufficient infiltration into the slope, the matric suction of the soil decreases, and this in turn results in an increase in the soil water content. As a result, the additional shear strength provided by the matric suction could be reduced enough as an impact of climate change to trigger a landslide.

4.4.2 Landslide Hazard Zonation

The results of landslide model are mapping into Tarakan map both in baseline and projection condition. In baseline condition, landslide are located in 13 different locations as follows: 4 location in North Tarakan district, 2 locations in West Tarakan district, 4 locations in Middle Tarakan district; while 3 locations in East Tarakan district as shown in Figure 4.42. Meanwhile, there are still 13 different locations for projection condition, but theirs potential probabilities are in different level from low, moderate, high, to very high as shown in Figures 4.43 for 2010-2020 period (left side) and 2020-2030 period (right side).

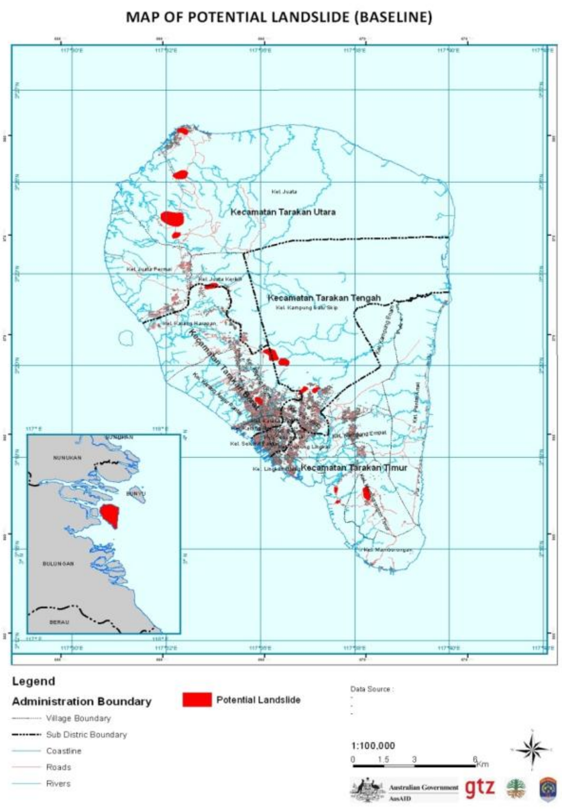
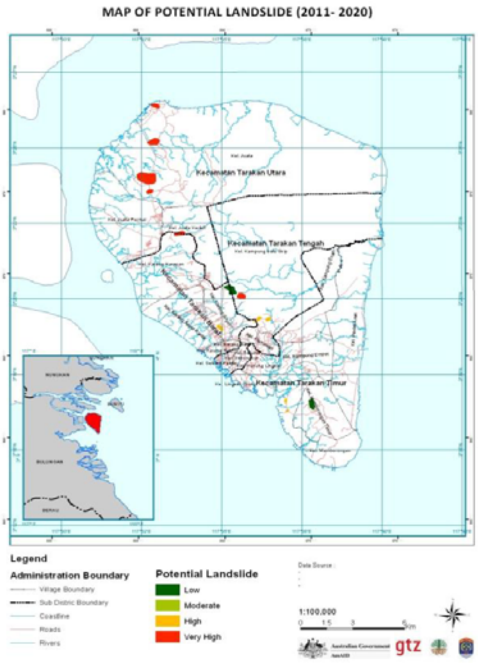


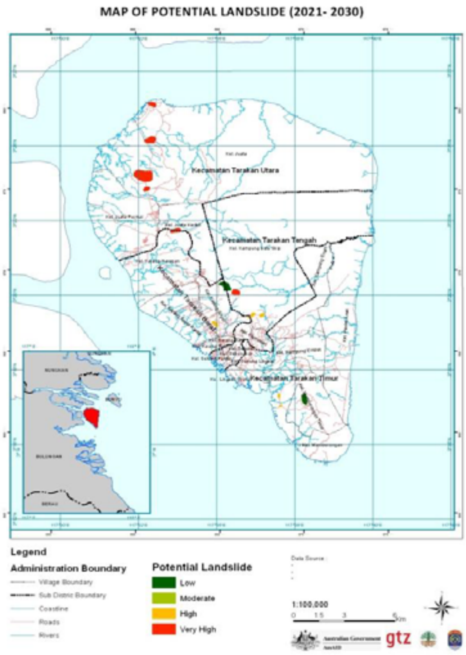
Figure 4. 24 Map of Landslides

Level of hazard are determined by safety factor from table 4.6 and 4.7, the range of safety factor divided using statistical method to determined the level of hazard.

Figure 4.23 is map of potensial landslide in baseline period; while Figure 4.23, left, is potensial landslide hazard in projection period of 2010-2020; and Figure 4.23, right, is potensial landslide hazard in projection period of 2020-2030. Figure 4.23 (left) and Figure 4.42 below are result from landslide modeling.



Projection 2010-2020



Projection 2020-2030

Figure 4. 25 Map of Potensial Landslide

V. ANALYSIS OF VULNERABILITIES TO CLIMATE CHANGE

5.1 Identification of Vulnerability Component

The overall vulnerability of Tarakan's water sector has been analyzed using the GIS method and AHP. The two methods need to be in the same unit. Assumptions used in each indicator: (1) All indicators are changed into 1 hectare grid, (2) Each indicator value are continue; and (3) Value approach is normalized linierally.

There are nine primary components of vulnerability based on their significant to the hazard and availability of data. The nine primary components are described in the following sub-chapter.

5.1.1 Population Density

Population in a location of hazard determines its level of risk. Tarakan has a relatively high population density with uneven distribution. In 2010, Tarakan's total population was 193,099 people and the population density in average was 112/km^2. Its population growth projection until 2030 ranges from 95 people/year to 2,961 people/year (excerpted from BPS, 2006). High population density increases Tarakan vulnerability to all climate change hazards.

Population data is usually presented in administrative unit, in this case, village. For example, Juata Laut area is 7948.59 Ha with a population density of 1.3 person/Ha, and Karang Anyar area is only 640.07 Ha with a population density of 43 persons/Ha. Another example is Selumit Pantai with an area of 47.8 Ha and population density of 136 persons/ Ha. This difference will cause high level of analysis errors.

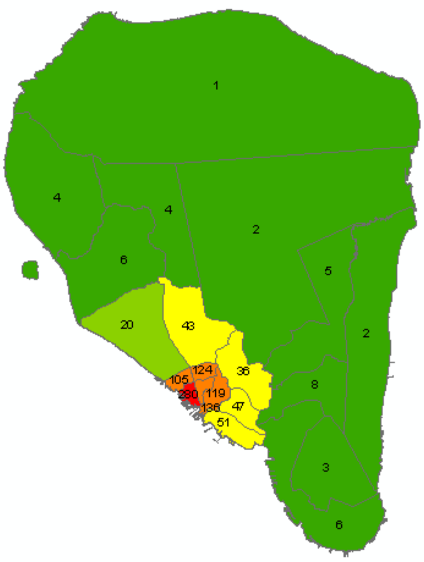


Figure 5. 1 General presentation (before analysed in this study) of population density for each administratif (village) in Persons/Ha.

***Note*: Number expressed number of population density per 1 hectare (Ha) area in average; for example 1 means 1 person/Ha in average**

Problems also occur in the future projection of population. Generally, population projection is done based on administrative unit. However, according to the spatial planning, there are several new settlements development. This new settlements are based on land availability and guidelines of Tarakan City development. Thus, population growth is more accurate if based on municipal population growth analysis.

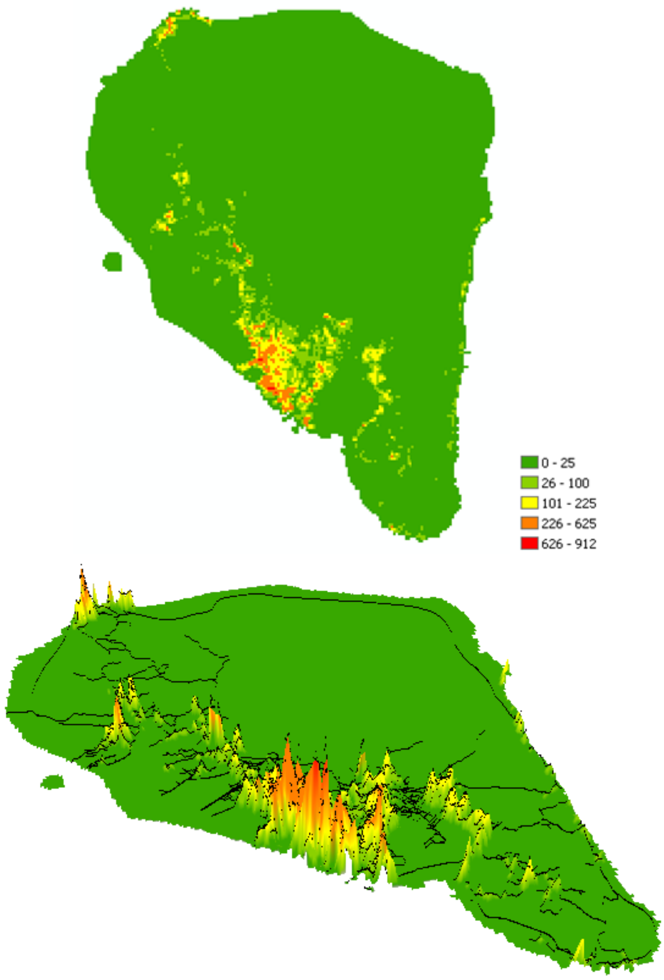


Figure 5. 2 Spatial baseline of population density (persons/Ha)

In the projection condition (2030), we assume that the population distribution will develop around the development of regions. Meanwhile, the development of region can be indicated by road planning and is limited by settlement planning. Others assumptions that used in modeling of population density in the projection period as illustrated in Figure 5.3 are :

- Population growth only happened in regions of settlement planning
- The existence of roads in regions of settlement planning shows that the settlement is ready to develop

Population growth level is determined by current population density

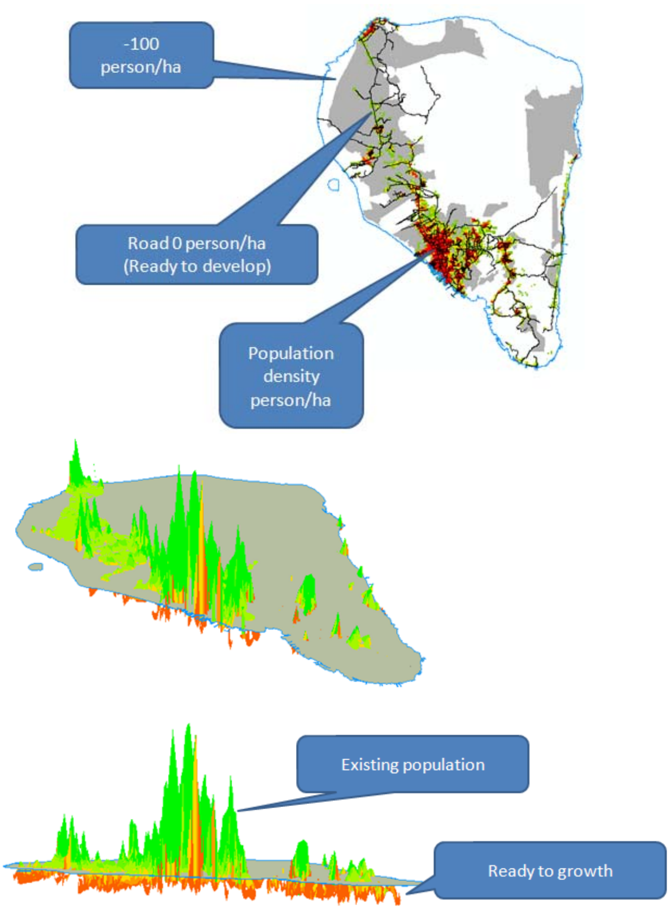


Figure 5. 3 Illustration of population growth model

Based on the simulation using those assumption and available data, we obtained 2030 population density level, shown in the following figure.

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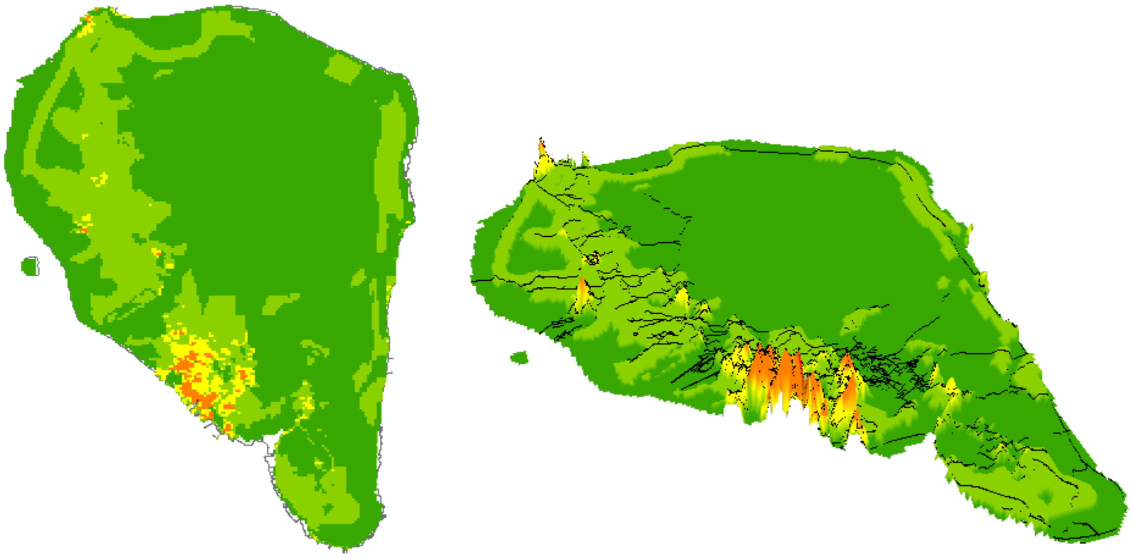
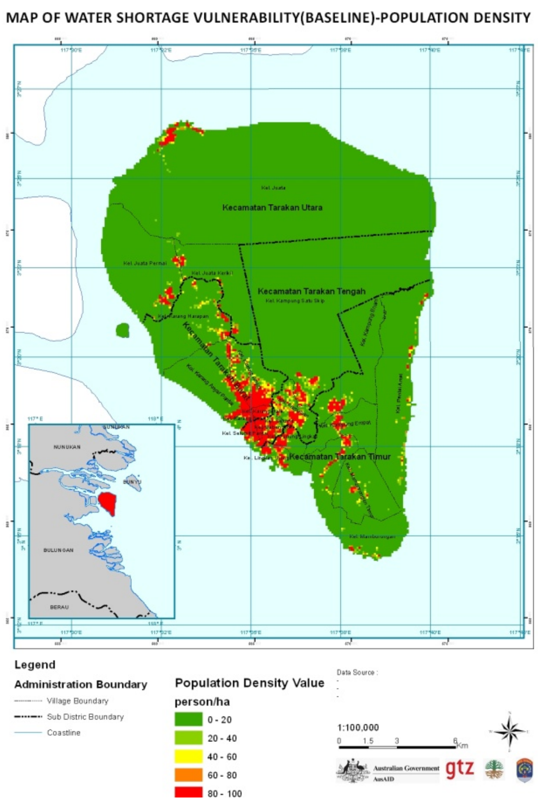
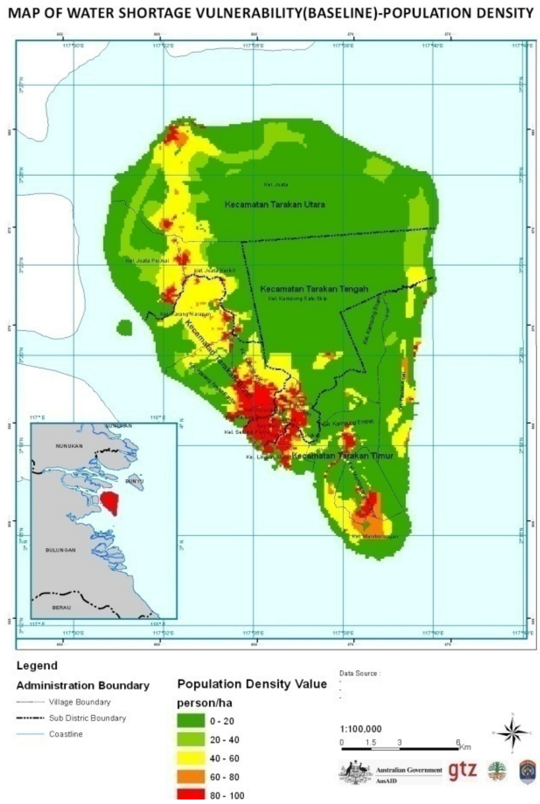


Figure 5. 4 Condition of 2030 population density resulted from modeling in this study. The colors express levels of population density where ranged from very high density (*red*) to very low density (*green*).

Population density reaches maximum value in 100 persons/ha. If more than 100 persons/ha, it will be assumed to be at maximum value. These values are each given linear weighting. It also applies to vulnerability of floods and landslides. Meanwhile, for water shortage, the population density value is converted into water needs value. Using these last assumptions and weighting, we produce maps of population density for both baseline period (2010) and projection period (2030) as in Figure 5.5.





Population density reaches maximum value in 100 persons/ha. If more than 100 persons/ha, it will be assumed to be at maximum value. These values are each given linear weighting. It also applies to vulnerability of floods and landslides. Meanwhile, for water shortage, the population density value is converted into water needs value. Using these last assumptions and weighting, we produce maps of population density for both baseline period (2010) and projection period (2030) as in Figure 5.5.

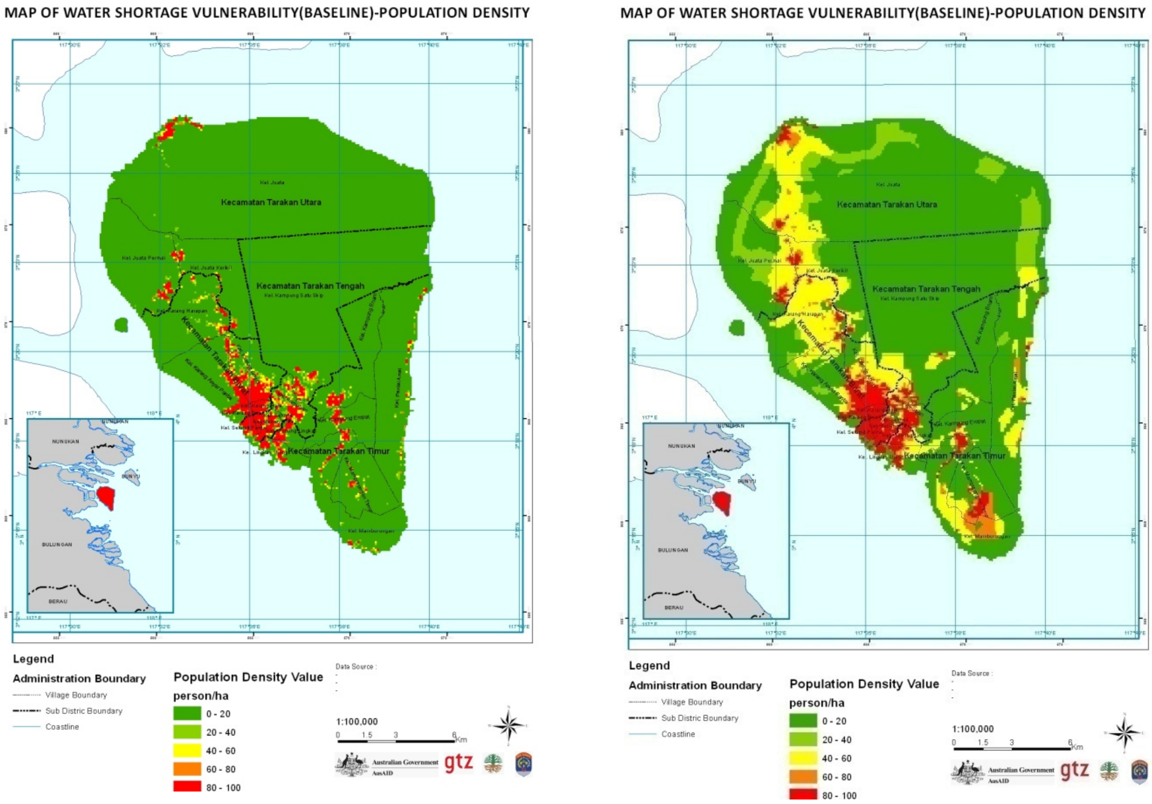
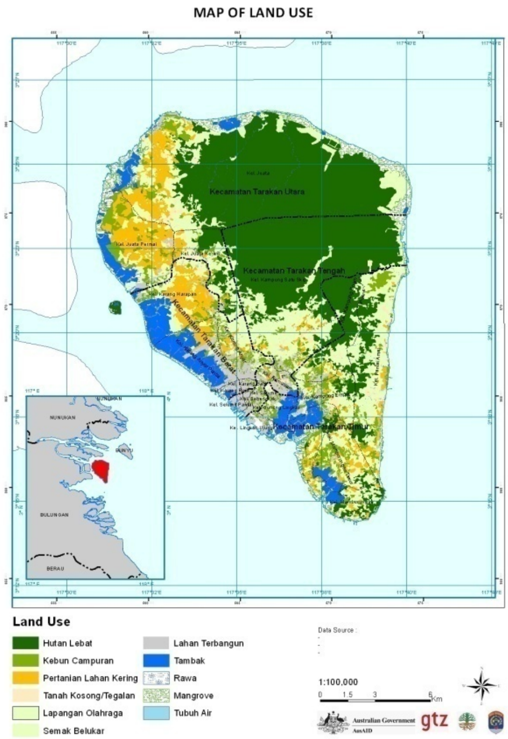


Figure 5. 5 Population Density at Baseline Condition (left) and Projection Condition (right)

5.1.2 Landuse

Apart from the population density, the level of risk is also influenced by landuse type. Current landuse is based on 2008 Landuse from the BAPPEDA of Tarakan while the projection condition uses the 2030 landuse Spatial Planning. The 2008 (current) landuse map and the 2030 landuse map are presented in Figure 5.6. These two landuse maps have different types. To maintain consistency, landuse is seen from its economic value during floods and landslides and from its water needs for water shortage. Assumptions of each economy value is presented in Tabel 5.1 below.



