Appendix-C

NATURAL CONDITIONS

THE STUDY
ON
CRITICAL LAND
AND
PROTECTION FOREST REHABILITATION
AT TONDANO WATERSHED
IN
THE REPUBLIC OF INDONESIA

Volume-II

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NATURAL CONDITONS

CHAPTER 1 INTRODUCTION

This ‘APPENDIX-C NATURAL CONDITIONS’ mentions about the Topography, Geology, Meteorology, Hydrology of the Study Area and the Intensive Area.

In Chapter 2, natural conditions for entire study area are mentioned. In section 2.1, topography, geomorphology, and basin characteristics are mentioned. The Sudy Area is is divided into four sub-basins, namely, Noongan, Tondano, Klabat, and Tikala sub-basins. In section 2.2, geology of the study area is described. Geological formation of the Study Aea explained based on the geological map of the Manado Quadangle North Sulawesi (1:250,000). In Section 2.3, meteorology is described. It includes meteorological stations, data of rainfall, temperature, relative humidity, and wind. In Section 2.4, hydrology of the Study Area including gauge stations, kind and period of available data, in-flow and out-floe of Lake Tondano, turbidity, water surface level of Lake Tondano, river flow in lower reaches of Tondano River, and water balance in the Study Area, and found problems on available data are described.

In Chapter 3, natural conditions in the Intensive Area are described. In Section 3.1, topography and geology of the Intensive Area is mentioned. Topographical features of East Area, West Area, and South Aarea of Lake Tondano are mentioned. Geology in the Intensive Area also described for each of East Area, West Area, and South Area. In Section 3.2, meteorology of the Intensive Area, mainly rainfall, is mentioned. In Section 3.3, hydrology in the Intensive Area and Lake Tondano is written. In Section 3.4, soil characteristics in the Intensive Area is mentioned based on the field survey.　Soil profile, infiltration rate, physical and chemical properties, and soil type and its distribution are included.　In Section 3.5, problems on available data are mentioned.　It pointed out that the data are very limited on (1) erosion and sedimentation, (2) water quality of the Lake, and (3) water balance of the lake.

CHAPTER 2 NATURAL CONDITIONS FOR THE STUDY AREA

2.1 Topography

2.1.1 Topography

The study area is located at the north latitude between 1° 06' and 1° 30', and at the east longitude between 124° 45' and 125° 02', extending about 45km long in north–south with about 10 to 15km wide in east-west. The area is 547.55km^2 including 46.38km^2 of Lake Tondano.

The area is characterized geo-morphologically by the occurrence of volcanism resulting in volcanic landscapes, such as stratovolcanoes, caldera or craters, and lava flows. The western and southern parts are crowned by younger stratovolcanoes. Some of the volcanoes are still active and erupted several times in the last 20 years.

Manado, the capital city of the region, is located at the mouth of Tondano River in the northwest end of the study area. The northern part of the study area near Manado comprises its lowest area, and the lower area below 200m above sea level (ASL) extends from Manado toward Kauditan along the northern boundary of the study area. The highest point of the study area is Mt. Klabat of 1990m ASL located at the north-east end of the study area followed by Mt. Soputan of 1556m ASL located at the south-west end, both of which are volcanoes.

High points on the boundary of the study area are mostly volcanoes, such as Mts. Mahawu (active, 1372m), Masarang (1252m), Paketengan (974m), Tampusu (active, 1206m), Kasuratan (1059m), Lengkoan (1153m), Soputan (active, 1556m), Manimporok (1556m), etc.

Elevation in the study area becomes higher toward south. The northern area, especially between Sawangan-Kamanta line and Mt. Mahawu-Makaweimbein line, is rugged and deeply dissected mountainous land. Elevation of the northern area ranges from sea level to 1300m ASL. While the southern part, south of the Mt. Mahawu-Makaweimbein line, is higher than 680m, which is old drainage area of Lake Tondano before the outlet of the lake developed at Tonsealama.

Lake Tondano is located in the southern part of the area, that is 12km long in north-south and 3km wide in its northern half and 5km wide in southern half with the area of 4638 hectares. The study area includes several active volcanoes in the south and west of the lake. The lake created by the eruption of the big Tondano Volcano in some 1 to 1.5 million years ago, which filled the valley of the old crater. Eastern side of the lake is composed of old volcanic rocks, however, the western and southern sides composes recent volcanic rocks and covered with soil and lava of recent volcanic activities.

Average slope in the area, measured by square elements with 465m long sides on the 1:50,000 topographical map, varies from flat to 70%. Following table shows proportion of the area by different slope classes.

Percentage Area by Slope

Slope(%)	Share(%)	Slope(%)	Share(%)
<3	18.55	35-40	3.49
3-8	15.18	40-46	2.21
8-13	15.43	46-51	0.98
13-19	14.38	51-56	0.58
19-24	11.91	56-62	0.11
24-30	9.99	62-67	0.29
30-35	6.75	>67	0.15

The area steeper than 24% slope accounts for about 1/4 of the area and most of them are located along the boundary peaks surrounding the study area, and around Mahawu, Pinandelan, and Makaweimbein mountains in the central part of the north of Lake Tondano.

In the watershed of Lake Tondano, most rivers have seasonal flow. Permanent rivers are found Noongan sub-basin in the south and Remboken in the west. The elevation of headwaters of permanent streams is at about 850m ASL, judging from paddy field distribution. The elevation of the river mouths are same to that of the lake water surface, which varies from 681.5 to 684 m ASL depending rainfall and water consumption by the hydro-power station.

In the northern part of the study area the rivers originate from three higher mountains, namely Mt. Klabat in the northeast, Mahawu mountains in the west, and Pinandelan and Makaweimbein mountains in the east. The rivers with permanent flow originate at about 200 m ASL from Mt. Klabat. Permanent flows appear at the elevation of 800 to 1,200 m ASL in the rivers from Mahawu. They are at 600 to 800 m ASL in the rivers from Pinandelan and Makalonsouw.

Drainage pattern is mostly dentritic, which resembles the branching of a tree, in the area. However, radial pattern is found on the mountain slopes of Mt. Klabat, and parallel pattern on the slopes of Mt. Soputan.

Regarding drainage system, total length of the streams in the area measured 744.3km on the 1:50,000 topographical map. The streams classified by a stream order, which defined as a hierarchical classification of streams based on the magnitude of their channels and position in a drainage area. The outmost tributaries being designated first order streams, two first order streams uniting to form a second order stream, two second order streams joining to form a third order, and so on until the main river, opening to the mouth, is reached. Tondano river at the river mouth in Manado defined 6th order stream.

Number and Length by Stream Order of the Streams of Tondano Drainage System

Stream Order	Number of Streams (no.)	Total Length by Order (km)	Average Stream Length (km)
1	428	419.1	0.98
2	107	164.5	1.54
3	25	92.4	3.70
4	8	30.6	3.83
5	2	35.6	
6	1	2.1	
Total	571	744.3	

Drainage density, length of stream per unit area, is 1.29km/km^2. Regarding the fall of stream flowing into Lake Tondano, the gentlest one is 50 m fall in 11km distance, or riverbed slope of 1/220, which is in the middle and lower reaches of the Panasen river in Noongan sub-watershed. While, in the lower reaches of Tondano River near Manado, it is 125m fall in 27km distance, or 1/216 in slope. In the middle reaches of Tondano River, which is the section from the outlet of the Tonsealama power station to Sawangan, it is 100m fall in 2.5km distance, or 1/25 of slope. Fall of stream of the minor rivers ranges between 1/10 and 1/30 depending features of the ground surface.

There are small lakes, besides Lake Tondano. Since they formed in the depressions on alluvial sediment in the south of Lake Tondano, they are very shallow and seasonal. Swamp area extends along the northern shore of Lake Tondano, where inundates during high water seasons.

2.1.2 Geomorphology

The landscape of the study area can be divided into three groups, namely: Mountains, Piedmont, and Plain.

(1) Mountains

The mountain landscape is classified into sub-groups, (a) Mountains, and (b) Hill lands.

1) Mountains

The mountain landscape is defined as an elevated, rugged, deeply dissected land portion characterized by important relative height differences in relation to lower-lying surrounding landscape units. In the area, it can be distinguished into three relief types:

(i) Volcanic cone or stratovolcano, dominantly covered by volcanic ash, tuff, and lava, having moderate to strongly dissected upper and middle slopes with gently sloping to very steep slopes (3–60%),

(ii) Lava flow, dominated by andesitic or basaltic lava flow originated from Tompusu volcano, having slight to moderate dissection with gently to moderate steep slopes (3–25%), and

(iii) Ridges, which were formed of older volcanic lava and tuff. Generally, this relief is strongly to very strongly dissected with steep slopes of 25-75%.

2) Hill lands

Hill land is rugged land portion characterized by the repetition of high hills, generally elongated, with uneven summit heights, separated by a moderately dense hydrographic network.

This landscape can be divided into two relief types: one is having moderate to strong dissected, with steep slopes (15-45%), and another is the lower part of the hills, covered by alluvial and colluvial materials from the hills, having undulating relief with 3-8% slopes.

(2) Piedmont

This group is classified into sub-group of (a) Plateau, and (b) Piedmont.

The plateau landscape is a large, flat, unconfined, relatively elevated land portion, which is commonly limited on at least one side by an abrupt descent (escarpment) to lower land. The surface topography remains table-shaped or gently undulating. This unit occupies a small portion in the study area. The materials are volcanic ash and tuff with dark color. The dissection is slight to moderate, and the dominant slope is 3 to 15%, except the scarp, which has a 15-25% slope.

The piedmont is a sloping land portion lying at the foot of more elevated landscape units, such as mountains and plateaus. In the study area, this unit consist of a foot slope of Klabat and Soputan volcanoes covered with sandy volcanic ash materials, slightly dissected with slope of 0-8%, and foot-slopes resulting in hills of ridges covered by volcanic tuff (Tondano tuff), generally strongly dissected, with slope of 8-25%. This landscape is found in south and northeast in the study area.

