Appendix-H

EROSION

AND

SEDIMENTATION

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

Volume-III

APPENDIX-H

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APPENDIX-H

SOIL EROSION AND SEDIMENTATION

CHAPTER 1 INTRODUCTION

This 'APPENDIX-H SOIL EROSION AND SEDIMENTATION' describes about the erosion and sedimentation, and flood in the Study Area and the Intensive Area.

In CHAPTER 2, present condition of entire Tondano watershed is mentioned. In Section 2.1, soil erosion including its history, type, causes, soil loss tolerance, soil loss estimate are described and the soil loss is compared with other study results. Sedimentation and properties of accumulated sediment, floods, and water quality including discussion on eutrophication are also described. Countermeasures against erosion hazard, such as soil conservation farming and erosion control facilities are mentioned. In section 2.2, soil erosion control plan is shown. In the section various erosion control measures, such as soil conservation practices, river bed protection and river bank protection works, slopes protection works on hillside and for road are described. Monitoring on hydrology and sedimentation, water quality is suggested.

In CHAPTER 3, feasibility study in the Intensive Area is mentioned. In Section 3.1, present condition of the Intensive Area, such as slope distribution, geology and geomorphology, sheet and gully erosions, slope failures on hillside and along the roads, and river bed and river bank erosions are mentioned, and soil loss was calculated by USLE. Other issues such as sedimentation, flood, and water quality in the Intensive Area also described. Addition to it, existing erosion control facilities, erosion hazard, and existing data are mentioned. Section 3.2 mentions erosion control plan with its basic approach. The plan includes erosion control by non-facility measures on agricultural lands, such as traditional terrace, minimum tillage, no-till, and terrace. Then soil loss is calculated for present condition and improved condition. Erosion control structures for torrents and slopes, erosion control plan for each zone, and monitoring for erosion and sedimentation, water quality, and water balance is proposed with their cost estimate and implementation schedule. In Section 3.3, design of soil erosion control facilities is mentioned. Section 3.4 describes recommendations.

CHAPTER 2 MASTER PLAN STUDY FOR THE STUDY AREA

2.1 Present Condition of Tondano Watershed

2.1.1 Past Studies

BRLKT prepared a master plan in 1986, which called POLA on land rehabilitation and soil conservation for the Tondano Watershed. Several activities on watershed management have been carried out based on the POLA.

POLA indicates that there was severe erosion in the area and the lake suffered from heavy sedimentation. Erosion was estimated 145.515 ton/ha/year using USLE in 1986. The conclusion, however, have to be reviewed, because there has been great change on socio-economic condition which affected land use and farm produce.

BRLKT reported on sediment yield in 1989, which was calculated using 'sediment delivery ratio'. It mentioned sediment yield was 3.78 ton/ha/year from Noongan sub-watershed and 6.76 ton/ha/year from Tondano sub-watershed. Total annual sediment yield to Tondano Lake was reported 107,441 ton/ year, or equivalent 5.41 ton/ha/year.

Department of Public Works (*Pekerjaan Umum, PU*) did a watershed management study in 1995/96, titled 'Technical Planning of Prevention of Sedimentation and Erosion of Tondano Watershed in Minahasa District'. The report mentions three stages of sedimentation, which are production (soil loss by erosion), sediment transport, and deposition. Sedimentation in the lake is the result of these processes. The conclusion is that estimated annual erosion is 8,224,556 ton in total calculated by USLE. Sediment yields of the drainage areas are roughly 400 ton/year from one small river, or 6400 ton/year from 16 small rivers of the drainage area.

Hikmatullah showed soil erosion hazard in the Tondano watershed in his study of "Erosion Hazard assessment in Tondano Lake Catchment North Sulawesi, Indonesia, with respect to its Possible Siltation" in 1994. His study area is until Tonsealama and total area is 26,200 ha. His conclusion is in below table.

Soil Erosion Hazard in the Study Area

Class	Soil Loss (ton/ha/year)	Area (ha)	
Very Low	<5	20,609	(78.7%)
Low	5 – 12	4,060	(15.5%)
Moderate	12-25	1,360	(5.2%)
High	25-60	134	(0.5%)
Very High	>60	37	(0.1%)

2.1.2 Soil Erosion

The study area had been considered that severe erosion in the estates and agricultural lands resulted in heavy sedimentation in Tondano Lake during the period from 1970 to 1990, however, erosion occurs little at present.

2.1.2.1 Erosion as Historical Facts

According to the land use history in the area, the Netherlands East Indies introduced coffee produce in Minahasa in 1820s and it increased very much in 1830s. Its produce was 5,360 liters in 1822. During 1830's, the produce increased every year 201,000 liters. Peak produce was 1,809,000 liters in 1856. In 1862, it decreased to 508,128 iters because of people's protest by non-cooperation with destroying ripe coffee. Land clearing for coffee trees planting might result in severe soil erosion from the hilly areas.

Toward the end of 19th century, cultivation changed into coconut and then Dutch introduced clove in 1890. Clove became popular as an ornamentation plant in 1920, and since 1950 it has been commercial crop. During Japanese occupation from 1942 to 45, a part of clove plantation replaced by maize and cotton, which might lead erosion. Area of clove plantation was 5,538 ha in 1950 and it expanded to 35,805 ha at 1962. Clove was most important cash tree crop in the period of 1972-89. During this period an extensive land clearing or deforestation occurred on the hill slopes around the lake and severe erosion might lead high sediment yield, since the land surface was completely cleared before transplanting of the seedlings and for harvesting in the clove estates according to the people. Because of fallen price of the clove since 1989, the farmers were discouraged to continue clove cultivation that leaded drastic reduction of erosion. Clove plantations exist still, but some are abandoned, and others have been diversified to other crops, such as vanilla, cacao, and inter-cropping with food crops and vegetables.

During the flourished period clove plantation, it is believed that severe erosion resulted in high sediment yield. In Eris on the east shore of Tondano Lake, the lake shore was several meters inside from the present shore line and boats could travel in the Eris river, but it is about 1 m wide concrete lining drain now. Ministry of Forestry constructed a small earthen check dam in the upper reaches of Eris river about 15 years ago for sediment control, but it is understood as a irrigation dam by the local population, since then sediment has piled up in its reservoir. The reservoir area has reduced to about 2/3 of its original area at present. PU constructed the check dam in Touliang Oki River in 1996 based on their estimate of sediment. Though it has a small pond area of about

1,000 m^2, there is a little sedimentation and in-flowing riverbed keeps its original figure after 4 years. It indicates sediment yield is little at present.

Above facts show that erosion was very severe before 1990 during clove cultivation boom.

2.1.2.2 Possible Type of Erosion

There are several types of erosion not only soil loss on agricultural lands and forestlands but also slope failure along the rivers, roads, on the hill-slopes and scouring in the rivers, etc. Here, type of erosion is categorized as following by its origin.

Type of Erosion

Point source:	Riverbed erosion (degradation) River bank erosion (slope failure/landslide/mass movement) Road slope erosion (slope failure/landslide/mass movement) Slope failure/landslide/mass movement on hill slope
Non-point source:	Soil loss from agricultural lands and forestlands

2.1.2.3 Possible Causes of Erosion Hazard

(1) Potential Debris Flow and Riverbed Erosion

Though bed degradation proceeds always by stream flow, hazardous riverbed erosion (degradation) comes into view usually only by debris flow.

Major factor affecting occurrence of a debris flow is the slope gradient of the riverbed, because other factors, such as size of bed materials, area of drainage basin, rainfall intensity are expected almost similar in a limited area. Debris flow occurs where unstable deposit accumulated on the riverbed that exceeds 25% slope.

Riverbed erosion tends to occur in the upper reaches of the streams where unstable deposits accumulated on the riverbed. Riverbed erosion could be accelerated when the riverbed slope is more than 25%.

(2) Slope Failure Possibility

In the study area, minor scale landslides have been observed. Minor slope failures are also observed on the slopes steeper than 40 degrees in the east side of the lake. It means the study area have chance of occurrence of landslide or mass movement unexpectedly. On the other hand, minor slope failure could occur between Makalonsouw and Eris because of highly weathered weak rocks.

1) River Bank

Most river bank in the upper reaches seem to be stable, since the weak foundation rocks have been eroded deeply and unstable soil layer remains little on the riverbanks.

In the lower reaches of the streams, the riverbanks could collapse when the riverbed is scoured deeply. Therefore, occurrence of riverbed erosion could be a trigger of riverbank slope failure. Lower reaches of the rivers in Noongan sub-basin and those on the hill foot of Mt. Klabat have been eroded, since the alluvial deposition with gentle bed slope is consisted of sandy volcanic soils. Dimension of the bank failures in these small rivers is 10-20 m^3 at one occasion or 2-4 m high with 5-10 m long at the maximum.

2) Cut slopes along the road

There are many cut slopes along the roads of less than 6 m high in the mountainous area. Cut slopes are very steep slope usually. However, slope failures were observed only on the slopes around Mt. Mahawu. Most slope failures occurred where the land above the slopes were used for crop farming, where farmers made low ridges along the shoulder of the cut slope. Observed slope failure is shown in following table. Only 5 sections of failed slope affected traffic, but it could be removed by labor work.

Number of Slope Failed Section along the Road

Section	Height of failed slope		
	H>4 m	2-4 m	<2 m
Rurukan-Sumalangka	3	5	4
Sumalangka-Rumengkor	11	12	13

Note: length is 1 to 30 m

3) Hillside Slopes

Hillside slope failures were observed several sites on the slope of more than 40 degrees, where the slopes are composed of highly weathered tuff breccia. In the study, since detailed land configuration was measured on the 1:50,000 topographical map, the place of potential slope failure could not be pinpointed.

4) Soil Erosion from Agricultural Lands

Agricultural lands need careful soil conservation measures where the slope exceeds 25%. Therefore, very careful soil erosion control measures have to be prepared in the agricultural lands more than 25% slope.

Based on above discussion, critical slope gradients are tabulated below by typical erosion hazard type.

Critical Slope to Erosion Occurrence

Erosion of non-point source (spread land)	Such as agricultural lands, forestlands, etc.	More than 25%
Erosion of non-point source (linear source)	Rivers bed/ bank erosion in Noongan sub-basin, Klabat sub-basin	less than 5% (in meandered sections)
	Slope failure along roads	More than 25%
Erosion of point source	Slope failure/landslide	More than 45%

2.1.2.4 Soil Loss Tolerance

Soil loss tolerance (SLT) or permissible soil loss is defined as the maximum level of soil erosion that will permit a high level of crop productivity to be maintained economically and indefinitely. The soil loss tolerance varies with soil types.

SLT is a judging standard of soil loss. If the soil loss is less than or equal to SLT, the soil loss can still be accepted. However, if the soil loss is more than SLT, measurements to reduce the soil loss should be taken into consideration until a level of equal or less than the soil loss tolerance has been reached.

Wischmeier and Smith (1978) mentioned that in determining soil loss tolerance one should consider the following aspects: (a) thickness of top soil, (b) soil physical properties, (c) controlling gully erosion, (d) decrease organic matter, and (e) nutrient loss.

Hammer (1981) proposed an equation to predict soil loss tolerance based on equivalent soil depth and expected resource life period:

STL = (Ed/RL)

Where, Ed: equivalent soil depth, and
RL: resource life (generally about 300 to 1000 years)

Wood and Dent (1983) proposed another equation to estimate TSL by considering minimum depth and rate of soil formation. Arsyd (1989) mentioned that the rate of soil formation in humid tropic was estimated twice as high than in the temperate regions. Therefore, the soil loss tolerance in humus tropic should be higher than in the temperate region. Thompson (1957) proposed the tolerable soil loss in the USA ranged from 1.1 to 1.35 mm/year. Browning et. al. (1985) suggested that soil loss tolerance ranged from as low as 4.5 ton/ha/year on soil with restrictive layer to as high as 13.5 ton/ha/year on soils with deep root zone. Arsyd (1989) proposed a guideline shown in the following table to determine soil loss tolerance for Indonesian soils, where the magnitude is greater than that in the United States.

Guide for Determining Tolerable Soil Loss for Indonesian Soils (Arsyd, 1989)

No.	Soil properties and substratum	TSL	
		(mm/yr)	(ton/ha/yr)
1	Very shallow soil overlying rock	0	0
2	Shallow soil overlying rock	no data	
3	Very shallow soil overlying weathered rock (unconsolidated)	0.4	5.2
4	Deep soil overlying rock	no data	
5	Shallow soil overlying weathered rock	0.8	10.4
6	Moderately deep soil overlying weathered rock	1.2	15.6
7	Deep soil with impermeable subsoil overlying weathered substrata	1.4	18.2
8	Deep soil with low permeable subsoil overlying weathered substrata	1.6	20.8
9	Deep soil with moderate permeable subsoil overlying weathered substrata	2.0	26
10	Deep soil with permeable subsoil overlying weathered substrata	2.5	32.5

Hikmatullah gave soil loss tolerance to Tondano watershed as below table. On the other hand, BRLKT indicates the tolerable soil loss 13.5 ton/ha/year.

Soil Loss Tolerance

Class	Soil loss (ton/ha/year)
Very low	<5
Low	5-12
Moderate	12-25
High	25-60
Very high	>60

2.1.2.5 Potential Erosion Hazard

Potential erosion hazard area is specified based on the criteria discussed previous sections. Potential erosion maps were prepared for potential hazard by debris flow, riverbed and river bank erosion, slope failures on hillside and alond roads, and soil erosion from agricultural lands. In the study, overlapped area of all the maps above was determined 'Potential Hazard Area', shown in Figure H.2.1, confirmed through the field observation. Since the study area has similar rainfall intensity and belongs to a few kinds of similar geological composition, potential erosion hazard depends upon the slope of the site.

2.1.3 Preliminary Estimate of Soil Loss

2.1.3.1 Method

Soil loss in the area is estimated by USLE (Universal Soil Loss Equation). The equation is expressed as following.

$$A = R\ K\ L\ S\ C\ P$$

Where A: computed soil loss per unit area per year (ton/ha/year)

R: rainfall and runoff factor

K: soil erodibility factor
L: slope length factor
S: slope steepness factor
C: cover and management factor
P: support practice factor

For computing soil loss, the study area was divided into 2754 elements with the size of 465 x 465 m^2. Above factors in USLE for each element was determined by the method mentioned below.

2.1.3.2 Determination of each Factor

(1) R-factor

R factor was estimated based on the rainfall distribution in the study area. Data were selected considering observation period, continuity of data, and distribution of the stations. Kayuwatu, Airmadidi, Tondano, Remboken, Telap, and Noongan stations were selected finally.

R factor in the area was calculated using Lenvain formula shown below, which is used where the 30-min rainfall intensity data is not available.

$$Rm = 2.21 \times (Rain)^{1.36}$$

Where, Rm: monthly rainfall erosivity
Rain: monthly rainfall in cm

(2) K-factor

The values of K-factor depend on the characteristics of soil. In the study area, soils derived from volcanic ash are characterized by a number of unique properties related to the presence of amorphous materials, and are classified as Andisols, whereas soils derived from lava flows have a finer texture and are classified as Mollisols and Alfisols.

K-factor was determined referring existing soil maps. They are

(a) Semi-detailed Soil Map (scale 1:50,000), Danau Tondano Area, North Sulawesi Province, Center for Soil and Agro-climate Research, BOGOR, 1995. This map covers the area of N 1^{O} 8.5' to, and E 124^{O} 46' to 124^{O} 09'. The coverage is only a part of the study area.
(b) Soil Map of Minahasa, Faculty of Agriculture, University of Sam Ratulangi, Manado, 1974. Covering Whole area of Kabupaten Minahasa, scale 1: 250,000.
(c) Soil Map of Watershed of Tondano, Sub Balai RLKT Tondano di Tomohon, 1998/1999.

(3) S-factor

S factor was determined by slope gradient. It is measured by counting the number of contour lines on the 1:50,000 scale topographical map in each element, which has side length of 465 m each on latitude and longitude direction. Slope was calculated by dividing side length by the number of contour line in each element.

(4) L- factor

L factor is determined by 1:50,000 topo-map and confirmed by the field observation. Procedure to determine L factor is explained in Attachment-H.1, and slope length by land use is tabulated as following.

Slope Length

Item No.	Land Use/Crops	Slope Length (m)
1	Irrigated rice	40.0
4	Maize	1.0
19	Vegetables	1.0
44	Estate with good cover	40.9
47	Secondary forest	58.0
48	Natural forest	58.0
90	Estate-vegetable mixed area	20.9
91	Estate-crops mixed area	20.9
99	Urban area	25.0
999	Wetland	50.0

(5) C-factor

C-factor is determined based on the recommended values with some modification by field observation. Procedure to determine C factor is described in Attachment H.1. Applied values of C factors for soil loss calculation are shown in the table in next page.

(6) P factor

P factors used in the calculation are tabulated in the table below. Detail of procedure to select P factor is mentioned in Attachment H.1.

C and P factors

No.	Vegetation	C factor	P factor
1	Irrigated rice	0.01	0.04
4	Maize	0.245	0.15
19	Vegetables	0.7	0.15
44	Estate crops with good cover	0.027	0.745
47	Forest with sparse cover	0.005	1.0
48	Forest with good cover]	0.001	1.0
90	Estate-vegetable mixture	0.364	0.448
91	Estate-maize-peanut mixture	0.136	0.448
99	Urban area	0.18	0.15
999	Wetland	0.01	1.0

2.1.3.3 Soil Loss Estimate

Soil loss in the study area is shown by sub-basins basis. Each sub-basin has about 10 km^2 area. The result is shown in Figure H.2.2. The amount of soil loss from each sub-basin is shown in the table in next page. Erosion from Tikala basin is highest in the study area followed by Tondano river basin, that is below Tonsealama hydropower intake, and the average soil loss of the total study area is estimated 24.24 ton/ha/year.

2.1.3.4 Critical and Potential Critical Land

Judging from the computation of soil loss and field observation, there is no critical land, except very minor scale farmland on the steep slopes. However, there are potential critical lands in the Study Area, according to the soil loss calculation.

Based on the sub-basin basis analysis, soil loss from Noongan Basin is lowest among 6 sub-basins followed by Tondano Lake West Basin. However, Tondano River Basin and Tikala Basin in the middle and northern part of the Study Area are eroded severely. Some of the basin of minor tributaries shows soil loss amount of more than 40 ton/ha/year. Such areas need careful soil conservation in agricultural land. Distribution of potential critical lands is shown in the Figure H.2.2.