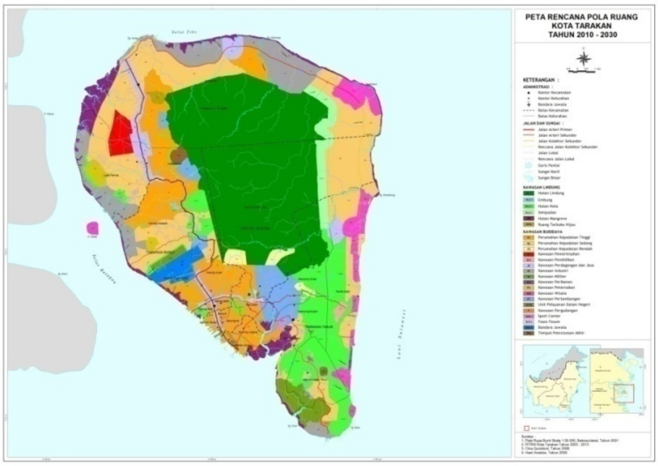


Figure 5. 6 Landuse of Tarakan in 2009 (*above*) as and 2030 (*below*). *Note*: the current landuse (2008) is presented in special map of landuse, while the 2030 landuse is presented in spatial planning map of Tarakan City 2010-2030 (*Peta Rencana Pola Ruang Kota Tarakan Tahun 2010-2030*)

Table 5. 1 Vulnerability Value of Landuse Type

Landuse 2008	Landuse 2030	Landuse Value (Rp/m^2)
Dense forest	Protected forest, City forest	0
Mangrove forest	Mangrove forest	0
Water body	River, reservoir, swamp	0
Cemetery	General cemetery park	0
Housing	High density housing	2,500,000
	Medium density housing	

	Low density housing	
Commercial region	Trade and service region, Industrial region, Warehouse region	10,000,000
Govermental office	Governmental region	10,000,000
Church, Temple, Mosque, Monastery	Public/Social facility	2,500,000
Market		2,500,000
Health center, clinic		5,000,000
Hospital		10,000,000
Kindergarten, elementary school	Education region	2,500,000
Junior highschool		3,000,000
Senior highschool		4,000,000
Terminal	Transportation	3,000,000
Harbour	Harbour	10,000,000
Airport	Airport	20,000,000
Main road	Main road	100,000 x 15
Secondary road	Secondary road	60,000 x 10
Local road	Local road	40,000 x 6
	Animal farm	100,000
***Tambak* (embankment)**	Fishery	100,000
	Tourism area	2,500,000
***Kilang Minyak* (oil refinery)**	Mining	250,000
	UPND Pertamina	20,000,000
***Lapangan Olah Raga* (sport field)**	Sport Center	250,000
Plantation		50,000
Mixed plantation		50,000
Dry land agriculture		50,000
Moor		50,000

In each 1 ha grid, the values are averaged, such as in the analysis of populaition density. The maximum value of landuse is IDR 25 bilion/ha. These values will also be normalized according to the maximum value. Based on these assumptions and available data, we produce maps of landuse for baseline period (2010) and projection period (2030) as in Figure 5.7.

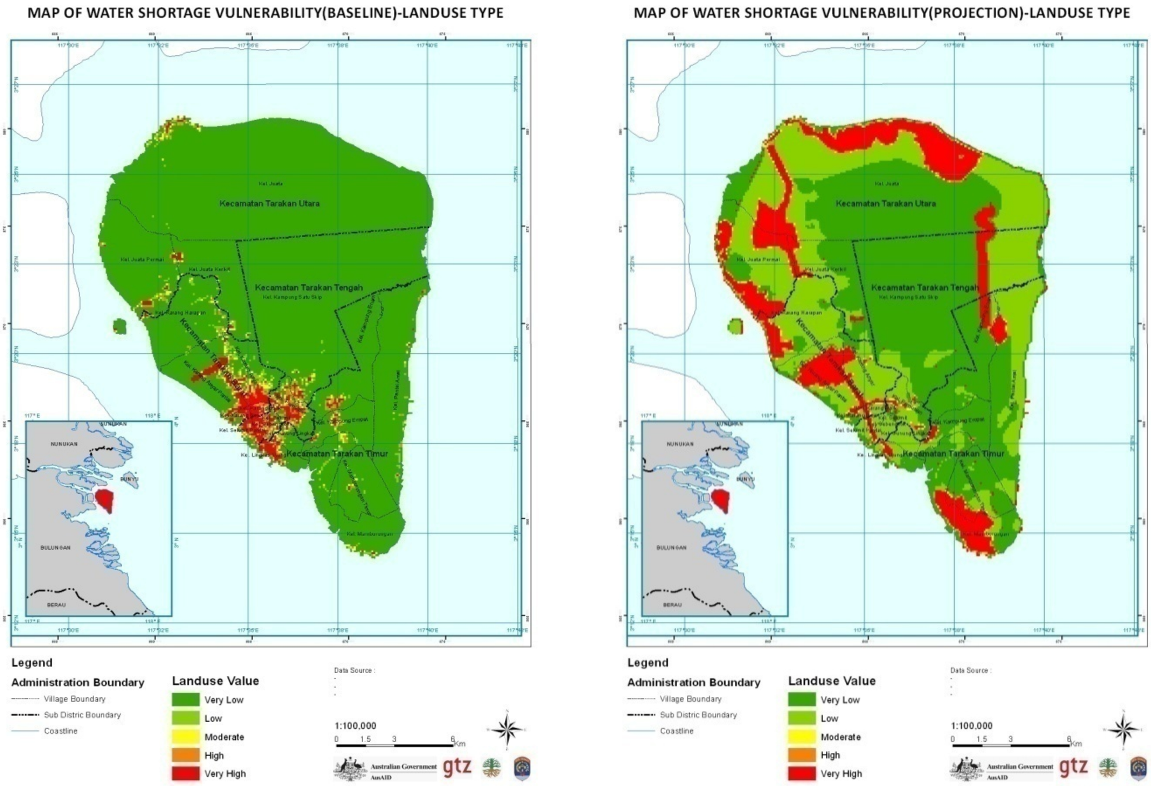


Figure 5. 7 Vulnerability of Landuse at Baseline Condition (Left) and Projection Condition (Right)

5.1.3 Role of Infrastructures

Disasters often caused great collateral damage, especially if there are important infrastructures. If a landslide occurred on a road, then every activity on the road cannot be conducted. Hence, the role of infrastructures are apart or components of vulnerability.

Current distribution of water-related infrastructure can be seen from the current infrastructure data of PDAM. Others infrastructures can be identified from landuse map. Future infrastructure condition is based on the 2030 Spatial Planning. Hence, the infrastructure classes in both planning must be uniform to be used in the analysis. For that purpose, we make a comparison between current infrastructures and projection infrastructures. After the comparison is found out, then we arrange the classification for all infrastructures based on function similarity and put the value to each class. The result of this classification is presented in Table 5.2 below. Based on these process and assumptions, we produced maps of role infrastructures for baseline period and projection period which are presented in Figure 5.8.

Table 5. 2 Class of Infrastructure Role

2008 Infrastructure	2030 Infrastructure	Class of Infrastructure	Infrastructure Value
commercial regions (oil refinery) markets	trade and service regions; UPND Pertamina	commercial regions	1
	industrial regions; warehouse regions	industrial regions	1
governmental offices	governmental regions	governmental regions	2
		educational regions	1
Hospitals health centers, clinics churches; temples; mosques; monasteries		Public facilities, social facilities	3 2 1
Airports	airports	Airports	3
Harbors	harbors	harbors	3
main roads	main roads	main roads	3
secondary roads	secondary roads	secondary roads	2
local roads	local roads	local roads	1

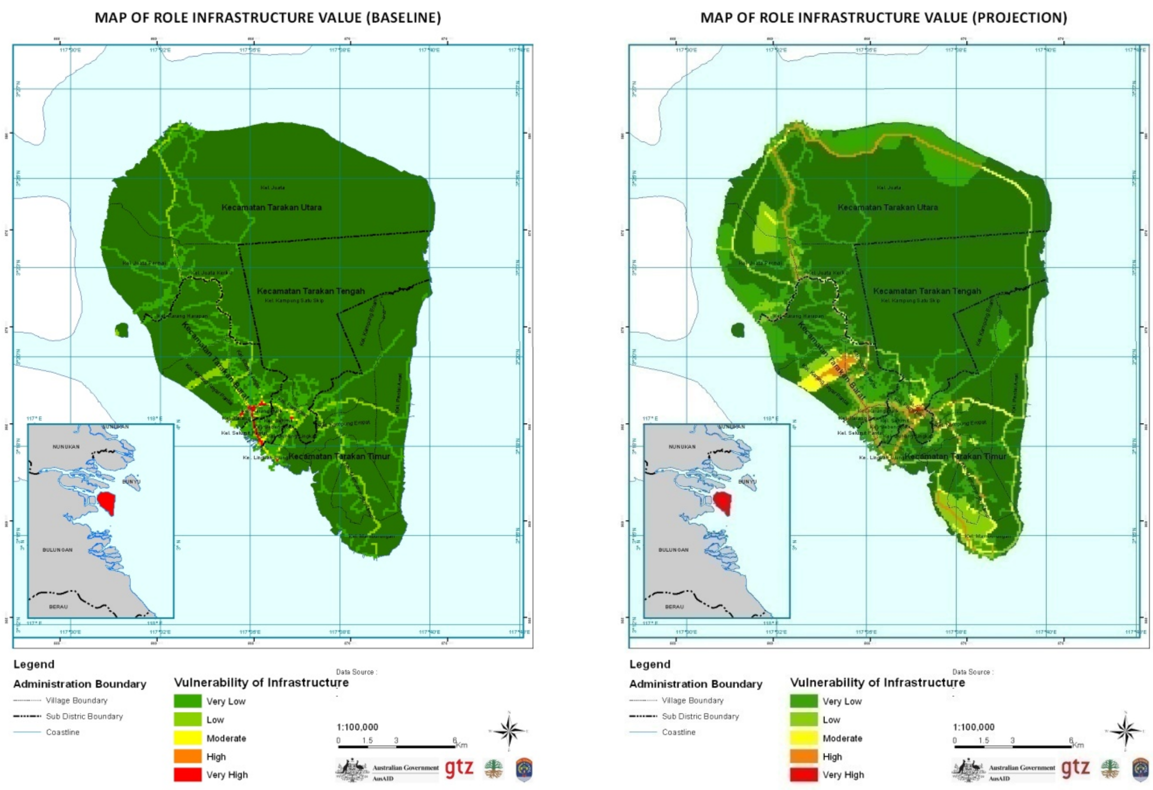


Figure 5. 8 Map of Role Infrastructure at Baseline Condition (Left) and Projection Conditon (Right)

5.1.4 Water Demand

Water demand is an indicator used to analyze water shortage. Water shortage is worsen by higher water demand. The level of water demand is analyzed from two components: people and industries' water needs. Based on the standard of WHO, people's water needs is 144 liter/person/day. Industries' water needs is around 0.3 – 0.8 liter/ha/second or 25-70 m3/ha/day (Ministry of Public Works). This standard of water needs for industries is used due to no data mentioning the level of water consumption in each industry. Based on the 2030 Spatial Planning of Tarakan City, the location of industries and others landuse have been clearly depicted, thus, water demand will be very easy to calculate with area assumption and assumptions of standrds water need for others landuse. In this study, standard of water needs based on landuse are as follow (Table 5.3):

Table 5. 3 Water demand assumption depend on landuse

Landuse types	Water demand (m^3/ha/day)
Industries	50
Trades and services	40
Airports	40

Hospitals	30
Government	25
Religious places	25

Based on the above assumptions, we obtained the water demand distribution for every river discharge, and for every hectare of current condition and 2030 condition (Figure 5.9).

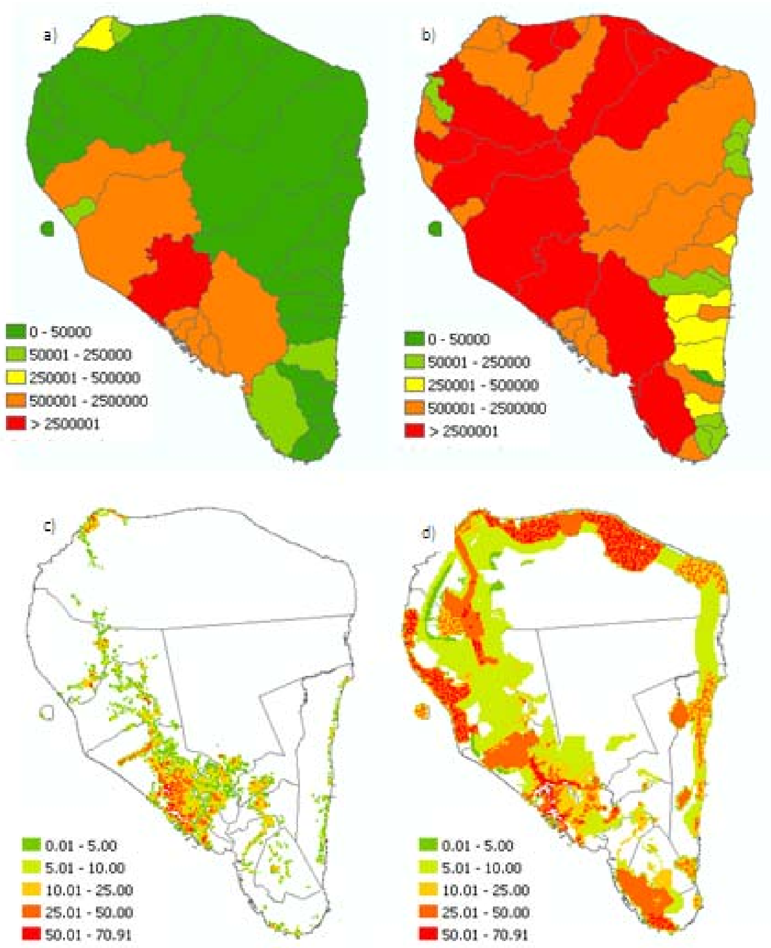


Figure 5. 9 Tarakan Municipality water demand for every river discharge in 2010 (a) and 2030 (b), and spatial water demand (per hectare) in 2010 (c) and 2030 (d)

5.1.5 Water Resources

The impact of climate change to water availability depends on the amount of water sources utilized. The higher the dependence of water sources to climate, the bigger the impact of climate change. Utilized water sources is obtained from 2008 Village Potential (*Potensi Desa*). Based on the data, there are 10 water sources utilized in Tarakan:

1. unprotected spring
2. protected spring

3. unprotected well
4. protected well
5. drilled well
6. retailed piped water
7. gauged piped water
8. bottled water
9. rain water
10. river water

In the projection condition, it is assumed that 90% of the households of Tarakan City will be served by PDAM network. This assumption is based on the target within the Masterplan of PDAM.

5.1.6 Water Quality

Water availability study considers water quantity and quality. Large quantity of water does not mean that it can be used directly, if the water quality is low. Thus, the quality factor also determines the water availability.

Based on surveys, a large number of swamp areas or former swamp areas contain very high iron. This iron is due to the nature of swamps which experience long inundation from neighboring rivers and they only discharged through evaporation. Waters with such kind of quality is not suitable especially for drinking water. So, water bodies in areas of previously swamps or currently swamps are assumed as having low quality and hence, they cannot be utilized. The existence of swamps can be observed by using Landsat images of 2003.

This quality problem is only concerned in the baseline condition in which almost all of the people utilize surface water. The projection condition (2030) using the assumption of 90% of households will be served by PDAM, it can be assumed that the water quality condition is guaranteed, therefore the vulnerability level due to water quality can be ignored.

Figure 5. 10 Surface water quality condition at baseline period. Red color means low quality and green color means good water quality. In projection period it is assumed that the water quality condition is good or the vulnerability level due to water quality can be ignored

5.1.7 Government Programs

Government programs in handling disasters are very important. However,the programs usually contain reactive action or disaster-response, meaning there will be actions only after disasters. If there are landslides, government involvement is based only on landslide occurred on roads (based on studies), while in floods, government involvement will be focused to government facilities and other important infrastructures. Currently, areas which received special treatment from government are roads, government facilities, and important infrastructures.

In the projection condition, it is assumed that government involvement in treating disasters is on maximum condition (covers all areas).

5.1.8 PDAM Services

One of the roles of government is to mitigate the impacts of disasters. PDAM, as one of the government institutions, also has a role in handling the impacts of fluctuation of water availability or water supply. Also, the existence of PDAM will play a very important role in controlling water usage in such a way that contributes to water conservation. The important aspect of PDAM services for this study is the percentage of households which can access PDAM services.

To obtain data of population serviced by PDAM in each village or district, it is assumed that the area of PDAM services is represented by the distribution of PDAM network both in the number of services as well as the map of the PDAM network. Based on the 2007 Masterplan of PDAM of Tarakan City, it is known that the area of PDAM services covers 33% of the total population of Tarakan City. PDAM services in 2010 reached 60% of the population and in 2030 are projected to reach 90% of the population.

Table 5. 4 PDAM Customer base on data (2006) and projection Analysis (2010 and 2030)

Kelurahan	Kecamatan	Pelanggan PDAM		
		2006	2010	2030
Mamburungan Timur	Tarakan Timur	1468	2531	2531
Lingkas Ujung	Tarakan Timur	6454	10409	10409
Mamburungan	Tarakan Timur	1145	2472	7526
Gunung Lingkas	Tarakan Timur	0	417	4401
Selumit Pantai	Tarakan Tengah	6539	12679	16347
Selumit	Tarakan Tengah	130	577	3984
Karang Rejo	Tarakan Barat	1988	3955	6856
Sebengkok	Tarakan Tengah	7359	13858	15019
Karang Balik	Tarakan Barat	2363	4345	7875
Kampung Empat	Tarakan Timur	2853	4529	4529
Karang Anyar Pantai	Tarakan Barat	11963	17855	17855
Karang Anyar	Tarakan Barat	15717	27573	27573
Karang Harapan	Tarakan Barat	4573	7621	7621
Kampung Enam	Tarakan Timur	326	875	3957
Pantai Amal	Tarakan Timur	0	0	2488
Juata Kerikil	Tarakan Utara	1317	2629	4705
Kampung Satu Skip	Tarakan Tengah	0	0	4682
Juata Permai	Tarakan Utara	2201	4340	6877
Juata Laut	Tarakan Utara	3224	6375	10401
Pamusian	Tarakan Tengah	4946	9683	14131

5.1.9 Social Welfare

Social welfare is used to represent the involvement of society in minimizing impacts of disasters, and is measured based on house types and society's income/capita. In the projection, social welfare is not included due to government involvement is assumed in maximum condition.

5.2 Overview of Water Sector Vulnerability

5.2.1 Vulnerability to water shortage

Vulnerability to water shortage can be define in three components and five indicators as in Table 5.5. The map of vulnerability to water shortage resulted from GIS analysis that involves all these vulnerability components are presented in Figure 5.11.

Table 5. 5 Water Shortage Indicator

Component	Indicator	Sub Indicator	Weighting
Exposure	Water Demand		0.278
Sensitivity	Water Resource		0.279
	Water Quality		0.175
Adaptive Capacity	Population Welfare	Society's income	0.117
		House Type	0.087
	PDAM Network		0.064

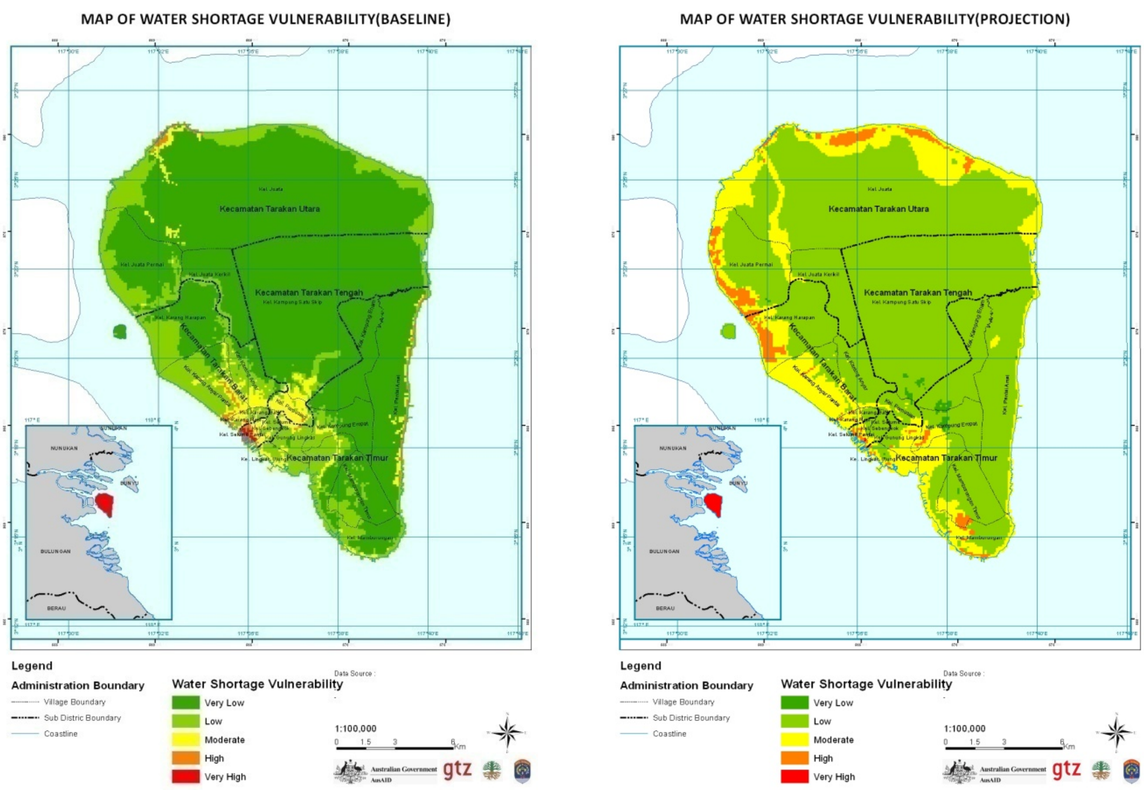


Figure 5. 11 Vulnerability of Water Shortage at Baseline Condition (Left) and Projection Condition (RIght)

In the baseline period, the highest vulnerable area is in the Central Tarakan district including Selumit, Selumit Pantai, and part of Sebengkok villages. Next to the highest vulnerability is high vulnerability. Regions with high vulnerability in baseline period are Karang Anyar, Karang Anyar Pantai, Karang Rejo, Selumit Pantai, Sebengkok, and Juata Laut villages. But in the projection period, the vulnerability level increase along the developed coastal regions. Regions which need special attention in projection period are the northern of Juata Laut, Juata Permai, Karang Harapan, and Memburungan which are developed to become industrial and settlement areas.

5.2.2 Vulnerability to floods

Vulnerability to flood can be define in three components and five indicators as in Table 5.6. The map of vulnerability to flood resulted from GIS analysis that involves all these vulnerability components are presented in Figure 5.12.