(3) Plain

Plains are large, flat, unconfined, low-lying land portions with low relief (less than 10 m of altitude difference) and gentle slopes. Some streams contribute to form a complex fluvial system.

This landscape covers a large portion either in the south or in the north of the study area. This unit can be distinguished into two sub-units based on lithology, namely, a plain developed from lacustrine deposits, found in surrounding the lake, having flat to slightly concave relief, and a plain formed from alluvial-colluvial deposit, slightly higher than the lacustrine plain, having flat to slightly undulating topography (0-5% slopes). The deposition usually consists of clay overlaying sandy and gravelly materials.

2.1.3 Basin Characteristics

The Tondano river basin is divided into four sub-basins, namely, Noongan, Tondano, Klabat, and Tikala.

(1) Noongan Sub-Watershed:

Noongan sub-basin has two main streams, namely Panasen river and Saluwangko river (name in the 1:50,000 topographical map, which is also called Ranowelang River in another reference). Both streams are perennial rivers. They are the biggest and second biggest rivers among the streams flowing into the lake. Panasen river has about $64km^2$ of drainage area and Saluwangko river has about $42km^2$. The drainage area of the two rivers has about 50% of total drainage area of Lake Tondano. The two streams give highest contribution of water to supply the lake.

Both rivers originated from Mt. Soputan. The drainage pattern is radial in the upper reaches on the slope of Mt. Soputan, and becomes sub-parallel in the middle reaches, finally is dentritic in the lower reaches.

Panasen river is the biggest stream with 5 to 6m wide in the lower reaches. Flow rate of the river was measured once a month at the bridge about 2km upstream from the river mouth in 1999 by Molenaar et al. of Sam Ratulangi University, which shows the flow rate varied 0.4 to $1.9m^3/sec$. In the lower reaches of the river, degradation of the riverbed and erosion on the banks occurs during high floods. The riverbed is 3 to 5m lower than the paddy fields on both sides in its lower reaches. The river has three major tributaries of which two are flowing in the residential area of Langowan town. The annual average discharge of Panasen river is less than Saluwangko river, of which drainage area is 2/3 of Panasen, because many intake weirs have constructed for irrigation in its middle reaches.

Saluwangko river, which passes through Kakas town, is the second biggest river among the in-flowing rivers to the lake, having a width of about 5m in the lower reaches. Flow rate, which measured once a month at the bridge in Kakas town in 1999 by Sam Ratulangi University, ranges 0.4 to 2.8m^3/sec. The riverbed is more stable than that of Panasen river, and degradation and bank erosion are not distinct.

(2) Tondano Sub-Watershed

The sub-watershed is divided into Upper Tondano Sub-Watershed and Lower Tondano Sub-Watershed by hydropower intake.

1) Upper Tondano Sub-Watershed

In the upper Tondano sub-watershed, there are 40 streams, of which 35 streams including above mentioned 2 rivers in Noongan sub-watershed flow into Lake Tondano directly. Other 5 streams flow into Tondano river, which is the only river out-flowing from the lake, between Toulour and the Tonsealama hydropower intake. The streams in the upper Tondano watershed, except Mawalelong river (or Bowolean river) in Remboken, are considered seasonal stream that has flow only in the rainy season.

Out of 35 streams, which are flowing into the lake directly, 20 streams are originated from the dividing peaks in the east side of the lake, 2 rivers from Noongan sub-watershed from the south that mentioned above, and 13 streams from the western hills.

Drainage area of the rivers in the upper Tondano sub-watershed is small. Drainage areas are 22km^2 for Mawalelong river, 12km^2 for Toubeke river, 11km^2 for Tounsukun river, and 7km^2 for Tougela river, and other 31 streams are less than 2.7km^2 each as shown in the following table. The drainage patterns are mostly single straight line, because the most of the streams originates from the steep mountains in the east and west of the lake.

In-flow rivers to Lake Tondano

Sub-basin No.	Name of Watershed	Area (km^2)	Sub-basin No.	Name of Watershed	Area (km^2)
I. Noongan sub-watershed					
1	Saluwangko	47.55	2	Panasen	62.10
II. Lake Tondano west coast sub-watershed					
3	Passo 1	0.40	4	Passo 2	0.25
5	Passo 3	2.10	6	Mawalelong	22.60
7	Leleko	2.08	8	Urongo 1	1.28
9	Urongo 2	0.30	10	Paleloan 1	2.30
11	Paleloan 2	0.78	12	Tounsaru	2.70
13	Tougela	6.75	14	Toubeke	12.18
15	Koya	1.20			
III. Lake Tondano east coast sub-watershed					
16	Kaweng 1	1.98	17	Kaweng 2	0.73
18	Kaweng 3	0.70	19	Watumea - Telap	1.73
20	Telap 1	0.38	21	Telap 2	0.45
22	Toulimembet	2.75	23	Ranomerut 1	0.70
24	Ranomerut 2	0.67	25	Ranomerut 3	0.35
26	Tandengan 1	1.40	27	Tandengan 2	0.90
28	Eris	1.60	29	Watumea - Eris	1.40
30	Serawet	1.80	31	Tounipus	1.60
32	Tondano Indah	1.10	33	Toliang Oki	2.57
34	Kaarisan Toliang Oki	0.80	35	Tounsukun	11.67
IV. Tondano river sub-watershed					
36	Koya	2.22	37	Roong	8.92
38	Sumalangka	7.17	39	Taler	10.15
40	Ranowangko	7.15	41	Tonsealama	1.70

Mawalelong river had water flow throughout the year having about 4m width near the river mouth to Lake Tondano. Flow rate, which measured once a month at the bridge in Remboken town in 1999 by Sam Ratulangi University, ranges 0.46 to 0.95m^3/sec. Other rivers had flow rate of less than 0.1m^3/sec except heavy rainy days.

Minor streams on the east and west lakesides have mostly been used for irrigation canals or drainage channels in paddy areas, and some have been changed into drainage ditches in the residential areas. No minor river keeps original shape currently.

2) Lower Tondano Sub-Watershed

Lower Tondano sub-basin is composed of Tondano River and its tributaries. It extends from Tonsealama to the river mouth at Manado. Tondano river is perennial river. Main stream comes from Lake Tondano through Tonsealama hydropower station. There are four major tributaries, namely Tikala river, Linamunan river from Klabat sub-basin, Kuala Rurukan and Kuala Suduan.

Kuala Rurukan is originated from Mt. Mahawu, of which land use is mostly agricultural land of vegetable cropping in the area of higher than 1,000m and mixed farming of estate tree crops and maize, except the forest around Mt. Mahawu. Kuala Rurukan has average bed-slope of 1/11.

Kuala Suduan from Mt. Makaweimbein, of which land use is mostly forest. Kuala Suduan has average bed-slope of 1/20.

(3) Klabat Sub-Watershed

Klabat sub-basin is composed of the rivers originated from Mt. Klabat and their tributaries with its area of $70km^2$. Land use of the watershed is mostly estate of coconut trees. The rivers from Mt. Klabat are seasonal in their upper and middle reaches and the headwaters of perennial flow reveal at the elevation of about 200m ASL. The riverbed slopes is about 1/90 in upper 6km section from confluent to Tondano River.

(4) Tikala Sub-Watershed

Tikala sub-basin is composed of the rivers originated from Mts. Mahawu and Tingtingon. The area of the watershed is $98km^2$. Land use of the watershed is mostly estate of coconut and clove trees. The drainage area is divided into two parts, namely western part and eastern part. Both areas are rugged and deeply dissected. Major tributaries have perennial flows. The riverbed slopes is about 1/300 in 8km section from the confluent to Tondano River and 1/40 – 1/80 in its upper 5km section. The bed-slope is steeper than 1/15 in the upper reaches of the tributaries.

2.2 Geology

2.2.1 Stratigraphy

The geology of Sulawesi Island is of great geotectonic importance, as it forms the link between the East Asiatic Island area on the one side, and the festoon of the great Sunda Mountain system on the other side.

Sulawesi island and its surroundings in central Indonesia may represent a center point of typical triple junction plate convergence within transitional complex of Central Indonesia due to the westward-moving Pacific Plate, the northward-moving Indo-Australian Plate, and the southward-moving Eurasian Craton.

Tectonostratigraphy, Sulawesi Island can be divided into 5 distinctive terrain, namely

(a) Pelaeozoic Banda Micro-continents,

(b) Cretaceous Eastern Sulawesi Ophiolite Belt,
(c) Late Cretaceous-Palaeogene Central Sulawesi Metamorphic Belt,
(d) Tertiary Western Sulawesi Magmatic Belt, and
(e) Quaternary Minahasa-Sangihe Volcanic Arc.

The last terrain comprises the north part of Sulawesi where the study area is situated. It is characterized by an acute and extremely convex volcanic belt, stretching from Sangihe Island in the north and terminates at Una-una Island in the south. Young quaternary volcanic activity is found only in the Minahasa section.

Lake Tondano is an old crater resulting from a paroxysmal eruption of a big Tondano volcano during the late Tertiary to early Quaternary periods. The materials are composed of pumice tuff, lapilli, and breccia. The lake originated by the filling of the drainage in a longitudinal rift valley on the crest of Minahasa geanticline bordered to the south east by the Lambean scarp and to the northwest by a row of young volcanoes, namely Soputan, Tampusu, Lengkoan, Kasuratan, Masarang, and Mahawu.

2.2.2 Geological Formation

According to geological map of the Manado Quadangle North Sulawesi shown in Figure C.2.1, scale of 1:250,000, the study area is composed of four main geologic formations, namely: Lacustrine and Fluviatile deposits (Qs), Young volcanic rocks (Qv), Tondano Tuff (QTv), and Older volcanic rocks (Tmv).