2.1.3.5 Comparison with other Soil Loss Estimates

In this study, average soil loss in the study area estimated 24.24 ton/ha/year. On the other hand, BRLKT reported soil loss in the area 145.52 ton/ha/year in 1986, which reflects then situation amid of clove boom. The study by Ministry of Public Works, which was for the check dam construction, showed very high value of soil loss of 235 ton/ha/year in 1995, since they might simply apply recommended values of the factors for USLE. Soil loss estimated by Hikmatullah’s study in 1996 was roughly 4.6 ton/ha/year, which is based on accurate soil survey including soil infiltration rate of the soil layers.

The difference between each calculation reflects then condition of the watershed when computation was done and the values of the factors for the equation. Especially computed amount of soil loss depends on the accuracy on the factors of slope length (L), cover and management (C), and support practice (P). Selection of the values of each factor has to be based on careful observation of the site condition.

Estimated Erosion by Sub-Basin

	Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)
Noongan Basin							
1	19.79	2	16.95	3	5.16	4	8.52
5	13.22	6	16.60	7	12.70	8	11.76
9	5.93						
Average							**11.55**
Tondano Lake Basin-West							
11	14.03	12	17.17	13	14.44	14	20.77
15	9.19	16	27.09				
Average							**18.11**
Tondano Lake Basin-East							
21	14.06	22	19.04	23	20.27	24	23.44
25	21.55						
Average							**20.37**
Tondano River Basin							
31	24.05	32	16.19	33	24.75	34	14.22
35	18.23	36	34.38	37	27.44	38	40.14
39	87.61	40	34.22	41	34.49	42	31.28
43	18.42	44	13.49	45	28.47	46	12.96
Average							**30.30**
Tikala Basin							
51	21.29	52	45.59	53	43.52	54	25.59
55	29.75	56	31.78	57	25.03	58	37.10
59	20.75	60	46.73	61	76.63	62	33.19
Average							**34.01**
Klabat Basin							
71	38.74	72	33.30	73	15.75	74	19.15
75	19.85	76	14.15				
Average							**23.80**
Total Area							**24.24**

2.1.4 Analysis of Sediment Transport

Since sedimentation is the result of erosion, higher soil loss or erosion may results heavier sedimentation generally. However, eroded materials do not always go to the streams or lakes directly. Most parts of the eroded material remain on the ground surface caught by vegetation filters or settled in the depressions during transport. Even erosion is very severe and the runoff water from the plot contains very high concentration of eroded materials, the water drained from the area could contain a little eroded material if the eroded plot is surrounded by moderate vegetation belt having filtering ability.

Sediment yield, which is directly related to the amount of sedimentation, is the product from a specified area to the stream or lake. Sediment yield depends on the ground relief and vegetation on the traveling route of runoff water. Several studies have been done to estimate sediment in the lake.

BRLKT estimated annual sedimentation based on calculation of erosion by USLE and sediment yield using sediment delivery ratio. The result was 107,441 ton of annual total sediment yields to Tondano Lake.

PU estimated sediment by stream discharge and sediment concentration measurement. Annual sediment yield into the lake is shown about 6,400 ton from 16 rivers, which are not specified.

Hikmatullah (1996) studied the stream discharge and sediment concentration in the Tondano watershed in order to obtain a sediment discharge entering the lake. He calculated sediment discharge as shown in the below table based on the assumption that three major streams of Panasen, Ranowelang, and Bowolean have permanent flow, and other streams are dried up 6 months in a year. He used the following formula to estimate sediment discharge.

$$Q = C \times Qw$$

Where, Qs: suspended sediment discharge (g/l)
C: suspended sediment (mg/l)
Qw: stream discharge (m^3/s)

The result is presented in below table. Daily suspended load entering the lake is about 26.75 ton/day in wet season and 15.13 ton/day in dry season. Total suspended load in a year is estimated 7,538 ton.

Stream Discharge and Suspended Sediment in Tondano Catchment

Stream	Discharge (m^3/s)	Suspended Sediment (mg/l)	Sediment discharge (ton/day)	
			in wet season	in dry season
Panasen	0.4514	119	4.64	4.64
Wori	0.6258	116	6.27	-
Ranowelang	0.8544	76	5.61	5.61
Karembeng	0.0928	93	0.75	-
Bowolean	0.3846	147	4.88	4.88
Wowolean	0.0637	100	0.55	-
Toubeke	0.3195	93	2.57	-
Lelema	0.1102	79	0.75	-
Toulouroki	0.773	100	0.67	-
Tounsukun	0.0262	12	0.03	-
Serawet	0.0287	12	0.03	-
Total			26.75	15.13

Molenaar observed discharge and suspended sediment in 7 rivers throughout the year in 1999. His result is shown following table.

Annual Sediment Load (Wash load)

River	Monthly Average (ton/month)	Total Annual (ton/year)	Annual Sediment Yield (ton/km^2/year)
Toulour	10.39	3790.95	
Touliang Oki	0.30	108.50	48.2
Toubeke	1.28	468.84	38.5
Tougela	0.57	207.72	30.8
Tounsaru	0.24	89.09	33.0
Tountimomor	5.63	2055.90	33.1
Kakas	5.11	1866.02	39.2
Panasen U/S	1.08	395.89	
Ranoweleng U/S	4.99	1822.48	
Remboken	2.45	892.58	39.5

Using his observation, average annual sediment yield is estimated 37.5 ton/km^2/year. Total sediment yield from the drainage area of Tondano Lake is calculated 7,441 ton/ year.

Above calculations, except by BRLKT, gives similar quantity of sediment yield from the drainage basin of Tondano Lake by different analysis and measurement. However, the analysis is based on the measured suspended solid, which is considered wash load. It means the sediment yield calculated above shows a part of sediment transport, and suspended load and bed load are not included in the analysis. Quantity of the total sediment into the lake must be higher than above values consequently.

In above studies, BRLKT's result is extremely high compared with three other results. The reasons are BRLKT used different methodology and year of the study done was quite different. BRLKT's result is based on only calculation and done in 1980' and other three studies are based on direct measurement of sediment after 1995.

2.1.5 Sedimentation

2.1.5.1 Sediment Accumulation

Since the sediment by wash load is consisted of fine particles, it might settle on the places far from the shore. On the contrary, bed load and sediment load must deposit near the mouth of the rivers since they are consisted of rather coarse materials.

Delta has developed at the river mouth of Panasen rivers in the south of Tondano Lake. It is composed mainly sandy materials of bed load and sediment load transported by flow.

On the other hand, as shown in previous section, sediment yield composed mainly of wash load estimated 6,400 to 7,538 ton. Annual accumulation of the sediment on the lake bottom is estimated approximately 0.1 mm thick with the assumption of the density of accumulated sediment 1.2 on the bottom of the lake.

2.1.5.2 Bathymetry of the Lake

Sounding of the lake to get the depth and capacity of the lake has been done by the current study (April 2000), PLN (1994), and PU (1996). The data show approximately same result about the depth and capacity.

2.1.5.3 Sediment Properties

Hikmatullah reported some properties of the bottom sediment in Lake Tondano. In a shallow places, sand is contained more than 27% and clay contents is less than 42% while in a deep places sand is less than 7% and clay contents exceeds more than 61%. The bottom sediment has 3 to 7% of organic matter. The pH ranges between 3.1 and 6.4. It is as shown next table.

Some Properties of lake Bottom Sediment of Lake Tondano

Location	Depth (m)	Org-C (%)	Sand (%)	Silt (%)	Clay (%)	pH	EC (mmhos/cm)
Tonsaru (1)	6	5.7	7	20	73	6.4	1.18
Tonsaru (2)	9	3.24	33	25	42	5.7	0.56
Tandengan	5	7.62	5	34	61	4.7	1.55
Urongo	14	7.31	5	31	64	5.0	1.45
Toulimembet	19	6.02	2	23	75	3.1	2.09
Toulimembet	12	4.22	27	38	35	5.7	0.94
Kakas	14	6.90	6	29	69	3.6	1.99
Kaweng	10	3.89	40	31	29	5.1	1.14
Kaweng	20	5.51	-	-	-	-	-
Kaweng	11	2.72	40	25	35	5.8	0.35
Watumea	13	7.25	4	30	66	5.8	-
Outlet	2.5	9.76	16	27	57	7.0	0.37
Toulour	3	4.93	12	21	67	7.3	0.34

2.1.6 Floods

2.1.6.1 Around Lake Tondano

Flooding occurs in Tondano town and paddy areas around the lake, which are located in the north of the lake and the areas are prone to inundate during high water surface period. The paddy areas along the small rivers in the south of the lake also flood prone area.

In the north of Tondano Lake, inundated area is flat area along the north shore of the lake. Since the area originated lacustrine deposit, the ground surface is close to the lake water level and the slope of the ground in the north of the lake is 1/900 to 1/2,400. On the other hand, slope of the bottom of the lake is 1/300 in northwest part and 1/130 in northeast part. Therefore, the heightened lake water level makes wide area inundated. The lake water surface has varied between 681.5 m to 684 m ASL in the last two decades. Because of the flood, people living the area in the north of the lake are suffering from difficulty of getting clean water, access, and mal-hygiene.

The paddy areas along the small rivers in the south of the lake also flood prone area, especially Noongan sub-basin, are inundated areas, but the flooding area is limited. Major cause of flooding in Noongan sub-basin is raised riverbed by sedimentation in the intake weir pond and narrowed flow sections by the bridges.

2.1.6.2 Lower Reaches of Tondano River

In Tondano River basin, the channels meander and make bottlenecks in its lower reaches. Flood flows in rainy season tend to be choked at the narrow gorges and inundate the lowlands.

According to 'North Sulawesi Water Resources Management Plan', there was extensive flooding in Manado city in 1996; the depth of flooding was over two meters in some areas. Floodwater receded after about tree days. Flooding caused considerable damage to property and disrupted life in the city. Three kotamadya Manado are subject to flooding: Malalayang, Wenang, and Sario.

In the field observation in the lowland in Manado, the flood mark indicated water level about 1 m higher than the terrace level where people live near the Kairagi bridge.

The lowland along the river had been left as flood prone areas in past. However, recent development of Manado city results concentration of population to the city area and creates shortage of safe residential areas. People gathered to the urban area build houses in the flood prone areas as mentioned above, consequently. Most flood damages in the lower reaches of Tondano River basin is a result of uncontrolled expansion of residential areas.

2.1.7 Water Quality of Lake Tondano

Users including domestic, industrial, and irrigation are dependent on an adequate water supply of usable quality. However, concerns on water quality are often neglected whenever good quality water is supplied sufficiently. Water quality in Lake Tondano is still good, but it will change in the near future by the development and increase of population around the lake.

2.1.7.1 Past Studies

Several studies have been done to analyze water quality. In 1979, Ecological survey of Tondano Lake had done by Dr. Mohamad Soerjani et. al. The result is shown in the table below.

Tondano Lake Ecological Survey (Mohamad Soerjani et.al., 1979)

Item	Measured	Tolerable value
PH	6.8 – 8.7	6.5 – 8.5/5 – 9
DO (ppm)	7.3 – 8.2	5 – 6 optimum
Temperature (°C)	25 – 27	
Clearness (m)	1.5 – 2.5	
EC (mmho/cm)	205 – 223	1500
TSS	137 – 341	400
Alkaline (mg/l $CaCO_3$)	77 – 159	<400
Water hardness (mg/l $CaCO_3$)	55 –93	61 – 120
Ca (ppm)	32.9 – 49.8	25
Phosphate (mg/l)	in good condition	0.051 – 0.1
Nitrogen (mg/l)	0.16 – 0.17	<1.5
S (mg/l)	0.19 – 0.61	

Whitten et. al. (1987) reported chemical composition of surface water of the lake, which is shown in the table below. The result of Whitten et.al. shows the contents of nitrogen and phosphate separately, by NO_3 and NH_3, and by PO_4 and OrP, respectively.

Water Quality (Whitten, 1987)

TSS	PH	BOD	$CaCO_3$	SO_4	SO_3	SiO_2	PO_4	OrP	N-NO_3	N-NH_3	Ca
1.45-2.05	6.3-7.5	0.7-1.9	55.68	0.19-0.61	11.5-18.3	0.2-0.7	0.04-0.1	0.05-0.08	0.33-0.48	0.16-0.17	32.9-37.9

All values are in ppm, except pH, Orp: Orthophosphate,

In 1995, Fishery department studied ecological status of Tondano Lake. They took samples from 15 points in the lake. The result is shown in next table.

Water Quality of Tondano Lake (Fishery Department, 1995)

Ortho P mg/l	N-NO_3 mg/l	N-NH_3 mg/l	SO_4 mg/l	EC mmho/cm	Clearness (m)	DO Mg/l	Temp °C
0.15	0.70	0.22	10.92	0.27	2	6.2	26.0
0.06	0.42	0.12	0.34	0.22	3	5.6	25.8
0.14	0.56	0.24	0.45	0.23	3	6.8	24.9
0.52	0.45	0.17	0.74	0.22	2	8.0	25.0
0.45	0.54	0.18	0.66	0.24	2	8.8	25.8
1.20	1.20	0.86	0.86	0.22	2	8.0	24.7
0.82	0.46	0.22	0.36	0.22	3	7.3	24.7
2.84	2.46	1.12	0.34	0.22	3	7.4	24.6
3.90	5.60	1.28	0.45	0.24	3	7.4	24.8
0.94	0.62	0.24	0.65	0.22	3	8.6	25.0
1.67	1.82	0.68	0.34	0.22	3	8.6	25.0
2.20	4.00	0.98	0.23	0.23	2	6.5	25.0
0.34	0.42	0.45	0.34	0.22	2	4.4	25.0
0.23	0.34	0.22	0.12	0.22	2	7.3	24.9
0.45	0.65	0.34	15.2	0.26	2	4.5	25.8

Hikmatullah (1996) reported chemical composition of several rivers flowing into the lake, outlet of the lake, and intake of power station as shown in the below table. According to his report, all samples showed similar properties. The electrical conductivity is lower than 4 mmhos/cm. Ca, Mg, and Na dominate the content of cations, while carbonate and chloride dominate anions. Phosphate and sulphate are low. The pH is neutral to slightly alkaline, as an indication of higher content of bases. Relatively higher nutrients can stimulate growth of aquatic plants in the lake.

Chemical Composition of Water Samples

Location	EC	PH	NH_4	K	Ca	Mg	Na	Fe	NO_3	PO_4	SO_4	Cl	HCO_3
Panasen	0.37	7.4	0.02	0.11	1.21	0.93	0.79	0	0.03	0	0.5	0.52	2.48
Bowolean	0.43	7.2	0.02	0.2	1.0	0.6	1.79	0.01	0.04	0.01	0.69	0.78	2.44
Ranowelan	0.23	7.4	0.02	0.06	0.88	0.78	0.32	0	0.03	0	0.02	0.16	2
Toubeke	0.39	7.1	0.02	0.19	1.25	0.9	0.85	0	0.08	0.01	0.52	0.76	2.28
Outlet	0.27	7.7	0.01	0.08	0.56	0.65	0.85	0	0.01	0	0.25	0.5	1.72
E. Power	0.28	7.2	0.02	0.09	0.6	0.68	0.82	0	0.02	0	0.22	0.54	1.88

All values are in me per liter except EC and pH.

In 1998-99 annual report of BRLKT, they reported water quality of the lake, but it is not clear when they took the water sample. The report says the average water temperature at the depth of 1.5-2.5 m is in the range of 25-27^oC and it is 31-48 ^oC in the areas close to the thermal springs. It reported that lake condition was declining from oligotrophic to eutrophic based on increase of turbidity, salinity, electro-conductivity, nitrate, phosphate, and calcium. BRLKT result on water quality is shown in next table.

Water Quality (by BRLKT, 1998)

Temperature ^OC	Turbidity	Fe Mg/l	pH	DO mg/l	BOD mg/l	COD mg/l	Cl mg/l	Ca mg/l	Na mg/l
27.0	1.0	0.038	7.33	5.71	5.21	26.66	0.01	23.3	14.96

In the JICA study, water quality test had been done for in-flowing rivers and lake. The samples were taken from the points shown in Figure H.2.3. The results of water quality test are shown in Table H.2.1. Tested items for lake water are water temperature, turbidity, pH, total suspended solid (TSS), dissolved oxygen (DO), biological oxygen demands (BOD), chemical oxygen demands (COD), total nitrogen (T-N), and total phosphorus (T-P). For river water, item is only suspended solid (SS). Fifty water samples were taken each from the lake and from the rivers.

Test results of the lake water are tabulated in following table.

Water Quality (JICA Study, March 2000)

	Temperature ^OC	Turbidity	TSS mg/l	pH	DO mg/l	BOD mg/l	COD Mg/l	Total N Mg/l	Total P mg/l
Max	27.0	4.72	8.2	7.78	6.7	22.1	36.6	3.81	3.99
Ave	26.1	2.86	3.9	7.42	5.9	12.0	20.1	2.54	2.47
Min	25.0	2.00	1.1	6.37	5.1	4.7	13.2	1.11	0.66

Regarding COD, it is 20.1 mg/l now, 26.66 mg/l in 1998. BOD is 122.0 mg/l in March 2000, 5.21 mg/l in1998, and 0.7 to 1.9 mg/l in 1987. Turbidity and TSS are 2.86 and 3.9 mg/l, respectively at present. Total N is 2.54 (1.11 to 3.81) mg/l and Total P is 2.48 (0.66 to 3.99) mg/l at present.

Though the above values vary with quantity of in-flowing water, above data shows that water quality of the lake is deteriorating. The causes are supposed such as domestic waste water, fish culturing, pesticide and fertilizer, eroded organic soil, etc., however it is difficult to specify dominant pollutant at present.

2.1.7.2 Eutrophication

(1) Eutrophication processes

Eutrophication is defined as the nutrient enrichment of a water body which results in the stimulation of an array of symptomatic changes, among which increased production of algae and macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and to interfere with water use. A lake or reservoir receives inflow of water from its surrounding drainage basin along with materials carried in the water from the land surface. The water quality and ecosystem in the lake therefore, reflect the cumulative impacts of all the water and material in-flow into the lake.

It is generally accepted that aquatic macrophytes can play a significant role in the eutrophication of a lake. With no human interference, the growth of aquatic plants in the lake is usually minimal, and termed natural eutrophication. However, human settlement and the associated change, can increase the input of plant nutrient such as phosphor and nitrogen into the lake and stimulate aquatic plant growth and subsequently stimulate growth of fish and other organisms, and termed cultural eutrophication.

Excessive aquatic plant growth can interfere significantly with the use of aesthetic quality of water body, e.g. taste and odor problems of drinking water, health effects, etc. Sembel reported that as aquatic plant population dies and sinks to the bottom of the water body, their decay by bacteria could reduce oxygen concentration, which are too low to support fish life. Oxygen deficient condition can also result in excessive level of Fe and Mn in the water, which can interfere with drinking water. Besides these negative effects, eutrophication has its positive aspects to consider, such as to enhance the production of fish and other species of mollusk as source of protein.