Table 5. 6 Floods Indicator

Component	Indicator	Sub Indicator	Weighting
Exposure	Population Density		0.344
	Landuse		0.259
Sensitivity	Role of Infrastructure		0.182
Adaptive Capacity	Population Welfare	Society's income	0.051
		House Type	0.092
	Government Program		0.072

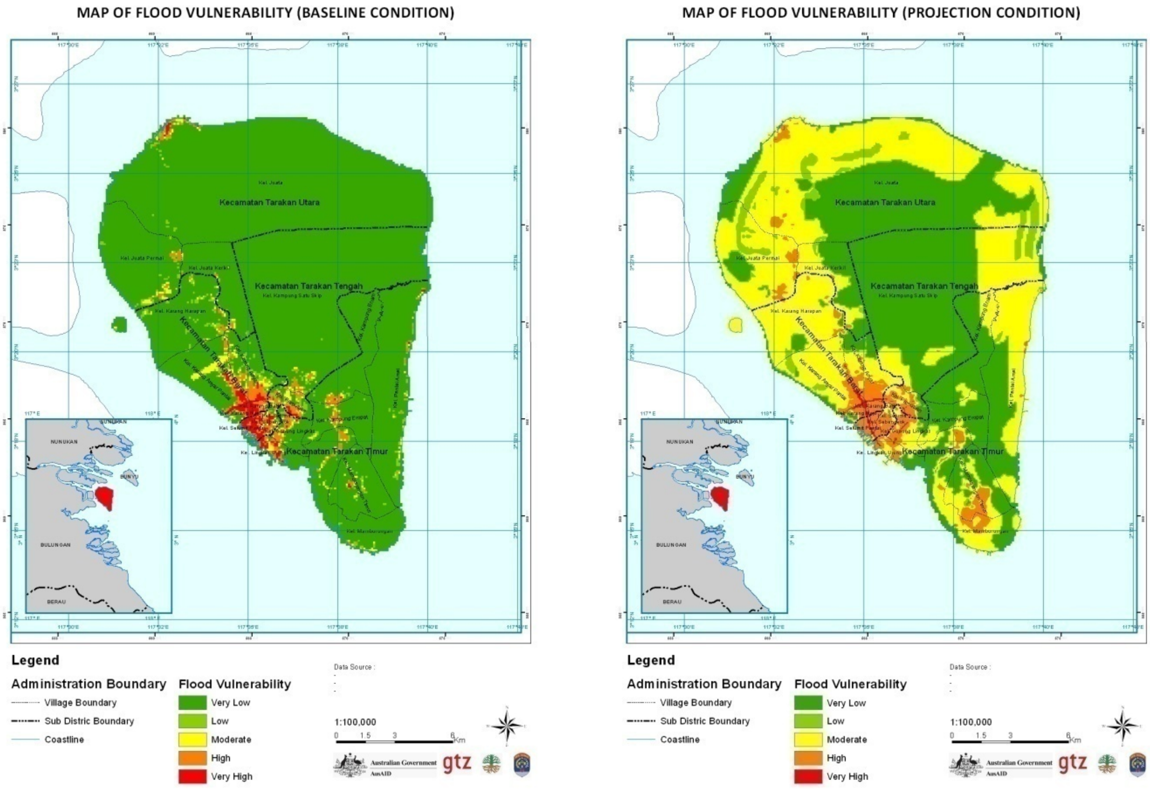


Figure 5. 12 Vulnerability of Floods at Baseline Condition (Left) and Projection Condition (RIght)

In the baseline period, the highest vulnerable area is in the Central Tarakan district including Selumit, Selumit Pantai, and part of Sebengkok villages. In those regions vulnerability level is very high. Next to very high level of vulnerability is high vulnerability. Regions with high vulnerability in baseline period are Karang Anyar, Karang Anyar Pantai, Karang Rejo, Selumit Pantai, Sebengkok, and Juata Laut villages. The moderate vulnerability is surrounding the region of very high to high level of vulnerability. Regions with moderate vulnerability in baseline period among others are parts of Pamusian, Gunung Lingkas, Lingkas Ujung, Karang Anyar, Karang Empat, and Juata Laut villages.

In the projection period, the vulnerability level increase along the developed coastal regions and, to some extent, also in inland region. Regions which need special attention in projection period are the northern of Juata Laut, Juata Permai, Karang Harapan, and Memburungan. These areas will be developed to become industrial and settlement areas such that their vulnerabilities to water shortage hazard become high to very high level. Others area which very high to high vulnerability level are Selumit Pantai, Selumit, Sebengkok, Pamusian villages; parts of Pamusian, Gunung Lingkas, Lingkas Ujung, Karang Balik, Karang Rejo, and Kampung Empat villages.

Others areas need attention because of theirs level vulnerability are widely change from low or very low in baseline period to moderate. These areas are including Karang Anyar Pantai, Karang Harapan, Juata Permai, north part of Juata Laut, west part of Kampung Satu Skip, west part of Kampung Enam, Mamburungan, and Karungan villages.

5.2.3 Vulnerability to landslides

Vulnerability to landslide can be define in three components and five indicators as in Table 5.7. The map of vulnerability to flood resulted from GIS analysis that involves all these vulnerability components are presented in Figure 5.13.

Table 5. 7 Landslides Indicator

Component	Indicator	Sub Indicator	Weighting
Exposure	Population Density		0.380
	Landuse		0.242
Sensitivity	Role of Infrastructure		0.157
Adaptive Capacity	Population Welfare	Society's income	0.070
		House Type	0.087
	Government Program		0.064

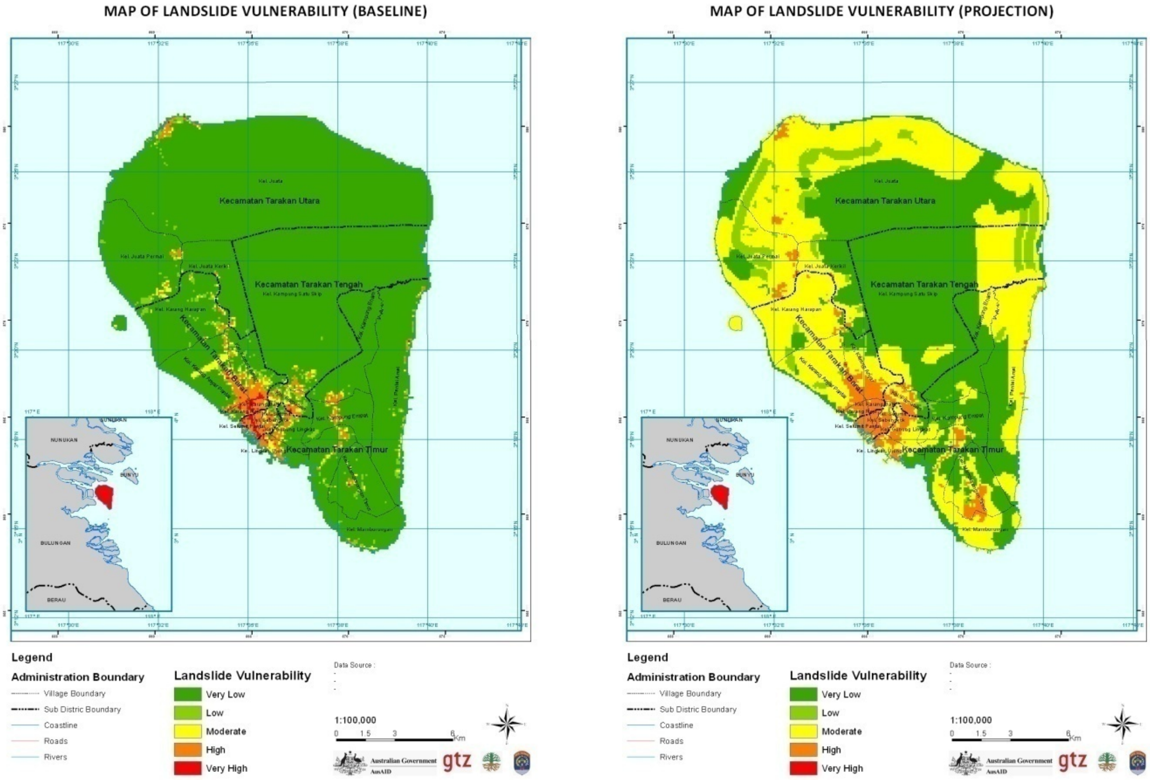


Figure 5. 13 Vulnerability of Floods at Baseline Condition (Left) and Projection Condition (RIght)

Regions with increasing vulnerability to landslides include areas developed into settlement. This is because the population and landuse weighting become dominant, more than 80% of the total weighting. Thus, every developed areas become more vulnerable to landslides.

The weighting of government program is only 6.4%, causes indifferent vulnerability between landslides and floods. Hence, the levels and regions of each level of landslide vulnerability are similar to levels and regions of each level of flood vulnerability. Therefore, regions with high vulnerability in baseline period are Karang Anyar, Karang Anyar Pantai, Karang Rejo, Selumit Pantai, Sebengkok, and Juata Laut villages. Meanwhile, regions with moderate vulnerability in baseline period among others are parts of Pamusian, Gunung Lingkas, Lingkas Ujung, Karang Anyar, Karang Empat, and Juata Laut villages. Also, in the projection period, the vulnerability level increase along the developed coastal regions and, to some extent, also in inland region. Regions which high to very high vulnerability level are part of Juata Laut, Juata Permai, Karang Harapan, Memburungan villages; Selumit Pantai, Selumit, Sebengkok, Pamusian villages; parts of Pamusian, Gunung Lingkas, Lingkas Ujung, Karang Balik, Karang Rejo, and Kampung Empat villages.

VI. ASSESSMENT OF RISK TO CLIMATE CHANGE

6.1 Identification of Climate Change Risk on Water Sector

The risk of climate change, magnitude and spatial distribution, is determined by its level of hazard and vulnerability. This study assesses the risks of each hazard identified before: water shortage, floods, and landslides. As it has been stated in the assessment method (Chapter 3), risk is a function of hazard and vulnerability (Affeltranger, et.al, 2006). Function here means an magnification by the addition modus. Practically, the risk is drawn in a map to see its distribution for minimum of two periods, baseline and projection, so we can see the risk temporally and spatially. The map consists of overlay of two maps previously produced, map of hazard and map of vulnerability for each hazard. The risk level is classified into 5 levels, they are very low, low, moderate, high, and very high.

6.1.1 Water shortage risk

Water shortage risk is a function of water shortage hazard and its vulnerability. Water shortage hazard consists of natural water supply component and increasing water needs per watershed unit, which when overlayed produce map of water shortage hazard as in Figure 4.8, Chapter IV. Meanwhile, the vulnerability consists of water demand, sources of water utilized by society, water quality, PDAM service, and social welfare components.

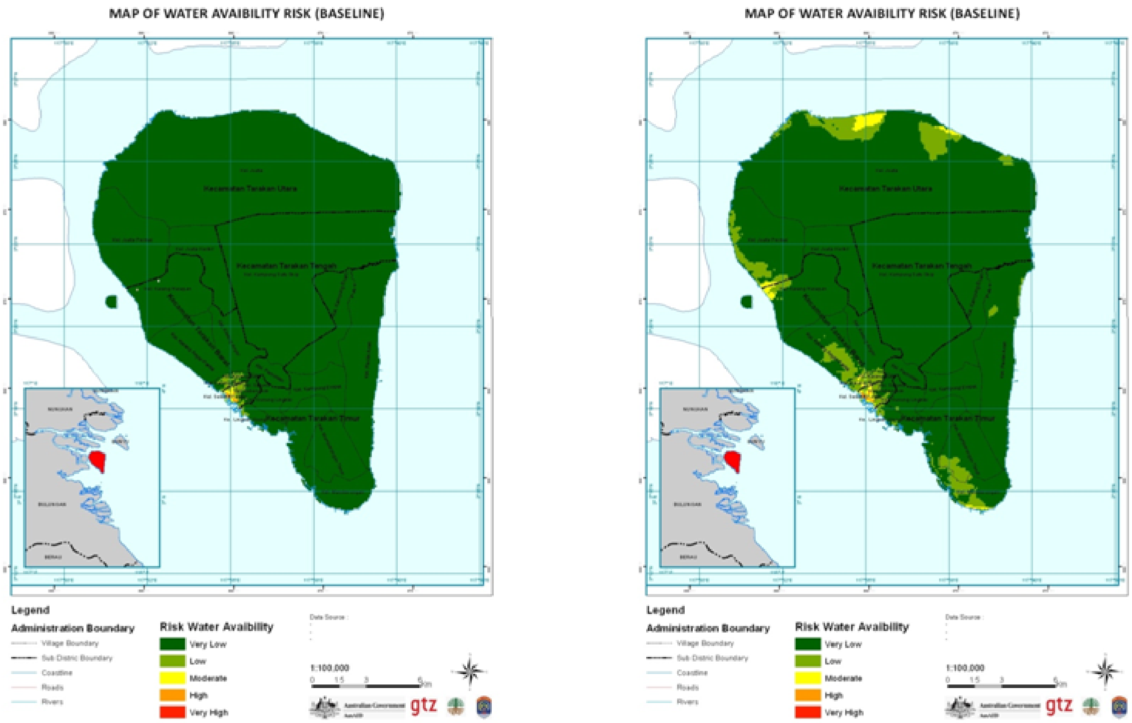


Figure 6. 1 Map of water shortage risk, for the baseline/current period, 1990-2020 (*left*) and projection period of 2010-2030 (*right*).

Figure 6.1 above, left and right, are map of water shortage risk of Tarakan City that resulted in this study. From the figure above we can see that the water shortage risk in Tarakan is relatively low in the baseline period and slightly increase in the projection period. There are four levels of water shortage risk in Tarakan: high, medium, low, and very low risks. There is not any significant area of region with very high risk both in baseline period and projection period. The widest spatial distribution risk level is very low risk both in baseline period and projection period. Table 6.1 present the water shortage risk and its distribution over watershed and administrative region in baseline period.

Table 6.1 Water shortage risks and their spatial distribution in baseline period (2010)

Level of Risk	Watershed	Area (km^2)	Administrative Region (village)
Very High	-	-	-
High	Kampung Bugis	0.08	Small part of Selumit, small part of Selumit Pantai
	Sesanip	0.05	Small part of Karang Rejo
Medium	Kampung Bugis	0.26	Part of Selumit, part of Selumit Pantai
	Sesanip	0.12	Part of Karang Rejo
Low	Kampung Bugis	1.07	Part of Selumit, part of Selumit Pantai, part of Sebengkok
	Sesanip	0.46	Part of Karang Rejo, part of Karang Balik

Very Low	All watershed, except part of waterhsed Kampung Bugis and Sesanip which high to low level of risk	248,76	All administrative region except regions of high, medium, and low level of the risk

As in Table 6.1, in the baseline period, the water shortage risk is high in the very small area of 0.08 km^2 in the Kampung Bugis watershed which covers parts of Selumit and Selumit Pantai regions. Next, the high risk is located in Sesanip watershed with a total area of 0,05 km^2 which consists of part of Karang Rejo region. Surrounding the region of high level of the risk is medium level of the risk. This medium level of the risk is found in two regions, they are Kampung Bugis watershed, with a wider area of around 0.26 km^2, and Sesanip watershed, with a less wide area of 0.12 km2.

Further risk in baseline period is low level risk of water shortage. This low level risk in baseline period distributed also in Kampung Bugis watershed with a total area of 1,07 km2 which covers part of Selumit village, part of Selumit Pantai village, and part of Sebengkok village; and Sesanip watershed with a total area of 0.46 km2 which spreads in part of Karang Rejo village and part of Karang Balik village.

The last is very low level of the risk which is the largest region. This region of very low level of the risk covers almost all (99%) of Tarakan’s region except region whit high, medium and low level of the risk which have been mentioned previously.

In the projection period, there is a slight increase of low to medium high risks and an increase of area of medium and high risks, compared to previous period. In the projection period, generally, the high and medium risks areas are wider than the same level in the baseline period. The increasing risk is caused by the decreasing water supply due to decreasing precipitation trend and increasing evapotranspiration and water needs. However, in the projection period also is not any significant area of very high level of the risk. The distribution of water shortage risks are shown in the following Table 6.2.

Table 6.2 risks and their spatial distribution in projection period

Level of Risk	Watershed	Area (km^2)	Administrative Region (village)
Very High	-	-	
High	Kampung Bugis	0.09	Small part of Selumit, small part of Selumit Pantai
	Pamusian	0.05	Small part of Pamusian
Medium	Kampung Bugis	0.43	Part of Selumit, part of Selumit Pantai, part of Sebengkok
	Mangantai	0.21	Small part of west Juata Laut
	Maya	0.01	Small part of central-north Juata Laut
	Pamusian	0.16	Small part of Pamusian
	Persemaian	0.56	Small part of Karang Harapan

	Other watershed	1.21	Small part of central-north Juata Laut, Karungan, and Pantai Timur
Low	Bengawan	1.45	Part of Juata Laut
	Binalatung	0.06	Part of Kampung 1 Skip
	Kampung Bugis	2.68	Small part of Selumit, small part of Selumit Pantai, Sebengkok
	Karungan	2.6	Part of Karungan
	Mangantai	2.4	Part of west Juata Laut
	Maya	0.03	Part of central-north Juata Laut
	Pamusian	0.81	Part of Pamusian, Gunung Lingkas, Lingkas Ujung, Mamburungan,
	Persemaian	0.8	Part of Karang Harapan
	Sesanip	1.06	Part of Karanganyar & Karang Anyar Pantai
	Other watershed	6.37	Small part in west Juata Laut, Pantai Timur, south Mamburungan, etc
Very Low	All watershed except parts of watershed with high, medium and low level of the risks		All administrative region except regions of high, medium, and low level of the risk

In the projection period, as in Table 4.5, the risk areas of high levels of water shortage are 0.09 km^2 in Kampung Bugis watershed and 0.05 km^2 in Pamusian watershed. The area in Kampung Bugis covers small parts of Selumit and Selumit Pantai villages region, while the area in Pamusian spreads in small parts of Pamusian village region. The area of medium risk level area is wider than the high risk level area, that is 2.58 km^2, distributed in Kampung Bugis, Mangantai, Maya, Pamusian, Persemaian, and others watershed. Administratively, the region of this high level risk of water shortage covers part of Selumit, Selumit Pantai, and Sebengkok village; small parts of west Juata Laut, central-north Juata Laut, Pamusian, Karang Harapan, Karungan, and Pantai Timur.

Further risk region is low risk level. This low level of the risk has an area larger than the high and medium risk levels, which totally is 18.26 km^2, with a distribution following the distribution of medium risk level in Bengawan, Binalatung, Kampung Bugis, Karungan, Mangantai, Maya, Pamusian, Persemaian, Sesanip, and others watersheds. Administratively, the region of this high level risk of water shortage covers, among others, part of Juata Laut (central-north and west part), Kampung 1 Skip villages; small parts of Selumit, Selumit Pantai, and Sebengkok; parts of Karungan, west Juata Laut, Pamusian, Gunung Lingkas, Lingkas Ujung, Mamburungan, Karang Harapan, Karang Anyar, Karang Anyar Pantai, Pantai Timur, south Mamburungan.

Lastly, the very low risk level area is the largest risk area with a total of 229.82 km^2, or 92% of total Tarakan's area, spread out in all watersheds in Tarakan except parts of watershed whit high, medium and low level of the risk which have been mentioned previously.

6.1.2 Flood Risk

The flood risk is distributed in 12 watersheds, vary from very low risk, low risk, moderate risk, high risk, to very high risk. Below are the explanations of the 12 flood risk areas in Tarakan Municipality.

1) Semunti

The map of flood risk in Semunti watershed is shown in Figure 6.2 below.

Baseline Projection 2030

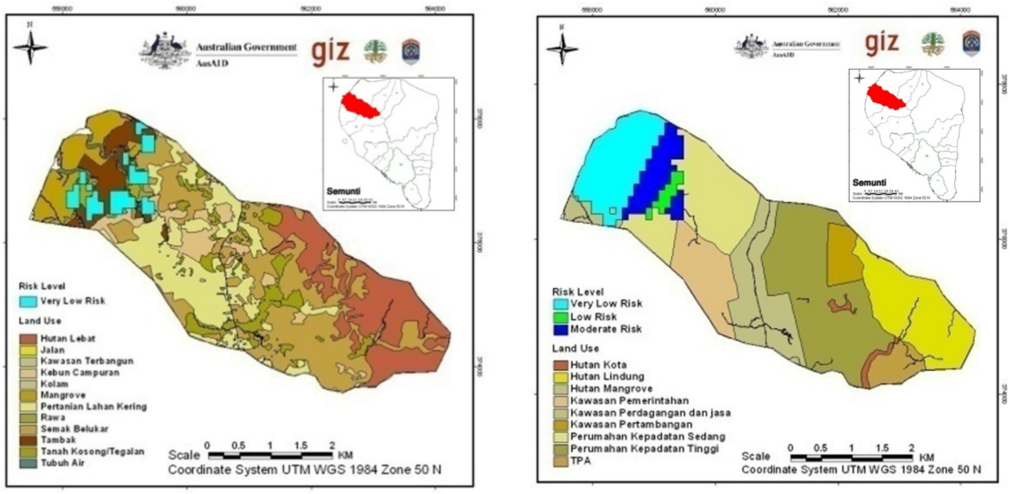


Figure 6.2 Map of Risk in baseline and projection condition at Semunti Watershed

In the baseline condition, the risk level of Semunti watershed is very low risk and covers about 0.553 km^2 that consists of ponds, swamps, and mangrove areas, as shown in Figure 6.2, left side. Meanwhile, in the projection condition, the risk level increased into 3 levels, very low risk, low risk, and moderate risk. Very Low level is the largest area of risk. Meanwhile, the Moderate level covers moderate density residential areas, as shown in Figure 6.2, right side.

Table 6. 3 Risk Table of Semunti Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.553	ponds	1.535	mangrove
		swamps		
		mangrove		
Low Risk	-	-	0.173	residential

Moderate Risk	-	-	0.74	residential

2) Bengawan

In the baseline condition, the Bengawan watershed consists of 3 levels of risk that are very low risk, low risk, and moderate risk. The moderate risk area covers residential areas, as shown in Figure 6.3, left side.

Table 6. 4 Risk Table of Bengawan Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	1.382	pond	0.456	forestry area
		mangrove		
		agriculture land		
		cropland		residential
		shrubs		
Low Risk	0.032	residential	-	-
Moderate Risk	0.011	residential	1.133	industrial area
				forest city
				residential (high)
High Risk	-	-	0.03	residential (high)

In the projection condition, the Bengawan Watershed consists of 3 level of risk as follows: Very Low Risk, Moderate Risk, and High Risk level. The area of Very Low Risk is decreasing to 0.456 km^2. Meanwhile, the Area of Moderate Risk is increasing to 1.133 km^2. The High Risk Level covers high density residential (housing), as shown in Figure 6.3, right side.