(1) Lacustrine and Fluviatile deposits (Qs)

This formation is composed of sand, silt, conglomerate, and marl clay. Alternating beds of loose sand, silt, and pumice tuff, graded beds, locally cross-bedded, generally horizontal but partly very gently dipping. It forms terraces with an undulating surface. A part of this formation constitutes the surrounding lake Tondano in the north part and the south part. This deposits form as a lacustrine plain in which most of the materials originated from Tondano eruption.

(2) Young volcanic rocks (Qv)

This unit has the most extensive distribution, mainly in the western part of the study area. The rocks are composed of lava, bomb, lapilli, and ash, which make up the young stratovolcanoes, e.g. Soputan, Lokon, Mahawu, Tampusu, Lengkoan, Klabat, and Tangkoko volcanoes. Some of them are still active.

Lava flowed from Soputan and Lokon and is mainly basaltic, whereas lava from

Mahawu and Tangkoko are mainly andesite. Obsidian flows near Tataaran and Kiawa villages were derived from Tampusu and Lengkoan respectively. Mohr (1944) mentioned that hypersthene-andesite are apparently the most abundant, basalt less so, and hornblende andesite still less in occurrence in the Minahasa region.

(3) Tondano Tuff (QTv)

Tondano tuff has an extensive distribution, and is composed of coarse volcanic clastics mainly of andesitic composition with angular to sub-angular components, characterized by abundant of pumice fragment, tuff, lapilli tuff, and breccia. Very dense ignimbrite with flow structure occurs around Kombi village. The pyroclastic materials are considered to have originated from paroxysmal eruptions during the formation of Tondano caldera. This unit occurs around the lake Tondano forming low undulating ridges, such as the eastern part of Tondano town, and the southern part of the study area, around Kakas village.

(4) Older volcanic tocks (Tmv)

This formation is dominantly composed of breccia, lava, and tuff. The lava flows generally are andesitic to basaltic. The breccia is very coarse grained, andesitic composition, locally conglomeratic with intercalation of tuff, sandstone, and claystone, and lenses of limestone.

This unit has a large distribution in the eastern part of the study area. Younger volcanic materials have covered a part of this unit.

2.2.3 Lithology/ Parent Materials

According to Hikmatullah (1996), the lithology of the study area can be separated into seven groups based on the geological information supported by field observation and aerial photo interpretation and is described below.

(1) Lacustrine Deposit

The lacustrine deposit consists of stratified materials, sand, silt, and clay. In the lower layers, a whitish unconsolidated weathered pumiceous tuff has been covered by new materials, which have a clayey texture and a dark color. The soil survey team (CSAR, 1995) reported that around Tondano town and Kakas village, a thin peat layer (< 1m thick) was found. It can be inferred that swampy areas occurred in the past time. Close to Kakas village, stratified material composed of loam overlaying sands and gravel originated from former river deposits, were also found.

(2) Alluvial-colluvial

The alluvial-colluvial deposit consists of clayey to loamy materials, which are distributed along the stream channel and foot-slopes of the hill lands and mountains.

(3) Sandy Volcanic Ash

The volcanic ash consists of sandy materials originating from Soputan eruption, having an extensive distribution in the southwest part of the area. The thickness is more than 1 m near Noongan village and becomes less close to the lake. The materials have dark color, contain abundant volcanic glass, and have a bulk density more than 1.0 gr/cm^3 because of vitric sand. Underlying this material, a lighter colored and loamy–silty textured one was found.

(4) Loamy Volcanic Ash

This material was derived from Masarang and Mahawu volcanoes, and it has a loamy to silty texture, dark yellowish color, and is friable and smeary. Bulk density is less than 0.9 gr/cm^3. The distribution is found in the northwest and northeast of the study area.

(5) Tondano Tuff

Tondano tuff is composed of loamy to sandy materials, containing abundant pumiceous fragments, and volcanic glass. This tuff is found on the hill land landscape, a remnant of Tondano volcano, south of Remboken village, and to the east of Tondano town.

(6) Young Andesitic-Basaltic Lava

The rocks originated from Tompusu, Masarang, and Mahawu volcanoes, show a high porosity that indicates much more gas during the formation. These rocks are relatively easy to be weathered because they are basic rocks with high content of dark materials. The materials have a dark color and a clayey texture. The distribution of these rocks is found around Remboken-Tonsaru villages in the west, and the Watulambot-Tataaran villages in the northwest.

(7) Older Andesitic-Basaltic Lava

The older volcanic rocks are composed of andesitic-basaltic lava-flows have been weathered into materials that have dark color and clayey texture. Part of this material has been covered by younger material from Tondano tuff or other volcanic eruption.

2.3 Meteorology

2.3.1 Meteorological Stations

The meteorological stations are located at Kayuwatu, Manado, and Tondano. These stations have recorded temperature, humidity, rainfall, wind, etc. Addition to them, rainfall has been observed at the stations of Airmadidi, Eris, Kakas, Luaan, Remboken, Telap, Langoan, Papakelan and Noongan. However, some of them are not measured continuously and also accuracy is doubtful. Therefore, rainfall data recorded more than 7 years until 1999 are collected for the study.

2.3.2 Rainfall

The average monthly rainfall data measured at above stations are shown in Table C.2.19 through C.2.54. Kayuwatu and Airmadidi in the area of lower elevation receive more rainfall than in the area around the lake of higher elevation. The mean annual rainfall is 2,738 mm at Kayuwatu and 1,442-2,364 mm around the lake.

Annual rainfall distribution shows that the area has rainfall throughout the year, however, rainfall is more from October to June than from July to September. Annual rainfall fluctuates much and it varies 1310 to 3900 mm in Kayuwatu, and 838 to 2893 mm around Lake Tondano since 1980 until 1999.

2.3.3 Temperature

Monthly mean temperature in Manado ranges 25.3 to 26.7°C throughout the year. Monthly maximum temperature ranges 30.1 to 32.9°C and it reaches 32.9°C in September, and monthly minimum temperature ranges 20.1 to 21.0°C throughout the year. In Tondano, monthly mean temperature ranges 21.9 to 22.5°C and monthly maximum temperature ranges 26.6 to 27.9°C and the minimum temperature ranges 18.3 to 19.6°C.

The highest temperature occurs in September and the lowest temperature occurs in March and April in Manado. However, in Tondano, the higher temperature occurs April and May, and from September to December and lower temperature occurs in September. The monthly mean temperature is almost same throughout the year, and the difference between monthly mean maximum temperature and mean minimum is about 10°C in Manado and 8°C in Tondano in the year.

Precise data of temperature are shown in Table C.2.1 to C.2.3 for Manado and Table C.2.10 to C.2.12 for Tondano. Figure C.2.2(1) shows monthly mean temperature.

Temperature at Kayuwatu (Observation period 1985-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Mean	25.3	25.4	25.5	25.8	26.1	26.3	26.2	26.7	26.6	26.3	26.0	25.9	26.0
Max.	30.2	30.1	30.9	31.5	31.9	31.7	31.7	32.3	32.9	32.4	31.5	30.7	31.5
Min.	20.5	20.6	20.4	20.4	20.9	21.0	20.9	21.0	20.3	20.1	20.6	20.8	20.8

Source: BMG

Temperature at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Mean	21.9	22.0	22.2	22.3	22.6	22.5	22.2	22.1	22.3	22.5	22.4	22.5	22.3
Max.	26.6	26.6	27.0	27.6	27.5	26.9	26.5	26.6	27.5	27.9	27.6	27.2	27.1
Min.	18.9	19.1	19.1	18.9	19.4	19.4	19.5	19.0	18.3	18.4	18.9	19.6	19.0

Source: BMG

2.3.4 Relative Humidity

The average relative humidity is high throughout the year as shown in Table C.2.4. The monthly humidity varies 75 to 89% with an average annual value of 84% at Kayuwatu, and at Tondano, it ranges 85 to 91% with an average annual value of 89%. The relative humidity is higher in Tondano than in Manado.

As the study area is located at North 1 º 7’ to 1 º 30’ in latitude, daytime is almost 12hours throughout the year. The average monthly sunshine duration varies from 6 hours in January to 8.8 hours in August with an average annual of 7.2 hours at Kayuwatu. It varies from 6 hours in December to 8.8 hours in September with an average annual of 7.2 hours at Tondano.

Figure C.2.2 (2) and C.2.3 (1) show monthly mean relative humidity and monthly mean sunshine duration, respectively. Table C.2.4 and C.2.13 show monthly mean relative humidity at Manado and Tondano, and Table C.2.5 and C.2.14 show monthly mean sunshine duration at Manado and Tondano.

Humidity and Sunshine Duration at Kayuwatu (Observation period 1985-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Humidity	89	87	88	87	87	83	79	75	76	82	88	89	84
Sunshine Duration	6.0	6.1	6.2	7.6	7.6	7.2	7.8	8.8	8.5	7.6	7.0	6.4	7.2

Source: BMG

Humidity and Sunshine Duration at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Humidity	90	90	89	89	91	89	88	85	85	89	90	89	89
Sunshine Duration	6.6	6.7	7.1	7.1	6.7	6.8	7.7	8.5	8.8	7.3	6.7	6.0	7.2

Source: BMG

2.3.5 Wind

The average monthly wind velocity varies from 0.7m/sec in December to 1.7m/sec in August in Kayuwatu and from 0.6m/sec in November and December to 2.4m/sec in February at Tondano. Wind velocity is rather higher from June to September in lowlands, while it is higher from December to March in highlands. Dominant wind direction is N to NW from November to April, and S to SE from June to September. October and May are turning points of the wind direction. Maximum wind velocity varies much by year. In Kayuwatu, maximum wind velocity recorded at 27.3m/sec in August 1992 followed by 26.8m/sec in August 1987. In Tondano, maximum wind was recorded at 20.5m/sec in December 1996 followed 19m/sec in August 1995. Strong wind appeared from June to December.