(2) Condition of Tondano Lake

Lake Tondano is classified as ‘eutrophic’ based on its fertility or nutrient loading, phyto-plankton counts, and organic productivity. The catchment of Tondano Lake is surrounded by relatively dense settlements and intensive use of agriculture land. Consequently, cultural eutrophication may take place. It is characterized by the occurrence and fast growing population of aquatic plants, such as algae, and macrophytes.

Research by Surjani found that aquatic plants can be divided into (1) floating plants, and (2) submerged plants. Soeroto et. al. reported that population density of aquatic plants in Tondano Lake is classified very high, especially along the shore of the lake. Whitten et. al. mentioned that the average number of phytoplankton (green algae) in Tondano Lake is 2415 per liter. The high concentration of phytoplankton tends to absorb more light and the water becomes a bit turbid.

The data on the sediment from the lake bottom shows similar values for various depths. In general, the clay content is high, with exception of the location close to the river mouth or shoreline, which has lower clay but higher sand content. The sand fraction is deposited close to the shoreline, and does not reach the center of the lake.

2.1.8 Current Countermeasures against Erosion Hazard

2.1.8.1 Soil Conservation Farming

To reduce soil erosion from the agricultural lands, soil conservation farming is extensively applied in the area.

(1) Estate

In the estates, 30 to 40% of the area applies agroforestry typically cultivating maize under the trees, and mixed with tree crops, such as coffee, cocoa, wood for firewood, etc. In the area of cultivating maize, they apply contour farming and they use the lands by 3 to 4-year period rotational farming. In this case, maize grows 4 months in 3 to 4 years and remained period is left as grassland. Remained 60 to 70% of the area are monoculture estate, or left various trees growing thick without care. In any case, ground surface is covered well with vegetation resulting good soil conservation practices.

(2) Vegetable Gardens

Typical soil conservation practice is employed in vegetable cropping area in Rurukan. They apply high bed cultivation on contour. The beds are about 80 cm of width and

15 cm of height in upper side and 50 cm on the lower side. The furrows are about 50 cm wide and 15 cm deep. The furrows are sufficient capacity to store runoff from each bed and to accumulate eroded soil.

(3) Maize Cropped Land

For most maize cultivation, they harvest once a year; 4 months are maize cultivation and left the land without care in remained period. Farming practice is same to that in estate, but more complete. In one maize farm, slope changes from 5 to 22 degrees from lower part to upper part. Ridges have 40 cm width and 20 cm height, and furrows have 60 cm width.

2.1.8.2 Erosion Control Works

(1) Check dam

Check dams to trap sediment and to store water and soil have been constructed several sites around the lake. Among them, the largest one is located in Touliang Oki river constructed by PU in 1996. Its drainage area is about 0.75 km^2. Though the pond area is as small as about 1200 m^2, there is little sedimentation in the reservoir and in-flowing riverbed keeps its original condition in March 2000. According to PU, they are monitoring the accumulated sediment in the reservoir. Ministry of Forestry constructed small earthen dams in Tondano Lake watershed; one of them is in Eris river, which constructed for irrigation in the middle of 1980s. It has trapped sediment effectively; even it was constructed to store water. At present, the storage area of the dam has reduced to about 2/3 of its original reservoir area.

(2) River Protection

Gabion work is applied in the lower reaches of Panasen river in the south of the lake to protect riverbed and riverbank around the bridge. Since most of the minor streams around the lake is modified to irrigation canal or drains of paddy area, they are maintained well.

2.2 Soil Erosion Control Plan

2.2.1 Basic Strategy

Erosion control plan to the Tondano watershed is chartered to conserve the area from erosion hazard. The Tondano watershed area is classified into zones; namely, **P Zone**, **B Zone**, **F Zone** and **S Zone**. The B Zone is separated by their condition as **Bm1 Zone, Bm2 Zone, Bm3 Zone, and Bw Zone**. The strategy of the erosion control plan is mentioned for each zone below.

2.2.1.1 P Zone

P Zone is consisted of forest, natural and secondary forest. The zone is located mostly on very steep slopes (>40% gradient).

The purpose of the P Zone is to maintain the function of the forest of runoff control, keeping original ecosystem, and maintaining land fertility. Control of runoff owes to high water holding capacity and high infiltration rate of the soil layer developed by root system and accumulated fallen leaves.

The way to keep the function of the forest is to keep the forest from disturbance and to rehabilitate if necessary.

2.2.1.2 Bm1, Bm2, and Bm3 Zones

Bm1, Bm2, and Bm3 Zones are consisted of estates and arable uplands, a part of which are applied agroforestry. The zones occupy sloped areas, more than 15% slope in estates and more than 8% slope in arable uplands, both of which is necessary for erosion control measures.

The purpose of the Bm1, Bm2, and Bm3 Zones is to keep the land from erosion hazard by conserving forest functions of runoff control and maintaining land fertility.

The way to keep the Bm1, Bm2, and Bm3 Zones is as follows. First, to remain and increase tree vegetation on the slopes of more than 25% slope. Second, to facilitate erosion control measures including agroforestry on the slope of 8 to 25% for arable uplands and 15-25% for estates.

2.2.1.3 Bw Zone

Bw Zone is consisted of vegetated lands and wetlands, a part of which are forest and/or cultivated lands. The zone occupies sloped areas along the river.

The purpose of the Bw Zone is to keep the agricultural land and the slopes from erosion hazard and to reduce sediment yield to the lake and streams.

The way to keep the Bw Zone is to provide vegetation belt on the riverbanks and around the lake. In addition, erosion control structures will be laid in the channels.

2.2.1.4 F Zone

F zone is considered to be acceptable any type of land use with minimum awareness to erosion hazard. Most of the farming zone is used for paddy field. The zone occupies the area with less than 15% slope in estates, and less than 8% slope in arable uplands and paddy field.

The purpose of the F Zone is to produce farm product mainly, including estate crops.

The way to keep the F Zone is to sustain the productivity of existing agricultural lands by minimum erosion control measures if necessary.

Based on above strategy, erosion control plan for each zone was researched. Figure H.2.4 shows the Map of Watershed Management Plan by conservation works. Table H.2.2 shows recommended watershed management plan.

2.2.2 Soil Erosion Control Plan

2.2.2.1 Basic Consideration

(1) Soil Loss Tolerance Limit

For the soil erosion control plan, allowable soil loss is determined considering soil condition in the field. In the study, the 'Guide for Determining Tolerable Soil Loss for Indonesian Soils' of Arsyd (1989) shown on page H-7 is referred to determine tolerable soil loss. The Study Area is composed of volcanic soils over the area and soil layer is usually very thick.

(2) Factors affecting Occurrence of Erosion Hazard

Watershed conservation in the upper watershed intends to maintain the functions of the forest, it also anticipates keeping possible critical lands away from deterioration. To prevent land degradation structural method and non-structural or vegetation measures are applicable. Structural measures are characterized to show the result in a short period, which perform more efficiently with help of non-structural measures. However, structures have been employed a few in the area since they are costly to construct. To reduce construction cost and to minimize maintenance and rehabilitation cost, structures composed of locally available material, such as stone, bamboo, logs, etc., are recommendable. Several structural measures for conservation practice are researched here. The table in next page shows physical measures for reducing potential erosion hazard.

Available Measures for Erosion Control

Type of Erosion	Type of Measures
Soil erosion from agricultural land	Soil conservation farming practice, agro-forestry, terracing, diversions, contour bunds
Soil erosion from estate	Agro-forestry, terracing, diversions, contour bunds
Riverbed erosion	Cross structures on riverbed, check dams
Slope failure by riverbank erosion	Riverbank revetment, cross structures on riverbed, check dams, vegetation works
Debris flow, Lahar	Check dams
Slope failure along roadd	Slope protection works, diversions
Slope failure on hillside	Vegetation works, slope protection works

Various natural and human factors act upon erosion hazard events. Typical factors are rainfall, geology, topography, vegetation, and suitability of the structures to the site. However, since similar physio-graphical conditions of rainfall, geology, soil, and vegetation command over the study area, grade and length of slope predominate over occurrence of erosion event.

The table below shows how each factor contributes on occurrence of each type of erosion.

Extent of Factors affecting Erosion Hazard Potential

Type of Erosion	Factors affecting				
	Slope	Soil/ geology/ sediment	Rainfall/ discharge	Vegetation coverage	Manage-ment
Soil erosion from agricultural land	Very high	High	Very high	Very high	Very High
Soil erosion from forest land	Very high	High	High	Very high	Moderate
Soil erosion from estate	Very high	High	Very high	Very high	Moderate
Riverbed erosion	Very high	Very high	Very high	Very low	Very low
Slope failure/ landslide by riverbank erosion	Moderate	Very high	Very high	Moderate	Low
Lahar (debris flow)	Very high	Very high	Very high	Very low	Very low
Slope failure /landslide along roads	Very high	High	Very high	Moderate	Low
Slope failure /landslide on hillside	Very high	Very high	Very high	Moderate	Very low

Since soil erosion or soil loss from land surface has different mechanism on its occurrence from other type of erosion, in which the impact of raindrops plays significant driving force on the soil loss. It needs different measures protecting from erosion hazard from other types of erosion. Typical measures are shown below by slope gradient.

Suitable Surface Soil Loss Control Measures/Land Use

Type of Conservation Measures	Surface Slope (%)				
	<8	8-15	15-25	25-40	>40
Soil erosion from land surface	Agricultural land with moderate conservation measures	Agricultural land with careful conservation measures	Agroforestry with moderate land cover	Agroforestry with thick land cover	Permanent vegetation (Forest, etc.)

Control of flood flows in the streams or ravines is regarded beyond the capability of local population if it is torrent. Since vegetation measures contribute little to control torrent, structural measures are recommended in the streams to reduce erosion hazard.

Factors and Extent affecting Erosion Hazard by Riverbed Gradient

Type of Erosion	Slope (%)					
	<5	5-10	10-15	15-20	20-40	>40
Riverbed erosion	Very slight	Slight	Moderate	Moderate	Severe	Extreme
Slope failure/ landslide by riverbank erosion	Very slight	Slight	Moderate	Moderate	Severe	Extreme
Lahar (debris flow) occurrence	none	none	Rare	Moderate	High	Very high

Factors and Extent affecting Erosion Hazard in Rivers by Bed Materials

Type of Erosion	Riverbed/slope material		
	Rock	Thin sediment	Thick sediment
Riverbed erosion	Very low	Low	High
Slope failure/ landslide by riverbank erosion	Very low	Low	High
Lahar (debris flow) occurrence	None	Low	High

Factors and Extent affecting Erosion Hazard on Cut Slopes along Road by Gradient

Type of Erosion	Slope (%)					
	<5	5-10	10-15	15-20	20-40	>40
Slope failure /landslide along roads	Very slight	Slight	Moderate	Moderate	Severe	Extreme
Slope failures/landslide on hillside	Very slight	Slight	Moderate	Moderate	Severe	Extreme

Factors and Extent affecting Erosion Hazard on Cut Slopes along Road by Geology

Type of Erosion	Slope material		
	Rock	Weathered rock	Unconsolidated
Slope failure /landslide along roads	Very low	Moderate	High
Slope failure /landslide on hillside	Very low	Moderate	High

2.2.2.2 Erosion Control Measures

(1) Soil Erosion Control Measures from Agricultural Land

Soil loss from the land surface is caused combined runoff with raindrop impact, which plays significant driving force on the soil loss. To reduce soil erosion from sloping agricultural lands, soil conservation farming and supplemental practices have to lessen both the energy of raindrops and surface flow depending on gradient of the land surface.

Soil conservation farming practices are rotational cropping, contour cropping, etc. Agro-forestry with thick canopy, especially multi-layer tree cropping, is effective to control soil erosion by reducing raindrop impact.

Structural measures are infiltration trenches, grassed waterways, diversion ditches, contour dikes, intercepting ditches, cut ditches, terracing, drains, etc. Below table describes the criteria leaded above idea.

Suitable Surface Soil Loss Control Measures

Type of Conservation Measures	Surface Slope (%)				
	<8	8-15	15-25	25-40	>40
Annual crop agricultural lands	Not necessary soil conservation measures	Soil conservation farming necessary	Agroforestry; careful soil conservation farming with simple erosion control measures	Agroforestry with thick land cover; complete structural erosion control measures with careful soil conservation farming	Not suitable for agricultural land; remain permanent vegetation (Forest, etc.)
Estate and Pasture	Not necessary soil conservation measures	Not necessary soil conservation measures	Agroforestry; simple soil conservation measures	Agroforestry with thick land cover; Careful soil conservation farming with erosion control measures:	Not suitable for agricultural land; remain permanent vegetation (Forest, etc.)

(2) Measures against Erosion in and around Rivers

In the upper watershed, the river channels are inherently erosive and considerable amount of boulders and stones accumulated. Therefore, if the runoff regime changed by land use alteration, there are chances of erosion hazard of debris flows and slope failures originated by vertical erosion (riverbed erosion, or riverbed degradation) and lateral erosion (river bank erosion).

To strengthen and improve river channels to erosion, structural measures along with vegetation measure are recommended. Measures are river bank protection works against lateral erosion, riverbed protection works against riverbed erosion (vertical erosion), check dams to regulate riverbed slope to stop riverbed and lateral erosion and occurrence of debris flow.

In minor ravines in the upper reaches with small discharge, water flows could be controlled by simple measures using local materials, such as soil, stones and boulders, brushwood, bamboo, logs, etc.

(3) Measures against Slope Failure

Slope failure is distinguished from landslide by its characteristics. Slope failures take place in sandy soils on steep slopes, occur suddenly with little indication in advance, and are influenced rainfall intensity. In the area, slope failures are distinct on the cut slopes along roads, especially on the slopes around Mt. Mahawu. Most slope failures along the road are caused by misuse of the slope shoulder; expanded cropping land to the slopes, layout of channels on the shoulder.

To reduce the misuse of the shoulders, it is recommended to guide the farmers not to use the shoulder for cultivation and to make the road boundary clear. In critical sections, low stone masonry walls are recommended to construct along the toe of the slope.

(4) Improvement of Roads

Field observation revealed that the existing minor roads needed to repair or to rehabilitate because damaged surface of the road is disturbing traffic. Hauling roads in estates are major cause of gully erosion occurrence in the estates. It is recommended to place coconut logs on the road surface to reduce erosion.

(5) Diversions and Infiltration Ditches

Diversion and cut-off ditches are constructed across a field to intercept and divert surface-run-off from the slope above and drain it to a safe outlet. The structures can be a form of a trench or low embankment and placed traversing the slopes.

Infiltration ditches are narrow trenches built along the contours to collect run-off and conserve moisture for trees and tree crops. The trenches can be built as a continuous line across an entire slope, over shorter distances, or for individual plants.

(6) Soil Loss Estimate after Implementation of Conservation Measures

When soil conservation practices are extended over the estate and arable upland, it is expected that estates mixed with annual crop farming area and agroforestry will expand. The L, C, and P factors for the USLE could change by implementation of soil conservation measures, consequently. Details of change of the factors are described in Attachment H.1.

1) L factor

Changed values of slope length (S) for USLE in the calculation of soil loss are shown in the table below.

2) C factor

Modified values of C factor for USLE are shown in the table below.

3) P factor

Modified values of P factor for USLE are shown in next table.

Slope Length (S), C and P factors

Land Use/Crops	Slope Length (m)	C factor	P factor
Irrigated rice	40.0	0.01	0.040
Maize	1.0	0.245	0.150
Vegetables	1.0	0.7	0.150
Estate with good cover	18.1	0.037	0.405
Secondary forest	58.0	0.005	1.000
Natural forest	58.0	0.001	1.000
Estate-vegetable mixed area	4.4	0.201	0.269
Estate-crops mixed area	4.4	0.201	0.269
Urban area	25.0	0.18	0.150
Wetland	50.0	0.01	1.000

4) Soil Loss Estimate

Soil loss estimate after implementation of soil conservation measures is computed as shown in Table H.2.3. The result is shown below table. Average soil loss of the total study area is estimated 11.94 ton/ha/year.

Estimated Erosion by Sub-Basin with Measures

	Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)		Soil loss (ton/ha/yr)
Noongan Basin							
1	9.41	2	8.31	3	3.24	4	4.40
5	6.57	6	4.82	7	6.36	8	4.84
9	3.95						
Average							**5.77**
Tondano Lake Basin-West							
11	5.54	12	8.28	13	7.18	14	10.36
15	5.38	16	9.65				
Average							**7.73**
Tondano Lake Basin-East							
21	7.99	22	10.18	23	11.02	24	12.02
25	13.51						
Average							**11.37**
Tondano River Basin							
31	9.09	32	7.95	33	12.30	34	7.76
35	11.99	36	15.25	37	14.58	38	18.23
39	22.38	40	17.93	41	18.08	42	16.72
43	9.84	44	7.15	45	15.35	46	10.77
Average							**13.46**
Tikala Basin							
51	11.37	52	23.80	53	22.61	54	13.86
55	13.67	56	16.48	57	13.36	58	19.82
59	11.08	60	22.25	61	36.74	62	19.49
Average							**18.71**
Klabat Basin							
71	19.55	72	17.75	73	9.22	74	10.97
75	10.38	76	8.23				
Average							**12.68**
Total Area							**11.94**

2.2.2.3 Monitoring

Monitoring is necessary to evaluate the effectiveness and suitability of the erosion control measures taken in the project area. For Tondano Lake, which is the only water resource in the area, little basic data is available on the flow rates and water quality, especially of in-flow rivers. To know and to evaluate hydrological regime in Tondano watershed, collection of continuous data on the river flow and rainfall is very important. For evaluation of water quality and sedimentation in the lake, observation and analysis are necessary on water quality, such as DO, COD, pH, Total-N, Total-P, transparency, sediment concentration, sampling of bottom material, accurate measurement and analysis of composed materials of deltas at the major river mouths, etc.

(1) Hydrology and Sedimentation

To evaluate change of hydrological regime by the watershed conservation works, observation of rainfall and flow rate of in-flow rivers to the lake is required. Continuous measurement by automatic recorder is recommended to collect data on flow rate and rainfall. Decreased peak flood flow, delayed flood peak, and increased base flow will be an indicator to show the effectiveness of the erosion control works.

To evaluate reduced sediment transport, observation of sediment concentration is necessary. Reduced sediment concentration will show the effectiveness of the erosion control works. Data have to be gathered through concentrated observation for several continuous days including rainy period.

Direct measurement of accumulated sediment in the reservoir of the existing check dams is helpful to confirm sediment transport. It is recommended to make regular observation of reservoir depth during low water period.