Baseline Projection 2030

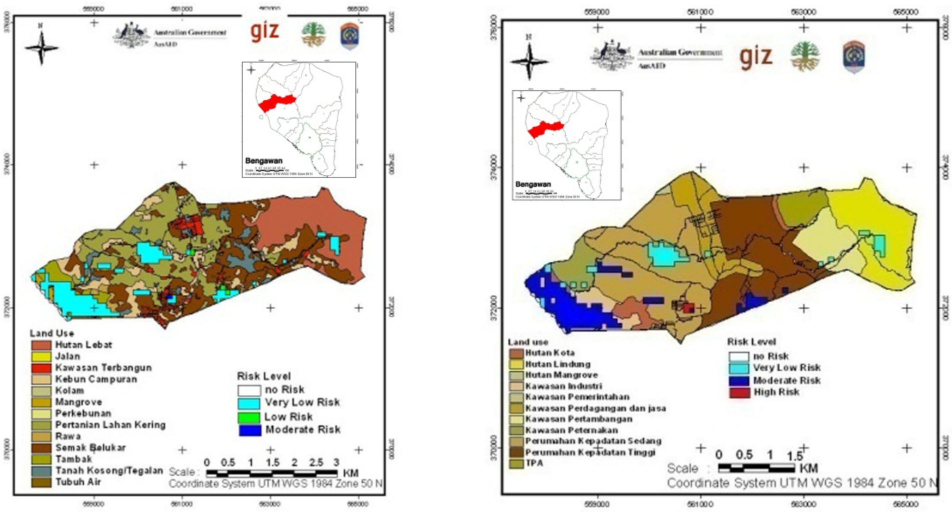


Figure 6.3 Map of Risk in baseline and projection condition at Bengawan Watershed

3) Persemaian

In the baseline condition, the Persemaian Watershed consists of 4 level of risk. The largest area of risk is the Very Low Risk Level and covers shrub and agriculture lands. It is followed by Low Risk, Moderate Risk, and High Risk level area. All of those risks cover residential areas and sporthall as shown in Figure 6.4, left side.

In the projection condition, the area of risk are decreasing, such as Very Low Risk and Low Risk level areas are decreased to 0.447 km^2 and 0.030 km^2 respectively. In the other risks, the area increased, such as Moderate and High Risk level area is increasing to 2.536 km^2 and 0.158 km^2. Industrial areas and high density residential areas are covered by Moderate Risk and High Risk Levels, as shown in Figure 6.4, right side.

Table 6. 5 Risk Table of Persemaian Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	1.407	shrubs	0.447	residential (moderate)
		agriculture land		forest city
Low Risk	0.226	residential	0.03	residential (moderate)
		sporthall		forest city
Moderate Risk	0.099	residential	2.536	industrial area
		sporthall		residential (high)
High Risk	0.021	residential	0.158	industrial area
		sporthall		residential (high)

Baseline | Projection 2030

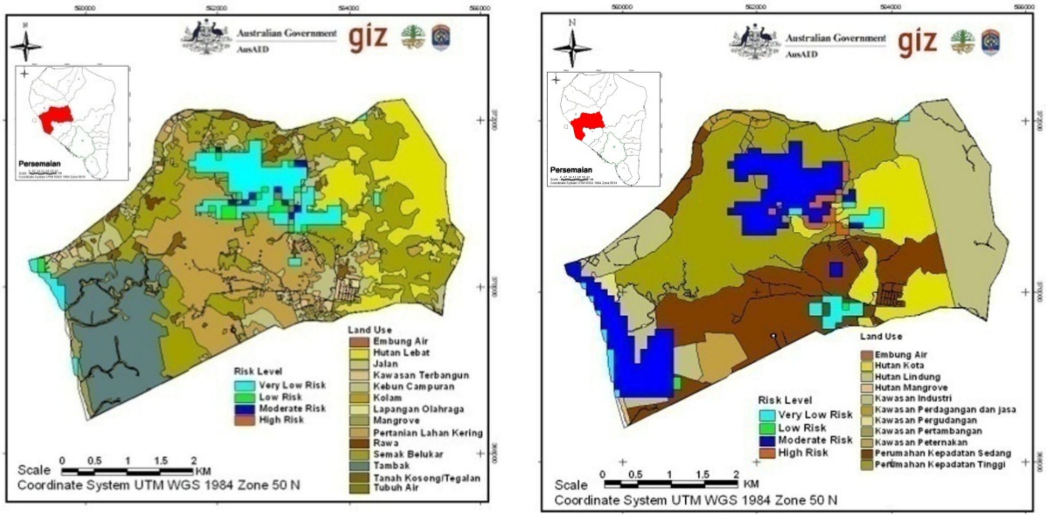


Figure 6.4 Map of Risk in baseline and projection condition at Persemaian Watershed

4) Sesanip

In the baseline condition, the Sesanip Watershed consists of 5 level of risk. There are Very Low Risk, Low Risk, Moderate Risk, High Risk and Very High Risk. Very Low Risk level is the largest area of risk with 0.423 km^2 as shown in Figure 6.5, left side.

In the projection condition, one area of risk is increasing but the others are decreasing. The area of Low Risk, Moderate Risk, and High Risk levels tend to increase significantly. The area of High Risk level is located at the Juwata Airport. Meanwhile, the area of Very Low Risk level area is decreasing to 0.130 km^2 as shown in Figure 6.5, right side.

Table 6. 6 Risk Table of Sesanip Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.423	ponds	0.13	mangrove
Low Risk	0.019	cropland	0.142	residential (high)
Moderate Risk	0.05	residential	1.501	residential (high)
		road		
High Risk	0.03	residential	0.337	Airport
		road		
Very High Risk	0.031	residential	-	-
		airport		

The Very High Risk level is not shown in the projection condition might be caused by the adaptive capacity in the vulnerability indicator such as improvement of drainage capacity, increasing embankment level, etc.

Baseline Projection 2030

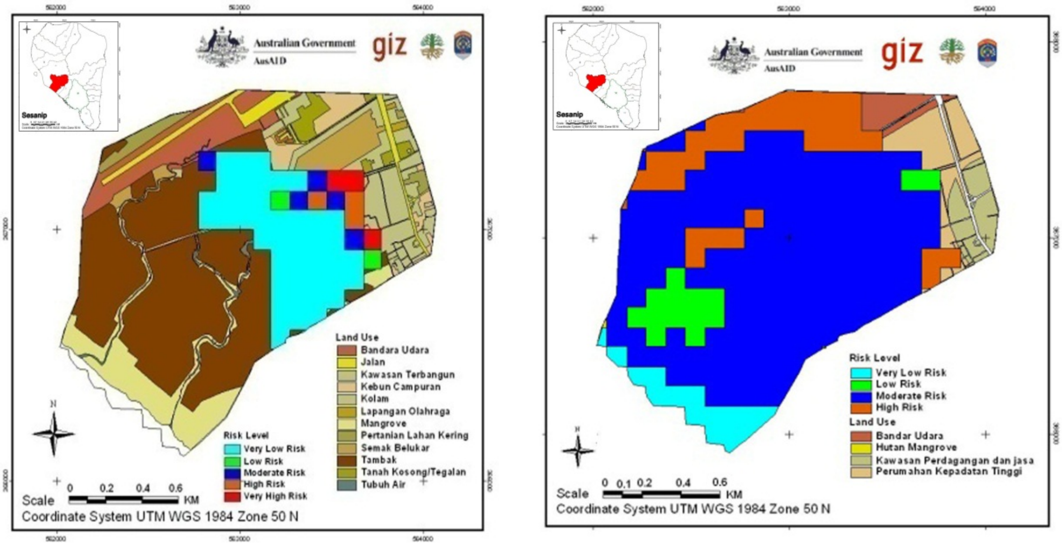


Figure 6.5 Map of Risk in baseline and projection condition at Sesanip Watershed

5) Kampung Bugis

In the baseline condition, the Kampung Bugis Watershed consists of 5 levels of risk. They are Very Low Risk, Low Risk, Moderate Risk, High Risk, and Very High Risk. The area of Very Low Risk Level is the largest area of risk. Most of the risk areas are located in the residential areas as shown in Figure 6.6, left side.

In the projection condition, the area of some risk levels is increasing, such as the area of Moderate Risk Level and High Risk Level. In the other hand, the area of risk is decreasing such as the area of Very Low Risk Level, Low Risk Level and Very High Risk Level. Land use coverage of most of the risk areas are high density residential areas and commercial areas, as shown in Figure 6.6, right side.

Table 6. 7 Risk Table of Kampung Bugis Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.663	residential	0.341	residential (high)
Low Risk	0.179	residential	0.051	residential (high)
Moderate Risk	0.107	residential	1.707	residential (high)
		road		commercial and services area
High Risk	0.11	residential	0.867	residential (high)
				commercial and services area
Very High Risk	0.261	residential	0.198	residential (high)

Baseline Projection 2030

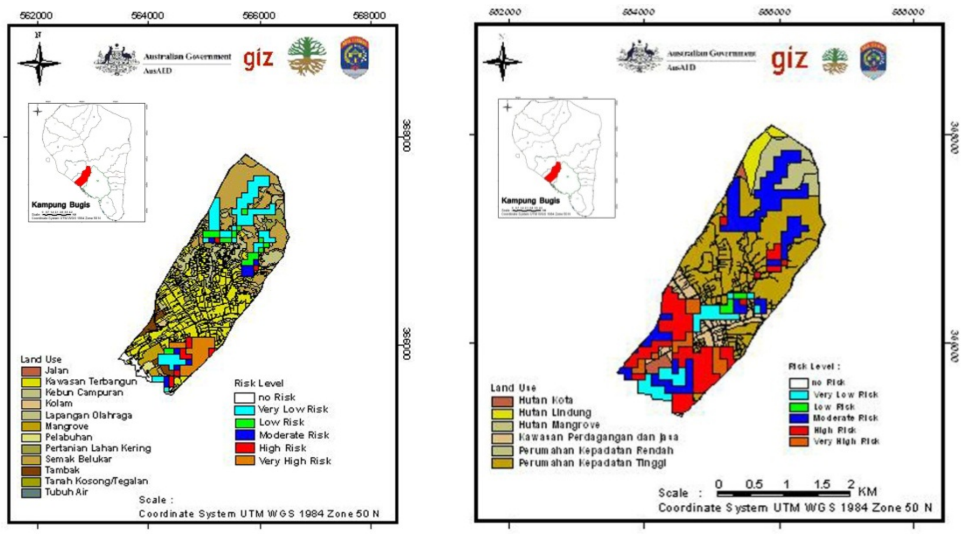


Figure 6.6 Map of Risk in baseline and projection condition at Kampung Bugis Watershed

6) Pamusian

In the baseline condition, the Pamusian Watershed has 5 levels of risk. The Very Low Risk level is the largest area of risk level. The High Risk and Very High Risk level areas cover residential areas and infrastructures. Figure 6.7, left side shows the map on risk in baseline condition.

In the Projection model, some of the risk levels will decrease, and others will increase. Very Low Risk, Low Risk, and Moderate Risk area will increase. Meanwhile, the High Risk and Very High Risk area will decrease. The High and Very High Risk level areas will cover high density residential areas.

Table 6. 8 Risk Table of Pamusian Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	2.219	ponds	3.336	mangrove
Low Risk	0.184	agriculture land shrubs	0.287	forest city industrial area
Moderate Risk	0.242	agriculture land shrubs	2.536	forest city industrial area
High Risk	0.259	residential road	0.239	residential (high)
Very High Risk	0.201	residential road	0.089	residential (high)

Baseline	Projection 2030

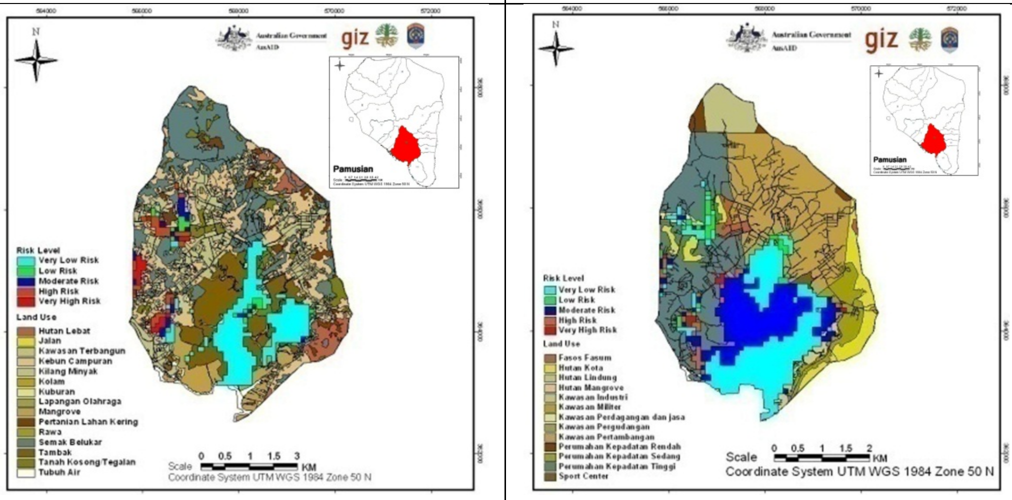


Figure 6.7 Map of Risk in baseline and projection condition at Pamusian Watershed

7) Karungan

In the baseline condition, the Risk Level of Karungan Watershed is only Very Low Risk Level and covers pond areas as shown in the left side of Figure 6.8. Meanwhile, in the projection condition, the level of risk in the Karungan Watershed is increasing into 4 levels of risk. They are Very Low Risk, Low Risk, Moderate Risk and High Risk as the largest area of about 0.889 km^2. Based on the 2030 RTRW, most of the risk areas cover military areas, as shown in Figure 6.8, right side.

Table 6. 9 Risk Table of Karungan Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.945	pond	0.163	mangrove
Low Risk	-	-	0.008	residential (moderate)
Moderate Risk	-	-	0.622	military area
High Risk	-	-	0.889	military area

Baseline Projection 2030

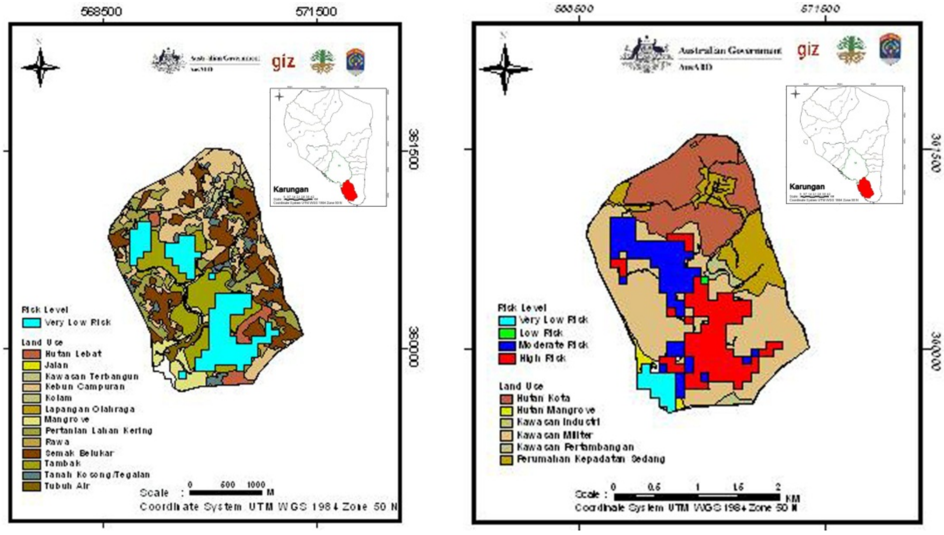


Figure 6.8 Map of Risk in baseline and projection condition at Pamusian Watershed

8) Amal Baru

In the baseline condition, the Amal Baru basin has 3 levels of risk. They are very low risk, low risk and moderate. The Very Low Risk level covers most of shrubs, forests, and agriculture lands. Meanwhile, the Low risk and Moderate Risk Levels cover residential areas as shown in Figure 6.9, left side.

In the projection condition, the Very Low Risk Level area is decreasing but the moderate risk level area is increasing about 41.1 percent more than the baseline. The Very Low Risk Level area will cover forests and sport center, while the moderate risk level area will cover residential areas and tourism areas. The right side of Figure 6.9 shows the map of risk in the projection condition.

Table 6. 10 Risk Table of Amal Baru Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.279	shrubs forest agriculture land	0.181	forest sport center
Low Risk	0.029	residential	-	-
Moderate Risk	0.01	residential	0.411	residential (moderate) tourism area

Baseline

Projection 2030

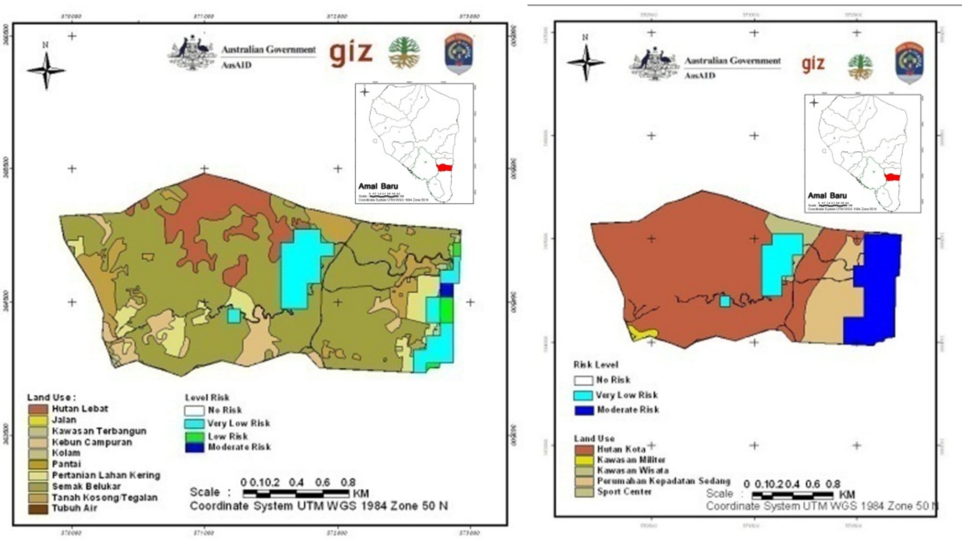


Figure 6.9 Map of Risk in baseline and projection condition at Amal Baru Watershed

9) Kuli

In the baseline condition, the Kuli Watershed has 3 levels of risk. They are Very low Risk, Low Risk, and moderate Risk levels. The Very Low Risk level is the largest area of risk. Most of the risk areas cover shrub and forest areas as shown in Figure 6.10, left side.

In the projection model, the level of risk tends to increase, such as Low Risk to High Risk due to land use changes from shrub and forests become moderate density residential areas. The Very Low Risk level area will decrease, but the Moderate Risk level area is increasing. Most of the risk areas will cover forest city and moderate density residential areas as shown in Figure 6.10, right side.

Table 6. 11 Risk Table of Kuli Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	1.714	shrubs	1.487	forest city
		forest		
Low Risk	0.012	shrubs	-	-
		forest		
Moderate Risk	0.01	residential	0.412	residential (Low)
High Risk	-	-	0.018	residential (Moderate)
				tourism area

Baseline Projection 2030

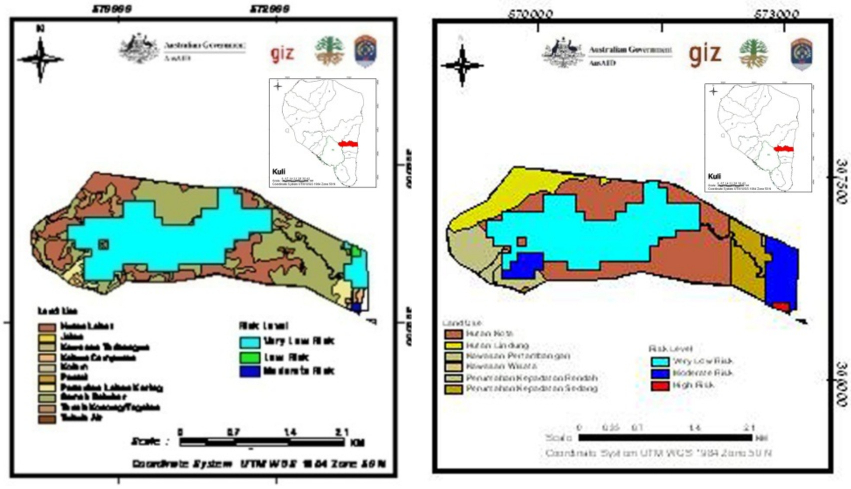


Figure 6.10 Map of Risk in baseline and projection condition at Kuli Watershed

10) Binalatung

In the baseline condition, the Binalatung basin has 4 levels of risk. They are Very Low Risk, Low Risk, Moderate Risk and Very High Risk levels. The Very low risk has the largest area with 2.291 km^2. Meanwhile, the Low Risk and Moderate Risk levels cover residential areas, as shown in Figure 6.11, left side.

In the projection condition, the Binalatung basin has 4 levels of risk. The Very Low Risk level is decreasing area of risk. Meanwhile, the Low Risk and Moderate Risk level will be increase area of risk. The High Risk Level covers moderate density residential areas. In Figure 6.11, it is shown in the right side.

Table 6. 12 Risk Table of Binalatung Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	2.291	shrub	1.33	green forest
		cropland		pond (embung)
		forest		
Low Risk	0.008	residential	0.0488	mangrove
Moderate Risk	0.020	residential	1.7068	residential (Low)
				tourism area
High Risk	-	-	0.0509	residential (moderate)
Very High Risk	0.015	residential	-	-

Baseline Projection 2030

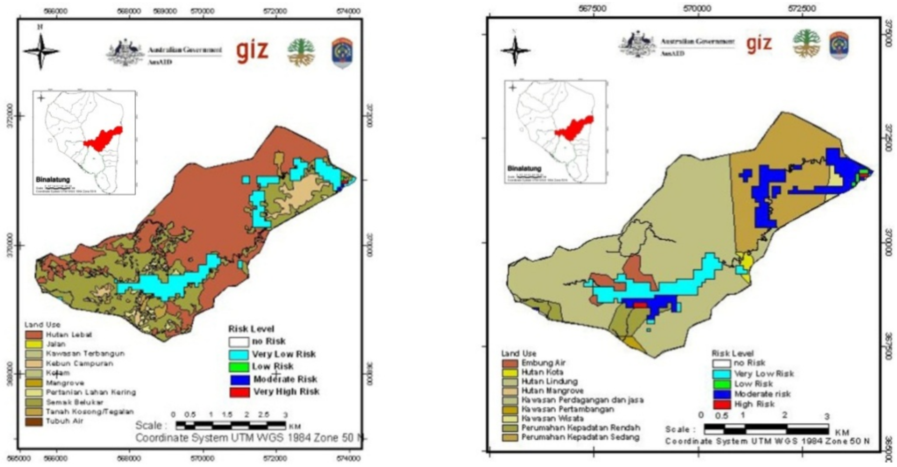


Figure 6.11 Map of Risk in baseline and projection condition at Kuli Watershed

11) Mangantai

In the baseline condition, the risk level of Mangantai Watershed is Very Low with an area of 0.630 km^2 and covers forest areas as shown in Figure 6.12, left side.

In the projection condition, about 0.258 km^2 of risk area becomes Moderate Risk Level and 0.418 km^2 becomes Very Low Risk level area. The Moderate Risk area will cover moderate density residential areas and industrial areas. In Figure 6.12 at the right side, map of risk in the projection condition is shown.