Figure C.2.3 (2) shows monthly mean wind velocity and Table C.2.6 through C.2.9 and Table C.2.15 through C.2.18 are data on wind velocity and wind direction.

Wind Velocity and Direction at Kayuwatu (Observation period 1985-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Wind Velocity	0.9	0.9	0.9	0.8	0.8	1.3	1.4	1.7	1.3	0.9	0.8	0.7	1.0
Wind Directions	N-NW	N-NW	N	N-NW	N-S	S	S	S-SE	S-SE	N-S	N-NW	N-NW	

Source: BMG

Wind Velocity and Direction at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Wind Velocity	1.7	2.4	1.8	1.3	0.8	1.0	1.5	1.1	0.8	0.6	0.6	1.2	0.8
Wind Directions	N-NW	N-NW	N	N-NW	N-S	S	S	S-SE	S-SE	N-S	N-NW	N-NW	

Source: BMG

2.4 Hydrology

2.4.1 Gauge Stations

There are four gauge stations in the Tondano watershed measuring flow rate and lake water surface. PU measures the flow rate of the Tondano River at Kairagi, about 6km upstream from the river mouth in Manado. PLN measures the inflow to the hydropower plant at Tonsealama. In addition, PLN operates two gauge stations for the lake water surface observation at Toulour, outlet of the lake, and at Telap, middle of the east coast of the lake.

2.4.2 Kind and Period for Available Data

(1) Period for Available Data

Kairagi gauge station measures flow rate of Tondano River, and the record is available from 1985 to 1997 except 1992 and 94. Inlet of the hydropower station at Tonsealama has record from 1996 to 1999, however the discharge of spilled water over the gates is not measured, so that out-flow of the lake are not measured during flood period. While, Toulour gauge station has the record of the water surface from 1980 to 1999, and Telap station has record from 1993 to 1999, however accuracy of the latter is doubtful. Data of above gauge stations are available by weekly or monthly.

(2) Other available flow data in the watershed

Discharge of the in-flowing rivers to Lake Tondano has been measured by Hikmatullah (1996), Molenaar (1999) and BRLKT (1998) as shown in below table and Table C.2.55 through C.2.57. However, since the measurements had done only once by Hikmatullah and BRLKT, and Molenaar measured once a month, no data show continuous flow rate. In the JICA study period, flow rate and TSS (total suspended solid) was measured 4 times at 50 sites as shown in Figure C.2.4 and the data are shown in Table C.2.58.

Measured Discharge of the Rivers into Lake Tondano

	Discharge (m^3/s)		Discharge (m^3/s)
Panasen	0.4514	Wori	0.6258
Ranowelang	0.8544	Karembeng	0.0928
Bowolean	0.3846	Wowolean	0.0637
Toubeke	0.3195	Lelema	0.1102
Tolouroki	0.0773	Tounsukun	0.0262
Serawet	0.0287		

Source: Hikmatullah (1996)

Average Discharge and Catchment Area

No.	Name of River	Catchment Area(km^2)	Discharge (m^3/s)
1	Tombangan	11.25	0.14310
2	Mawalelong	20.25	0.69333
3	Toubeke	13.00	0.02625
4	Saluwangko	22.85	0.09600
5	Panasen	15.25	0.73125
6	Touliangoki	8.19	0.08565

Source: BRLKT (1998)

Monthly Discharge of the Rivers into Lake Tondano

	Discharge(l/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Touliangoki	90	18	23	35	41	111	34	98	60	313	5	23
Toubeke	26	3	88	214	145	82	98	97	74	81	66	24
Tougela	277	15	30	58	87	89	5	6	87	115	59	40
Tounsaru	10	10	4	27	21	144	23	13	87	84	6	4
Tountimomor	1887	676	1003	445	675	1595	924	404	1592	570	706	580
Kakas	953	828	1455	760	763	2839	1273	728	2366	885	1379	403
Remboken	619	699	947	688	779	655	606	541	799	460	938	592

by Molenaar (1999)

2.4.3 In-flow to Lake Tondano

Molenaar measured the flow rate monthly in 7 streams as shown in below table, however, it is not continuous data since those data obtained direct measurement of flow velocity and flow section at the site. Flow rates differ so large by measured timing that the data are not suitable to estimate in-flow to the lake.

Monthly Average Discharge in the River flow into Lake Tondano (m^3/s)

	Area (km^2)	Average Discharge (m^3/s)	Unit Discharge ($m^3/km^2/s$)
Touliangoki	2.25	0.071	0.0321
Toubeke	12.18	0.083	0.0068
Tougela	6.75	0.072	0.0107
Tounsaru	2.70	0.036	0.0134
Tountimomor(Panasen)	62.10	0.921	0.0148
Kakas(Saluwangko)	47.55	1.219	0.0256
Remboken (Mawalelang)	22.50	0.693	0.0307

** Source: Molenaar, Measurement: monthly from Dec. 31, 98 to Nov. 29, 1999*

2.4.4 Out-flow from Lake Tondano

PLN has measured the intake discharge of the hydropower plant throughout a year as shown in Table C.2.59. The measured flow rate is not always same to outlet discharge from the lake since the gate at the intake spills excess water away during high water period. Intake discharge to the hydropower plant in the period of 1986-90 and 1996-99 are tabulated below.

Discharge for Hydropower at Tonsealama (m^3/s)

Year	1986	1987	1988	1989	1990	1996	1997	1998	1999
Discharge (m^3/s)	10.51	11.07	10.33	10.09	9.37	9.90	5.59	5.28	9.48

Source: PLN

Out flow from the lake measured by Molenaar in 1999 shows variation of outflow at

Toulour (See Table C.2.56). The outflow varies from 1.5 m^3/s to 11.2 m^3/s in a year. In 1999, average out flow was 6.42 m^3/sec with maximum outflow of 11.1 m^3/sec in May.

Monthly Discharge of In-flowing River to Lake Tondano (1999)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Toulour	2.73	5.45	1.49	7.52	7.81	11.15	7.68	3.48	9.44	7.80	10.24	2.26	6.42

2.4.5 Turbidity

River water is turbid only after heavy rain and usually clean, however turbidity changes by rivers. After heavy rainfall, turbidity is very high in the rivers in Tikala sub-basin and one tributary Saduan (Karatang) river near Sawangan of Tondano River. Observed supended solid (SS) by the JICA study team is shown in Table C.2.58.

2.4.6 Lake Water Surface Level

The lake water surface changes depending rainfall in the watershed of Lake Tondano. PLN has measured the water surface of the lake as shown in Table C.2.60. The measuring stations are located at Toulour, at the beginning of out-flowing river from the lake and at Telap in the middle of the east shore of the lake. Figure C.2.5 shows change of the water surface of Lake Tondano observed at Toulour from 1980 to 1999. The lake water surface fluctuated from 681.3m ASL of the lowest to 684m ASL of the highest in last 20 years.

Capacity of the lake is approximately 500 million m^3 at the water surface of 683m ASL.

2.4.7 River Flow in Lower Reaches of Tondano River

Discharge of Tondano river is measured only at Kairagi gauge station (see Table C.2.61). Monthly discharge at Kairagi ranged from 5 to 22 m^3/sec in 1985 to 1995 as shown in the following table. Drainage area of the Kairagi station is 467.4km^2, in which the area of the watershed of Lake Tondano occupies 250km^2. Discharge in the rivers in the Lower Tondano Sub-watershed, Klabat Sub-watershed, and Tikala Sub-watershed were measured 4 times during JICA study from March to May. The record is listed in Table C.2.58 and .the measured points area shown in Figure C.2.4.

Monthly Discharge of Tondano River at Kairagi (1985-95)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dis-charge (m^3/s)	16.03	15.96	15.09	15.38	14.82	14.68	14.57	14.80	13.16	13.31	13.97	14.36

Source: PU

2.4.8 Water Balance in the Study Area

In the watershed of Lake Tondano, annual yield of drainage basin is estimated as the table below. The percentage runoff, Q/R, are below 50% except Remboken, however, percentage runoff computed by the outflow at the outlet of Lake Tondano is higher than the percentage runoff into the lake. Even the estimate by the inflow is rough, but the difference of annual yield calculated by in-flow (31%) and out-flow (52%) is too large. It means significant quantity of ground water might flow into the lake directly since the percentage runoff of the rivers passing the paddy rice field is low and several hot springs are gushes out to the lake directly.

Annual Yield of Flow and Rainfall

River	Area (km^2)	Average Flow rate (m^3/s)	Q: Annual Yield (10^6m^3)	R: Rainfall (mm)	Q/R(%)
Remboken	22.6	0.693	21.85	1518	63.7
Saluwangko	47.55	1.219	38.44	2452*	33.0
Panasen	62.1	0.921	29.04	2452*	19.1
Toubeke	12.18	0.083	2.618	1815**	11.8
Tougela	6.75	0.072	2.271	1815**	18.5
Tounsaru	2.70	0.036	1.135	1815**	23.2
Touliangoki	2.25	0.071	2.239	2066***	48.2
Tondano Outlet	199.9	6.419	202.430	1959****	51.7

*Rainfall stations are in: * Noongan, ** Luaan, *** Telap, **** Average of 4 stns.*

In the watershed of Lake Tondano, discharge to the Tonsealama hydropower is considered to be as annual yield of drainage basin. Next table shows percentage yield of the watershed of Lake Tondano computed by total amount of annual rainfall and observed discharge to Tonsealama hydropower station. The percentage yield is estimated 70-76% by the data of 1996 and 99, because the period from the last half of 1997 to the first half of 1998 was extraordinarily drought year. While the yield of Tondano River watershed at Kairagi point is 44.7% or 1,079 mm to 2,413mm annual rainfall by the study of PU.