(2) Water quality

To monitor water quality of Tondano Lake, regular measurement of lake water is most important. There are several analyses on the lake water quality. However, measured items and sampling points are quite different by each analysis. Samples have to be collected at fixed points and regularly. In the Lake, water samples have to be taken from several different depths at several points. Measurement shall be done regularly.

CHAPTER 3 FEASIBILITY STUDY FOR THE INTENSIVE AREA

3.1 Present Conditions

3.1.1 Slope Distribution

(1) Slope analysis and Mapping

Slope analysis in the Intensive Area was done using the topo-map of 1:10,000 scale. Slope gradient was measured by counting the number of contour lines of 5 m intervals in a square element that has side length of 200 m by 200 m. Slope gradient map is shown in Figure H.3.1.

(2) Slope Distribution by Area

Slope distribution in the West, East and South areas reflects the specific topographical feature of each area as mentioned in Appendix-C 3.1.1. The slope distribution in each area has demonstrated in Figure H.3.2.

3.1.2 Geology and Geomorphology

3.1.2.1 Geology

Basic geologic information is mentioned in Appendix-C 3.12. Below table shows geological characters related on erosion.

Geological Characteristics on Erosion

Area	West	East	South
Rock Type	Andesite, basalt (Quaternary) and Tuff (Pliocene)	Breccia and Tuff (Miocene)	Tuff and Volcanic ash (Quaternary)
Depth of Weathering	Lava: very shallow, Tuff: more than 1 m	Very deep	Surface covered with unconsolidated ash Tuff: more than 1 m
Structure	Stratified volcanic (lava), Lava: not weathered, Tuff: moderately weathered	Stratified volcanic, Breccia extremely weathered	Stratified Volcanic, Pyroclastic Recent deposit, thick fallen volcanic ash layer
Possible type of erosion	Potential rock falling on steep slopes	Erosion by slope failures/ landslides on process, High potential of mass movement	Potential soil erosion on steep slopes

3.1.2.2 Geomorphology

(1) West Area

The area is composed of several layers of lava flow. The front end of the lava flow forms steep slopes, which are composed of boulders of which voids are filled with finer soil. When the vegetation cover is removed and surface runoff concentrates, severe soil erosion could occur easily on these steep slopes. However, since the skeleton structure of steep slopes is formed with boulders and it is generally strong, so that the slope failure will occur exceptional except rock falling.

(2) East Area

Geologically, the layers of tuff-breccia and tuff are highly weathered into considerable depth, which leads the area inherently weak to erosion. Minor but deep channels have been developed and slope failures have been triggered by riverbed degradation. This process is still in progress. Channel development and slope evolution are active from the viewpoint of the geological time-scale (of hundreds or thousands-year period).

(3) South Area

There is very active volcano of Soputan that is located at just 1 km outside of the southern boundary, which spouts occasionally volcanic ash. Such volcanic ash covers the ground surface in the area widely, of which thickness is a few meters on the underlying semi-pervious weathered tuff layer. Owing to very high infiltration capacity of the volcanic ash, there is no runoff except in very heavy rainfall. Such geological condition makes low drainage density in the area. Steep slope in the higher elevation is susceptible to erosion, however, erosion potential is low on the gentle slopes.

3.1.3 Estimate of Soil Loss

3.1.3.1 Determination of Factors for USLE

The Universal Soil Loss Equation (USLE) was applied to estimate soil loss. The USLE is expressed in previous Section 2.1.3.1.

The Intensive Area was divided to 3044 elements, which are squares with side length of 200 m x 200 m. To estimate the amount of soil loss, the values of the factors in USLE for each element was determined by the method mentioned below.

3.1.3.2 Determination of Values of each Factor

(1) R factor

For calculating R factor, rainfall data from Tondano, Remboken, Telap, and Noongan stations were selected considering observation period, continuity of data, and distribution of the stations. R factor was calculated same manner mentioned in 2.1.3.2. R factor for each element was determined applying Thiessen Polygon. Calculated values of the R factor are shown in the below table, and their distribution is shown in Figure H.3.3.

Values of R factor

Station	Tondano	Remboken	Telap	Noogan
R factor	1,109	806	1,014	1,546

(2) K factor

The K factor depends on the characteristics of soil. The K factor determined based on the result of soil survey. Based on the soil survey, soils in the intensive area classified into 10 categories as shown in Figure H.3.4, considering especially origin of the soil, and hydrological features (infiltration rates). Values of the K factor used in USLE calculation is tabulated in the below table.

Values of K factor

Soil Type	K factor	Soil Characteristics
1	0.1520	Alluvial deposit
2	0.1785	Alluvio-colluvium deposit
3	0.1785	Terrace/Piedmont sedimentation
4	0.0801	Volcanic sandy ash (Quaternary)
5	0.0479	Volcanic ash (Quaternary)
6	0.0464	Weathered Andesitic & Basaltic lava (Quaternary)
7	0.0580	Weathered Obsidian lava (Quaternary)
8	0.0479	Volcanic ash and lava (Quaternary)
9	0.0600	Volcanic ash and lava (Pliocene)
10	0.0764	Weathered old volcanic rocks (Miocene)

(3) SL factor

Slope was measured on the topographical map. Distribution of the slope gradient in the intensive area is shown in Figure H.3.1.

L factor was determined on the 1:10,000 topo-map and confirmed by the field observation as shown in the next table.

(4) C factor

C factor in USLE measures the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled continuous fallow. It is usually expressed as an annual value for a particular cropping and management system. The value C was decided based on the recommended values with some modification by field observation. Factors applied in the calculation of erosion are shown in the below table.

Values of Slope Length, C factor and P factor

Land Use	Slope Length (m)	C Factor	P Factor
Natural /Semi-natural Forest (1)	31	0.001	1.000
Secondary Forest (2)	31	0.005	1.000
Planted Forest (3)	31	0.005	1.000
Estate (4)	31	0.027	0.745
Mixture of Estate and Dry –Farming (5)	21	0.364	0.448
Dry Farming Land (6)	1	0.245	0.150
Pasture Land (7)	39	0.027	0.745
Paddy Field (8)	40	0.010	0.040
Swamp (9)	50	0.010	1.000
Water Body (10)	-	-	-
Settlement and Others (11)	25	0.180	0.150

(5) P factor

P factor is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture. The farmers are applying soil conservation practices, such as traditional terrace, contour ridges or high-beds with deep furrows, contour hedges by trees, bench terrace, etc. The value of C factor varies with these practices. P factors are tabulated in the above table.

3.1.3.3 Estimated Soil Loss

Soil loss was calculated by an element of its area of 4 ha (200 m x 200 m). The result of the calculation is shown in Figure H.3.5 as a classified soil loss map. Average soil loss over the Intensive Area is about 19 ton/ha/year as shown in the below table, and 12.5 ton/ha/year in the West Area, 20.4 ton/ha/year in the East Area, 27.6 ton/ha/year in the South Area. However, soil loss amount of median of each area is different and they are 7.8 ton/ha/year over the entire Intensive Area, 5.5 ton/ha/year in the West Area, 13.2 ton/ha/year in the East Area, 4.76 ton/ha/year in the South Area. Since several elements have extremely steep slopes, calculated amount of the soil loss is very high. The area with more than 100 ton/ha/year of soil loss shares 6.3% in the South, followed by the East of 2.5% and the West of 0.5%. This specified topographic features makes the average soil loss high in the South.

Estimated Soil Loss by Area (ton/ha/year)

Area	Average	Median	Sub-Area	Average	Median
All	19.05	7.81			
West	12.48	5.45			
East	20.44	13.22	Eris (E-N)	23.32	16.69
			Kakas (E-S)	9.64	7.81
South	27.64	4.65	Soputan (S-W)	25.66	4.65
			Kawatak (S-E)	37.44	5.03

Below table shows percentage of area by the amount of soil loss. In the West and South Areas, about 50% of the area are estimated less than 5 ton/ha/year of soil loss, however it is only about 28% in the East Area. On the other side, 36% of the area in the East are categorized to 10 to 25 ton/ha/year of soil loss area.

Percent Area by the Amount of Soil Loss (%)

Area	Soil Loss (ton/ha/year)					
	<5	5-10	10-25	25-50	50-100	>=100
All Area	**43.66**	**11.56**	**22.83**	**12.55**	**6.67**	**2.73**
West Area	**48.79**	**13.07**	**23.11**	**11.56**	**2.95**	**0.53**
East Area	**27.61**	**10.43**	**36.37**	**18.36**	**4.74**	**2.49**
Eris	23.57	9.61	36.19	21.47	6.01	3.15
Kakas	42.70	13.48	37.08	6.74	0.00	0.00
South Area	**51.37**	**10.39**	**9.36**	**8.45**	**14.16**	**6.28**
Soputan	51.85	10.43	9.47	7.96	14.40	5.90
Kawatak	48.98	10.20	8.84	10.88	12.93	8.16

3.1.4 Critical and Potential Critical Land

(1) General

Critical land in this study is defined as the place, which has following condition:

- Severe soil erosion,
- Low possibility of natural re-vegetation, and
- High possibility of erosion expansion.

The locations of critical land were identified through the site survey in Phase II field work. As a result, the JICA Study Team found that critical lands are not distributed widely in the Intensive Area. However, a several numbers of pinpoint scale critical lands, which require the rehabilitation, were observed.

Meanwhile, potential critical land in the study is defined as the area, which has following condition:

- No severe erosion at present, and
- High possibility of occurring severe erosion in future.

The locations of potential critical lands were estimated on a sub-watershed basis basically, since the data for predicting future erosion in the pinpoint scale are not available for several types of the erosion. For this purpose, 30 numbers of sub-watersheds were determined, using following criteria:

- Area which is located upstream of the paddy field or settlement,
- Area with more than 100 ha of catchment area and non-weathered soil, and
- Area with more than 30 ha of catchment area and weathered soil.

The location of sub-watersheds is presented in Figure H.3.6.

(2) Soil Erosion

1) Critical Land

Through the site survey, the JICA Study Team identified pinpoint scale critical land regarding soil erosion at 18 places, of which area is 20.8 ha in total (See Figure H.3.7 for the location).

2) Potential Critical Land

Potential critical land regarding soil erosion is defined as the land, which might has severe soil erosion, if unsuitable land use and unsuitable farming practice are continued. In the study, 6,290 ha of area, which was classified into Zone Bm1 or Bm2 was taken as the potential critical land.

3) Soil Erosion Hazard Sub-watershed

To decide the location of new check dam, soil erosion hazard sub-watersheds are specified. First, the amount of surface erosion in sub-watershed basis was estimated by USLE with present condition. Next, the amount of estimated surface erosion was compared with tolerable level of surface erosion. When the sub-watershed has excess soil erosion from the tolerable level, the area is judged as a soil erosion hazard sub-watershed. According to the result of estimation, following sub-watersheds are selected for soil erosion hazard sub-watershed (See Figure H.3.7 for the location and Attachment-H.1 for the USLE calculation).

Soil Erosion Hazard Sub-watershed Specified by USLE

SW - No.	Area (ha)	Estimated Surface Erosion with Present Condition (ton/year)	Tolerable Surface Erosion Level (ton/year)	Balance (ton/year)
12	301	7,886	7,178	-708
13	201	9,771	6,040	-3,731
16	61	1,750	958	-792
17	100	1,756	1,560	-196
18	43	944	663	-281
19	30	573	468	-105
20	62	2,771	974	-1,797
21	44	925	682	-243
22	67	2,361	1,038	-1,323
24	138	4,259	2,148	-2,111
25	129	4,740	2,008	-2,732
26	48	1,286	746	-540
28	86	1,928	1,342	-586
29	76	1,248	1,192	-56
30	198	5,104	3,084	-2,020
Total	1,584	47,304	30,082	-

Note : SW = Sub-watershed

More over, the JICA Study Team identified another 616 ha of potential critical land regarding soil erosion from the agriculture and agroforestry points of view.

(3) Hillside Slope Failure

1) Critical Land

In the Intensive Area, the JICA Study Team observed 5 hillside slope failures (See Table H.3.1, Figure H.3.8 and H.3.9 to H.3.13 for the detail). Among the 5 hillside slope failures, site Mt. Maimberg shown in the picture was classified as a critical land regarding slope failure on hillside taking following criteria into account (See following table and Figure H.3.14 for the detail of procedure):

Hillside Slope Failure at Mt. Maimberg

- The slope failure is situated in the P Zone,
- The slope failure has low possibility of natural re-vegetation, and
- The slope failure has high possibility of expansion.

Critical Land regarding Slope Failure on Hillside

Location	Area (ha)	Possibility of Natural Re-vegetation	Possibility of Slope Failure Expansion
Mt. Maimberg	0.30	Low	Middle

2) Potential Critical Land

In the Intensive Area, 5 existing hillside slope failures were located only on the slope steeper than 40° and area of them are less than 0.3 ha. Meanwhile, slope gradient of the Intensive Area was measured in a comparatively large scale, using the 200 x 200 m (4 ha) meshes data. As a result, location of the pinpoint scale slope failure did not appear clearly in the slope distribution map prepared in 200 x 200 m meshes, if the area steeper than 40° is selected for the potential critical land. Taking this condition into account, the JICA Study Team selected the potential critical land on hillside slope failure applying following procedure:

Step 1

- The areas of which slope gradient are steeper than 30° in 200 x 200 m meshes data were identified.

Step 2

- Possibility of the failure for the above-selected areas was estimated, considering topography, type of the soil and location of the existing slope failures on hillside. The result shows that 0.3 % of the above-selected areas have a possibility of the failure in East Area, 0.3% for the South Area and no possibility in West Area.

Step 3

- The area of potential critical land was calculated by multiplying the area selected in the Step 1 and possibility estimated in the Step 2.

The JICA Study Team confirmed the applicability of this procedure by comparing the result of estimation and location of the existing slope failures. The result of analysis is tabulated below (See Figure H.3.8 for the location).

Potential Critical Land regarding Slope Failure on Hillside

Location	Area steeper than 30° (ha)	Possibility of the Failure (%)	Potential Critical Area (ha)
Sub-watershed 11	8	0.2	0.016
Sub-watershed 12	12	0.2	0.024
Sub-watershed 13	4	0.2	0.008
Sub-watershed 14	128	0.2	0.256
Sub-watershed 15	4	0.3	0.012
Sub-watershed 16	8	0.3	0.024
Sub-watershed 17	4	0.3	0.012
Sub-watershed 18	12	0.3	0.036
Sub-watershed 19	4	0.3	0.012
Sub-watershed 22	8	0.3	0.024
Sub-watershed 29	4	0.3	0.012
Sub-watershed 30	8	0.3	0.024
Total	204	-	0.460

(4) Landslide

1) Critical Land

3 landslides were observed at Touliang Oki, Makalonsouw, and Tounsukun. However, there will not be severe damage at the bottom end of the landslides, since there are no intensive human activities. Besides of that, forest devastation were not observed in the landslide sites. Considering the above-mentioned conditions, the JICA Study Team concluded that the landslides in the Intensive Area are not in the critical condition.

2) Potential Critical Land

The JICA Study Team recognized that existing landslide sites in sub-watershed 24 and 27 are the potential critical land regarding landslide, considering its topography and geological conditions. However, landslide in sub-watershed 30 did not be classified as a potential critical land, since the landslide seems not active in present. The list of potential critical land regarding landslide is shown below (See Figure H.3.15 for the location).

Potential Critical Land regarding Landslide

Location	Area (ha)	Remarks
Sub-watershed 24	2.6 ha	Touliang Oki
Sub-watershed 27	2.5 ha	Tounsukun
Total	5.1 ha	

(5) Slope Failure along the Road

1) Critical Land

The JICA Study Team identified 4 slope failures along the road as shown in Table H.3.2, Figure H.3.16, and H.3.17 to H.3.20. Among these 4 sites, site Paleloan and Eris-3 were classified as critical land regarding slope failure along the road, considering their low possibility of natural re-vegetation (See Figure H.3.21 for the detail analysis). Following table shows the selected critical lands regarding slope failure along the road.

Critical Land regarding Slope Failure along the Road

Location	Area (ha)	Possibility of Natural Re-vegetation	Possibility of Slope Failure Expansion
Paleloan	0.005	Low	High
Eris-3	0.006	Low	Middle
Total	0.011	-	-

2) Potential Critical Land on Slope Failure along the Road

The JICA Study Team found some possibility of slope failure along the Eris-Watulaney road. The location of sub-watershed basis potential critical land is shown in Figure H.3.16.

Potential Critical Land regarding Slope Failure along the Road

Location	Length (m)	Remarks
Sub-watershed 17	500	Eris – Watulaney Road

(6) On-farm Road Surface Erosion

1) Critical Land

The JICA Study Team found on-farm road surface erosion in several places in the Intensive Area. The roads were unpaved and constructed for bullock-carts transportation and on foot traveling. However, since the scale of the roads is small and importance of them is relatively small, the JICA Study Team concluded that the places are not critical land. It is recommended to maintain them by the farmers themselves with proper extension services.

2) Potential Critical Land

Many of the on-farm roads, which have surface erosions, are located along the valley. Considering this matter, it can be said that the unpaved roads along the valley have some risk of surface erosion (See Figure H.3.22 for the location).

(7) Torrent and River Erosion

1) Critical Land

The JICA Study Team analyzed the characteristics of all the sub-watersheds using the 1:10,000 topographic maps (See Table H.3.3 to H.3.4 and Attachment H.2 for the characteristic of sub-watershed). If it is judged that the sub-watershed has some possibility of torrent devastation, torrent devastation survey on site was conducted to confirm the actual condition of the torrent (See Attachment H.2 for the location of site survey). Through the torrent devastation survey, two kinds of the torrent and river erosion were found. These are i) torrent and river bed erosion and ii) torrent and river bank erosion.

Critical Land regarding Torrent and River Erosion

Location	Length (m)	Possible Cause
1. Torrent Bed Erosion		
Sub-watershed 4	800	Intensive land use of the catchment area
The River Panasen Lower Reaches[1)]	5,200	Sandy volcanic soil
2. Torrent Bank Erosion		
The River Panasen Lower Reaches[2)]	900	Sandy volcanic soil
Total	6,000	

Note : 1) and 2) = located on the same place

<u>Torrent and River Bed Erosion</u>

Through the torrent devastation survey, the torrent in sub-watershed 4 was recognized as a critical land on torrent erosion (See Attachment H.2 for the detail). In addition to that, the river Panasen, which has severe erosion was classified as a critical land, even though it is located downstream of the Intensive Area. The following table shows the critical land on torrent and river bed erosion (See Figure H.3.23 for the location and Figure H.3.24 for the detail procedure of critical land selection).