Table 6. 13 Risk Table of Mangantai Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.63	forest	0.418	green forest
Low Risk	-	-	-	-
Moderate Risk	-	-	0.258	residential (moderate)

Baseline Projection 2030

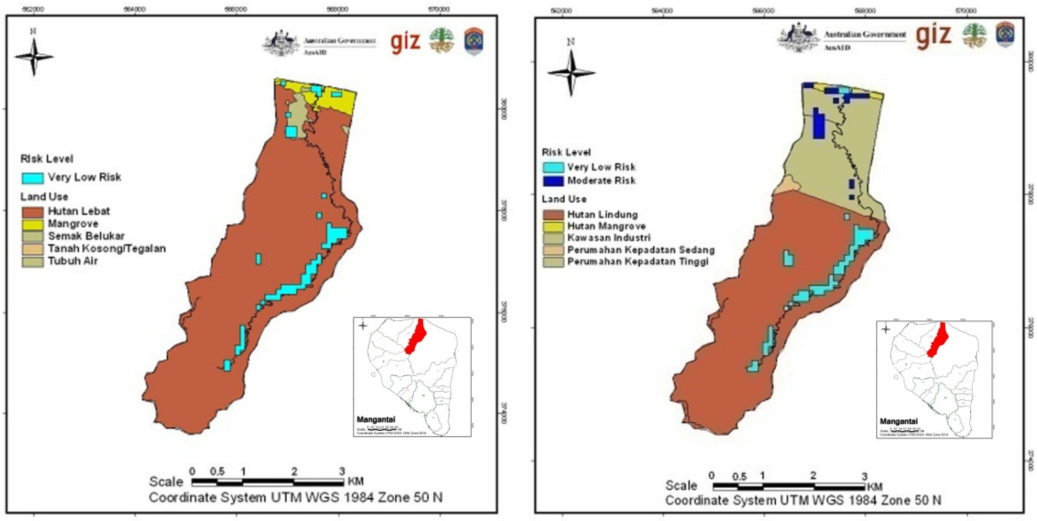


Figure 6.12 Map of Risk in baseline and projection condition at Mangantai Watershed

12) Maya

In the baseline condition, the risk level of Maya basin has a Very Low Risk of 0.458 km^2 that covers forest areas as shown in Figure 6.13, left side.

In the projection condition, the risk level of Maya basin has 3 levels. They are Very Low Risk, Low Risk, and Moderate Risk levels. The Very Low Risk level is the largest area of risk. The Moderate Risk area covers moderate density residential areas as shown in Figure 6.13.

Table 6. 14 Risk Table of Maya Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low Risk	0.458	forest	0.418	green forest
Low Risk	-	-	0.016	tourism area
Moderate Risk	-	-	0.111	residential (moderate)

Baseline Projection 2030

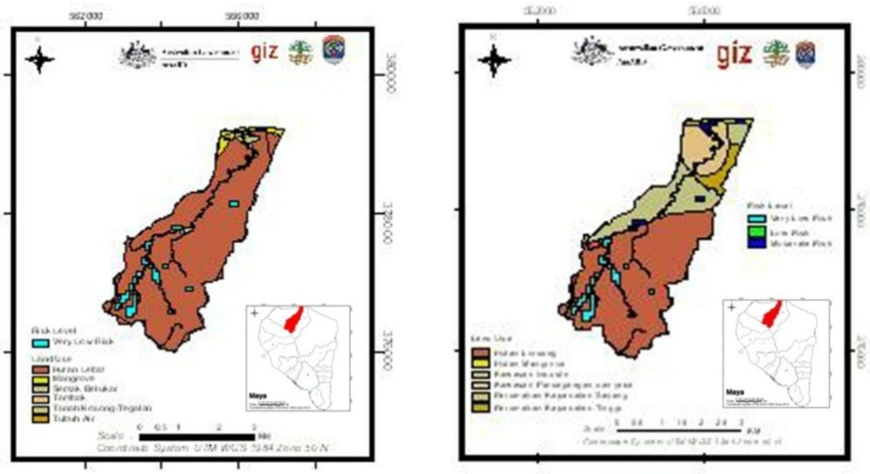


Figure 6.13 Map of Risk in baseline and projection condition at Maya Watershed

6.1.3 Landslide Risk

Risk is function of hazard and vulnerability (Affeltranger,et.al, 2006). Risk level was resulted from overlay between hazard map and vulnerability map. Risk level classified in 4 levels. There are very low risk, low risk, moderate risk, and high risk.

Landslide risk obtain from multiply Geographical Information System (GIS) process of landslide hazard and landslide vulnerability. Hazard map deal with a landslide trigger factor, they are historical landslide existing and ground water table recharge analysis map as climatic drive for projection condition, to predict climate change, while vulnerability deal with susceptibility of landslide, likes landuse area with high population, settlement, building and others as list in vulnerability chapter.

Table 1 and 2 below show probability of landslide that determined by safety factor. it decrease when ground water table increases and soil strength properties decreases and vice versa. Slope stability that showed by safety factor of each location is determined the level of risk, it was divided into 4 level based on the safety factor. The safety factor level of it class are ranged using statistical method, probability of landslide is obtained for projection condition 2011-2020 and 2021-2030, showed in table 1 and 2.

Table 6. 15 Landslide probability for projection condition 2011-2020

Code	Coordinate		GWT Recharge (m)	classification
	X	Y		
R21	561122	373218	4840	high risk

R15	562346	369854	3562	
R20	560270	378637	3510	
R16	561645	377558	3493	
R13	573029	368373	3468	
R14	563987	369439	3416	
R11	568135	365576	2479	risk
R12	568469	361480	2471	
R19	564263	366265	2468	
R17	571966	363894	2467	
R18	568593	364710	82	low risk

Table 6. 16 Landslide probability for projection condition 2021-2030

Code	Coordinate		GWT Recharge (m)	classification
	X	Y		
R21	561122	373218	3229	high risk
R15	562346	369854	2395	risk
R20	560270	378637	2354	
R16	561645	377558	2340	
R13	573029	368373	2320	
R14	563987	369439	2278	
R11	568135	365576	1652	moderate
R12	568469	361480	1645	
R18	568593	364710	1643	
R17	571966	363894	1642	
R19	564263	366265	77	low risk

The area of probability determine the level of map, then the map in figure 1 overlayed into land use map as shown in figure 2, the flat area and high population of vegetation covered let the level to lowest one, due to the risk then projection condition for 2011-2020 and 2021-2030 are obtained.

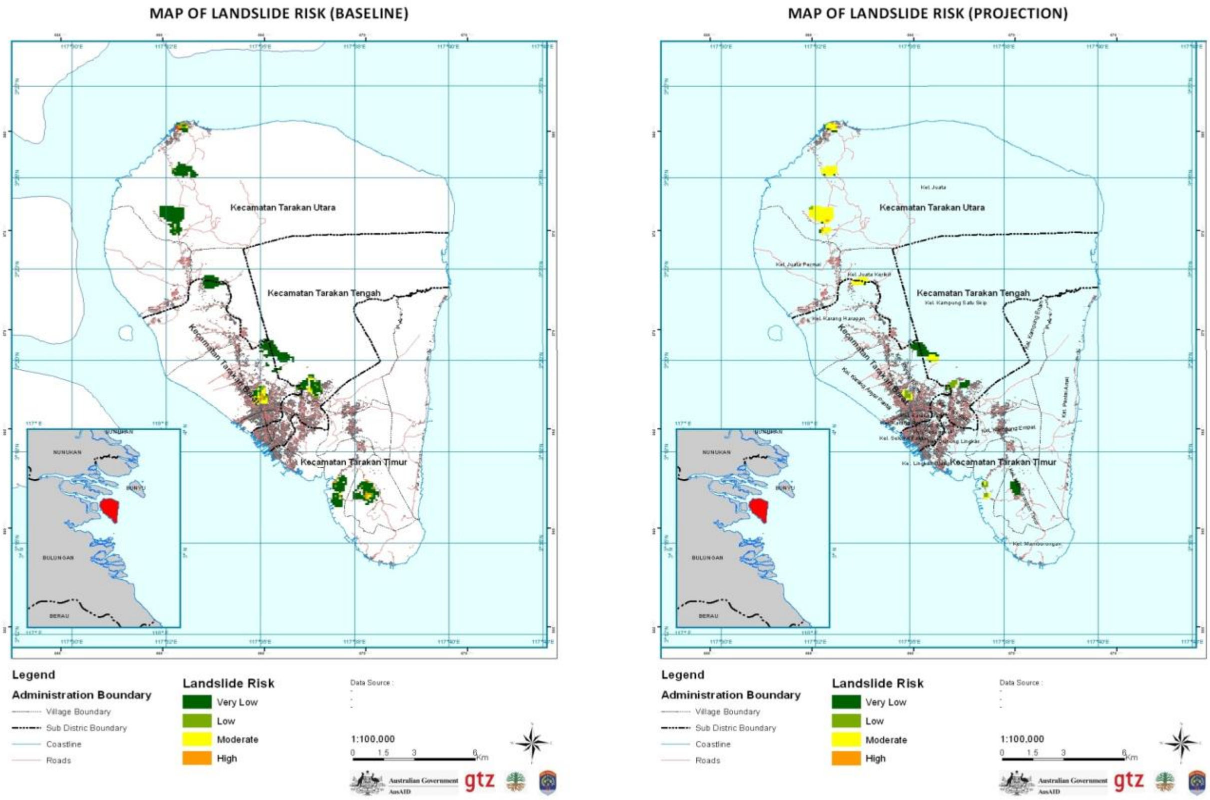


Figure 6. 14 Landslide risk for baseline and projection condition, left : baseline condition and right : projection condition

Figure 1 a left one, show risk map for baseline condition baseline, while a right one show risk map for projection condition. Both of the map, show changes between two maps, most of risk level are increasing from baseline condition to projection condition. As seen in figure most of risk level in North Tarakan sub-district are increasing from very low to moderate risk level, due to vulnerability are changes, the activity of population there are increasing. While, risk of East Tarakan sub-district looks different, the area are decreasing from baseline to projection condition, but the level of risk are increasing from very low to moderate level of risk, due to vulnerability are changes, the activity are spotted at few area and another area are non-population area that covered with vegetation. Meanwhile, West and Middle Tarakan risk level changes but not significant, as shown in table 3.

Table 6. 17 Risk level

District	Level of risk	
	Baseline	Projection
Tarakan Utara	very low	moderate
Tarakan Tengah	very low	very low
	Moderate	high
Tarakan Barat	Moderate	high
Tarakan Timur	very low	low
	Moderate	moderate

Figure 2 below are landslide map that overlayed to landuse map of baseline (2011) and projection (2030) condition. Map of landslide risk identified to what region is it, by overlaying landslide risk map to landuse map. The area of landslide risk divided into two main area, with different types of area, for settlement and non settlement area.

In Baseline condition, Tarakan Utara district has almost in very low level of risk, and the area covered by mangrove, bushes, farming, dryland farming, and field. Tarakan tengah has very low to moderate level of risk, and the area covered by forest, bushes, farming, and field. Tarakan Barat district dominated by moderate level of risk, and the area covered by field, bushes, farming, and some of them are located on building area. While tarakan Timur has very low level and some are moderate level of risk, the area is covered by forest, bushes, farming, field, and some are occured in building area .

VII. ADAPTATION STRATEGY ON WATER SECTOR

7.1 Context for adaptation

Adaptation in facing changes affecting water supplies is supposedly a part of water management. In this adaptation, climate change supposes to be one of the basic considerations in managing water, as in developing water supply infrastructures, etc.

As stated in the AR4, Integrated Water Resources Management (IWRM) should be an instrument to explore adaptation measures to climate change. The indicators of the IWMR as stated in the AR4 are: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems, consideration of climate change, and omitting the impediments to the flow of information.

To implement the IWRM in Tarakan as well as in many regions in Indonesia there are still many constraints. The constraints are unavailability of data, uninvolvement of local government, and the partial authority of central government. For example, the duty and authority of Public Works are still not included to the maintenance of water sources and water infiltration zones. IWRM steps are different in each region because of different natural characteristics and social cultures.

Table 7.1 consists of several IWRM indicators from AR4 (column 1); a qualitative assessment on the implementation status (column 2), and possibility of future development (column 3) in Tarakan City; including the reasons obtained during this study as a part of water sector adaptation strategies in Tarakan City (column 4).

Table 7. 1 IWRM indicators from AR4, current implementation status and future development possibilities in Tarakan

IWRM's indicator as in the AR4	Implementation in Tarakan	Future Development Possibilities	Reasons of Future Development
Capturing society's views	2	3	• Moderate area of local government • Low population density
Reshaping planning processes	2	4	• Better planning • Human and financial resources
Coordinating land and water resources management	2	4	• Relatively small area • Ideal protected forests
Recognizing water	2	5	• Available early water

quantity and quality linkages			resources data • Possible short term comprehensive surveys
Conjunctive use of surface water and groundwater	2	5	• Better planning • Human and financial resources
Protecting and restoring natural systems	2	4	• Relatively small area • Own conservation forest and city forests • Local govt. seriousness in managing environment
Consideration of climate change	2	5	• Local govt. seriousness in managing environment • There are risk and adaptation study to climate change in micro scale
Omitting the impediments to the flow of information.	2	4	• Human and financial resources

Notes: 1 = very low; 2 = low; 3 = moderate; 4 = high; 5 = very high

7.2 Adaptation Options in Principle

Referring to AR4, in principal, water sector adaptation in facing impact or risk of climate change is divided into two parts, which are adaptation from the supply side and adaptation from the demand side. The two adaptations should be complementary. Several adaptation options from AR4 are shown in Table 7.2, while Table 7.3 shows several examples of technological adaptation for water supply from UNFCCC, 2006.

Table 7. 2 Some adaptation options for water supply and demand (*Source*: the AR4)

Supply-side	Demand-side
Prospecting and extraction of groundwater	Improvement of water-use efficiency by recycling water
Increasing storage capacity by building reservoirs and dams	Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted
Desalination of sea water	Reduction in water demand for irrigation by importing agricultural products, i.e., virtual water
Expansion of rain-water storage	Promotion of indigenous practices for sustainable water use
Removal of invasive non-native vegetation	Expanded use of water markets to reallocate

from riparian areas	water to highly valued uses
Water transfer	Expanded use of economic incentives including metering and pricing to encourage water conservation

Table 7. 3 Example of adaptation technologies for water supplies (*Source*: UNFCCC, 2006)

Use category		Supply side	Demand side
Municipal or domestic		• Increase reservoir capacity • Desalinate • Make inter-basin transfers	• Use “grey” water • Reduce leakage • Use non-water-based sanitation • Enforce water standards
Industrial cooling		• Use lower-grade water	• Increase efficiency and recycling
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Alter ship size & frequency of sailings
Pollution control		• Enhance treatment works	• Reduce effluent volumes
		• Reuse and reclaim materials	• Promote alternatives to chemicals
Flood management		• Build reservoirs and levees	• Improve flood warnings
		• Protect and restore wetlands	• Curb floodplain development
Agri-cultur	• Rain-fed	• Improve soil conservation	• Use drought-tolerant crops
	• Irrigated	• Change tilling practices	• Increase irrigation efficiency
		• Harvest rainwater	• Change irrigation water pricing

Adaptation options in the tables can be grouped into two types of adaptation, hard adaptation and soft adaptation. Hard adaptation is physical adaptation, such as building reservoirs and other physical structures to adapt. Soft adaptation is intangible adaptation such as development of regulations, early warning system for floods, capturing society’s views, etc. Some main adaptation principals from the AR4 (Table 7.2) or UNFCCC (Table

7.3) for Indonesia are impossible to do because Indonesia is still a developing country. The suggested adaptation is placed in the adaptation framework.

7.3 Adaptation Option in Practice

The results of this study identify a number of risk adaptations to climate change, as summarized in Table 7.4

Table 7. 4 Summary of recommended adaptation to climate change in water sector on Tarakan City

Adaptation option in Tarakan's water sector	Impacts or Risk as Adaptation Targets	Management side of IWMR#)	Adaptation Options	Status in the assessment
Increase reservoir capacity	Water shortage	Supply side	Hard adaptation	EPI
Develop new reservoir or *embung*	Water shortage	Supply side	Hard adaptation	P
Desalinate	Water shortage	Supply side	Hard adaptation	P
Make inter-basin transfers (PDAM network)	Water shortage	Supply side	Hard adaptation	EPI
Harvest rainwater	Water shortage	Supply side	Hard adaptation	EPI
Build sluice gate (especially for western region)	Flood	-	Hard adaptation	EPI
Build reservoirs and levees	Water shortage Flood	-	Hard adaptation	P
Regulation related to flood for eastern region	Flood	-	Soft adaptation	EPI
Soil improvement (if possible in accordance with RTRW)	Landslide	-	Hard adaptation	P
Resettlement (if not according to RTRW)	Landslide	-	Hard adaptation	P
Capturing bureaucrat's views	Water shortage Flood Landslide	Supply side	Soft adaptation	P*
Capturing society's views	Water shortage Flood Landslide	Supply side	Soft adaptation	P*
Reshaping planning processes	Water shortage Flood	Supply side	Soft adaptation	P*

	Landslide			
Coordinating land and water resources management	Water shortage Flood Landslide	Supply side	Soft adaptation	P**
Recognizing water quantity and quality linkages	Water shortage Flood Landslide	Supply side	Soft adaptation	P**
Conjunctive use of surface water and groundwater	Water shortage Flood	Supply side	Hard adaptation Soft adaptation	P**
Protecting and restoring natural systems	Water shortage Flood Landslide	Supply side		P**
Consideration of climate change	Water shortage Flood Landslide	Supply side		EPI
Omitting the impediments to the flow of information.	Water shortage Flood Landslide	Supply side		P**

Note:
\# : especially for water resources
EPI : Existing activity and proposed to be improved
P : Proposed activity
P* : Has been done in this study, but needs to be conducted again
P** : Suggested, but the explanation steps are not yet discussed in this study
The following are recommended adaptation divided according to its risk.

7.3.1 Adaptation for water shortage risk

The adaptation strategies are based on 6 different zones. These zones are classified based on, among others, the following factors: location, water resources type, both surface water and groundwater; the current condition of theirs development, existing landuse, and spatial plan 2030. Those 6 zones are (Figure 7.1):

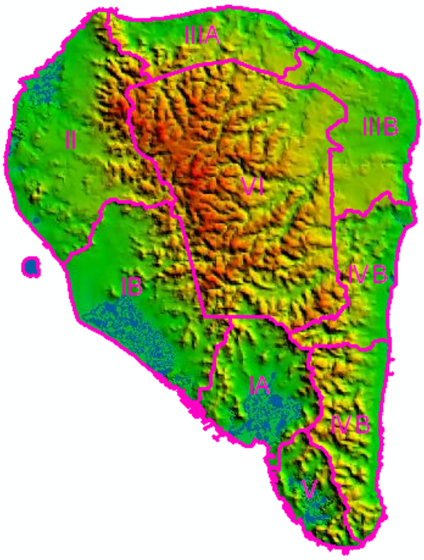


Figure 7. 1 Zoning for the adaptation strategy

1) Zone I

Zone I (central west side of Figure 7.1) is the current government centre of Tarakan. Today, the zone is depending on surface water (PDAM) and ground water. This zone consists of 7 river basins, and served by 3 water treatments plans (WTP's) of PDAM. This zone is divided into 2 zones, IA and IB, because the 2 zones have different ground water systems. Zone IA has an unconfined ground water system, while IB has a confined groundwater system.

2) Zone II

Zone II (northwest region in Figure 7.1) is planned to be the new government centre. Current water needs in this zone is still low, and can still be handled by WTP Juata Laut. Also, this zone is projected to be settlement areas, industries, and commercial. This zone consists of 11 river basins. Other than the high potential surface water, this zone also has a high potential ground water, especially confined groundwater.

Zone II has a clean water potential of 42.5 million m^3/year. This high potential surface water has been utilized 6.4 million m^3/year by the PDAM through three WTPs: Kampung Bugis, Persemaian, and Kampung Satu. The three WTPs actually have the production ability of 9.6 million m^3/year (meaning, currently only using 67.21% of its full capacity).

3) Zone III

This zone (north to northeast region in Figure 7.1) consists of 13 river basins, and located in the forests, but is planned to be developed into settlements and industries areas. This zone has high potential surface water, marked by the large river basin. But based on ground water studies, western Zone III is an unconfined aquifer and this aquifer is a recharge zone for confined aquifers in the western Zone III. Thus, it is suggested to develop this zone more to utilize its surface water, while the groundwater can be conserved.

The northern Zone III has low potential surface water. This is why Zone III needs to be divided into two, IIIA and IIIB. Zone IIIA, utilizes more confined groundwater in Juata Laut and a part of it must be supplied to Zone IIIB. Meanwhile, Zone IIIB utilizes surface water.

4) Zone IV

Zone IV is located in the eastern Tarakan City. This zone has been developed to be settlements and tourism areas. The water supply of this zone come from unconfined groundwater, springs, and rain water. In the 2030 RTRW, this zone will be developed as settlements, tourism, and education areas. Thus, its water needs won't be too high.

But the problem is this zone is only passed by one potential river basin, Binalatung. Hence this zone is divided into IVA and IVB. Zone IVA is the zone which can be served by Binalatung river basin, while Zone IVB utilizes rain harvesting and unconfined aquifers.

5) Zone V

Zone V is located in the southern Tarakan Island. This region is currently quite isolated and has limited surface water potential. But based on surveys, this zone has a high potential groundwater. Of course, this information needs further detailed studies, because in this study, we could not obtain enough detailed data. In the projection, this zone will be developed as military and industrial areas.

6) Zone VI

Zone VI is a conservation zone. It is in the area of protected forests. Based on its geological interpretation, this zone is a recharge area for confined aquifers in the western Tarakan.

7.3.1.2 Basic information and adaptation option for each zone

The basic information as a background for adaptation option and adaptation option itself for each zone are presented belows:

(1) Zone I

Zone I has the highest water needs, reaching 10.9 million m^3/year (350 lt/second) in 2010 and 27.3 million m^3/year (870 lt/second) in 2030. Currently, the water needs of Zone I is supplied from the PDAM with a maximum capacity of 10 million m^3/year (305 lt/second). This PDAM's maximum capacity is of course depending on its WTP's capacity (WTP =

water treatment plant). This study does not discuss the ability of PDAM to supply clean water, but focused on the nature's ability to supply water. Thus, this study is more concerned on rivers potential as standard water sources for each WTP.

The following (Table 7.5) is the potential standard water sources for three WTPs which supplied clean water to Zone I based on the calculation results of PDAM in 2007.

Table 7. 5 Capacity of WTP in Zone 1, 2007

WTP (Water Treatment Plant)	Calculation of PDAM (2007)		
	Discharge max	Discharge Min	Discharge average
-IPA Kmp.Bugis	0.1	0.05	0.075
-IPA Persemaian	0.21	0.09	0.15
-IPA Kmp.Satu	0.24	0.06	0.15

Source: recalculation from PDAM's data, 2007

But the information accompanying the discharge information which explains the climate condition is very minimum, thus, river potential is calculated based on the results of this study. Based on the calculation results (simulation) in this study, the average discharge of rivers in the three WTPs are presented in Table 2.6.