Yield Rate of Lake Tondano Watershed

Year	Total Amount of Rainfall (MCM)	Intake of Hydropower (MCM)	Yield Rate (%)
1996	448.26	312.21	69.65
1997	219.57	176.29	80.29
1998	391.06	166.51	42.58
1999	391.82	298.96	76.30

2.5 Problems on Available Data

Since the drainage areas of the in-flow streams to the lake are small mostly, runoff occurs in a short time after rainfall. Addition to it, stretch of rainfall area is narrow and rainfall is locally. It means dense arrangement of rainfall and flow rate measuring stations and continuous observation are essential to know the rainfall-runoff relation. In this context, existing data are insufficient to evaluate present hydrological characteristics of the watershed of the Tondano basin.

CHAPTER 3 NATURAL CONDITIONS FOR THE INTENSIVE AREA

3.1 Topography and Geology

3.1.1 Topography

In the phase-2 study, the intensive area is designated in the watershed of Lake Tondano, which is located latitude between 1° 06' and 1° 20' north, and longitude between 124° 45' and 124° 58' east. The total area of the intensive area is counted 11,885 ha out of 25,000 ha of the watershed of Lake Tondano.

The area is characterized volcanic landscapes, which formed geo-morphologically by the occurrence of volcanism. The west and south areas are crowned by younger stratovolcanoes of Quaternary, while eastern part is composed of old volcanic rocks of Tertiary.

The intensive area is divided into three areas by geographical points of view, and the areas are named East area, West area, and South area of Lake Tondano, respectively. Characteristics of the areas are mentioned below.

(1) West Area

The West area situates in the west of Lake Tondano with area of about 49km^2. The major villages in the area are Tataaran, Tonsaru, Paleloan, and Urongo in sub-district Tondano; Leleko, Paslaten, Timu, Sinuian, Kaima, Sandengan, Kasuratan, Tampusu, Parepei, and Pulutan in sub-district Remboken; Passo in sub-district Kakas.

The area is bounded on the west by the mountain ridges including high peaks of volcanoes of Mts. Paketengan (Kasuan), Tampusu, Kasuratan, and Lengkoan. Its east boundary is the shore of Lake Tondano. The lava flow plateaus characterize the surface features. Several lava flows pile up vertically with relative height of 25 to 100m making alternation of wider gentle slopes and narrower steep slopes, which shows the ground form like stairs. Massive rocks of weathered lava are observed at the shoulders of the steep slopes. Gentle slopes have been cultivated, and steep slopes are mostly covered with trees and shrubs. Limited areas around the mountaintops of Tampusu and Lengkoan are designated protection forest areas. Mt. Tampusu is the highest peak in the area with its elevation of 1206m ASL followed with Mt. Lengkoan of 1153m ASL.

The surface feature of the area is alternation of gentle slope and steep slope. On the foot of Mt. Tampusu, gentle slopes have less than 10% gradient, while steep slopes have more than 30 degrees. Slope distribution shows average slope gradient of the area is 19.1%. The slope distribution is shown in Figure C.3.1.

Thirteen rivers originate from western hills of which 10 rivers have drainage area of less than $3km^2$. The biggest river in the area is Mawalelong River with $22.6km^2$ of drainage area, which originated Mt. Tampusu and Mt. Lengkoan. Mawalelong River has perennial flow, while other rivers are considered seasonal flows. The stream channels have been used mostly for irrigation canals or drainage channels in paddy areas.

(2) East Area

The East Area is located at the east of Lake Tondano with its area of about $34km^2$. Major villages are Makalonsouw in sub-district Toulimambot; Touliang Oki, Ranomerut, Tandengan, Eris, Watumea, and Telap in sub-district Eris; Toulimembet, Tasuka, Kaweng, Sendangan, Touliang, Simbel in sub-district Kakas.

The area is bounded on the east by the mountain ridges including the peaks of Mts. Kaluta, Rintis, Kamintong, Lembean, Kaweng, and Tombangan. Its west boundary is the shore of Lake Tondano. The area could be divided into two sub-areas of 'Eris sub-area' bordered on the lake in east and 'Kakas sub-area' extended between Kaweng and Simbel.

The 'Eris sub-area' has narrow width in east and west and long in north and south with the area of about $27km^2$, and high mountains on the east boundary makes the mountain slopes very steep. Relative height between the water surface of the lake and mountain tops ranges 100 to 500m and the east-west width from the boundary to the lake extends 500 to 2500m. The northern half of the sub-area tends to be eroded inherently, because the area is composed of highly weathered tuff breccia and tuff in Miocene. Severe erosion by frequent slope failures and landslides has developed heavily dissected surface features, and minor channels have carried eroded materials, which developed small deltas or fans at their river mouths and they are used as paddy field now. There are four roads crossing the east boundary at the depressions between the high peaks. The slopes are used for secondary forest, clove plantation, and patchy upland farming lands. There are protection forest areas around the Mt. Kaluta and Mt. Kamintong. Mountains on the boundary have elevation of from 730m to 1156m ASL at Mt. Kaluta, which is the highest peak in the area located at the east of Makalonsouw village, followed with Mt. Kamintong at the east of Eris of 1153m ASL. Western boundary in the south of Eris is the lake shore having the elevation of about 683m and that in the north is road having the elevation of about 685m. Slope gradient in the whole East Area is steeper than other areas. Slope distribution shows average slope gradient of the area is 28.8%. While, the 'Eris subarea' has 30% of average slope gradient.

The 'Kakas sub-area' is featured with high peaks with steep slopes of Mts. Kaweng and Tombangan on the east boundary. Its area is about 7km^2. The slopes are used as clove plantations and patchy upland farming lands. There is protection forest area around Mt. Kaweng. Mountain ridges along the boundary have elevation of from 800m to 1000m. The 'Kakas sub-area' has each of average and median slope gradients of 25%. The slope distribution is shown in Figure C.3.1.

Twenty streams originate from the dividing ridges in the East area. The biggest stream in the area is Tounsukun River of its catchment area of 11km^2. However, other rivers are minor with the drainage area of less than 3km^2. The drainage patterns are mostly straight from the steep mountain ridges to the lake. Minor streams in the East area have been used mostly as irrigation canals or drainage channels in paddy areas, and some have changed into drainage ditches in the residential areas.

(3) South Area

The South Area is situated in the southern-most area of the watershed of Lake Tondano with the area of about 35km^2. Major villages are Tonsewer and Touure of the sub-district Tompaso; and Tumaratas, Ampreng, Raringis, Noongan, Wenebetan, Kaayuran Atas, Manembo, and Teep of the sub-district Langoan. About 3/4 of the area belongs to sub-district of Langowan and remained part to Tompaso. The South area is bounded on the south and west by high ridges including the peaks of Mts. Soputan Tua, Manimporok, Maimbeng, Potong, Kawatak, and Sosoan. The lower boundary is roads on the hill-foot. The area could be divided into two sub-areas of 'Soputan sub-area' featured by mountain foot of volcanoes and 'Kawatak sub-area' located at between Noongan and Manenmbo featured by very steep slopes.

The 'Soputan sub-area,' which has the area of about 29km^2, is situated at the southern volcanic mountain area. The sub-area is bounded on the south by the mountains of Mts. Soputan Tua, a volcano situated between Soputan Tua and Manimporok, Manimporok, Maimbeng. Its west boundary is the ridge of undulated hill and north by road from Tonsewer to Wenebetan through spring-line villages of Touure, Tumaratas, Raringis, and Noongan. The sub-area extends toward east from the volcanoes with rather steep slopes in higher elevations to the piedmont plain of gentle slope. The area is covered with various volcanic materials erupted from the volcanoes, which have high infiltration ratio. The area below 1100m is used in the shape of an agroforestry, upland farming with moderate numbers of trees. The altitude of the southern mountains is 1500 to 1650m high and the spring-line villages situate at between 800 and 850m ASL. The slope gradient of the area of above 1000m ranges 20% up to 70% and that of below 1000m is mostly 3 to 15%. Slope distribution of the 'Soputan sub-area' is 23% in average, while the gradient of slopes of the whole South Area is 25% in average. The slope distribution is shown in Figure C.3.1.

The 'Kawatak sub-area' is featured with very steep mountain slopes of Mt. Kaweng and Tombangan on the southern boundary. Width of the area is less than 1km. The slope of Mts. Kawatak and Potong is designated protection forest, which includes extremely steep slopes of more than 100% slope gradient. Around the Kawatak village, they are farming on the slopes of more than 60%. Mountain boundary has elevation of from 730m to 1166m at Mt. Kawatak and lower boundary has elevation of about 700m. The maximum slope gradient in the area reaches 122% and slope distribution of the 'Kawatak sub-area' is 33% in average.

The two major rivers flowing into Lake Tondano originate from the area. Panasen river is the biggest stream with its drainage basin of about $64km^2$ followed with Saluwangko river of $42km^2$ drainage area. The topographical map shows many branch channels of the major rivers; however, they are covered with thick sandy deposit originated from the volcanoes. They have no flow in the section between at the elevation of 800m and 1200m except heavy rainfall periods, consequently. Even such condition, the two major rivers have perennial flows, because there are springs near the lower boundary of the area. The drainage pattern is radial in the upper reaches on the slope of mountains, and becomes sub-parallel in the lower slopes.

3.1.2 Geology

(1) Geologic Formation of the Intensive Area

According to the geological map of North Sulawesi, the intensive area is composed of four main geologic formations, namely Older volcanic rocks (Tmv), Tondano Tuff (QTv), Young volcanic rocks (Qv), and Lacustrine and Fluviatile deposits (Qs).

Older volcanic rocks (Tmv) have a large distribution in the East area of the intensive area. This is formed in Miocene and it is the oldest formation in the region, which is dominantly composed of breccia, lava, and tuff. The breccia is very coarse-grained andesitic composition, locally conglomeratic with intercalation of tuff, sandstone, and claystone. Highly weathered tuff breccia forms mountain ranges of the eastern boundary.