<u>Torrent and River Bank Erosion</u>

The JICA Study Team identified severe river bank erosion on the lower reaches of the river Panasen.

2) Potential Critical Land on Torrent and River Erosion

Following potential critical lands were identified through the torrent devastation survey.

Potential Critical Land regarding Torrent and River Erosion

Location	Length (m)	Extent	Possible Cause
1. Torrent Bank Erosion			
Sub-watershed 10	1,500	Slightly severe	Unsuitable land use of the torrent bank, Sandy volcanic soil
Sub-watershed 17	500	Not severe	Intensive land use of the catchment area
Total	2,000	-	-

Note : SW = Sub-watershed

Torrent and River Bed Erosion

Through the torrent devastation survey, no potential critical land on torrent and river bed erosion was identified.

Severe River Bank Erosion along the River Panasen

Torrent and River Bank Erosion

The JICA Study Team observed that there are several non-severe torrent erosions in the sub-watershed 10 and 17, which are classified as potential critical land on torrent erosion.

(8) Debris Flow

1) Critical Land

Devastated Torrent at Sub-watershed No. 4

Through the site survey, the JICA Study Team identified the hazard on debris flow at the main torrent of sub-watershed 4 using following criteria (See Figure H.3.25 for the location).

- Torrent bed slope is steeper than 25%,
- Existence of unstable deposit on the torrent bed,
- Existence of intensive human activities in the downstream, and
- No existing check dam on downstream.

Critical Land regarding Debris Flow

Location	Length (m)	Existence of Human Activity in the Downstream	Possible Cause
Sub-watershed 4	800	Yes	Intensive land use of the catchment area

2) Potential Critical Land on Debris Flow

Potential critical land on debris flow was identified using following criteria:

- Torrent bed slope is steeper than 25%,
- Existence of unstable deposit on the torrent bed, and
- Existence of check dam on the downstream.

In the Intensive Area, it is identified that several torrents in West Area meet the above-mentioned criteria. Following table shows the potential critical land on debris flow.

Potential Critical Land regarding Debris Flow

Location	Length (m)
Sub-watershed 3	700
Sub-watershed 6	500
Sub-watershed 7	400
Sub-watershed 8	1,000
Total	2,600

(9) Summary of Identified Critical Land and Potential Critical Land

Identified critical land and potential critical land is summarized in the following table.

Summary of Identified Critical and Potential Critical Land

Type of Erosion	Critical Land		Potential Critical Land
	Number of the Site	Area / Length	Area / Length
Soil Erosion	6 sites	2.14 ha	1,584 ha
Hillside Slope Failure	1 site	0.30 ha	0.46 ha
Landslide	0	0.00 ha	5.10 ha
Slope Failure along the Road	2 sites	0.01 ha	500 m
On-farm Road Surface Erosion	0	0.00 m	3,500 m
River Bed Erosion	2 rivers	6,000 m	-
River Bank Erosion	1 river	900 m	2,000 m
Debris Flow	1 river	800 m	2,600 m

Note : SW = Sub-watershed

3.1.5 Mining

In the Intensive area, two quarry sites are operating and several are left without protection. Most quarry sites are located along the roads and their scale is minor. Their extents are less than 20 m wide and less than 5 m high. There is no protection measures taken in the quarry against erosion, and it makes the slopes more unstable than the roadside slopes. During rainfall, it was observed that considerable volume of eroded material gushed out from the operating quarry because of rock falls and collapse of slopes. The locations of quarry site are shown in Figure H.3.26.

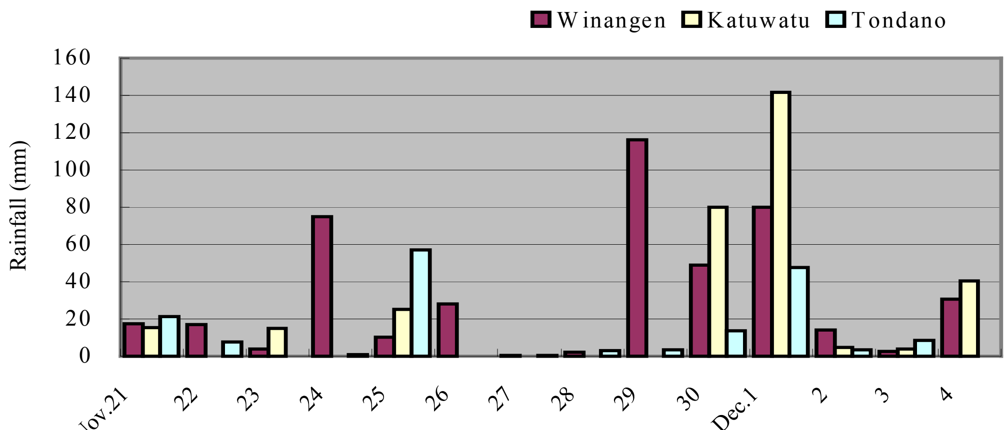
3.1.6 Sedimentation

Some properties of sediment on the bottom of the lake has reported by Hikmatullah, which shows clay contents is more than 60% at 8 points out of 12 sampling points, more than 5% of organic contents at 8 points, and pH of lower than 5 at 4 points. High sand contents were found along the southeast shore, from Toulimebet to Kaweng. Regarding change of the depth by sedimentation, the results of bathemetry of the lake in 2000 by the JICA Study team shows that sedimentation in the lake has not changed since 1992.

In the Phase-II study, sedimentation in the reservoirs in several check dams was researched. It shows that the accumulated sedimentation could be expressed as a function of drainage area. Using the data, sediment delivery ratio was estimated. The result is described in Section 3.9.

3.1.7 Flood

According to the report of 'North Sulawesi Water Resources Management Plan' by CIDA, extensive flooding was reported in Manado city in 1996; the depth of flooding was over two meters in some areas. Flood water receded after about three days. Flooding caused considerable damage to property and disrupted life in the city. Three kotamadya Manado were subject to flooding: Malalayang, Wenang, and Sario.



Rainfall from November 21 to December 4

During the phase-II study period, serious flood attacked over the Minahasa district, where huge flood damages were reported. Manado city was attacked by flood again, and the area along Tondano River, especially in Kotamadga Wenang, inundated a few days with 2 m deep water.

Daily rainfall is usually less than 20 mm according to the rainfall record in the area. Accidentally, the area received very heavy rainfall between November 24 to December 1 as shown in the figure. At Winangen in the middle way between Manado and Tomohon, it was 114 mm of continuous rainfall from November 24 to 26, and rainfall reached at 245 mm from November 29 to December 1. Rainfall, however, distributed quite different by place in the area, it was 25 mm at the Manado airport from Nov. 24 to 26 period, and 222 mm in Nov. 30 and Dec. 1. In Tondano, it was 57 mm in Nov. 25 and 61 mm in Nov. 30 and Dec.1.

Weekly rainfall records at several points in the Study area are shown the table. Five stations recorded more than 200 mm rainfall in the week of Nov. 28 to Dec. 4.

Weekly rainfall

(mm)

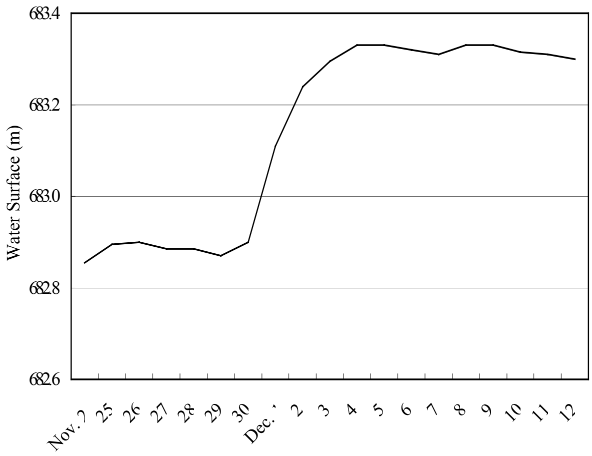
Station	Nov. 13-20	Nov. 21-27	Nov. 28 - Dec. 4	Dec. 5-11
Luaan	87.5	92.5	117.5	7.5
Telap	30.0	20.0	131.0	7.0
Leleko	95.0	35.0	202.0	22.5
Noongan	88.5	74.5	218.5	11.5
Lahendong	39.5	49.0	216.5	20.0
Winangen	n.a	152.2	294.9	n.a
Kayuwatu	n.a	55.6	270.7	n.a
Tondano	n.a	86.7	79.5	n.a

In Manado, inundated area by the flood was along Tondano River from Kairagi to Istiqlal near river mouth and along Tikala River, tributary of Tondano River. Most of the area was reported seriously inundated with 0.5 m to 2 m deep water and thousands of houses were in the water. The flooding is one of the worst ones in the history.

The road between Manado and Tomohon was blocked about 2 days by the slope failures. Slope failures were occurred at 13 places, of which five places were major accident and shut the road, and the remains were minor.

In the Intensive Area, flood damages were reported at Leleko, Remboken. In Leleko, the residential area and paddy fields were inundated two days with 1 to 2 m depth of water. The cause of flooding was supposed that the flood could not flow smoothly in narrowed channel sections at the bridge because of heavy rainfall.

During the flooding period, water surface of Tondano Lake rose about 40 cm within 3 days as shown in right figure.



Lake Water Surface at Toulour

Several causes are given about the occurrence of the flooding in Manado, however most probable causes are very heavy rainfall, meandered channel in the lower reaches of Tondano River, steep bed-slopes of the river, decreased channel flow section by fishnets and housing, expansion of residential area in the middle reaches and lower reaches, etc. Among them, the problems that has its roots in urbanization is the most important.

3.1.8 Water Quality

Several studies have been done to analyze the water quality of Tondano Lake including Phase-I study of current JICA study. The conclusions are; (1) relatively higher nutrients can stimulate growth of aquatic plants in the lake, (2) the lake condition has been declining from ‘Oligotrophic’ to ‘Eutrophic’, (3) water quality of the lake is deteriorating, (4) water quality is classified as ‘eutrophic,’ based on the fertility or nutrient loading, phyto-plankton counts, and organic productivity of the water in the lake.

Current condition of Lake Tondano is classified as ‘eutrophic’ condition, which is characterized by the occurrence and fast growing population of aquatic plants, such algae and macrophytes. This might be a result of cultural eutrophication by relatively dense settlements and intensive use of agriculture land in the surrounding area of Tondano Lake.

3.1.9 Existing Erosion Control Facilities

To confirm the present condition of erosion control facilities, the inventory survey was carried out by visiting and interviewing method. In particular, check dams among them are the largest and most important facility in the Intensive Area, so that the JICA Study Team made detailed site survey for them.

(1) Check Dam

1) Location

The JICA Study Team surveyed 17 existing check dams (location of which are shown in Figure H.3.27. The results of inventory survey are summarized in the following table, and details are given in Table H.3.5, Table H.3.6, and Attachment H.3.

Distribution of the Existing Check Dams (Unit:nos.)

Area				Zone				
West	South	East	Others	Bm1	Bm2	Bm3	F	Others
7	3	6	1	5	9	1	1	1

2) Type

Three types of existing check dams were identified in the Intensive Area. There are: (a) wet masonry gravity check dam, (b) earth fill check dam, and (c) gabion box check dam. Out of them, Provincial Irrigation Office constructed a wet-masonry gravity check dam at Touliang Oki in 1997/1998. The others two types of check dams have been constructed by Ministry of Forestry (BRLKT or District Forestry Service). Following table shows the types of existing check dams constructed by Ministry of Forestry.

Wet Masonry Gravity Check Dam at Touliang Oki

Types of Existing Check Dams Constructed by Ministry of Forestry

Type	Local Name	Purpose
Gabion check dam	Dam Penahan	1. Flood control 2. Sediment control 3. Extension of re-greening activities 4. Increase of water table
Earth fill check dam	Dam Pengendali	1. Flood control 2. Sediment control 3. Water supply for inland fishery 4. Water supply for irrigation 5. Water supply for domestic use 6. Extension of re-greening activities 7. Increase of water table

Source : Design books of Dam Penahan and Dam Pengendali
Note : Wet Masonry Gravity Check Dam was constructed by Provincial Irrigation Office

Gabion Box Check Dam at Tontimomor

Earth Fill Check Dam at Tumaratas

3) Condition

Through the site survey, the JICA Study Team identified several problems on the existing check dams. The most severe problem is the dam body damage at Touure. The damage could be due to slope failure from the torrent bank, which has interfered with smooth spillway flow. The other problems were identified at the dam Leleko, Kasuratan and Tontimomor, which are tabulated below.

Identified Problems on Existing Check Dams in the Intensive Area

Code No.	Name of the Dam	Dam Type	Identified Problem
CD-5	Leleko	Earth fill check dam	A part of downstream slope of the dam body has slipped.
CD-6	Kasuratan	Earth fill check dam	A part of downstream part of the spillway has broken-down.
CD-8	Touure	Earth fill check dam	Dam body has collapsed.
CD-11	Tontimomor	Gabion box check dam	Gabion dam body has been damaged.

Condition of Existing Check Dams in the Intensive Area

Code No.	Name of the Dam	Zone	Agency	Type	Construction Year	Condition of Sediment Control[3]
CD-1	Tataaran II	Bm1	BRLKT	Earth fill	1983/1984	Functioning
CD-2	Tataaran II	Bm1	BRLKT	Earth fill	1984/1985	Functioning
CD-3	Tataaran I	Bm2	BRLKT	Earth fill	1983/1984	Abandoned
CD-4	Roong	Bm2	BRLKT	Earth fill	1982/1983	Functioning
CD-5	Leleko	Bm2	BRLKT	Earth fill	1984/1985	Damaged Partially
CD-6	Kasuratan	Bm3	BRLKT	Earth fill	1991/1992	Damaged Partially
CD-7	Pulutan	Bm2	DFS[1]	Earth fill	1995/1996	Functioning
CD-8	Touure	Bm2	BRLKT	Earth fill	1991/1992	Not Functioning
CD-9	Tumaratas	F	DFS[1]	Earth fill	1993/1994	Functioning
CD-10	Tounelet	Bm2	DFS[1]	Earth fill	1997/1998	Functioning
CD-11	Tontimomor	-	DFS[1]	Gabion box	1997/1998	Damaged Partially
CD-12	Telap	Bm1	DFS[1]	Gabion box	1994/1995	Functioning
CD-13	Eris	Bm1	BRLKT	Earth fill	1984/1985	Functioning
CD-14	Tandengan	Bm1	BRLKT	Earth fill	1984/1985	Functioning
CD-15	Ranomerut	Bm2	BRLKT	Earth fill	1983/1984	Functioning
CD-16	Touliang Oki	Bm2	RIO[2]	Wet masonry gravity	1997/1998	Functioning
CD-17	Touliang Oki	Bm2	BRLKT	Earth fill	1983/1984	Functioning

Note 1: *DFS = District Forest Service*
2: *RIO = Regional Irrigation Office*
3: *Condition of water supply is not shown in the table. See Figure H.3.27 for the locations.*

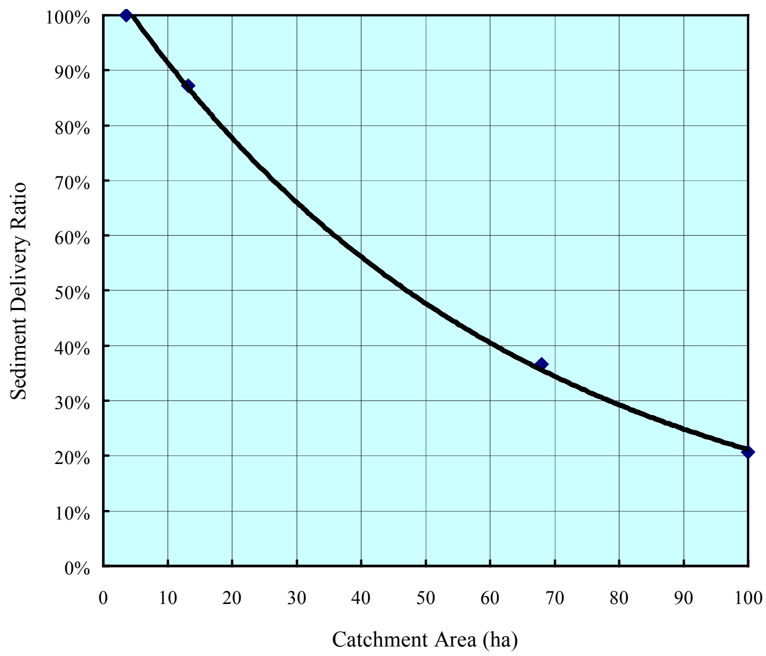
4) Sediment Yield and Sediment Delivery Ratio

The JICA Study Team surveyed sediment yield of existing check dams in and around the Intensive Area. Since the survey has conducted in the rainy season, the JICA Study Team could get the data only for 4 check dams. In the catchment area of these 4 check dams, slope failure or landslide was not observed. Consequently, volume of soil erosion was assumed to be the total volume of sediment production in the catchment area. With this assumption, the sediment delivery ratio was estimated from the total volume of soil erosion, which is equal to the total sediment production. Following table and figure show the result of estimation.

Sediment Yield and Sediment Delivery Ratio of Existing Check Dams

Name of the Dam	Catchment Area (ha)	Sediment Yield (ton/ha/year)	Estimated Sheet Erosion by USLE (ton/ha/year)	Sediment Delivery Ratio (%)
Tounsaru	100	2.0	9.8	21
Leleko	68	3.6	9.8	37
Pulutan	13	16.4	18.8	87
Simbel[1]	4	86.7	86.7[2]	100

Note [1] : *260 m outside of the Intensive Area*
[2] : *Since the location is outside of the Intensive Area, sheet erosion estimation is not available. Consequently, the sediment delivery ratio was assumed to be 100%, considering the size of catchment area.*



Surveyed Sediment Delivery Ratio

(2) Soil Erosion Control Facility

1) Location

In the Intensive Area, Ministry of Forestry (BRLKT and District Forestry

Service) has provided soil erosion control facilities under the "Model Unit of Natural Resources Conservation Program" so-called UPSA. Below mentioned are the supports by the Ministry in UPSA:

- Terrace construction;
- Drainage system construction;
- Seedling supply; and
- Fertilizer supply.

The JICA Study Team surveyed following typical UPSA program in the Intensive Area.