Table 7. 6 Comparison of WTP's capacity or WTP's discharge in Zone 1 between observed and simulation results in the study B

WTP	Observed Discharge	Simulated Discharge (m^3/second)		
		Baseline	Current	Projection
-IPA Kmp.Bugis	0.4174	0.4186	0.3853	0.3696
-IPA Persemaian	0.2032	0.2038	0.1876	0.1800
-IPA Kmp.Satu	0.2518	0.2525	0.2325	0.2230
	0.8725	0.8749	0.8054	0.7726
	0.4362	0.4375	0.4027	0.3863

If it is assumed that the river water is utilized 50% at maximum, then the baseline condition is still relatively safe (0.35 m^3/second < 0.4375 m^3/second). On the baseline condition, the problem is the clean water infrastructures, such as PDAM's network. But on the projection condition (2030), the water needs of this zone increases to 250%. A very large discharge then is needed. A bigger problem is that the average river discharge in the projection period decreases 12%. Meanwhile, in the extreme condition, the decrease can be even bigger.

Water demand of 1,574 million m^3/year (0.0499 m^3/second) cannot be fulfilled by surface water. Another alternative to overcome future clean water problems is by utilizing groundwater. The utilization of groundwater can bring negative impacts if not well planned. In the unconfined aquifers, recharge process is faster so damages can be healed faster.

Generally, unconfined aquifers (popular term: “shallow groundwater”) are utilized by people. But utilization of groundwater from unconfined aquifer in large and constant number can cause constant land subsidence. Furthermore, it could cause inability to utilize unconfined groundwater. Thus, utilization is better to do to confined groundwater.

In relation, groundwater utilization to overcome the possibility of water crisis in Zone I will be related more to confined aquifers. Based on the interpretation of geology and geoelectric data, not all of Zone I have confined groundwater. This is why Zone I is divided into IA and IB. **Zone IA relies more to clean water supplies from PDAM, while Zone IB relies more to groundwater resources.**

Based on the calculation of water needs, Zone IA has a relatively constant water demand of 4,397,235 m^3/year (0.14 m^3/second) in the baseline condition and 6,552,654 m^3/year (0.21 m^3/second) in the projection condition. The data still shows that Zone IA can still be supplied by PDAM of Tarakan City through its three WTPs. Meanwhile, Zone IB experiences a large increase of water needs to 303% (from 6,788,195 m^3/year in the baseline condition to 20,566,862 m^3/year in 2030). **The water needs of Zone IB is partly fulfilled by the PDAM and the rest is supplied by utilizing groundwater.**

Confined aquifers in Zone IB have an average thickness of 85.6 m (min 9.6 m, maximum 157.3 m) and average aquifer depth of 96.8 m (maximum 190 m) from the ground surface.

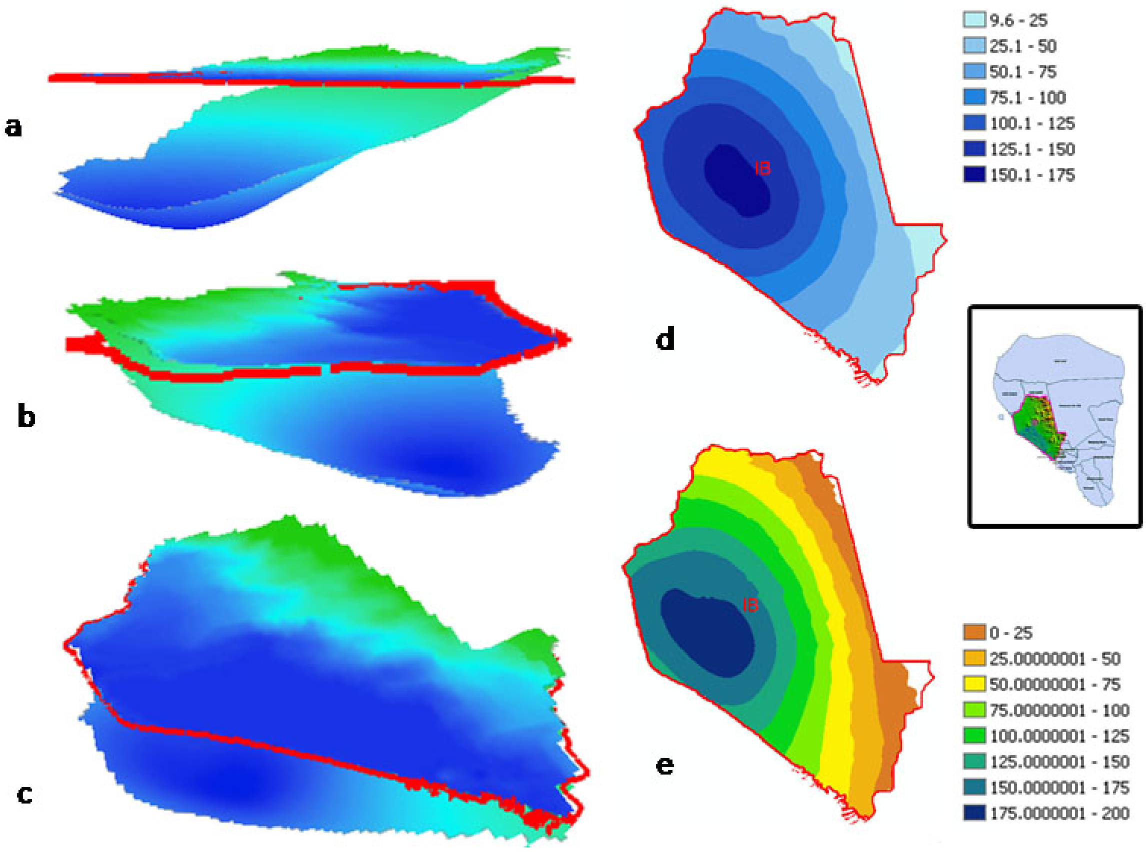


Figure 7. 2 Confined aquifer are beneath conglomerate layer, 3D visualization (a, b, c), aquifer thickness in meter (d), and aquifer depth in meter below ground surface (e)

Groundwater exploitation is suggested to be under government control, to simplify monitoring and control. It is due to the difficulty of controlling the number of wells and water taken if it is up to the society (in this case, industry). In Zone I there is also one reservoir with a capacity of 200,000 m^3.

The existence of this reservoir is very helpful to help overcome the decreasing water supply due to climate variability. Based on the climate study of climate scientific basic team, in the baseline condition, there is a large rainfall decrease in the year. But this condition is not well simulated. So, we conducted regressions to obtain the estimation of extreme condition.

In Zone I, there is a reservoir with a capacity of 200,000 m^3. This reservoir is useful for mitigating the decrease of water availability due to climate variability. Based on the results of climate study by the climate scientific basic team, in the baseline condition, there was a high decline of precipitation in 1963 - 1970. But this condition is not well simulated.

The next period is similar between observation and climate simulation (Figure 7.3). We can obtain the deviation between the two data for 1970 to 2009. Based on the error calculation (using root mean square), the possible error value is +543 mm/year. Meaning, the decrease in the next years can be lower than 543 mm/year.

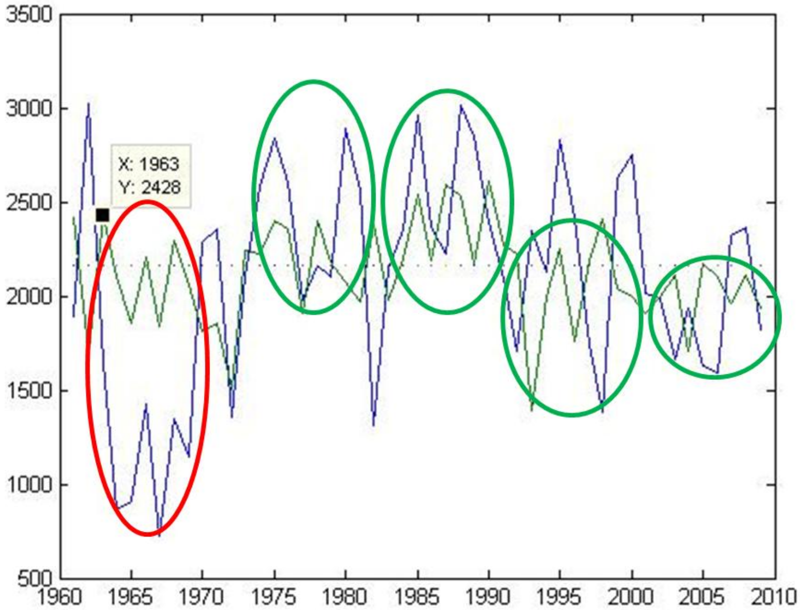


Figure 7. 3 Curve of TRO (mm/year vs time (year) shown from 1960-2010 that contain simulation (green) and observation (blue). By neglecting the unsimilarities between data simulation and observation in 1960-1970 period, further simulation recommend a number of -543 mm/year as error value from the TRO.

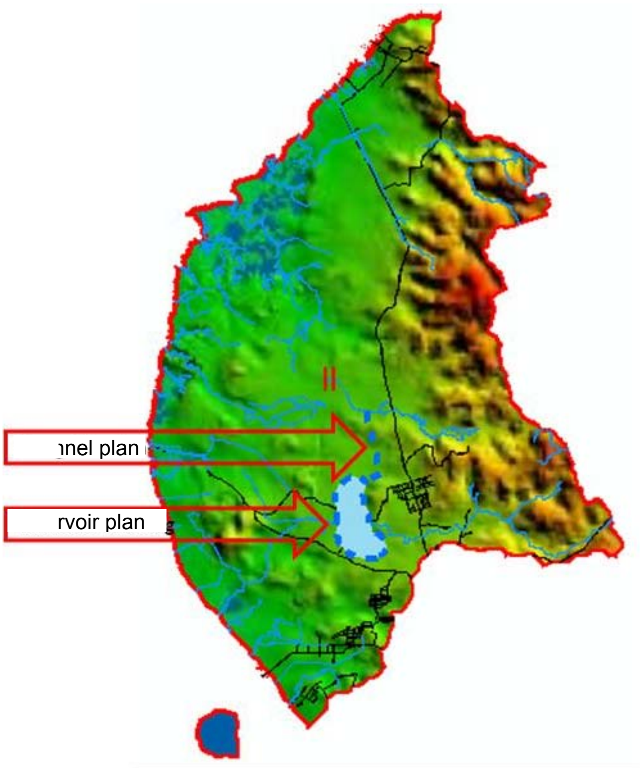
Meanwhile, based on the calculation of possible extreme condition, in the projection period, the water supplies will drop below average during 2024 – 2028.

(2) Zone II

This zone consists of 9 watersheds. Two of them have a large water potential, Semunti with a discharge of 24,724 million m^3/year and Bengawan with 29,478 million m^3/year. Unfortunately, these large potential are not yet utilized.

On the other hand, this zone is planned to be the centre of government office for the non established north Kalimantan province, other than settlements and industrial areas. Hence, they will increase the water demands to 19 times of current demands, yet is from 1,132 million m^3/year (0.0359 m^3/second or 35.9 litres/secpnd) become 21,599 million m^3/year (0.68 m^3/second or 680 litres/second). Currently, the water demands of Zone II is supplied by Juata Laut WTP with a discharge of 30 litres/second and the rest demands (arround 5 litres /second) is supplied through wells and springs. Large water demand in the projection condition (680 litres/second) must be considered. For this purpose, **one of the alternatives is to build another WTP in the watershed Semunti and Bengawan.**

Based on the highh variability of climate in the projection condition, the development of the two WTPs in the region needs to be accompanied by the **development of a reservoir and a channel as resource for its water supply.** The channel is an infrastructure for supplying water source from the adjacent river (Bengawan River) to the reservoir. These reservoirs and the channel also can be useful for preventing floods. The location recommended for the reservoirs is in the Figure 7.4 below.



Note:

- Reservoir plan is location for the two reservoirs proposed as the hard adaptation for the projection period
- Channel plan is location for proposed channel as infrastructured for suppying water from river to the reservoirs.

Figure 7. 4 Recommended location of reservoirs and channel as hard adaptation to water shortage risk in projection period for Zone II

The total water demand in the projection period in Zone II is 0.60 m^3/second or 18,932 million m^3/year. The development of WTPs and reservoir in Zone II as proposed above can overcome only 88% of the total water demands. **To completely fulfill the water demands in Zone II, a second alternative is needed, that is by utilizing groundwater**. This zone contains unconfined aquifers and confined aquifers where theirs depth range from 1 m to 200 m below local ground surface and their thickness range from 0 to 100 meters (Figure 7.5). Unconfined aquifers here are dominated by sand and a part of it are covered by alluvium layers, making it confined. As in Zone I, the confined aquifers are located in the clay sand layer beneath the conglomerate layer. The aquifers we can utilize are the confined aquifers layers. These aquifers are located at a depth started from around 130 m below the ground surface.

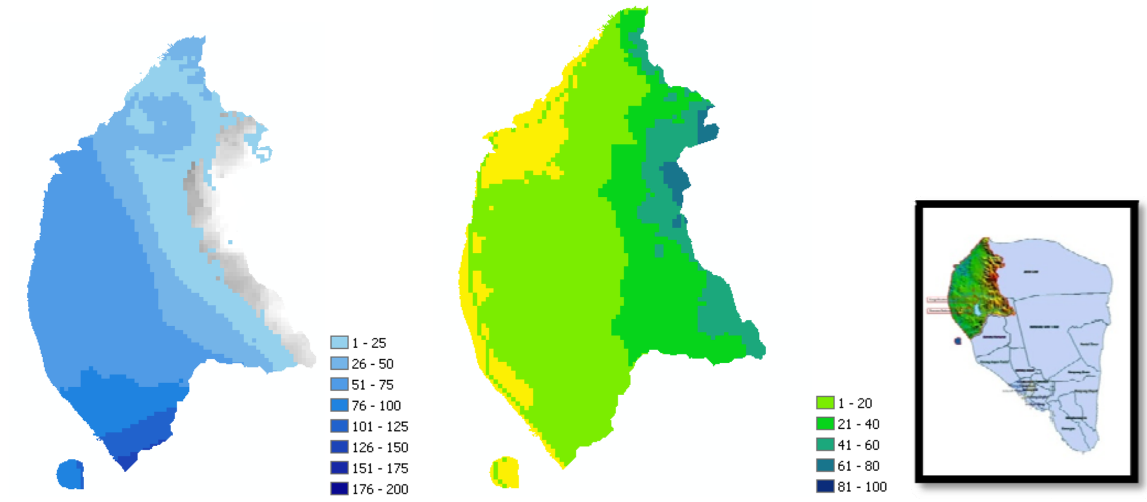


Figure 7. 5 Aquifers (groundwater) potency in Zone II to be developed as second alternative to fulfill water demand in projection period : depth of aquifers in meter (*left*) and aquifer thickness in meters (*center*), and location index (*right*). The yellow color is not confined uquifer.

(3) Zone III

Zone III (Figure 7.5) is located in Juata Laut and Kampung Satu Skip villages. The main watersheds in this zone are Maya watershed with Maya River as its main river and Mangantai watershed with Mangantai River as its main river. This region is not yet developed, but is planned to be settlements, industrial, and trading areas in projection period

Due to this planning, the water demand will increase from 0.127 m3/second (4.005 million m3/year) year to 0.788 m3/second or 24.840 million m^3/year. Today, a large part of the demand are from domestic need which supplied by wells and springs.

The large part of increasing demand in the projection is due to the planned industrial areas. This zone is on top of unconfined aquifers which is a part of the confined aquifer in the western Tarakan Island. **Thus, a wise decision of overcoming this future water supplies is to utilize surface water.** This zone has a large potential of surface water as seen from its four watersheds: Maya, Mangantai, A and B (Figure 7.6).

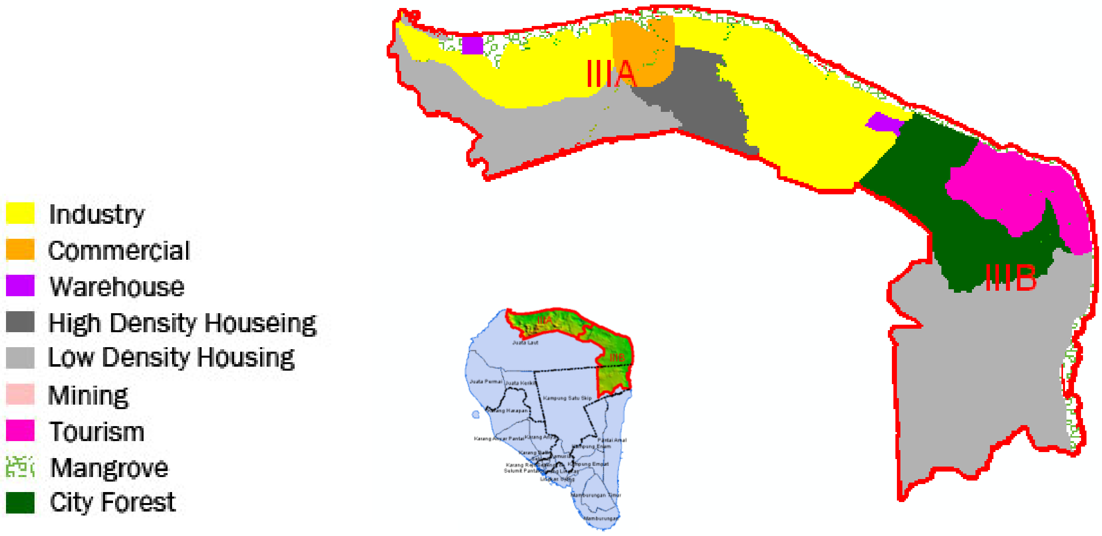


Figure 7. 6 Zone III that divides into 2 subzones, IIIA and IIIB and their land-use in the 2030 master plan (*right, upper*) and its location index (*left, below*)

Zone III can be divided into two subzones of IIIA and IIIB based on its spatial planning. Zone IIIA is dominated by industries, service trades, and settlements, while Zone IIIB is dominated by settlements and tourism areas. This is why Zone IIIA needs more water than IIIB (more than two times or 2.21 : 1).

But the surface water potential of IIIA is smaller than IIIB (1: 1.63). Zone IIIA is recommended to utilize surface water from Maya River and Mangantai River which have the potential of 0.69 m^3/second (21,826 million m^3/year) or 128% from the total water demand of Zone IIIB (Figure 7.6). But the problem lies on the users of Zone IIIA where largely users are industry, trade and services. Therefore, a further discussion whit local authority on water development is needed upon the development of reservoirs and WTPs in Zone IIIA.

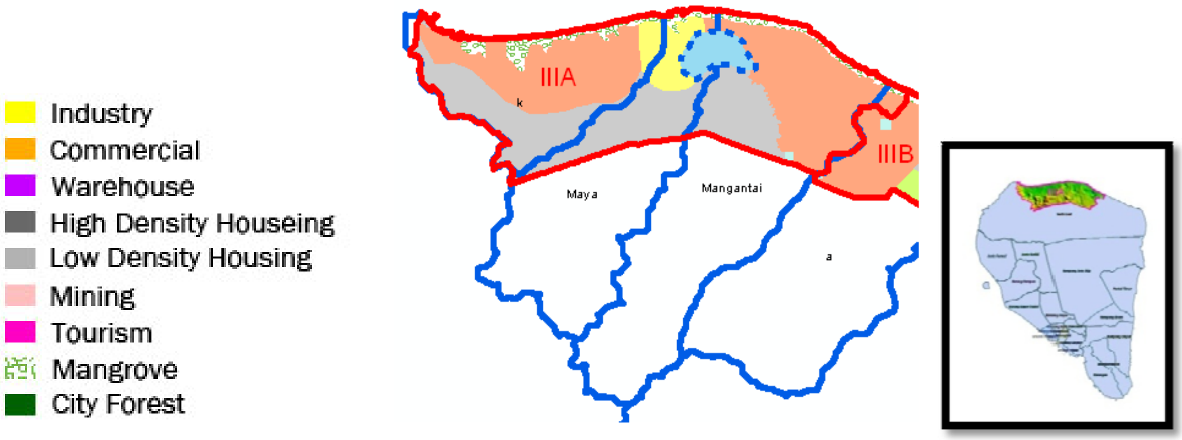


Figure 7. 7 Zone IIIA and the propossed *embung* or reservoar location (*blue with dashes border, center*) in lower Mangantai river for adaptation to water shortage risk in 2030

Meanwhile, Zone IIIB (Figure 7.7) has a relatively small water needs than Zone IIIB, but has a great potential of water from watersheds A and B. Because the water needs of Zone IIIB is relatively small, only 7,742 million m^3/year then the developed WTP only needed in watershed B. This watershed has a great potential reaching 0.6832 m^3/second (21,546 million m^3/year).

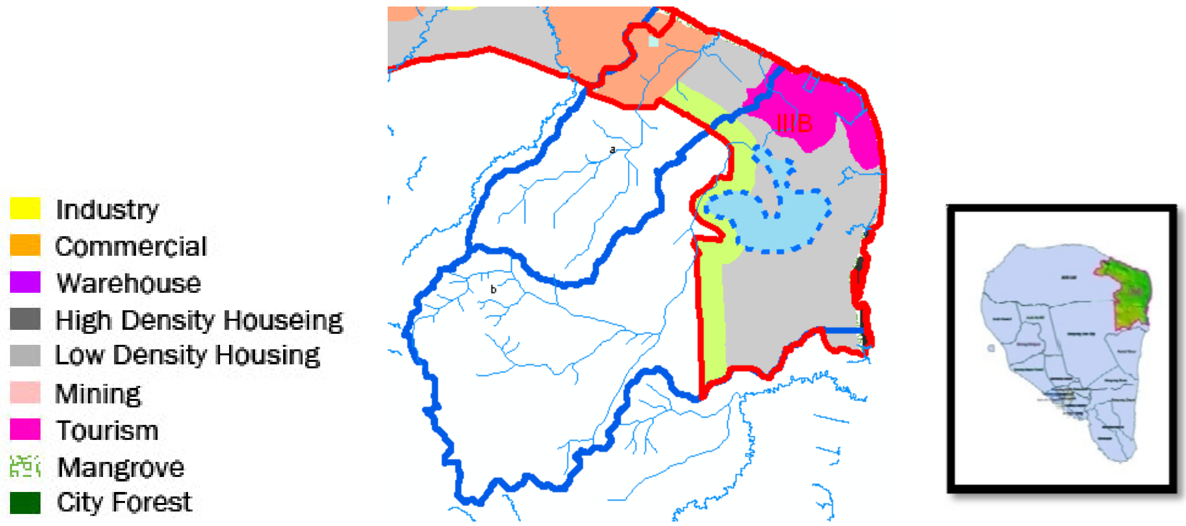


Figure 7. 8 Zone IIIB and the propossed *embung* or reservoar location (blue with dashes border) for adaptation to water shortage risk in 2030

(4) Zone IV

Zone IV is located on the eastern coastal of Tarakan (Figure 7.8). Part of Zone IV is planned to be settlements, tourism areas, and educational areas. A major part of Zone IV is passed by small watersheds and one large potential watershed, Binalatung. Currently, Binalatung watershed is utilized as the source of standard water for WTP Kampung Satu Skip which is projected to be utilized optimally as much as 0.126 m^3/second. The optimal discharge calculation in the settlement in the upstream of Binalatung shows 0.5338 m^3/second (16,835 m^3/year). This number is very large compared to the projected water needs of 8,086 m^3/year.