Tondano Tuff (QTv) is the product of voluminous eruption of the caldera formation in Pliocene to mid Quaternary formed semi-circular old Tondano, which is about 30km in diameter. Tondano Tuff is found Passo and Pulutan area in the West area of the intensive area. It is composed of pyroclastic materials, coarse volcanic clastics mainly of andesitic composition with angular to sub-angular components, characterized by abundant of pumice fragment, tuff, lapilli tuff, and breccia. The pyroclastic materials are considered to have originated from paroxysmal eruptions during the formation of Tondano caldera.

Young volcanic rocks (Qv) have the most extensive distribution, mainly in the West and South areas of the intensive area. Andesite volcanism followed the Tondano tuff eruption mainly on the caldera ring fractures, and formed the volcanoes of Soputan, Mahawu, and Lokon. Similar andesitic eruption took place in the center of the caldera forming the Kasuratan and early G. Lengkoan volcanic sequences. The youngest period of activity is again andesitic occurring predominantly on the ring fractures of the Tondano Caldera at Lokon, Empong, Mahawu-Masarang in the north and on Soputan complex in the south. The volcanoes of Empong-Lokon, Mahawu, and Soputan are presently active. The rocks are composed of lava, bomb, lapilli, and ash, which make up the young stratovolcanoes. Lava flows are mainly basaltic and andesite. Addition to it, obsidian flows are found at the Kasuan, Lengkoan, Serapi, and Sempu Mountains.

The Lacustrine and fluviatile deposits (Qs) constitute the plain area surrounding the lake Tondano in the north part and the south. This deposits form as a lacustrine plain in which most of the materials originated from Tondano eruption. This formation is composed of sand, silt, conglomerate, and marl clay.

(2) Geology in Intensive Area

West Area: The area is mostly covered with lava of young volcanic rocks of Quaternary except the area around Pulutan and Passo villages, which is recognized Tondano Tuff of Pliocene. Several layers of lava flows forms specific ground features of alternation of plateau and steep slopes. The top layer is composed of clayey weathered materials with andesite boulders.

East Area: The area is mostly constituted with volcanic rocks in Miocene, which is 7 to 26 million years ago. It is dominantly composed of breccia, lava, and tuff, which are heavily weathered into deep. The ground surface is consisted of clayey weathered tuff or tuff breccia.

South Area: The mountains on the western boundary are young volcanoes of Quaternary, Mt. Soputan and Mt. Manimporok, and sandy volcanic ash originated from the volcanoes covers the area widely. The southeast part of the area, Kaayuran Atas- Kawatak area, is composed with volcanic rocks of Miocene.

3.2 Meteorology

The meteorological station of BMG at Tondano is measuring temperature, humidity, rainfall, wind, etc. Rainfall has been observed at four stations of PLN and Langowan, Kakas and Papakelan by BMG.

3.2.1 Rainfall

Rainfall has recorded regularly at five stations around the intensive area. Below table shows monthly rainfall at five stations. Collected data were since 1990 until 1999 for Tondano and since 1993 to 1999 for others. Monthly rainfall is rather small in February, July, August, September, and October in the area.

Monthly Rainfall in the Watershed of Tondano Lake

(mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Luaan	165.6	131.2	152.9	107.4	203.0	180.8	128.7	83.9	77.1	159.0	196.4	143.0	1,729.0
Telap	149.6	83.6	149.5	156.1	201.6	187.8	130.5	111.5	54.8	136.4	200.7	158.0	1,720.1
Remboken	127.0	77.2	138.8	129.8	164.9	165.3	84.5	49.6	57.4	106.1	182.2	159.6	1,442.4
Noongan	182.7	157.5	224.2	190.1	212.9	246.9	221.2	159.4	107.6	185.6	278.4	197.5	2,364.0
Tondano	156.3	128.1	198.9	143.7	220.1	194.2	124.6	102.4	98.1	162.5	200.2	155.2	1,884.3

Observation period: Tondano (BMG) 1990 – 1999, other stations (PLN) 1993 – 1999

Average annual rainfall record shows higher rainfall at Noongan in the south of the lake and lowest at Remboken in the west of the lake. However, annual rainfall would be almost equal around the lake, except southern mountainous area, judging from the observation of rainfall distribution in the study periods and analysis of rainfall record. Observation showed that the rainfall area moves from northeast to southwest in October to May and it is supposed to be opposite direction in other months by wind direction record. A stretch of rainfall ranges a few kilometers in diameter in usual showers and with its duration of usually 2 to 3 hours. The rainfall intensity of showers is very high in 15 to 30 minutes at the beginning of rainfall and the intensity gradually becomes low.

Rainfall fluctuates very much by year, e.g. 1261mm in 1997 to 2582mm in 1996 at Tondano, 1032mm in 1997 to 2111mm in 1995 at Telap, 1353mm in 1993 to 3678mm in 1995 in Noongan.

Annual Rainfall in the Watershed of Tondano Lake

(mm)

	Tondano	Luaan	Telap	Remboken	Noongan
1990	1719.6	n.a.*	n.a.	n.a.	n.a.
1991	1870.6	n.a.	n.a.	n.a.	n.a.
1992	1495.1	n.a.	n.a.	n.a.	n.a.
1993	1426.2	918.2	1164.6	1549.1	1353.2
1994	1490.9	1526.3	1818.6	1711.7	2028.7
1995	2293.1	2385.9	2111.3	1472.2	3678.4
1996	2582.3	2207.6	1985.5	1815.3	2973.8
1997	1261.7	1048.3	1032.0	819.1	1500.4
1998	1953.9	2201.9	1862.0	1211.4	2560.7
1999	2219.2	1815.4	2066.0	1517.7	2452.1
Average	1831.3	1729.1	1720.0	1442.4	2363.9

*source; Tondano by BMG, others by PLN,   * n.a.; data not available,*

Daily rainfall data are available only at Tondano. Maximum daily rainfall in each month is shown in the following table. Maximum daily rainfall recorded at 112.4mm in January 1995.

Maximum Daily Rainfall at Tondano

(mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Max
1990	36.0	16.0	26.0	15.0	17.0	20.0	10.0	12.0	52.0	20.0	54.0	35.2	54.0
1991	82.0	56.0	44.0	48.0	60.0	32.0	96.0	32.0	4.0	52.0	40.0	35.2	96.0
1992	15.7	21.8	15.5	32.1	87.5	32.2	37.2	10.0	38.1	32.7	66.5	25.0	87.5
1993	26.6	8.6	37.5	52.6	72.0	17.6	28.9	61.5	21.2	79.5	85.3	24.2	85.3
1994	25.8	29.0	83.8	33.7	44.7	29.0	53.5	1.7	0.0	18.0	54.4	27.1	83.8
1995	112.4	20.4	27.5	42.0	54.0	40.5	30.5	75.8	56.0	60.8	33.3	35.7	112.4
1996	52.5	68.3	84.0	42.7	61.3	53.0	31.2	61.6	45.5	56.0	41.3	37.9	84.0
1997	33.9	31.2	13.3	67.7	48.1	1.4	52.9	0.0	3.3	47.7	67.4	31.3	67.7
1998	7.6	13.0	20.5	54.1	29.8	75.1	26.6	23.0	15.4	43.6	52.3	34.5	75.1
1999	44.0	58.0	87.2	28.0	59.5	46.8	17.5	51.7	67.0	32.5	22.1	31.1	87.2

Source: BMG at Tondano

Number of monthly rainy days in Tondano is shown in the following table. Annual number of the rainy days ranges 133 days to 250 days. The months from October to January, and May and June have more rainy days and August and September are less rainy days than another months.

Number of Rainy Days in Tondano

(days)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1990	18	10	18	12	16	12	12	5	8	16	18	16	161
1991	14	14	12	16	17	7	7	5	3	10	12	16	133
1992	12	11	6	4	24	17	14	4	8	18	16	20	154
1993	12	11	6	4	24	17	14	4	8	18	16	20	154
1994	18	14	28	20	16	18	3	3	0	7	20	12	159
1995	19	16	15	15	19	21	20	20	11	19	23	24	222
1996	25	24	22	20	24	26	19	18	10	22	20	20	250
1997	20	23	23	15	11	3	12	0	4	11	13	17	152
1998	17	3	10	18	23	24	28	19	13	22	25	24	226
1999	22	15	22	21	24	20	11	14	13	24	19	15	220
Average	18	14	16	15	20	17	14	9	8	17	18	18	183

Source: BMG

According to the soil loss research in Japan, soil loss from agricultural lands is extremely small quantity when the amount of continuous rainfall is less than 13mm. Applying this research result, the rainy days of less than 13mm rainfall were eliminated. Below table shows the number of rainy days without less than 13mm daily rainfall. Soil loss from the agricultural land could occur about 30 to 60 days in a year.

Number of Days of Probable Erosion

(day)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1990	5	2	3	1	4	6	0	0	6	5	9	6	47
1991	4	2	3	6	7	2	4	2	0	4	4	4	42
1992	1	1	1	1	3	2	3	0	3	7	7	4	33
1993	3	0	2	1	6	1	2	1	2	5	7	1	31
1994	2	3	7	4	6	2	1	0	0	1	5	3	34
1995	4	6	3	3	8	4	2	6	3	6	8	6	59
1996	4	6	4	5	7	3	5	5	4	6	5	5	59
1997	5	4	1	8	3	0	4	0	0	4	3	1	33
1998	0	0	1	3	5	9	5	4	1	6	7	7	48
1999	3	5	8	3	8	7	2	3	3	5	4	4	55
	3.1	2.9	3.3	3.5	5.7	3.6	2.8	2.1	2.2	4.9	5.9	4.1	44.1

3.2.2 Temperature

Mean temperature in Tondano is 22.3°C with 27.1 °C at the maximum temperature and 19 °C at the minimum.