Existing UPSA Program in the Intensive Area

Village	Sub-district	Implementation Year
Winebetan	Langowan	-
Touliang Oki	Eris	1999/2000

Source : District Forest Service

2) Type

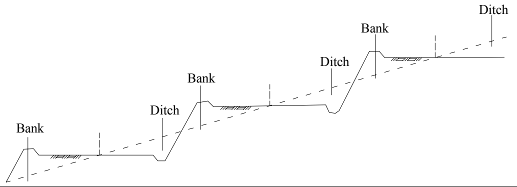
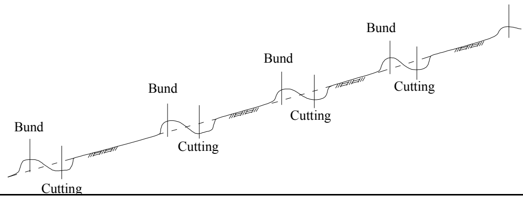
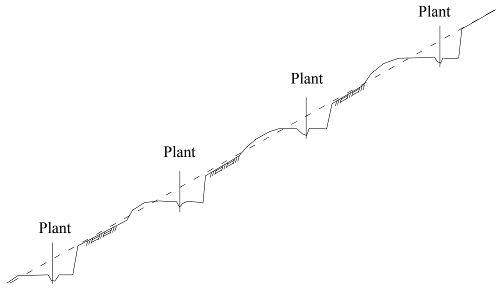
<u>Terracing</u>

In the UPSA program, three types of terrace are recommended. These are: (i) Bench Terrace (Teras Bangku), (ii) Contour Band (Teras Kridit), and (iii) Individual Terrace (Terrace Individu). Typical sections of the terraces are figured below:

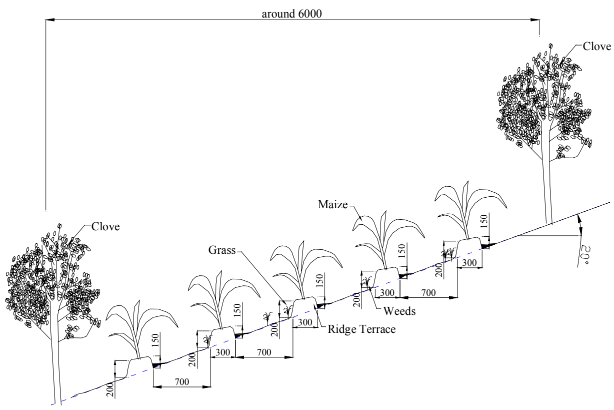
Outside of UPSA model plot, bench terrace and individual terrace are not common. However, contour band (or contour cropping with ridge terrace) is broadly used for the cultivating annual crops. Following figure shows the typical farming practice in the Intensive Area.

Bench Terrace Constructed by UPSA Program at Winebetan

Typical Section of Terraces Recommended in UPSA Program

Type of the Terrace	Recommended Section in UPSA Program
Bench Terrace	
Contour Band	
Individual Terrace	

Source : Project Design Book of UPSA



Typical Farming Practice in the Intensive Area
Unit: mm

<u>Drainage System</u>

BRLKT and District Forest Service are proposing two types of drainage channels, such as: (i) Diversion Ditch (Saluran Diversi), (ii) Waterway (Saluran Pembuangan Air), and (iii) Drop Structure for the UPSA scheme. Diversion ditches are placed upslope of the cultivated area to intercept water running into the plot. Water intercepted by diversion ditch or ridge of the plot flows into waterway and is conveyed to disposal point.

In the Intensive Area, above-mentioned drainage system is not common. However, thanks to the high infiltrate capacity of the land, high ridges are functioning as infiltration ditches. As a result, only small amount of surface water runoff is observed, even after the heavy rainfall.

3) Condition

Existing soil erosion control facilities are well maintained in the Intensive Area. However, it is essential to provide the facilities to the land, which has no proper soil conservation facilities.

(3) Torrent and River Bank Protection Works

1) Location and Type

In the West Area and East Area, a few numbers of river bank protection works were identified. Most of them were made of wet masonry and were provided in the settlement area to protect houses from the river bank erosion.

Effective Torrent Revetment Works at the River Panasen, H=2.5 m

In the South Area, land is composed of sandy soil. With this reason, river bank has low tolerance for the erosion, once it receives an intense water flow. The JICA Study Team identified severe river bank erosion at River Panasen. To avoid further erosion, former Ministry of Public Works has provided protection works made of gabion box as shown in the picture above. However, it is recommended to add several more protection works to stabilize the river bank.

2) Condition

The condition of existing river bank protection works is good and functioning well for the erosion control.

(4) Slope Protection Works for Hillside

1) Location and Type

The JICA Study Team identified slope protection works for hillside made of brushwood fence at two places of estate land in Eris.

Brushwood Fence Works at Eris

2) Condition

No problem is found for the existing slope protection works for hillside.

(5) Slope Protection Works for Road

1) Location and Type

The JICA Study Team identified several retaining walls along the major roads in the Intensive Area. The retaining walls are made of wet masonry as shown in the right.

Slope Protection Works for Road at Kakas, H=2.0 m

2) Condition

No problem was observed for the existing slope protection works for road.

3.1.10 Current Problems and Constraints from Physio-graphical Viewpoints

3.1.10.1 Erosion Hazard

In the Intensive Area, field observation and analysis revealed following problems.

(1) Soil Loss from Agricultural Land

In the intensive area, there is no gully erosion occurred. However, sheet erosion is found in some farms, where plants are still small and no conservation practice have applied, which are shown in Sub-section 3.1.3.1.

Soil loss calculation by the USLE gave average soil loss over the Intensive Area about 19 ton/ha/year. It is different by the areas and 12.5 ton/ha/year in the West Area, 20.4 ton/ha/year in the East Area, 27.6 ton/ha/year in the South Area. Tolerable soil loss is 15.6 ton/ha/year for the most part of East Area and 32.5 ton/ha/year for the other areas. The result of the computation showed that 43.6% of the East Area produces more than tolerable soil loss, and 8.1% in the West and 27.7% in the South. The areas, which erosion level is more than tolerable soil loss, needs corrective, or improving measures to decrease soil loss.

Agroforestry with additional soil conservation practices could be proposed to reduce soil loss from the agricultural lands. It meets the purpose of the project since the tree crops will work not only for increase of the produce but also for decrease soil loss.

(2) Slope Failures

As mentioned in Section 3.1.3.3, slope failures are observed at 5 sites only in the East Area. However, their scale is less than 600 m^3 except one at Mt. Maimbeng (it is triggered by abondoned quarry site confirmed in the last field invetigation). The other four sites have been re-vegetated naturally. Slope failure at Mt. Maimbeng seems to be expanding from the weathered layer.

Minor scale roadside slope failures have occurred only on the cut slopes as mentioned in Section.3.1.3.2. The slope failure along the Eris-Watulaney road was observed the cut slope could expand in near future.

Above erosions of slope failure in Mt.Maimbeng and roadside slope failure in Eris-Watulaney road are necessary to take corrective measures.

(3) Torrent Erosion

Field observation concluded four torrents were under critical situation, such as high flooding possibility, eroded banks, and bed degradation. The causes were aggressive land use addition to inherent weakness. All of them could affect adversely in the future to the productive paddy field and residential areas.

3.1.10.2 Lack of Basic Data

Tondano Lake has very important role in the region, as the biggest water source. Many specialist, researchers, local people have been argued about the lake, especially on erosion, sedimentation, and water quality. However, it was found during field study that the scientific data showing present condition are limited. For example, water quality of Lake Tondano is classified as 'eutrophic,' however, it has not been examined to specify what is the major pollutant, such as domestic waste water, fish culturing, pesticide and fertilizer, eroded organic soil, etc. Judging from existing data, it is impossible to specify the major cause of eutrophication since available data is insufficient to analyze current condition. It is necessary to specify the major pollutant for taking corrective activities. Regarding rainfall, it varies much by places and time and runoff occurs in a short time after rain. However, there is no flow rate measurement done in the in-flowing streams to the lake.

For proper management of the lake and its watershed, scientific data is indispensable to analyze the status of rainfall distribution, flow rate of inflow rivers, erosion rate, sedimentation, and water quality.

Most farmers were observed applying traditional soil conservation farming practices, which is generally effective to control erosion. However, they need more modification depending on the local condition, such as slope gradient, soil property, etc. To improve the practices, information on soil conservation knowledge and practices have to be distributed through extension services.

3.2 Erosion Control Plan

3.2.1 Need of Erosion Control

In previous sections, possible erosion hazard was discussed. Considering geophysical condition and current development trend, erosion hazard could be occurred in the area. As mentioned in previous Section 3.1.3, sheet erosion in the agricultural land was found even it is very small scale. As same as sheet erosion, slope failures, road side-slope erosion, and bank erosion in torrents were found out in the area. They are mostly minor scale or defined as a potential critical land, however, some of them could expand the extent of the area. In such case, erosion control measures shall be prepared to stop erosion hazard. In the following sections, corrective and rehabilitation measures against potential erosion hazard will be proposed.

3.2.2 Basic Approach

In the Intensive Area, the farms that need erosion control is mostly composed of steep and narrow areas. Addition to this, the farms are belongs to individual farmers. It seems that introduction of simple on-the-farm practices, which could be applied by each farmer, is the most appropriate to these farms. To reduce soil erosion from the agricultural lands, basic idea is to apply such simple erosion control practices including agroforestry, and to minimize structural measures in the farms. On the other hand, erosion in the river channels and natural slopes usually needs structural approach, since the extent of the erosion is large and the driving force of the erosion is strong. Such erosion will damage the farms along the rivers or on the hill foot and such damage will affect not only single farmer. The corrective or protective measures become usually large scale, and individual farmer could not afford financially and technically. Therefore, the erosion control measures in the torrents or slopes shall be established in the project.

3.2.3 Soil Erosion Control by Non-Structural Measures

Slope Distribution by Land Use

(%)

Slope Class	1	2	3	4
	Forest	Estate	Mixture of 2 & 4	Dry farm land
>40%	7.67	8.09	1.50	0.19
40 to 25	4.53	16.34	8.40	2.03
25 to 15	1.53	7.48	14.88	3.84
15 to 8	0.23	1.23	5.52	3.30
<=8%	0.42	0.46	5.98	6.37

In the Intensive Area, land use pattern has been determined by the slope of the land. This is shown in the following table. In the Master Plan, the land which has more than 40% slope was categorized in Protection Zone and limited its use only for forest. Estate of less than 15% slope and dry farming land of less than 8% slope were categorized in Farming Zone. The land which has slope between above were categorized in Buffer Zone. At present, almost half of the forestland area is more than 40% slope, and about 1/4 of estate has more than 40% slope. However, half of estate has 25 to 40% slope. Regarding the land of mixture of estate and dry farming, about 1/4 of them is situated more than 25% slope.

Land use pattern in the Intensive Area differs much including improper pattern of land use. From the point of view of soil loss, improper land use is major problem on sustainable land use. In the case of the estates, and the mixture of estate and dry farming land, the lands under the trees are used for maize cropping. Their cultivation practice not always appropriate, and inappropriate use has to be corrected with help of proper erosion control farming practices.

3.2.3.1 Soil Erosion Control Measures

(1) Erosion Control Cultivation

Introduction of agroforestry contributes to reduce the effective rainfall energy by intercepting falling raindrops by leaves and branches of trees. Dense population of trees, such as multi-story tree cropping, covers ground surface wider and improve erosion control capacity. This agroforestry will be a major tool to reduce erosion along with increase production in the area, and details are mentioned in Appendix-G.

Practice of tillage and planting on the contour, in general, is effective in reducing erosion. However, farming lands in the Intensive Area are so steep and small that the current practice needs some monifivation depending on the farm condition. Below practice are typical soil conservation measures

- Traditional terraces which is a mixture of removed weeds residues and soil, similar to the contoured residue strips, that is contoured strips of heavy crop residue mulch. Traditional terrace could be suitable up to 30% slope. However, it needs to make larger and stronger for steep slopes.
- Ridge and furrow, a practice which crops are planted on the ridges or in the furrows depending on the nature of the crops.
- Contour listing, a practice in which crops are planted in the furrows. Some farmers apply in the area. Applicable up to 40% slope.
- Controlled-row grade planting, a practice in which crops are planted on ridge with undiminished channel capacity. This is introduced already. This is applied up to 40% slope.
- Stripcropping, a practice in which contoured strips of sod are alternated with equal-width strips of row crops or small grain. This method is applicable on steep slopes in the estates. Applicable up to 40%.
- Close-growing vegetation, which is also effective to reduce raindrop velocity and obstruct runoff flow. This is already applied in the area.
- Mixed crops cultivation, in which several kinds of crops are planted together to increase surface coverage. It is modified to agroforestry in this plan.
- Vegetation covering, a practice which covers the surface with grass, grass-like plants, or broadleaf herbaceous plants. This is very effective method to reduce raindrop energy and velocity of surface flow. It will be introduced in the estates which will not cultivate under the trees.
- Mulches intercept falling raindrops so near the ground surface that the drops regain no fall velocity, and they also obstruct runoff flow and thereby reduce its velocity and transport capacity. Crop residues left on the surface works for mulches. A few farmers apply mulches, it is effective in the period after harvest until grasses grown.

(2) Tillage Control

The type, frequency, and timing of tillage operations influence porosity, roughness, cloddiness, compaction, and micro-topogaraphy. These, in turn, affect water intake, surface storage, runoff velocity, and soil detachability, all of which are factors in potential erosion. Tillage control supports to maintain the soil structure in favorable condition. The practices are minimum tillage that tills only planting rows with little disturbing soil, and no-till method that digs holes for seeding. These practices are already applied for maize by some farmers in many places.

(3) On-farm Technical Measures

The most common on-farm level technical measure is terrace. The steep backslope terrace is most common on steeper land. It can be applied up to 25% slope, because the width of farm will be less than 10 m wide when it is applied on steeper land. The bench terrace, which has planting width down to 2 m. This is applicable on steeper land above 25% slope. Broadbase terrace is suitable on gently sloping land with the channel and ridge cropped.

Intercepting waterways for the disposal of overland flow from upper slope are a recommendable practice where infiltration rate is low.

3.2.3.2 Determination of Values of USLE Factors

R factor, K factor, and Slope gradient are not affected by the corrective measures, the they are same value mentioned in Section 3.1.4. Length of slope, C factor, and P factor are varied by introducing improved farming practice. They are shown in the table below.

Revised Slope Length, C-factor and P-factor

Land Use	Slope Length (m)	C Factor	P Factor
Natural /Semi-natural Forest (1)	31	0.001	1.000
Secondary Forest (2)	31	0.005	1.000
Planted Forest (3)	31	0.005	1.000
Estate (4)	23	0.027	0.400
Mixture of Estate and Dry –Farming (5)	9	0.140	0.350
Dry Farming Land (6)	1	0.253	0.150
Pasture Land (7)	31	0.027	0.600
Paddy Field (8)	40	0.010	0.040
Swamp (9)	50	0.010	1.000
Water Body (10)			
Settlement and Others (11)	25	0.180	0.150

3.2.3.3 Soil Loss Estimate

Soil loss will be reduced by implementing proposed measures. It is estimated using USLE as same as described in Section 2.1.3.1. The result is shown in following table.

Over the Intensive Area, anticipated amount of soil loss will decrease to 1.93 ton/ha/year by implementation of soil conservation measures from 19.05 ton/ha/year of present amount of soil loss.

Since, in general, the amount of soil loss is larger on the steeper lands though the erosion control measures are implemented, the steeper the land, the more careful measures will be required.

Estimated Erosion after completion of the Project

(tons/ha/year)

Area		Average	Median	Sub-Area		Average	Median
All	w/ Project	1.93	0.91				
	Present	19.05	7.81				
West	w/ Project	1.17	0.72				
	Present	12.48	5.45				
East	w/ Project	2.79	1.12	Eris (E-N)	w/ Project	3.09	1.39
	Present	20.44	13.22		Present	23.32	16.69
				Kakas (E-S)	w/ Project	1.70	0.32
					Present	9.64	7.81
South	w/ Project	2.26	1.26	Soputan (S-W)	w/ Project	1.76	1.26
	Present	27.64	4.65		Present	5.84	2.14
				Kawatak (S-E)	w/ Project	4.78	2.25
					Present	37.44	5.03

3.2.4 Erosion Control using Facilities

3.2.4.1 Erosion Control Facility for Critical Land

(1) Slope Protection Works for Hillside

1) Site

Since the slope failure on hillside at Mt. Maimberg has certain extent of area and low possibility of natural re-vegetation, it is required to rehabilitate it using facility (See Figure H.3.28).

2) Proposed Facility

Taking account of condition of the site, combination of gabion box slope protection works (up slope) and bamboo terrace works (middle slope) would be recommended (See Figure H.3.29).

(2) Slope Protection Works for Road

1) Site

The slope protection works for road are required for the site Paleloan and Eris-3.

2) Proposed Facility

Types of the slope protection works for road for the selected 2 sites were determined using the chart presented in Figure H.3.30. The result shows that grading and sod facing works will be conducted for the site Eris-3 and gabion box slope protection works will be provided for the site Paleloan.

(3) Protection Works for Torrent and River Erosion

1) Torrent and River Bed Protection Works

Site

To determine the specific sites, following criteria were applied.

- The location with severe river bed degradation,
- The location without curve section.

Based on the criteria above mentioned, 6 locations on the River Panasen was selected for the sites of river bed protection works (See Figure H.3.28).

Proposed Facility

River bed protection works will be provided to avoid further river bed degradation. River bed protection works has different objectives from the check dam. One of the major objectives is to stabilize and keep the existing river bed gradient. Consequently, it does not have storage capacity for the sediment trap.

There are two alternative types of the river bed protection works, which could be applied for the Project. These are wet masonry river bed protection works and gabion box river bed protection works. The JICA Study Team selected a gabion box type for facilities using the chart shown in Figure H.3.30.

2) Torrent and River Bank Protection Works

Site

River bank protection works will be provided at the bend of the downstream of River Panasen to prevent further river bank erosion. Total length of the works is about 900 m.

Proposed Facility

Gabion box river bank protection works would be most appropriate given its flexibility and availability.

(4) Check Dam for Debris Flow Control

1) Site

It is required to provide the debris control facility at site Tataaran to prevent disaster of debris flow.

2) Proposed Facility

To control the debris flow, wet masonry gravity check dam with suitable thickness is proposed. Proposed height of the dam is 6 m, although further detail study is required.