The problem is that Binalatung River is located in the northern edge of Zone IV, meanwhile, the region of Zona IV is stretching from north to south as long as 14 km. This long distance won't be optimal in developing clean water infrastructures. This is why Zone IV is divided into two, IVA and IVB. **Zone IVA is served by WTP Binalatung**, **while to fulfill the water needs of Zone IVB there are other alternatives such as shallow groundwater, desalination, and rain harvesting**.

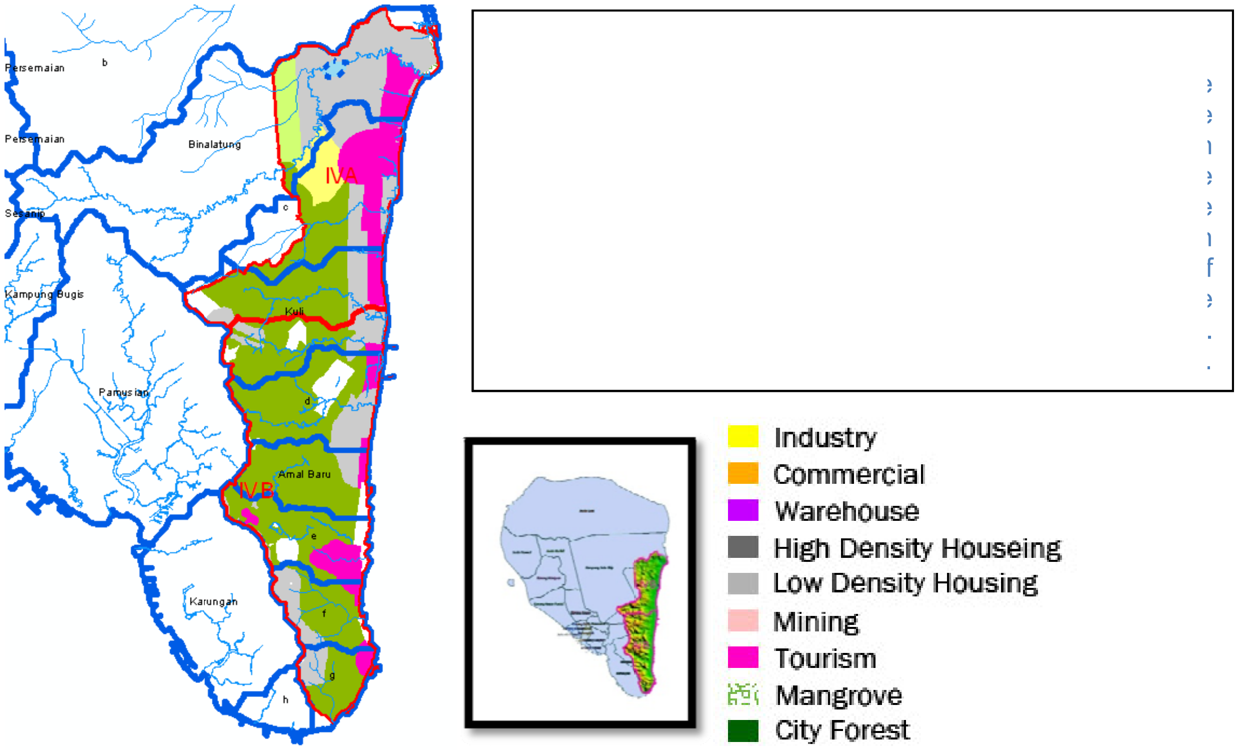


Figure 7. 9 Zone IV in adaptation option or strategy, show land-use planned for settlements, educations, and tourism.

The desalination perhaps is the last alternatives for adaptation to water shortage risk in projection period. Meanwhile, the development gorundawater and rain harvesting for the adaptation are proposed to be developed fisrt. Groundwater potency in Zone IVB need further study. Meanwhile, the rain harvesting has been done by peoples, but to optimize the service and quality of clean water, government role is needed.

The designs of rain harvesting infrastructures by the government in Zone IVB are developed to overcome water needs problems to help develop eastern regions as tourism and educational areas. For that reason, the proposed infrastructure of rain harvesting as sources of water supply can be designed as educational objects and the same time also as tourism objects. For instance, it is can be designed as education and tourism objects of climate change adaptation in Tarakan Island.

(5) Zone V

Zone V is located in the southern Tarakan City. The water demand of this zone is only 0,234 million m^3/year and a large part of it is utilized by the fish processing factories. People in this zone has been utilizing groundwater as its clean water source and other also utilizes springs. But the minimum data on this location, especially the groundwater data, has made this zone difficult to calculate its groundwater potential.

Based on surveys, this zone has a good potential and quality of groundwater. Two deep wells of groundwater in the survey shows an aquifer with a depth of 25 – 30 m beneath the ground surface with a water table of 0 m from the ground surface (flowing). Picture in Figure 7.9 is one of those wells with pumping facility for groundwater withdrawal in Zone V.

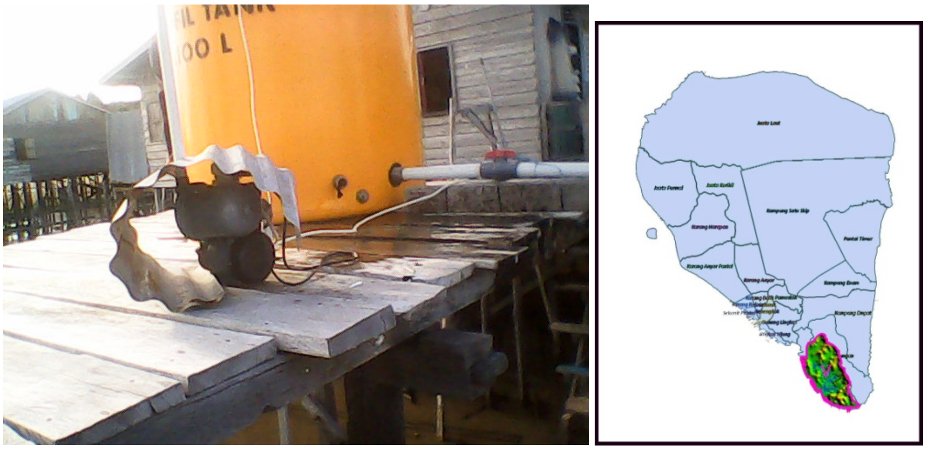


Figure 7. 10 One of deep wells own by peoples with a depth of 26 m in Zone V (*left*) and location index of Zone V(*right*)

To fulfill this water needs of 6.87 million m^3/year in the projection condition, hopefully, the utilization of groundwater potential will be enough. However, groundwater potency and its usage in this zone is needed a further study. As alternatives, sea water desalination and rain harvesting are also plausible.

(6) Zone VI

Zone VI is conservation zone for water resources in Tarakan City. In this zone, not any water resources are recommended to use. Moreover, Zone VI is strongly recommended as conservation zone for water surface as well as groundwater recharge.

Figure 7. 11 Index location for Zone VI.

7.3.2 Adaptation for flood risk

Adaptation options to climate change are divided into 3 levels (Klein, et.al., 1997). There are strategy level, population level, and individual level. In the Tarakan Island, adaptation options of this assessment tend to use strategy adaptations that focused to development and rule implementation for changing population and individual attitudes to climate change. Adaptation options for risk flood in this Tarakan Island assessment are divided into 3 areas (Figure 7.10). The areas has been classified based on existing land use, land use change planning in 2030 (RTRW 2030), and inundation area of flood hazard model.

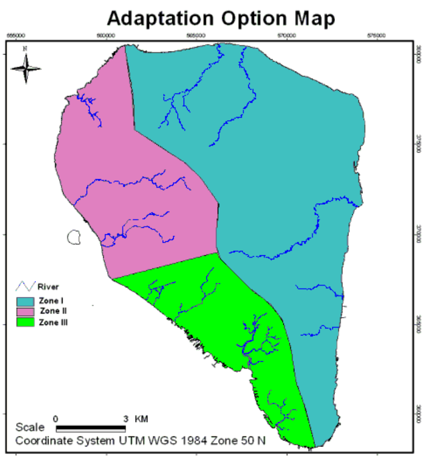


Figure 7. 12 The three areas of adaptation option for flood risks

1) Zone I

Zone I location extends from the northeastern to the southeastern of Tarakan Island. This area covers 5 major watersheds. There are Maya, Mangantai, Binalatung, Kuli, and Amal Baru. In the existing land use, this area covers most of forests, shrubs, croplands, and agriculture lands. Meanwhile, in the 2030 RTRW, most of this area will be designated as protected forests and forest city.

Land Use (2008)	Land Use RTRW 2030

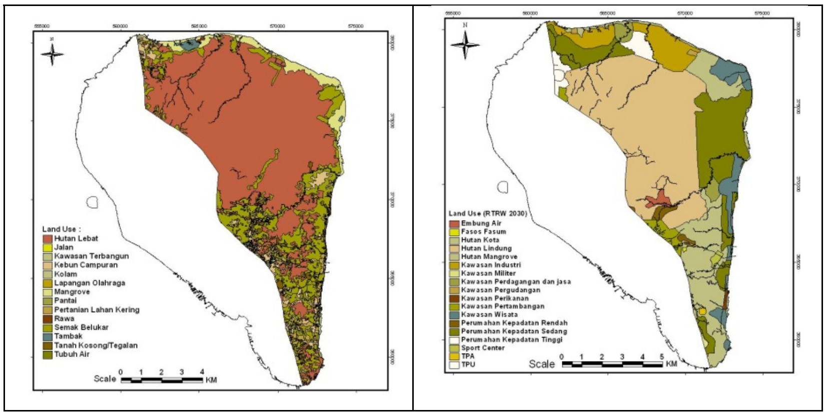


Figure 7. 13 Land Use type of Zone I

Beside land use, adaptation option is determined by the type of inundation area of flood hazard and where the inundation located. The total inundation area in the Baseline model is 3.3356 km^2. It will increase to 4.8354 km^2 in the year 2030. This area has 4 levels of risk. They are Very Low Risk, Low Risk, Moderate Risk, and High Risk.

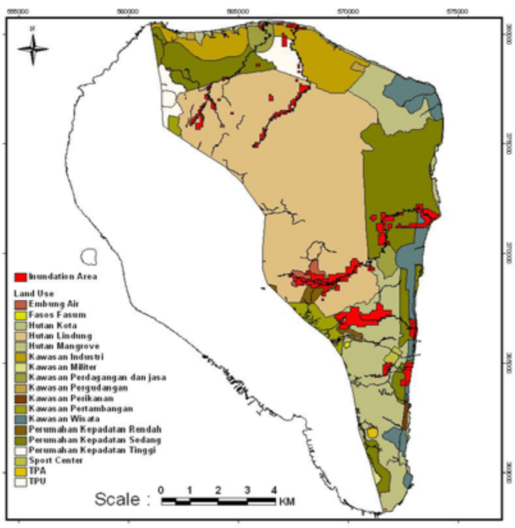


Figure 7. 14 Inundation Area to Land Use Type of Zone I

Based on the situation, the adaptation options for this area divided into 2 strategies: integrated water resources management (IWRM) and restoring the river function such as delimitation border of rivers due to the regulation of Tarakan City No. 27 of the year 2001.

The Integrated Water Resources Management (IWRM) should be an instrument to explore adaptation measures to climate change, but so far is in its infancy. Successful integrated water management strategies include, among others: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural system, and including consideration of climate change. In addition, integrated strategies explicitly address impediments to the flow of information. A fully integrated approach is not always needed but, rather, the appropriate scale for integration will depend on the extent to which it facilities effective action in response to specific needs. In particular, an integrated approach to water management could help to resolve conflicts among competing water users. IWRM clearly impacts on many other policy areas (e.g., energy projections, nature conservation). Hence there is an opportunity to align adaptation measures across different sectors. There is also a need to identify what additional tools are required to facilitate the appraisal of adaptation options across multiple water-dependent sectors (IPCC AR4).

The Restoring of the river function, such as delimitation border of rivers due to The Regulation of Tarakan City Government No. 27 of the year 2001. It states that the determination of the border river in rural river that has embankments will be adjusted for necessity of the district due to the master plan of the area. Meanwhile for the rural river which no embankments, the border river will be set to 25 m until 50 m from the riverside if there are no roads or infrastructure buildings. But if there are roads or infrastructure buildings, the border river will be set into 25 m until 60 m from the riverside.

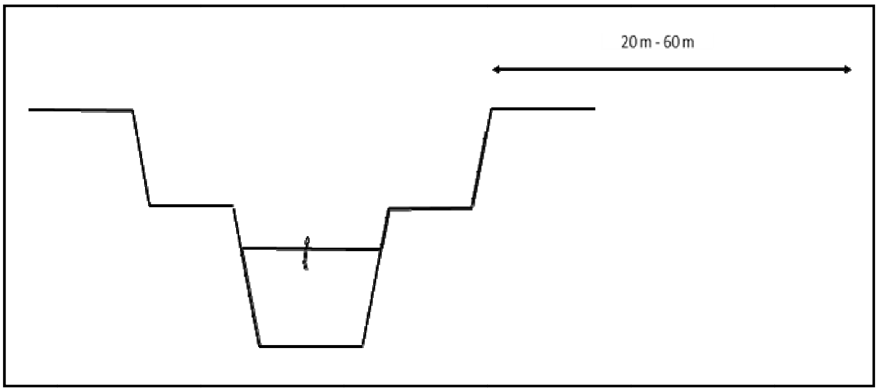


Figure 7. 15 Border River

Table 7. 7 Adaption Option in Each Watershed for Baseline and Projected in Zone I

Land Use Type		Watershed	Hazard Level	Vulnerability Level	Risk Level	Adaptation Option
Baseline	Projection					

• Forest • Road • Residential • Cropland • Pond • Mangrove • Beach • Agriculture land • Swamp • Stream	• City Forest • Protected Forest • Public Infrastructure • Pond • Mangrove • Industrial area • Military Area • Commercial and Service Area • Warehouse Area • Fisheries Area • Mining Area • Tourism Area • Low Density Residential Area • Moderate Density Residential Area • High Density Residential Area • Landfill • Sport Center • Cemetary	• Maya • Mangantai • Binalatung • Kuli • Amal Baru	• No Inundation • Inundation Area	• Low • Moderate • High	• Very Low Risk • Low Risk • Moderate Risk • High Risk	• Integrated Water Resources Management (IWRM) • The Restoring of the river function

2) Zone II

Zone II covers 3 major watersheds. They are Semunti, Bengawan, and Persemaian. Based on the 2030 RTRW, this area will be the new downtown of Tarakan City where the government central of Tarakan city, new commercial area, and new residential area will be built. In the existing land use, this area covers most of shrubs, agriculture lands, croplands, and forests.

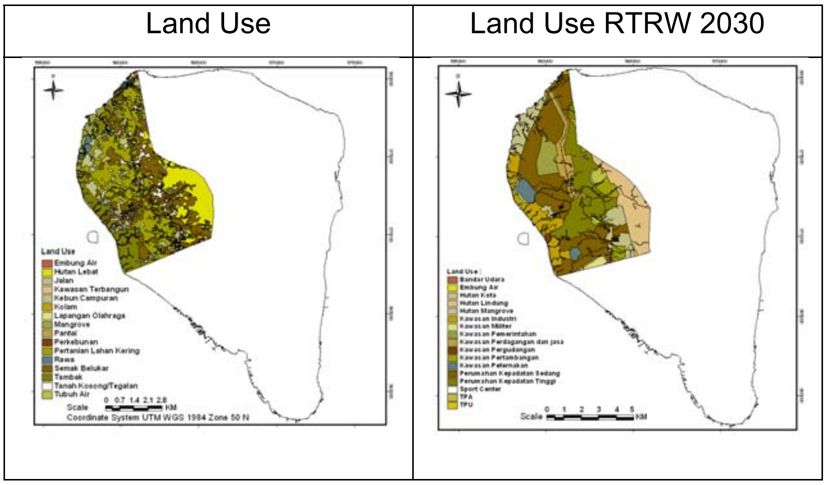


Figure 7. 16 Land Us eType of Zone II

In the Baseline model, the total inundation in this area is 2.3576 km^2 and 5.508 km^2 for the 2030 projection model.. The levels of risk in this area are very Low risk level to high risk level. The risk area consists of 2.838 km^2 of Very Low Risk, 0.203 km^2 of Low Risk, 4.409 km^2 of Moderate Risk, and 0.188 km^2 of Very High Risk.

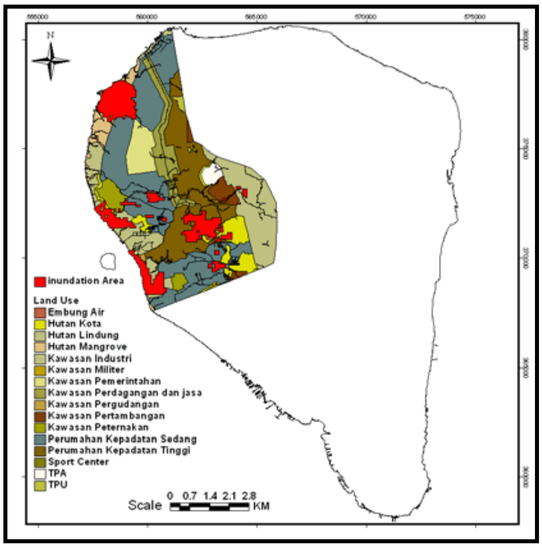


Figure 7. 17 Inundation Area to Land Use Type of Zone II

According to the results of risk assessment, the adaptation options for this area are the combining of IWRM strategy, and restoring the river function and pond.

The Pond provides two primary services. First, the pond has a function as a basin that is designed to catch runoff water from higher elevation areas, and retains the runoff before releasing it into streams. Second, the pond will be used as a water storage that will have to supply as water source. The pond should be built near the middle stream area. Retention pond is used to prevent or minimize flooding during high water periods. The pond is usually designed with an overflow pipe to control water levels and disperse water evenly. Typically shallow, retention pond usually has slow, sloping floors. It rarely takes up much land and average less than 1 acre (4046.86 m^2) in total size. Most ponds are built in areas that have surrounding land capable of accommodating high water during rainy periods. Allowing for excess surrounding land is considered essential for proper function and safety.

Figure 7. 18 Retention Pond

Table 7. 8 Adaption Option in Each Watershed for Baseline and Projected in Zone II

Land Use Type		Watershed	Hazard Level	Vulnerability Level	Risk Level	Adaptation Option
Baseline	**Projection**					
• Pond • Forest • Road • Residential • Cropland • Mangrove • Beach • Agriculture Land • Swamp • Shrubs • Stream	• Pond • City Forest • Protected Forest • Mangrove • Industrial Area • Military Area • Government Area • Commercial and Service Area • Warehouse Area • Mining Area • Farm Area • Moderate Density Residential Area • High Density Residential Area • Sport Center • Landfill • Cemetary	• Semunti • Bengawan • Persemaian	• No Inundation • Inundation Area	• Low • Moderate • High	• Very Low Risk • Low Risk • Moderate Risk • Very High Risk	• Integrated Water Resources Management (IWRM) • The Restoring of the river function • Retention Pond

3) Zone III

Zone III covers 4 major watersheds. They are Sesanip, Kampung Bugis, Pamusian, and Karungan. In 2030, this area will consist Airport, public infrastructure, City Forest, protected forests, mangrove, Industrial areas, military areas, warehouse areas, Mining areas, farm areas, tourism areas, sport center, low density residential areas, moderate density residential areas, and high density residential areas.

Land Use Existing (2008)	Land Use 2030

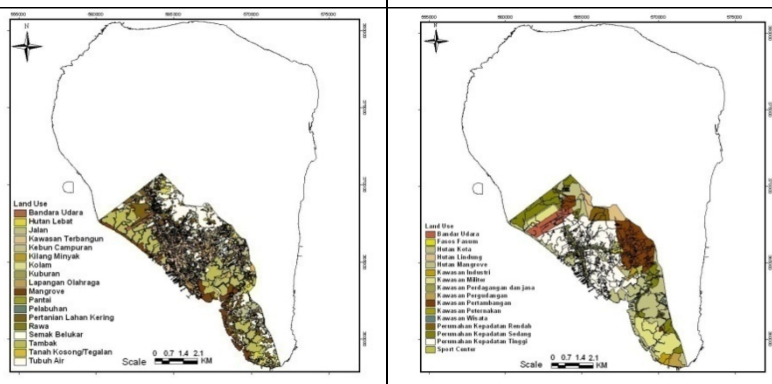


Figure 7. 19 Land Use Type of Zone III

Total inundation in the Baseline condition is 3.365 km^2, but in the year 2030, this area has 11.436 km^2 of inundation area. This area has 5 levels of risk. In details they are 3.970 km^2 of Very Low Risk, 0.488 km^2 of Low Risk, 5.664 km^2 of Moderate Risk, 2.332 km^2 of High Risk, and 0.287 km^2 of Very High Risk.

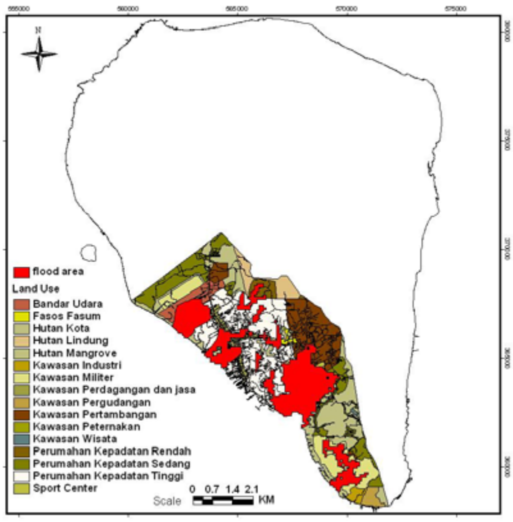


Figure 7. 20 Inundation Area to Land Use Type of Zone III

Based on results of risk assessment and land use type, the adaptation options for this area are installation of sluice gate at the river, levee, and pumping. The options were chosen because the riverside area has become residential areas.

Installation of sluice gate prevents tidal into the river. Meanwhile in the upstream of sluice gate, the river will be pumped to avoid inundation in the downstream area. The river will have to be pumped when the water level elevation is reaching the levee elevation. The water of river will be pumped from the upstream of sluice gate to the downstream.