Temperature at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Mean	21.9	22.0	22.2	22.3	22.6	22.5	22.2	22.1	22.3	22.5	22.4	22.5	22.3
Max.	26.6	26.6	27.0	27.6	27.5	26.9	26.5	26.6	27.5	27.9	27.6	27.2	27.1
Min.	18.9	19.1	19.1	18.9	19.4	19.4	19.5	19.0	18.3	18.4	18.9	19.6	19.0

Source: BMG

3.2.3 Relative Humidity

The monthly humidity varies 85 to 91% at Tondano. Average daily sunshine in a year is 7.2 hours at Tondano.

Humidity and Sunshine Duration at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Humidity	90	90	89	89	91	89	88	85	85	89	90	89	89
Sunshine Duration	6.6	6.7	7.1	7.1	6.7	6.8	7.7	8.5	8.8	7.3	6.7	6.0	7.2

Source: BMG

3.2.4 Wind

The average monthly wind velocity varies from 0.6m/sec in November and December to 2.4m/sec in February at Tondano. Dominant wind direction is N to NW from November to April, and S to SE from June to September. October and May are turning points of the wind direction.

Wind Velocity and Direction at Tondano (Observation period 1992-99)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
Wind Velocity	1.7	2.4	1.8	1.3	0.8	1.0	1.5	1.1	0.8	0.6	0.6	1.2	0.8
Wind Directions	N-NW	N-NW	N	N-NW	N-S	S	S	S-SE	S-SE	N-S	N-NW	N-NW	

Source: BMG

3.3 Hydrology

3.3.1 Gauge Stations

PLN is measuring intake discharge to the Tonsealama hydropower plant, which could be regarded as an outlet discharge from the lake. PLN also has made regular observation of the lake water surface at the two gauge stations at Toulour at the outlet of the lake, and at Telap, middle of the east shore of the lake. However, regular or continuous flow records are not available on discharge of the in-flowing rivers to Lake Tondano.

3.3.2 In-flow to the Lake

Although several records of flow rate are available for the rivers flowing into the lake, however, all of them show the flow rate of a moment and not continuous, so that the data are not suitable for estimation of flow rate to the lake.

3.3.3 Out-flow from the lake

Intake discharge of the hydropower plant has been measured at Tonsealama by PLN. There are no continuous flow data into the lake, however annual amount of rainfall could be an indicator of in-flow amount. Annual amount of rainfall was compared with hydropower intake discharge as shown in the below table. Discharge or intake from the lake was more than 70% of annual rainfall except the year 1998 that was affected El Nino. In the period from June to October in 1997 and January to April in 1998, rainfall was extraordinary small.

Annual Rainfall Amount and Intake Discharge to the Hydropower

	Annual Amount of Rainfall (mil. Cum)	Discharge to Tonsealama Hydropower (mil. cum)	(cum/sec)	Percent Runoff (%)
1996	423.470	304.751	9.664	72
1997	218.540	165.567	5.250	76
1998	376.515	156.598	4.966	42
1999	392.561	291.534	9.244	74

Source: PLN

3.4 Soil

3.4.1 Soil Survey

Soil surveys were done by the Center for Soil and Agro-climate Research in Bogor in 1995, and by the Faculty of Agriculture of Sam Ratulangi University of Manado in 1974. In the phase-II study, supplemental soil survey was conducted to research hydrologic soil characteristics and to re-check former soil survey result for watershed management and erosion control purpose.

During Phase-II field study, supplemental soil survey was conducted in the Intensive Area. Since the Intensive Area was divided into 3 areas and each area was thought having specific soil characteristics by its geological condition. The locations of the test pits are distributed equally over the areas as shown in Fig. C.3.2 (2.2.1 “Location Map of Sampling Sites”) and Table C.3.1. Twenty sites was selected for soil survey, where sampling, observing soil profile, and in-situ infiltration tests was done. The dimension of the test pits is 1.0m in depth and area of 1m by 1m in width. Undisturbed and disturbed soil samples were taken at surface, and depth of 33cm, 66cm, and 1m of each test pit. Undisturbed samples were for density and porosity measurement, and disturbed samples were for size distribution, water contents, plasticity, and chemical test.

The soil survey includes following in-situ observation and laboratory tests. In-situ observation includes (a) infiltration rate, and (b) soil profile observation.

Laboratory test includes the tests of soil physical characteristics and chemical characteristics. The physical test includes (a) porosity, (b) density, (c) moisture contents, (d) particle size distribution, (e) plasticity, and (f) specific gravity. The chemical test includes (a) pH test, (b) CEC, (c) total N, (d) carbon content, (e) organic matter content, (f) available P_2O_5, and (g) exchangeable K.

3.4.2 Soil Characteristics

The result of the soil survey showing soil profile, infiltration rate, physical and chemical characteristics of the soil are shown in the Table C.3.2 to C.3.5.

Field observation and the result of the laboratory soil tests indicate soil characteristics are classified into 3 groups matching to the areas, namely south group, east group and west group.

(1) Soil Profile

Typical soil profiles are shown next three tables. In south, soils are sandy and black colored and composed of more than 1m thick volcanic materials, which originated from eruption. Sand content is very high and easy to be transported when runoff formed rills. While in east the soil is clayey and brown or dark brown color, origin of the soil is weathered bedrock materials which is composed of old volcanic rocks, such as tuff and tuff breccia. Because of high clay content, the soil is very sticky. In west, soils are clayey and mostly dark brown colored. Origin of the soil is weathered volcanic rocks mostly. Clay content of the soil is high and it is tolerable to erosion. Soil profile of each site is shown in Table C.3.2.

Typical Soil Profile of South Group

Horizon/Layer	Depth (cm)	Explanation
A	0-30	Color: black (7.5yr 2/1), Structure: Crumb, Size: very fine to medium, Texture: sandy loam, Consistency: very friable to friable, Root condition: dense
C	30-49	Buried horizon; Sandy fraction
I	49-82	Color: brownish black (10yr 2/2), Structure: Crumb, Size: very fine to fine, Texture: sandy loam, Consistency: friable, Root condition: lacked
II	82-97	Color: black (10yr 2/1), Structure: crumb, Size: very fine to fine, Consistency: friable
III	97-100	Color: black (10yr 2/1), Structure: Crumb to blocky, Size: fine to medium, Texture: sandy loam, Consistency: friable

Typical Soil Profile of East Group

Horizon/Layer	Depth (cm)	Explanation
A	0-15	Color: very dark brown (7.5YR 2/3), Structure: blocky Size: fine to medium, Texture: clay, Consistency: friable to firm, Root condition: dense
B	15-77	Color: brownish black (75YR 4/3-4/6), Structure: blocky Size: medium-coarse, Texture: clay, Consistency: friable to firm, Root condition: lacked
BC	77-115	Color: brown (75YR 4/4-4/6), Structure: crumb to blocky Size: fine to medium, Texture: clay, Consistency: friable to firm, sticky, Root condition: lacked

Typical Soil Profile of East Group

Horizon/Layer	Depth (cm)	Explanation
Ap	0-10	Color: brownish black (7.5YR 3/2), Structure: Crumb to blocky, Size: fine to medium, Texture: clay loam, Consistency: friable, Root condition: dense
BA	10-31	Color: dark brown (7.5YR 3/3), Structure: crumb to blocky, Size: medium, Texture: clay, Consistency: friable to firm, sticky, Root condition: lack
B	31-86	Color: brownish black to dark brown (10YR 3/2), Structure: crumb to blocky, Size: medium to coarse, Texture: clay, Consistency: friable to firm, Root condition: lack
BC	86-102	Color: dark brown (7.5YR 3/4), Structure: blocky, Size: fine to medium, Consistency: firm and sticky, Root condition: lack

(2) Infiltration Rate

In filtration rate is very high in the Intensive area. In south, it is more than 20cm/hr in every place because of composed of sandy soils. In east and west, it is also very high though the soil is clayey. The reason is soil structures are mostly blocky and cracks are very much developed in the soil. It is very clear to compare 'Intake Rate' in situ and 'Permeability' in laboratory. Permeability of the soils in south group is higher than that of east and west group. Permeability was measured using container with disturbed soil, which reflects composition of soil. Observed infiltration rate at each site is shown in the Table C.3.3.

Infiltration Rate

	Location	Intake Rate (cm/hr)	Permeability (cm/hr)	Structure	Land use
1	Tonsewer	23.62	5.91	Crumb	Dry farm
2	Tumaratas I	48.00	2.01	Crumb	Dry farm
3	Tumaratas II	27.60	2.78	Loose-Crumb	Shrub
4	Tumaratas III	53.28	2.23	Loose-Crumb	Dry farm
5	Raringis	84.51	2.44	Crumb	Dry farm
6	Noongan	99.17	14.81	Loose-Crumb	Forest
7	Kaayuran Atas	37.85	2.36	Crumb	Grass & Woods
8	Kakas	16.02	1.02	Blocky	Grass & Woods
9	Tumpaan Kaweng	103.44	0.96	Blocky	Dry farm, very dry condition
10	Eris	79.44	0.62	Blocky	Grass & Woods
11	Tandengan	18.36	2.00	Crumb-Blocky	Clove & Grass
12	Touliang Oki	21.66	0.26	Blocky	Woods & Grass
13	Makalonsouw	14.35	0.62	Blocky	Clove & Grass
14	Tataaran	19.38	0.83	Crumb-Blocky	Woods & Grass
15	Parepei	22.68	0.85	Crumb-Blocky	Dry farm
16	Leleko	6.42	0.50	Crumb	Grass
17	Tampusu	2.45	0.27	Crumb-Blocky	Dry farm
18	Paleloan	37.50	0.35	Crumb-Blocky	Grass
19	Pulutan	37.74	0.75	Crumb-Blocky	Woods & Grass
20	Kasuratan	10.70	1.40	Crumb-Blocky	Dry farm

(3) Physical Characteristics

Physical characteristics of the soil were studied by undisturbed and disturbed samples. Porosity, density, moisture contents, particle size distribution, plasticity, and specific gravity are shown in Table C.3.4.