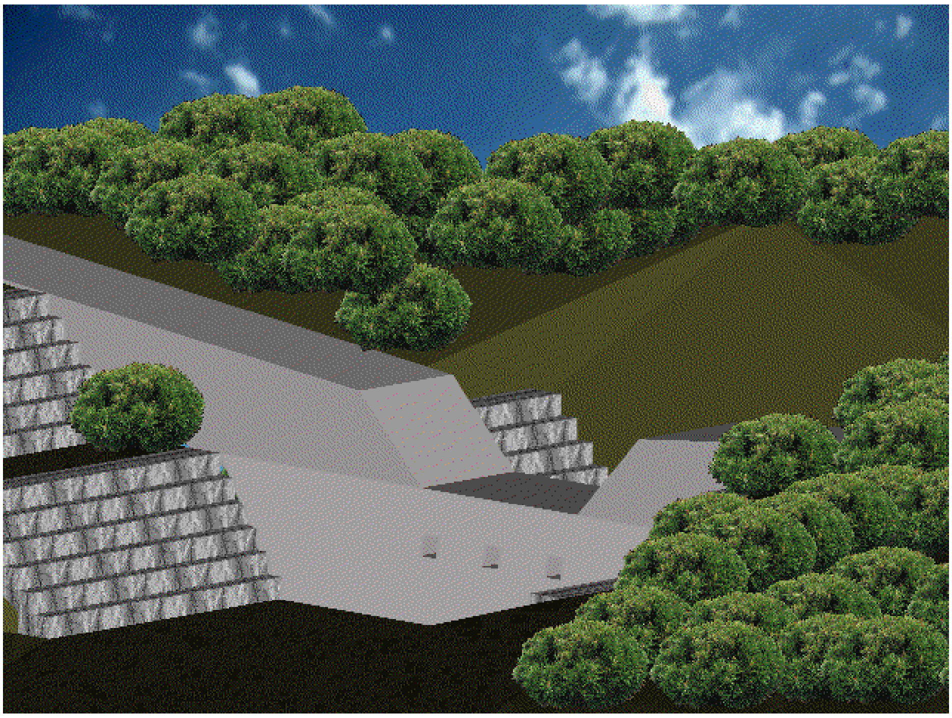


Image of Check Dam at Tataaran

3.2.4.2 Erosion Control Facility for Potential Critical Land

(1) General

In the several sub-watersheds, excess of sediment from potential critical land flows down to Lake Tondano, irrigation facilities in the downstream etc. until the project components are fully developed. To avoid this harmful sediment transport, sediment trap by check dam is required. The sites of the check dams were decided based on the following steps:

Step 1

Maximum use of existing checks dams through rehabilitation works of existing check dams was considered prior to plan the new construction of check dams.

Step 2

Existing construction plan of the check dam was surveyed to avoid overlapping of the construction plan.

Step 3

The amount of sediment yield at the proposed dam site was estimated to clarify the necessity of check dam.

Through the analysis, following rehabilitation works of existing check dams and construction of the new check dams were proposed.

(2) Rehabilitation Works of Damaged Check Dams

1) Site

Through the inventory survey, 4 damaged check dams were identified. Out of these 4 damaged existing check dams, rehabilitation works will be conducted for 3 dams to maintain the sediment control function of the check dams. Since the dam body of check dam Touure has been totally damaged, there is no possibility for rehabilitation. Details of the rehabilitation works are summarized below (See Figure H.3.27 for the location of existing check dams).

2) Required Rehabilitation Works

Following table shows the required rehabilitation works for the above-mentioned three damaged check dams.

Required Rehabilitation Works for Damaged Check Dams

No.	Location of Check Dam	Required Rehabilitation Works
1	Leleko in West Area	Re-embankment and sod facing works to repair the slipped downstream slope of the dam body.
2	Kasuratan in West Area	Riprap works on the downstream part of spillway to prevent further damage.
3	Tountimomor in South Area	Additional gabion works for the damaged gabion check dam to strengthen its structural stability.

(3) Construction of New Check Dams for Sediment Trap

Prior to the planning of new check dam construction, existing construction plan of check dams was surveyed. According to the interview of relevant agencies, the Regional Irrigation Office is planning to construct six check dams in the East Area of Lake Tondano under "Technical Plan of Erosion and Sediment Control at Tondano Watershed" study which was conducted in 1995/1996. The proposed locations are: (a) Tounsukun, (b) Tounipus, (c) Tondano Indah, (d) Touliang Oki, (e) Kombi, and (f) Telap/Tandengan. Out of the six dams, Regional Irrigation Office is going to construct check dam at Tounsukun in year 2001, so that the JICA Study Team judged that there is no necessity of dam construction at Tounsukun any more. Meanwhile, since there is no concrete construction plan for the other sites, check dam on them might be planned in the Study, if it is required. Figure H.3.31 presents the projected six check dam locations.

Next, the amount of sediment yield at downstream end of the sub-watershed was estimated to clarify the necessity of the check dams. The JICA Study Team considered three major sources of the erosion in the analysis. These are: (i) soil erosion, (ii) slope failure on hillside, and (iii) landslide. Slope failure along the road is not considered in the analysis, since the amount of erosion is negligible.

1) Method of Sediment Yield Estimation

Sediment yield from the respective sub-watersheds were calculated by using the formula as follows:

$$SY = (VSE + VSFH + VLS) \times SDR$$

where,

SY	:	Sediment yield (m^3),
VSE	:	Volume of soil erosion (m^3),
VSFH	:	Volume of slope failure on hillside (m^3),
VLS	:	Volume of landslide (m^3), and
SDR	:	Sediment delivery ratio (-).

Sediment delivery ratio was estimated based on the result of sediment yield survey on existing check dams. The figures of sediment delivery ratio used for the estimation are tabulated below (See Sub-section 3.1.9 for the survey).

Sediment Delivery Ratio for the Study

Catchment Area (ha)	0≤A<20	20≤A<30	30≤A<50	50≤A<100	100≤A
Sediment Delivery Ratio (%)	90	80	65	50	20

2) Result of Sediment Yield Estimation

The total volume of sediment yield is described in Table H.3.7. The result shows that among the 30 numbers of sub-watersheds, sub-watersheds 13, 14, 20, 22 and 25 receive a large volume of sediment yield (more than 500 m^3).

3) Site

The JICA Study Team decided the site of check dams considering following items:

- Sediment yield at proposed dam site (more than 500 m^3),
- Location of the existing check dam, and

- Risk of the downstream river bed erosion caused by the construction of check dam.

The JICA Study Team propose that sediment yield less than 500 m^3 must be controlled by the suitable erosion control measures on problem site, not by the check dam. See Figure H.3.32 for the detail of analysis.

The result shows that it is required to construct new check dams at sub-watershed No. 20, 22, and 25 to trap excess sediment yield. The location of proposed check dams are shown in Figure H.3.28.

Site of Proposed New Check Dams for the Sediment Yield Control

No.	Location	Sub-watershed No.
1	Tandengan in East Area	20
2	Ranomerut in East Area	22
3	Tounipus in East Area	25

4) Proposed Facility

For selecting the type of check dam, three alternatives were considered by material. These are: (a) wet masonry, (b) gabion, and (c) earth fill. The characteristics of the alternatives are summarized in the following table.

Alternative Types for the Check Dam Type

	Alternative	Advantage	Disadvantage	Conclusion
1	Wet Masonry Gravity Check Dam	1. High strength 2. Long life	1. Difficult maintenance	Suitable
2	Gabion Check Dam	1. High flexibility 2. Easy maintenance 3. Speedy Construction	1. Low strength 2. Short life	Not suitable
3	Earth Fill Check Dam	1. Stored water can be use for water supply	1. Low strength to overtopping 2. Spillway on the rock foundation is required 3. Farmers' over-expectation for the water supply	Not suitable

Out of the three alternatives, wet masonry was selected as suitable type considering its stability, sustainability and economic aspect.

Gabion box check dam would not be appropriate for the project, taking the characteristics of the torrents into account. Since the torrents have very narrow width comparing with the width of valley, so that it is required to design relatively long length of the dam crest to obtain necessary capacity of the dam. If the gabion box were applied with this situation, it might be difficult to lead excess floodwater to the spillway section, since a part of gabion box dam crest might be settled unequally. If the floodwater overflowed from the dam crest settled section, it would damage the dam stability severely. Considering this situation, it can be said that gabion box is not suitable material for the check dam, though it is suitable for small-scale river bed protection works.

Earth fill check dam will not be used, considering the following technical reasons: (a) low stability of the dam due to the low construction skills, (b) overflow water would erode dam body itself, after sediment yield fills up the dam capacity, and (c) farmers' over-expectation for the irrigation water supply.

3.2.5 Erosion Control Plan for Each Zone

In the Intensive Area, most agricultural lands are narrow and steep. Even such difficult situation, they need to increase yield because of shortage of land area. Introduction of agroforestry meets the necessity of local requirement. However, without positive soil conservation measures, application of agroforestry only for increase of number of the trees will not contribute for sustainable crop farming because of anticipated soil loss from the agricultural lands.

(1) P Zone

1) Non-structural Measures

This Zone should be not used for farming in principle. Reforestation is promoted.

2) Structural Measures

There is a slope failure at Mt.Maimberg in the South Area. This slope failure is recommended to be repaired using bamboo terrace work.

(2) Bm1 Zone

1) Non-structural Measures

Tree crops dominant agroforestry will be applied with traditional terrace, however, the farms pointed in 3.1.3.1 need below soil conservation measures. Bench terrace is most suitable method to apply in this Zone with intercepting waterways, if necessary. High bed with infiltration channel is suitable for permeable soil. Simpler method, such as stripcropping, controlled-row grade planting, contour listing, and ridge and furrow are applicable up to 40% slope. Stripcropping is most suitable on steeper slope. However, use of vegetation covering and close-growing vegetation are unsuitable to this Zone since dense agroforestry is applied already and the vegetation will not grow well under the shade. Mulches of crop residues are effective after harvest until crops grown.

2) Structural Measures

Slope failures at Eris-3 in the East Area should be repaired using gabion. A check dam of wet masonry type is necessary at Tandengan and Ranomerut in the East Area.

(3) Bm2 Zone

1) Non-structural Measures

Agroforestry will be introduced to reduce soil loss. Traditional terrace is necessary when the land is used for cultivation. It needs some modification to strengthen when used on the land more than 25% slope. Ridge and furrow, contour listing, and controlled-row grade planting are also applicable to this Zone.

On the other side, in a crop farming land, close-growing vegetation is recommended. Vegetation covering, which covers the surface with grass, grass-like plants, or broadleaf herbaceous plants, is very effective method in the estates where the land is not used for crop cultivation.

Crop residues mulch is very important during the period when the ground surface is bare. Minimum tillage, or no-tilling farming also contributes to decrease soil loss.

If slope of the land is between 15% and 25%, steep backslope terrace is suitable to reduce the slope of the land, where corrective measures are needed.

2) Structural Measures

Slope failure was found at Paleloan site in the West Area. It should be repaired by providing grading and sod facing work. A check dam should be constructed at Tataaran in the West Area for sand trapping purpose.

(4) Bm3 Zone

1) Non-structural Measures

This Zone needs a little attention to soil loss, because the land is not so steep. Agroforestry is promoted in this Zone, however, erosion control is not major purpose. Practice of tillage and planting on the contour is essential practice with help of ridge and furrow, or contour listing. In this Zone, traditional terrace is effective without any improvement. It is important to change the cropping practice into close-growing vegetation. Mulches of crop residues is effective in the period after harvest until crops grown.

Vegetation covering is recommended in the estates where the ground is not used for crop cultivation. Minimum tillage, and no-till farming are also effective measures to reduce erosion.

2) Structural Measures

No erosion control facility is required for the zone.

(5) Bw Zone

1) Non-structural Measures

This zone is not favorable for farming basically due to very steep lands on the river banks of more than 35% slope, but the lands are used for agriculture here and there. No crop agricultural activities are recommended here. Agroforestry of multi-story tree complex have to be expanded to protect the lake shore and river banks.

2) Structural Measures

No special erosion control facilities would be required.

(6) F Zone

1) Non-structural Measures

This Zone has little problem on erosion since the slope in this Zone is gentle. Agroforestry will be introduced, but it is not expected to reduce erosion since soil loss from this zone is limited. However, when the land is sloped even very gentle, it is recommended to apply soil conservation practice. Practice of tillage and planting on the contour is fundamental farming manner over the area. Close-growing vegetation, ridge and furrow are applicable in this Zone, and mulches are also effective for reduction of soil loss.

2) Structural Measures

Torrent erosion sites should be provided with proper protection measures such as groundsills and river revetment works. These erosion sites are located on the Panasen river in F Zone in the South Area. The required number of them would be 6 groundsills and 900 m river revetment works. In addition, one check dam should be constructed at Tounipus site in the East Area for sediment trap purpose.

3.2.6 Monitoring

3.2.6.1 General

Though Tondano Lake has been given very important role as the biggest water source in the region, scientific data are very limited to explain current condition, compared to the verbal information by the people. 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 the data showing the fact of erosion and sedimentation, but there were little observed data to analyze them.

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

3.2.6.2 Soil Erosion and Sedimentation

Measurement of soil loss is necessary for improving accuracy of soil loss estimate by computation. There are several equations to estimate soil loss, but the calculated amount of soil loss is not always same to the actual soil loss amount. There have been shown several estimates on the soil loss from the Tondano watershed by various agencies, but it is a question whether the results of calculation indicate real amount of soil loss or quite different from actual. To improve such situation, computed value of soil loss must be compared to the observed amount. Selection of appropriate coefficient matched to the local conditions leads to improve precision of the calculation. Considerable duration is necessary to observe and collect data on soil loss, i.e. until establishing the procedures to select appropriate coefficient.

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 on sedimentation is important to monitor the watershed condition. In the Tondano watershed, the check dams are small compared to their drainage area, so that the change of the amount of the erosion in the drainage area could be magnified in the reservoir, i.e. by the change of the depth in the reservoir. Sedimentation in the reservoirs could be direct indicator of the erosion control effort in its upper reaches. Monitoring of the sediment in the reservoirs is easy and gives correct information on the erosion control efforts, but the frequent measurement is necessary due to the fast change of the depth in the reservoir. On the contrary, accurate measurement of the sedimentation in the lake is not so easy. Since the area of the lake is only 4 times of its drainage area, the change of the depth of the lake will be magnified only 4 times of eroded depth, when total amount of the eroded materials go into the lake. Addition to it, the sediments on the bottom of the lake are composed of very fine materials and have not consolidated. Considering above conditions, accuracy of measurement by sonar, and expected annual amount of sedimentation, frequency of bathymetry, measurement of the depth of the lake, would be recommended once in a several years.

Since the amount of eroded soil is not equal to that of the sediment, sediment delivery ratio (SDR) is necessary to estimate sedimentation. It is expected that the SDR will fluctuate depending on rainfall intensity, flow rate, etc. To know the SDR, it is necessary to continue the measurement in a few specific rivers.

(1) Monitoring of Soil Loss

For measurement of soil loss, three (3) monitoring stations will be established. Their locations are recommended in West, East, and South Areas. Duration of monitoring will be 5 years, during which the most suitable coefficients will be selected for soil loss estimate to meet the local conditions.

1) Necessary Data and Equipment

Necessary data for soil loss estimate are rainfall, rainfall intensity, amount of soil loss along with slope, properties of the soil, land use, kinds of crops and their cropping practice, etc. Standard size of monitoring building with soil loss measuring plots will be prepared for the soil loss measuring stations. Soil loss measuring plots with sediment traps should be equipped. In the stations, following equipment will be installed to measure the soil loss.

Necessary Data and Equipment for Soil Erosion Monitoring Station

Data to be Monitored	Necessary Equipment
Rainfall	1. Automatic Rainfall Gauge
Amount of soil loss	1. Sediment trap 2. Balances for measuring soil weight 3. Drier

Note : Collected data will be send to the watershed information system.

2) Sites of the Stations

To clarify the most suitable coefficients to the local conditions, the sites of the measuring station are recommended in the West, East, and South Areas, since these areas has different soil type, different slope, and different type of farming. Proposed site of three soil loss monitoring station is shown in Figure H.3.33

(2) Monitoring of Sedimentation

For observation of the sediment, regular survey at the existing check dams and the Lake is recommended.

Necessary data are annual change of accumulated sediment, and analysis of bottom materials. Sampling and analysis will be done once in 5 years, and sample will be analyzed at the existing laboratory. Items of required analysis are chemical and physical properties to identify the source of origin of the materials. Measurement will be done by contract basis, but bench marks shall be placed by the project.

Necessary Equipment for Sediment Monitoring

Items to be Monitored	Necessary Equipment
Depth of the Lake	1. Bench marks

Note : Collected data will be send to the watershed information system.

(3) Monitoring of Sediment Delivery Ratio

Measurement of sediment delivery ratio needs the flow rate and sediment concentration in the river. Flow rate will be measured at 12 sites described in the following section. Sediment concentration will be measured at seven points by sampling water depending flow condition.

1) Necessary Data and Equipment

Necessary data are flow rate and sediment concentration of the flow. Since the rivers are very small, no special water sampler is necessary to measure sediment concentration. But for measuring flow rate, standard size of monitoring building and trapezoidal measuring flume in the SPAS scheme can be applied for the SDR monitoring station.

2) Site of the Station

The sites for measuring sediment concentration will be selected considering characteristics of drainage area, such as slopes, geology, land use, etc. Recommended sites are shown below table.

Recommended Observation Sites for Sediment Concentration

Data to be collected	Necessary Equipment
Sediment concentration	1.Pakawa at d/s Makalonsouw, 2.Touliang Oki at Check dam (existing), 3.Watumea-Eris, 4.Saluwangko at Kakas Bridge, 5.Panasen at Tountimomor Bridge, 6.Mawalelong, 7.Paleloan 1 (Tungkageerang), 8.Tougela

Note : Collected data will be send to the watershed information system.

3.2.6.3 Water Quality

Current condition of Lake Tondano is classified as 'eutrophic' condition. To improve the condition of the Lake, the major cause of deterioration has to be removed. But it is unclear what is the major pollutant of eutrophic now. It is necessary to clarify the sources causing eutrophication and to evaluate their contribution to eutrophication.

Usually deterioration of water quality is not caused by a single pollutant, and the success of the effort for the specific pollutant leads the alteration of major pollutant. Moreover, a new source could emerge in the future. Such possibility demands regular and continuous monitoring on the water quality in the future.

(1) Regular Monitoring of Water Quality

1) Necessary Data and Equipment

Continuous monitoring on the water quality is required in Tondano Lake. But considering the current status of the area that there are no industries except farming and woodworks in the watershed, frequency of water quality measurement is recommended 4 times a year. As shown the phenomena of 'Air Lewo,' which is explained rising of organic deposits from the lake bottom, water quality of the lake is obviously different by depth. It suggests water samples should be taken from different depth. It is recommended that water samples have to be collected at 4 different depths in the Lake, i.e. near surface, near bottom and 2 intermediate depths since the depth of the lake is different by the location in the Lake. Necessary measuring items are DO, pH, EC, N, P, BOD, Suspended solids, Plankton, and Clearness. Water analysis will be done in the existing laboratory.