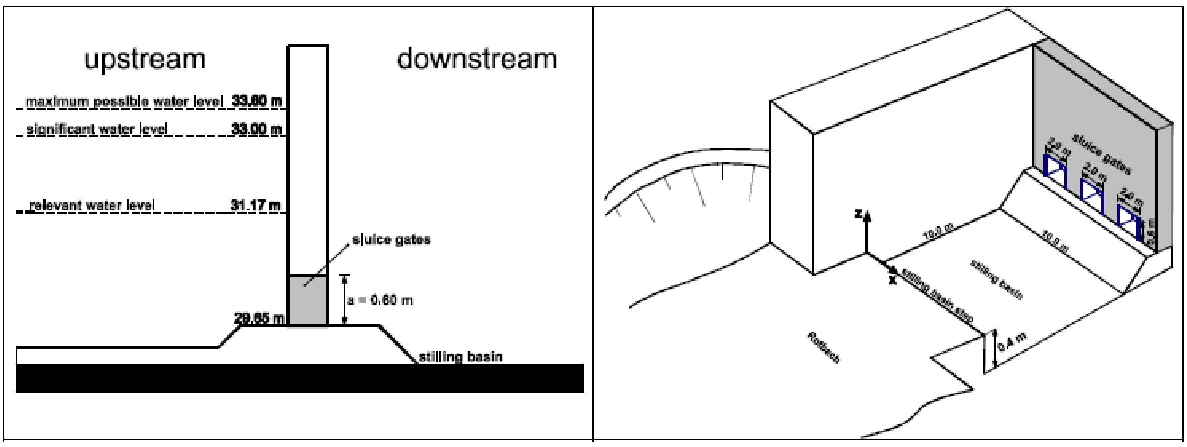


Figure 7. 21 Sectional View of The Weir and Perspective View of The Weir and Stilling Basin (Schlurmann, et.al.)

Table 7. 9 Adaption Option in Each Watershed for Baseline and Projected in Zone III

Adaptation Area	Land Use Type		Watershed	Hazard Level	Vulnerability Level	Risk Level	Adaptation Option
	Baseline	Projection					
III	Airport	Airport	Sesanip	No Inundation Inundation Area	Low Moderate High	Very Low Risk	Installation of Sluice Gate at The River
	Forest	Fasos Fasum	Kampung Bugis			Low Risk	Levee
	Road	City Forest	Pamusian			Moderate Risk	Pumping
	Residential	Protected Forest	Karungan			High Risk	
	Cropland	Mangrove				Very High Risk	
	Industrial Area	Industrial Area					
	Pond	Military Area					
	Cemetary	Commercial and Service Area					
	Mangrove	Warehouse Area					
	Beach	Mining Area					
	Port	Farm Area					
	Agriculture Land	Tourism Area					
	Swamp	Low Density Residential Area					
	Shrubs	Moderate Density Residential Area					
	Stream	High Density Residential Area					
		Sport Center					

7.3.3 Adaptation for landslide risk

There are two main idea about adaptation strategies of the effect of climate change on landslide at Tarakan, based on the landuse projection, in non-population area and area with population. They are forestation for non-population area and engineering works for population area. In principle, stabilizations are about reducing driving forces and resisting forces, the ilustrations shows below. As show in figure 1, landslide occur when shear stress that drive to landslide exceeds shear strength. Than factor of safety calculated using the formula below :

Factor of Safety :

$$Fd = \int_S S_d\,(W)ds$$

$$Fr = \int_S \tau_r\,(\mu_w\,, c'\,, \varphi')ds$$

$$FS = \frac{Fr}{Fd}$$

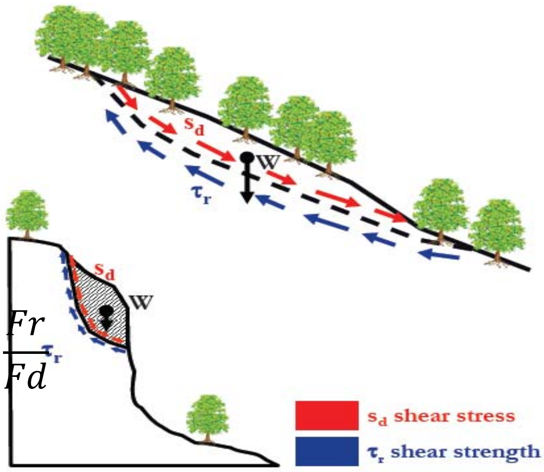


Figure 7. 22 Phylosophy of landslide

7.3.3.1 Forestation

The adaptation that considered to be taken in non-pupolation area is forestation, by covering land using vegetation. The vegetation (forests, bushes) allows evapo-transpiration increase and therefore limits infiltration, this is one of efforts to avoid ground water table recharge and soil strength decrease, due to infiltrate of water. Bush and tree vegetation, by its roots, insures a certain superficial stability, but over a limited depth. The effect of interception by the leaves reduces the erosion generated by the rain. In the other cases vegetation has no impact on slope stability, in particular for deep slides.

Figure 7. 23 forestation

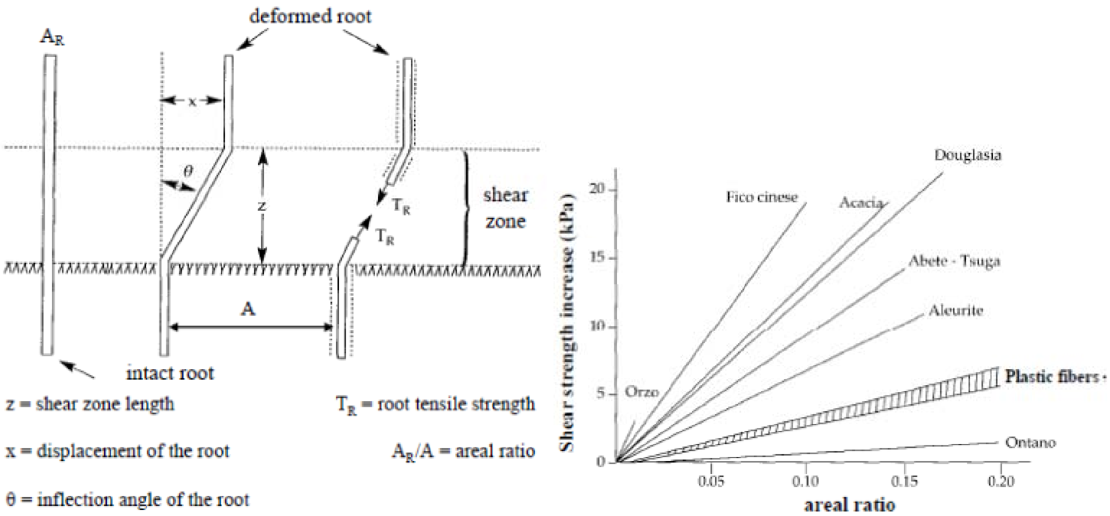


Figure 7. 24 left; shear strength of soil-root system, right; shear strength increase induce by root (puglisi, 1999)

Figure 3 shows shear strength of soil-root system in stabilization, but The roots have a limited stabilizing effect to a few meters depth, if the slide is deeper the forest can bear important movements and even survive. Tree roots do play a real role in providing mechanical coherence of the soil profile and the decay of tree roots are tree felling leads to gradual increase of landslide risk.

Forest vegetation and trees can play an important role in holding a soil profile together through their root systems, and the removal of trees and subsequent decay of tree roots may be part of the explanation of specific landslides. Ironically, however, the risk of landslides after removal of trees is partially because the trees prevented landslides to happen earlier, and contributed to the build-up of soil until this is too heavy for the existing slope steepness. Forestation are able to implemented in Tarakan Tengah, where the landuse area shows it is protected forest, city forest, and low density housing, with low and moderate level of risk. The area is suitable for forestation, since it is require a large enough land for plantation. Moreover, Tarakan Timur, where the landuse area shows it is city forest and medium density housing, in order to this area, it is required combination of forestation and engineering works, this implemented are shown in table 2.

7.3.3.2 Engineering works

In area with population, means in building area there no more space to take forestation as adaptation, its required engineering works. its adaptation need a prediction of landslide processes, The choice of strategies and actions to be implemented is function of economic, social, environmental, cultural, legal, technical and political indicators. They express the ambitions for development, the financial resources available, the needs of society and the regulations of the area of interest (Leroi et al., 2005).

Slow landslides frequently involve huge soil volumes and show velocities from slow to moderate, independently from the stage. Due to both the involved volumes and kinematic characteristics of slow landslides, stabilization works are more suitable than mitigation ones. Particularly, the design of stabilization works can often rely on data coming from monitoring that enhances the modelling of short and long term behaviour of the landslides. Rapid landslides are first failure phenomena characterised by the almost lack of premonitory signs and high velocities during the propagation stage. Both stabilization and mitigation works are possible but their design needs a detailed modelling of landslides behaviour based on the prevision of the potential occurrence without the help of any monitoring system.

The landslide size, as well as its mechanism, plays an important role in the determination of its sensitivity to climatic conditions, for large slides the movements may appear to be nearly constant whatever the rainfall variations. Whatever the rainfall variations the effect of size is also related to the slide depth for which the hydrogeological conditions have to be determined, for small slides a good correlation between movement and rainfall can often be observed. Deep-seated landslides generally display a fairly continuous movement that is hardly affected by increased seasonal variations. In some cases debris flows in streams flowing on the landslide may show an increased activity. Due to the summer increase of temperature, the evapotranspiration will increase and thus reduce infiltration. There are some engineering works that can be done in Tarakan, there are stabilization by mass movements, stabilization using anchor, drainage solutions.

To unload the top part of the slope, or to place fill on the toe of slide, the aim is to reduce slope angle. There are buildings of a rigid or semi-rigid structure, if possible with draining capacity, to maintain the unstable mass (gabions, reinforced earth structure, cross-draining masses), and build a structure that avoids erosion at the toe of the slide (also useful for protection against the effects of floods). But, the excavation of the soil cover above the landslide mass may accelerate rainfall infiltration and increase the movements of the sliding mass.

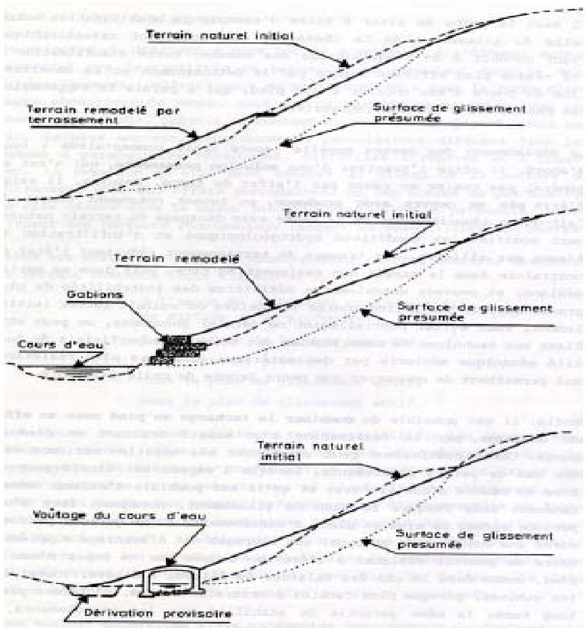
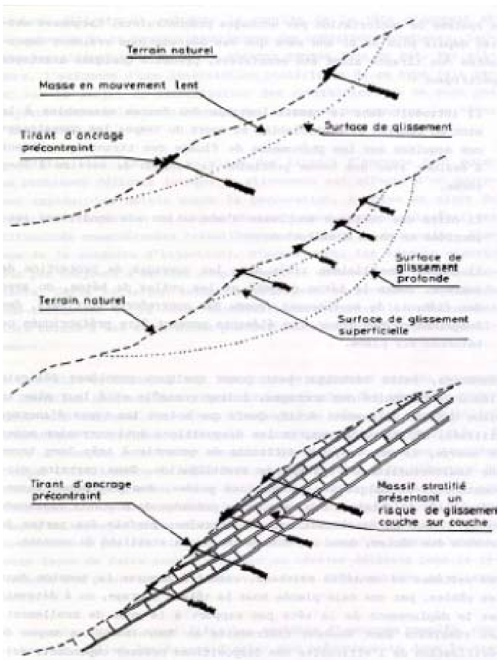


Figure 7. 25 Scaling, splitting, and removal of unstable rocks removal rocks, Slope regrading, Cut back, Toe weighting

But, the excavation of the soil cover above the landslide mass may accelerate rainfall infiltration and increase the movements of the sliding mass. There is need covered on opened area to avoid water infiltration that causes ground water table recharge as we know, it is one of landslide causes.

In some cases, reducing slope is considered unsuitable at that area, there are other alternatives such as installing passive anchors (bolts or bars set in tension as a consequence of the movements), prestressed anchors, with single or repeated tensioning (in order to compensate the tension losses). The piles or micropiles working in compression may be assimilated to this technique. They can be combined with anchors to avoid the displacement of their head, this method is generally costly with respect to a drainage scheme, but it apparently gives more guarantees (except if the grouted zone is still located in the landslide mass.



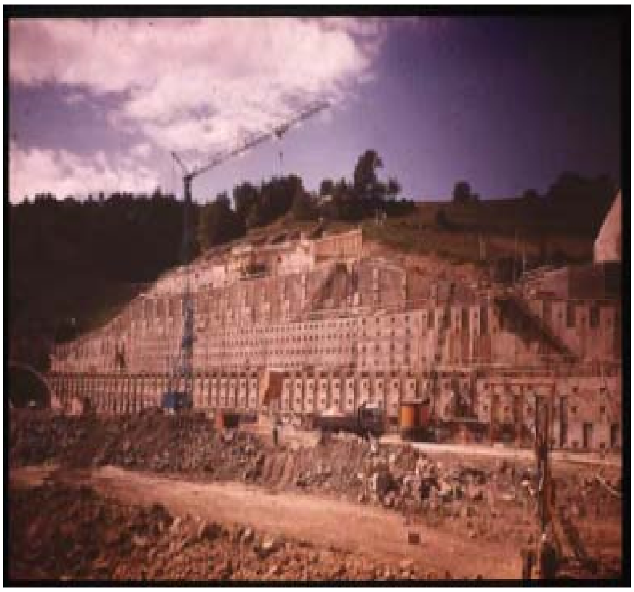


Figure 7. 26 Anchored wall

Drainage is the most adaptable in many different type of landslide, for any type of landslides (from small to large). Possibility to improve the drainage system in respect to the slope response. The aims of drainage are:

1. To lower the ground water level in the landslide mass

2. To reduce the pressure at the level of the slip surface

3. To reduce the flow affecting the landslide mass

In many cases in which the ground water conditions depend on direct infiltration, the interception of surface run-off as well as sub-surface flow may be useful to reduce the ground water level. However such works have a limited effect on rainfall or snow melt critical conditions that trigger crises in the landslide movements. Type of drainage as follows:

1. Surface drains and ditches
2. Shallow or deep trenches
3. Buttress-counterforts of coarse-grained materials
4. Vertical boreholes with pumping or delf draining
5. Vertical wells
6. Subhorizontal boreholes
7. Drainage galleries or tunnels
8. Vacuum dewatering (wellpoints)
9. Drainage by syphoning

This type of drainage have been used in many countries (Italy, France, Canada, Switzerland)

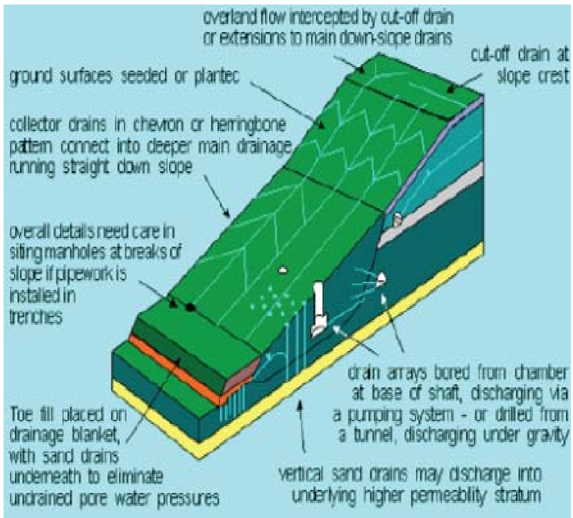


Figure 7. 27 appropriate drainage and type of subsurface and deep drainage

As shown in Table 7.5, engineering works are able to be implemented in Tarakan Utara, where the landuse is medium to high density housing, industrial, trading, and government area, Tarakan Barat, where the landuse area is high density housing and trading area, and moreover some of Tarakan Tengah, where the landuse is high density housing and mining area. As we know, in high population and assets, it is unable to take a rapid plantation, and will need an integrated engineering works based on type of landslide and the landslide size, as well as its mechanism, plays an important role in the determination of sensitivity to climatic conditions. Table 1 below shows the topology works for non-population and area with population.

Table 7. 10 Topology works of landslide stabilization

Landslide area	Stabilization	physical principle	work typology
Non-residential	Forestation	Reducing driving forces	Forestation and bioengineering
Residential	Engineering works	Reducing driving forces along failure surface	Scaling, splitting and removal of unstable rocks removal rocks, Slope regrading, Cut back, Toe weighting
		Shear stresses transfer Shear to elements founded	RETAINING STRUCTURES: Embedded walls, Gravity walls, Composite walls
			STRUCTURAL REINFORCEMENTS : Reinforced fills, Unstressed soil nails, Soil dowels, Reticulated micropiles, Lime nails/piles, Rock bolts and rock dowels
		Increase in total and Increase effective normal stresses acting along the failure surface	STRUCTURAL REINFORCEMENTS: Prestressed anchors, Prestressed soil nails

		Pore water pressure reduction	SURFACE PROTECTION AND DRAINAGE: Surface drainage channels, infilling tension cracks
			SUBSURFACE DRAINAGE: Trench drains, Drainage galleries, Cut-off drains, Vertical drains, Electro--osmosis
		Increase in strength of Increase slope-forming material	STRENGTHNING: Chemical admixstures, Recompaction, Shear trenches, Grouting

The integrated implementation of landslide stabilization are needed to take the large scale of impact of climate change to landslide, and the potential impact of climate change represents a major cause in the evolution of some landslides. We need detailed knowledge on geological, hydrogeological, and geomechanical condition of sand parameters. Table 7.6 below shows integrated adaptation options to be implemented on landslide areas.

Table 7. 11 Adaptation option on landslide area

Adaptation Area	District	Land Use Type		Hazard and Vulnerability Level	Risk Level	Adaptation Option
		Baseline	Projection			
1	Tarakan Utara	mangrove	medium density housing	very high	moderate	engineering works
		bushes	industrial			
		farming				
2	Tarakan Utara	field	trading area	very high	moderate	engineering works
		bushes	high density housing			
		dryland farming	medium density housing			
3	Tarakan Utara	farming	high density housing	very high	moderate	engineering works
		dryland farming	medium density housing			
		bushes	trading area			
		field	government area			
4	Tarakan Utara	dryland farming	trading area	very high	moderate	engineering works
		bushes				
5	Tarakan Barat	field	high density housing	very high	moderate	engineering works
		bushes	trading area			
		farming				

6	Tarakan Tengah	forest	protected forest	low	low	forestation
		bushes	city forest			
		field				
7	Tarakan Tengah	bushes	protected forest	very high	moderate	forestation
			low density housing			
8	Tarakan Barat	farming	high density housing	high	moderate	engineering works
		building region				
		field				
9	Tarakan Tengah	bushes	high density housing	high	low	engineering works
		farming				
10	Tarakan Tengah	bushes	mining area	high	low	engineering works
11	Tarakan Timur	forest	medium density housing	high	low	engineering works
		bushes				
		building region				
12	Tarakan Timur	building region	medium density housing	high	moderate	engineering works and forestation
			city forest			
13	Tarakan Timur	farming	city forest	low	low	engineering works and forestation
		field	medium density housing			
		bushes				

Several episodes of climate change have been observed or detected in the past, at these episodes have had an influence on the behavior of large landslides (last glacier retreat). But, the understanding of landslide mechanisms still needs to be improved under climate change conditions, it need to review new monitoring and modeling tools to predict the various landslide processes related to climate change. The gathering of more data, especially during pre-failure phases, will help preventing disasters through the development of monitoring systems and the adaptation of land planning and to focus on evidences of the effect of climate change on landslide hazard at local and regional scale.

The major aspect of climate change investigations lies however in the large range of uncertainties. This range depends essentially on future management policies, the trend is fairly limited during the next 30 years, but it may vary substantially in the long-term, causing extensive disaster situations in the whole world, then any prediction on landslide behavior may then be doubtful.

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References

Gofar Nurly, Lee Lee Min. *Integration of Extreme Rainfall in the Evaluation of Slope Stability*, PIT XII HATTI, Savoy Homann Hotel, Bandung, 18-19 November 2008

WU JR, ZHANG T and YANG J (1996) *Analysis of rainfall-recharge relationship*. J. Hydrol. 177 143-160, 1996

Xu, Y. & Tonder, G. J. V. *Estimation of recharge using a revised CRD method*. Water SA, Vol. 27, pp. 341-343. 2001

BREDENKAMP DB, BOTHA LJ, VAN TONDER GJ and VAN RENSBURG HJ (1995) *Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity*. WRC Report No TT 73/95

SOPHOCLEOUS MA. *Combining the soilwater balance and the water-level fluctuation methods to estimate natural groundwater recharge: Practical aspects*. J. Hydrol. 124 229-241. 1991

Bonnard Christophe. *Landslide and climate change : a World Perspective, But a Complex Question*. LARRAM. Ravello, September 7, 2007

Bonnard Christophe. *Landslide Risk Mitigation and Management*. LARRAM. Ravello, September, 2007

Sorbino Giuseppe. *Landslide Risk Mitigation By Control Works*. LARRAM. Ravello, September, 2007

Kawagoe S., Kazama S., and Sarukkalige P. R. *Probabilistic modelling of rainfall induced landslide hazard assessment***.** Hydrol. Earth Syst. Sci., 14, 1047–1061, 2010

K.K.S. Ho, F.W.Y. Ko. *Application of quantified risk analysis in landslide risk management practice: Hong Kong experience.* Georisk Vol. 3,No. 3, September 2009

R.A. Crovelli, J.A. Coe. *Probabilistic estimation of numbers and costs of future landslides in the San Francisco Bay region.* Georisk Vol. 3, No. 4, December 2009

K.T. Chau, Y.L. Sze, M.K. Fung, W.Y. Wong, E.L. Fong, L.C.P. Chan. *Landslide hazard analysis for HongKong using landslide inventory and GIS.* Computers & Geosciences 30 (2004) 429–443

S.S. Ramakrishnan, V.Sanjeevi Kumar, M.G.S.M. Zaffar Sadiq, M. Arulraj and K. Venugopal. *Landslide Disaster Management and Planning .A GIS based approach.* Indian Cartographer, 2002

Janak Bahadur CHAND, Yasuhiro MITANI, Ibrahim DJAMALUDDIN and Hiro IKEMI. *An Integrated Methodology for Assessment of Landslide Hazard around Residence Zones in Itoshima Area of Japan*. Memoirs of the Faculty of Engineering, Kyushu University, Vol.71, No.2, June 2011

Ancuţa Rotaru, Daniel Oajdea and Paulică Răileanu. *Analysis of the Landslide Movements*. INTERNATIONAL JOURNAL OF GEOLOGY, Issue 3, Volume 1, 2007