Physical characteristics by groups are shown in following table. Most distinct difference between them is composition (size distribution) of the soil. In the south, sand is more than 75% and clay is less than 10%, while in the east clay content is 50% or more but sand is less than 30% in average. The soil in the west is between above two.

Physical Properties of Each Soil Group

		South		East		West	
		Average	Range	Average	Range	Average	Range
Moisture Content	%	22.54	(20-29)	37.18	(33-39)	32.23	(29-35)
Bulk Density	g/cm^3	1.44	(1.36-1.53)	1.07	(1.02-1.14)	1.20	(1.10-1.32)
Porosity	%	46.57	(42-49)	59.58	(57-62)	54.78	(50-58)
Specific Gravity		2.65		2.65		2.65	
Plasticity Index	%	9.05	(7-10)	21.00	(18-29)	17.00	(13-23)
Coarse Sand	%	70.96	(63-78)	7.96	(4-13)	20.67	(16-28)
Fine Sand	%	5.98	(1-9)	9.80	(4-23)	7.23	(2-11)
Silt	%	14.15	(9-19)	23.71	(10-35)	35.32	(16-45)
Clay	%	8.91	(7-10)	58.53	(46-70)	36.82	(29-55)

(4) Chemical Properties

The items of pH, CEC, total N, organic matter content, available P_2O_5, and exchangeable K were tested. Three samples from different depth were examined. Below table shows average characteristics of top layer soils. Chemical properties at each site is shown in Table C.3.5.

Chemical Properties of Each Soil Group

		South		East		West	
		Average	Range	Average	Range	Average	Range
N-total	%	0.25	(0.2-0.3)	0.27	(0.2-0.3)	0.20	(0.16-0.26)
P-available	Ppm	75.03	(6-154)	16.67	(4-39)	19.36	(4-40)
K-dd	me/100g	0.21	(0.13-0.3)	0.21	(0.12-0.52)	0.43	(0.2-1)
Organic matter	%	2.47	(1-3.9)	3.30	(2.1-4.5)	2.12	(1.6-3.2)
CEC	me/100g	13.68	(12-17)	34.06	(25-52)	25.73	(20-29)
pH H2O (2:1)		6.58	(6.1-6.9)	6.32	(6-6.4)	6.50	(6.1-6.8)
pH KCl (2:1)		5.17	(5-5.3)	4.96	(4.8-5.1)	5.13	(5-5.4)

3.4.3 Soil Type and Its Distribution

Based on the test result of soil survey with referring geomorphology and existing soil map, the soil type was categorized to 10 types especially considering sensitivity to erosion.

- Soil type 1 of alluvial deposit composes the soil in paddy, which occupies small area in the intensive area mostly along the lake.
- Soil type 2, composed of volcanic origin alluvio-colluvium deposit, is found in paddies in the south of the lake, but its distribution is limited in the intensive area.
- Soil type 3 of terrace or piedmont sedimentation is composed of eroded volcanic materials and accumulated at the base of slopes.
- Soil type 4 is composed of Quaternary volcanic ash on piedmont. It is sandy volcanic ash of black color with 2.0 to 2.8% organic contents, and

distributed at the lower slopes of Mt. Soputan.

- Soil type 5 is Quaternary volcanic ash on hill slopes. It is found on the higher slopes of Mt. Soputan and its nature is similar to soil type 4.
- Soil type 6 is Quaternary weathered material of lava flow composed of Andesite and Basalt, which originated from several volcanoes. It is distributed on the west of the lake and formed the ground surface like stairs.
- Soil type 7 is Quaternary weathered material of lava flow composed of Obsidian, which is found only limited area in the West Area. It is originated from Mt. Kasuan.
- Soil type 8 is Quaternary volcanic ash and lava on the steep slopes of volcanic cones, which is found on the steep slopes of young volcanoes, such as Mt. Soputan, Mt. Tampusu, and Mt. Kasuratan and Mt. Lengkoan, which is consisted of volcanic ash or lava.
- Soil type 9 is Pliocene volcanic ash and lava on the steep slopes of volcanic cones, which is found on the minor volcanoes in Passo and Pulutan area in the southern part of the West Area. It originated from old Tondano volcano, which is consisted of weathered pyroclastic materials. It is mainly composed of clayey highly weathered tuff.
- Soil type 10 is highly weathered 'Old volcanic rocks' of Miocene, which constitutes boundary mountain ranges on the eastern side of the lake. It is composed of plastic clayey soils.

Distribution of above mentioned soil groups is shown in the Figure C.3.3.

3.5 Problems on Available Data

Lake Tondano is very important lake in the region, where there is little water source except Lake Tondano. People living around the lake and officers concerned to the watershed of Lake Tondano or Tondano River have said erosion and sedimentation in the watershed and the lake is very severe. Though water resource, and erosion and sedimentation are controversial issues, they have not explained by scientific data. The study team had encountered difficulty on collecting existing data and had question on their accuracy. The study, which started to solve the problems on erosion and sedimentation, needed erosion data, but there were little observed data to show the actual status.

For proper management of the lake and its watershed, collection and analysis of continuous scientific data is very important. For proper management of the Watershed of Tondano Lake, the data on (1) erosion and sedimentation, (2) water quality of the Lake, and (3) water balance of the Lake are necessary.

For example, for an analysis of erosion, rainfall intensity data of 30 minutes or 60 minutes is required for computation. However, rainfall data is 1 to 2 hours interval from 6 a.m. to 6 p.m. and from 6 p.m. to 6 a.m. it is in total.

Intake discharge data of the hydropower station at Tonsealama is available and it is equivalent to the flow rate of outflow from the lake except high flood period. However, the discharge of spilled water over the gates has not measured. Regarding lake water surface, the data from the two stations are different.

There are several records of flow rate of the rivers flowing into the lake, however, all of them show an instant flow rate and not continuous, so that the data are not suitable for estimation of discharge of in-flow into the lake. In the study area, according to the observation, rainfall shows huge difference by places and time and runoff occurs in a short time after rain. Because drainage areas of in-flowing streams to the lake are small and the rain area stretches a few kilometers more or less, which indicates rainfall differs locally. It means that dense arrangement of rainfall and flow rate observation and continuous measurement are essential to know the rainfall-runoff relation. In this context, existing data above are not enough to evaluate present hydrological characteristics of each minor watershed.

CHAPTER 4 NEED OF COMPLETE BASIC DATA

4.1 Present Status

Though Lake Tondano has been given very important role as the biggest water source in the region, scientific data are very limited to explain current situation. The study team had encountered difficulty on collecting existing data and had doubted on their accuracy. During the study period, many people explained how the erosion was severe in the watershed of Lake Tondano, and how the depth of the lake has changed by sedimentation, and the problem of water hyacinth of the lake. However, unfortunately the study team could not obtain the data observed scientific manner. Most of the information was only verbal information.

Ragerding erosion, there have been shown several estimates on the soil loss from the watershed of Tondano Lake by various agencies, but it is a question whether the results of calculation indicate real amount of soil loss or not.

The situation on water quality is better than that of erosion. There are several observation and records about the water quality. Current condition of Lake Tondano is classified as 'eutrophic.' However, the major pollutants are not specified. To improve the water quality of the lake, it is necessary to clarify the major pollutants of eutrophication and to evaluate their contribution to eutrophication.

Lake Tondano is the major water source of the region and every sector, such as hydro power, irrigation, fishery, domestic and industrial use, etc., expects to use the water. However, no agency is collecting data on water balance of the Lake except PLN, which has 4 rainfall gauge stations, 2 lake water surface gauge stations and intake flow of hydropower station. However, it was observed during field survey that the rainfall distribution around the lake is extremely uneven and flow rate of the rivers fluctuates much by time.

Despite Lake Tondano attracts considerable attention on erosion and sedimentation, water quality, and importance of water source, available quantitative and qualitative data collected by scientific procedure on such issues are very limited.

4.2 Need of Basic Data

The JICA Study started to solve the problems on erosion and sedimentation, however there were little observed data showing the fact of erosion and sedimentation to analyze present status. For proper management of the lake and its watershed, collection and analysis of continuous scientific data is very important. For proper management of the Watershed of Tondano Lake, the data on (1) erosion and sedimentation, (2) water quality of the lake, (3) water balance of the lake, are indispensable.

Regarding estimate of erosion or soil loss, usually it is computed by soil loss estimate equations. However, the calculated amount of soil loss is not always show to the actual soil loss amount. To improve accuracy of soil loss estimate, computed value of soil loss must be compared to the observed amount. For this purpose, it is necessary to observe and collect data on soil loss in the area.

Sedimentation is an indicator of the then situation as same as the water quality. The measured value of the sedimentation indicates the result of the effectiveness of the erosion control efforts. Continuous data gathering is important for sedimentation to monitor the watershed condition.

Current condition of Lake Tondano is classified as 'eutrophic.' To improve the condition of the lake, the major pollutant shall be specified and corrective measure could be taken to it. Also continuous monitoring on the water quality is required to keep the lake water clean for sustainable use of lake water.

Lake Tondano is the major water source of the region and used for hydropower, irrigation, fishery, domestic and industrial use, etc. It shall not avoid to compete the limited water source between the sectors. To establish efficient water distribution for the sectors, it is necessary to make clear the water balance of the lake water based on continuous accurate measurement.

To monitor the effect of the conservation work in the watershed of Lake Tondano, it is necessary to collect the data on rainfall distribution, flow rate of inflow and outflow, and lake water surface, since hydrological data explain the result of conservation works.