Necessary Equipment for Water Quality Monitoring

Data to be collected	Necessary Equipment
Water quality	1. DO meter 2. pH meter 3. EC meter 4. Secchii disc for water clearness
Water sampling	1. Water sampler 2. Motorboat

Note : Collected data will be send to the watershed information system.

2) Site of the Regular Monitoring

Site of the lake monitoring station were determined considering the below requirement:

- To distribute the sampling points evenly for specifying the major supplier of eutrophication of the lake water.

Eight monitoring sites are recommended as following.

- Toulour (Outflow of the Lake)
- Kakas (Inflow of the lake)
- Northern Center of the lake
- Southern Center of the Lake
- Eris (Fish Cultivation Site 1)
- Kakas (Fish Cultivation Site 2)
- Remboken (Fish Cultivation Site 3)
- Tondano (Fish Cultivation Site 4)

(2) Specifying Pollutant

1) Necessary Data and Equipment

Mainly chemical analysis of bottom materials is necessary. Several pollutants could be pointed out, such as farm chemicals of fertilizer, pesticide, insecticide, etc., domestic waste from the residential areas around the Lake, feeds of the cage aquaculture, accumulated eroded soils, hot spring water from the volcanoes, etc. The first analysis needs to evaluate the weight of each pollutant to the deteriorated water quality of the lake. Continuous monitoring is not required. Considering the period for effect of the corrective measures worked out, analysis of the bottom materials will be done every 5 years. Analysis of the soil has to be done in the existing laboratories.

Necessary Equipment for Water Quality Monitoring

Data to be collected	Necessary Equipment
Sampling of bottom materials	1. Soil sampler

Note : Collected data will be send to the watershed information system.

2) Site for Sampling

Sampling points should be determined considering land use, especially distribution of paddy fields, residential areas, cage aquaculture. Eight monitoring sites are recommended as same as that of water quality.

3.2.6.4 Water Balance

Tondano Lake 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, rainfall distribution around the lake is extremely uneven and there are many small streams. 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, and moreover make water management easy. It is recommended to monitor one specific minor watersheds as typical watersheds. The data will be applied for other similar minor watersheds.

(1) Necessary Data and Equipment

Rainfall distribution: 21 rainfall station, including 2 existing stations, are recommended to place around the lake as indicated in the below table. Every station will be equipped with recording rain gauge.

Flow rate of in-flowing rivers: 11 gauge stations are recommended. They are as follows. Every water gauge station will be equipped with recording water gauge in the gauge house.

Flow rate of out-flowing river: Flow rate of out-flowing river additional 1 gauge station between Toulour and Tonsealama. The water gauge station will be equipped with recording water gauge in the gauge house.

Lake water surface: Existing station of the PLN will be used for measurement of the lake water surface, but the water gauge has to be changed.

Necessary Equipment for Lake Monitoring Station

Data to be collected	Necessary Equipment
Rainfall	1. Recording rain gauge
Flow rate	1. Recording water level gauge
	2. Construction of gauge house

Note : Collected data will be send to the watershed information system.

(2) Sites of the Observation Stations

Sites of rainfall measurement and flow rate observation are recommended as shown in below table. Distribution of measuring stations is determined considering the below:

- Rainfall station will be placed at about every 10 km^2, considering stretch of the rain area.
- Flow rate measurement shall include 3 major rivers, i.e. Panasen river with drainage area of 62 km^2, Saluwangko river with drainage area of 48 km^2, Mawalelong river with drainage area of 23 km^2, and several typical minor rivers in different areas.

Recommended sites of rain gauge and water gauge stations are as following.

Recommended Observation sites for Rainfall and Flow Rate

Data to be collected	Necessary Equipment
Rainfall	1.Toulour (Tondano), 2.Tataaran, 3.Tounsaru, 4.Paleloan, 5.Leleko (existing by PLN), 6.Tampusu, 7.Pulutan, 8.Passo, 9.Tempok (Tompaso), 10.Karondoran (Langoan), 11.Tonsewer, 12.Tumaratas atas, 13.Noongan, 14.Kawatak, 15.Simbel, 16.Kakas, 17.Terap (existing by PLN), 18.Eris atas, 19.Ranomerut, 20.Touliang Oki atas, 21.Makalonsouw)
Flow rate	1.Pakawa at d/s Makalonsouw, 2.Touliang Oki at Check dam (existing), 3.Tandengan, 4.Watumea-Eris, 5.Saluwangko at Kakas Bridge, 6.U/S Saluwangko Kawatak (existing), 7.Panasen at Tountimomor Bridge, 8.Panasen at Langoan-Tompaso Bridge, 9.Mawalelong, 10.Paleloan 1 (Tungkageerang), 11.Tougela

Note : Collected data will be send to the watershed information system.

3.2.6.5 Watershed Information System

Total watershed information system is proposed to collect and analyze all the data mentioned above. In this system, addition to above mentioned data, following would be recorded and monitored:

- Location, date and scale of the hillside slope failure,
- Location, date and scale of the road cut slope failure,
- Location of the torrent bed degradation,
- Location of the torrent bank erosion, and
- Condition of the watershed conservation facilities.

To store and analyze the above-mentioned records, existing computer and GIS system in BRLKT office will be used.

3.2.6.6 Implementation Schedule

(1) Erosion and Sedimentation

Since soil loss monitoring aims at improving accuracy of soil loss estimate, it could be halt when sufficient data are collected. Duration of monitoring is proposed 10 years for the first phase.

Sediment delivery ratio (SDR) is necessary to estimate the amount of sedimentation, however it fluctuates depending on rainfall intensity, etc. To collect sufficient data for estimate of the SDR, duration of monitoring is proposed 10 years.

Regular data gathering on sedimentation in the Lake and reservoirs of check dam could be an indicator of the effect of conservation works. However, since the effect comes out slowly and it takes considerable time, frequency of bathymetry, measurement of the depth of the lake, would be recommended every 5 years.

(2) Water Quality

Water quality monitoring has two objectives; one is monitoring the effect of the works, and another is to judge the water quality whether it is suitable to various demands. Frequency of water quality measurement is recommended 4 times a year.

Success of the effort for the specific pollutant leads the alteration of major pollutant and new pollutants could emerge in the future. Such possibility demands ceaseless and regular monitoring of the water quality. Sampling and analysis will be done once 5 years.

(3) Water Balance

To establish fair water distribution rule, chronic water balance data are important. Rainfall distribution around the Lake, flow rate of inflow and outflow, and lake water surface needs to observe continuously.

(4) Torrent and Slope Erosion

Erosion in the torrents and slopes occurs incidentally. Observation and monitoring of these items are necessary to continue.

The monitoring schedule in Figure H.3.34 is proposed based on above idea.

3.2.6.7 Cost Estimate

(1) Basic Assumption

The construction cost consists of direct construction cost, engineering services and physical and price contingencies. Following basic consideration and assumption are made for estimate the project cost:

- The exchange rate used in the cost estimate is:
  US$ 1.00 = Rp. 9,100 = ＼ 115
  as of December 2000.
- Construction works will be executed full contract basis through competitive bidding. The contractor himself will provide the construction machinery and equipment required for construction. Thus, depreciation cost of machinery and equipment are considered in the estimate of construction unit rates.
- The unit rates of the works are divided into the foreign and local currency portions.

Respective currency portions include the following costs:

Demarcation of Local and Foreign Currency

Local currency portion:	Local labor cost, Cost of local material, Machinery cost, Inland transportation cost, etc.
Foreign currency portion:	Foreign labor cost, Cost of imported materials, Machinery cost, etc.

- The unit rates of the works are estimated at the December 2000 price on the basis of the current price prevailing in North Sulawesi and data obtained from standard price list of several government agencies and similar projects.
- Materials and equipment is provided firstly installed by the Project and is maintained and replaced by the Government of Indonesia later.
- Engineering service is provided by the Project with the administration support from the Government of Indonesia in the project implementation period. For the project running period, only administration support from the Government of Indonesia is applied.
- Ten years implementation period is applied for the project.

(2) Capital Cost

1) Direct Construction Cost

Direct construction cost can be obtained by multiplying construction unit rate and work quantity. Construction unit rates for the major works were calculated based on the local production rate of the works as much as possible. The data of local production rate of the works were collected from District Forest Service. Work quantities were preliminary estimated with feasibility study level accuracy (See Table H.3.8 to H.3.12).

2) Indirect Construction Cost

Indirect construction cost was assumed as a 20 % of the direct construction cost.

3) Monitoring Apparatus Cost

Monitoring apparatus will be import from foreign countries, since they may not be available in the local market (See Table H.3.13).

4) Engineering Services Cost

Local consultant team will organize the detail design and construction supervision with the cooperation of Ministry of Forestry (See Table H.3.14).

5) Administration Cost in the Project Implementation Period

Annual administration cost for the monitoring system development is shown in Table H.3.15.5) Capital Cost of the Monitoring System

Total capital cost for the erosion control facility development will be Rp. 2,358 million as shown in Table H.3.16. However, price contingency was not included here, since it will be added separately to the total capital cost of the project (See Appendix-J Section 4.1.7).6) Annual Disbursement Schedule

The annual disbursement schedule for the project implementation period shown in Table H.3.17 was prepared based on the implementation schedule presented in Figure H.3.34.

(3) Running Cost

1) Administration Cost for the Project Running Period

The JICA Study Team proposed to monitor the erosion and sedimentation only for the first 10 years by the project. However, other items such as water quality and water balance should be monitor throughout the 60 years. The Government of Indonesia will do this monitoring. For this reason, administration cost for the water quality monitoring and water balance monitoring was considered in the project evaluation (See Table H.3.18).

2) Monitoring Survey Cost

Monitoring of sedimentation (bathymetry survey) and sediment sampling & analysis will be done once in five years throughout the 60 years of the project life. The surveys will be made in contract basis (See Table H.3.19).

3) Operation and Maintenance Cost

Operation and maintenance cost should be provided to continue necessary monitoring works. Operation cost such as purchasing of the papers was estimated in the local currency and maintenance cost such as replacement of the parts of apparatus was estimated in the foreign currency, considering availability of the materials in the local market (See Table H.3.20).

4) Replacement of the Apparatus

Apparatus for the monitoring system are required to be replaced according to their useful life. Table H.3.21 shows their useful life and replacement cost.

3.3 Design of Erosion Control Facilities

3.3.1 Design Criteria

The erosion control facilities were designed using local standard as much as possible, considering their smooth construction. However, un-practicable standard design for the area were modified taking local conditions into account.

3.3.2 Check Dams

(1) Dam Height

The heights of check dams were preliminary decided taking account of the requirement shown below.

Requirement for the Check Dam Height

Purpose of the Dam	Requirement		Proposed Check Dam
To prevent the hazard of debris flow	Necessary height to control debris flow	⇨	Tataaran
To trap the excess sediment	Necessary height to obtain required dam capacity	⇨	Tandengan Ranomerut Tounipus

Following table shows the decided height of the proposed new check dams.

Dimension of Proposed Check Dams

No.	Location	Zone	Sub-watershed No.	Height (m)	Required Capacity (m^3)	Capacity (m^3)
1	Tataaran	Bm2	4	6.0	-	800
2	Tandengan	Bm1	20	5.5	1,268	1,300
3	Ranomerut	Bm1	22	6.0	903	1,000
4	Tounipus	F	25	4.5	662	800

(2) Spillway

1) Flood Runoff

Flood runoff of 100 years return period at the site was estimated by following rational formula. The JICA Study Team preliminary decided the dimension of spillway, according to the result of flood runoff analysis:

$$Q_p = 1/3.6 \times r_e \times A$$

$$r_e = f_p \times r$$

where,

Q_p : Peak runoff with clear water (m^3/sec),

r_e : Average effective rainfall in flood concentration time (mm/hr),

A : Catchment area (km^2),

f_p : Coefficient of Peak runoff (-), and

r : Average measured rainfall in flood concentration time (mm/hr).

The flood concentration time was estimated using Kadoya-Fukushima formula as shown below:

$$t_p = C \times A^{0.22} \times r_e^{-0.35}$$

where,

t_p : Flood concentration time (min), and

C : Coefficient of Land use.

Design flood runoff was calculated considering the suspended solids in the flow, using the following formula:

$$Q = Q_p (1 + \alpha)$$

where,

Q : Design discharge (m^3/sec), and

α : Ratio of suspended solid mixture (-).

Design rainfall of 100 years return period is calculated by Gumbel-Chow formula using the daily rainfall data at Tondano Meteorological Station (1990 - 1999). Coefficient of peak runoff was assumed as 0.85 considering the hilly topography and small area of catchment areas.

Estimated flood runoffs at the proposed 4 locations are summarized below (see Table H.3.22 for the detail).

Result of Flood Runoff Analysis

Check Dam Site	Tataaran	Tandengan	Ranomerut	Tounipus
R_{100} (mm)	130.0	130.0	130.0	130.0
Q_p (m^3/sec)	13.7	5.5	5.9	10.1
Q (m^3/sec)	16.4	6.6	7.1	12.0

Note : R_{100} = Rainfall with 100 years probability of exceedance at Tondano Meteorological Station estimated by Gumbel-Chow formula

Qp = Clear water flood runoff with 100 years probability of exceedance

Q = Design flood runoff (including suspended solid)

2) Spillway Dimension

Dimension of spillway was preliminary decided using the following formula.

where,

$$Q = 2/15 \cdot C \cdot \sqrt{2g} \left(3B_1 + 2B_2\right) h^{3/2}$$

C : Coefficient of discharge (-),

g : Acceleration of gravity (m/sec^2),

B_1 : Bed width of the spillway (m) (minimum 3 m),

B_2 : Width of overflow water (m), and

h : Overflow depth (m) (less than 2 m is desirable).

If the dam has debris flow hazard, the spillway height must be higher than the diameter of maximum river bed rocks.

Below table presents calculation results of the spillway dimension.

Spillway Dimension

Check Dam Site	Tataaran	Tandengan	Ranomerut	Tounipus
Height (m)	2.0	1.5	1.5	2.0
Bed With (m)	5.0	4.0	4.0	6.0
Side Slope Gradient	1 : 1.0	1 : 1.0	1 : 1.0	1 : 1.0

(3) Dam Body Stability

1) General Procedure

<u>Step 1</u>

First, dam crest width and downstream slope gradient of the dam crest was determined, considering the bump of the gravel.

<u>Step 2</u>

Next, upstream slope gradient of the dam was assumed.

<u>Step 3</u>

After that, design load in the various conditions was calculated.

<u>Step 4</u>

The stability of the dam was calculated using assumed upstream slope gradient in the Step 2 and calculated design load at Step 3. If the result shows that dam is not stable, go back to Step 2 and continue the procedure with different value of the upstream slope gradient.

2) Dam Crest Width

Dam crest width was determined considering the type of the flow passing through the dam. Following table shows the dam crest width of the proposed check dam.

Dam Crest Width of the Proposed Check Dams

Type of the Flow	Required Dam Crest Width	Correspond Check Dam
Bedload Transport	1.5 m	Tandengan, Ranomerut, Tounipus
Debris Flow	3.0 m	Tataaran

3) Downstream Slope Gradient

Downstream slope gradient of the dam body has decided as 1:0.2 taking the flowing down of the gravels into account.

4) Upstream Slope Gradient

Upstream slope gradient of the dam body is assumed as 1:0.3 tentatively, and the value was confirmed after the dam stability analysis.

5) Design Load

For the dam body stability analysis, following loads must be considered.

Design Load for the Gravity Check Dam Stability Analysis

Dam Height	Normal Period	Flood Period	Debris Flow Period
H < 15 m	-	1. Dead Load 2. Hydrostatic Pressure	1. Dead Load 2. Hydrostatic Pressure 3. Earth Pressure 4. Hydrodynamic Force of Debris Flow
H ≥ 15 m	1. Dead Load 2. Hydrostatic Pressure 3. Earth Pressure 4. Uplift Pressure 5. Seismic Inertial Force 6. Seismic Hydrodynamic Pressure	1. Dead Load 2. Hydrostatic Pressure 3. Earth Pressure 4. Uplift Pressure	1. Dead Load 2. Hydrostatic Pressure 3. Earth Pressure 4. Uplift Pressure 5. Hydrodynamic Force of Debris Flow

Note : H = Dam Height

Since the all of the newly proposed check dams are lower than 15 m in height, only dead load and hydrostatic pressure are used for the stability analysis.

Dead Load

Dead load is the weight of dam body itself, given by following formula:

$$W = W_c \cdot A$$

where,

W : Weight of dam body for the unit width (kN),

W_c : Unit weight of wet masonry (kN/m^3), and

A : Volume of dam body for the unit width (m^3).

Hydrostatic Pressure

Hydrostatic pressure is calculated by the formula shown below:

$$P = W_o \cdot h_w$$

where,

P : Hydrostatic pressure at depth h_w (m)

W_o : Unit weight of water (kN/m^3)

Unit Weight of Water for the Stability Analysis

Dam Height	Normal Period	Flood Period
H < 15 m	-	1.2 ton /.m^3
H ≥ 15 m	1.0 ton /.m^3	1.2 ton /.m^3

Earth Pressure

Earth pressure is given by following formulas.

$$P_{eV} = W_{se} \cdot h_e$$

$$P_{eH} = C_e \cdot W_{se} \cdot h_e$$

$$W_{se} = W_s - (1 - \nu) \cdot W_o$$

$$C_e = \frac{1 - \sin\phi}{1 + \sin\phi}$$

where,

P_{eV} : Component of vertical force of earth pressure (kN/m^2)

P_{eH} : Component of horizontal force of earth pressure (kN/m^2)

h_e : Expected depth of sediment at completion of dam construction (m)

W_{se}: Submerged unit weight of sediment (kN/m^3)

W_s : Dry unit weight of sediment (kN/m^3)

W_o : Unit weight of water (kN/m^3)

ν : Porosity of sediment (-)

C_e : Coefficient of earth pressure(-)

ϕ : Angle of share resistance of sediment (^{0})

Hydrodynamic Force of Debris Flow

Hydrodynamic force of debris flow was calculated by following formula:

$$F = \frac{\rho_d}{g} \cdot h \cdot U^2$$

$$\rho_d = \sigma \cdot C_d + \rho(1 - C_d)$$

$$C_d = \frac{\rho \cdot \tan\theta}{(\sigma - \rho)(\tan\phi - \tan\theta)}$$

where,

F : Hydrodynamic force of debris flow for unit width (kN/m),

ρ_d : Unit weight of debris flow (kN/m^3),

g : Acceleration of gravity (m/sec^2),

h : Thickness of debris flow (m),

U : Velocity of debris flow (m/sec),

σ : Density of gravel (kN/m^3),

C_d : Volume density of flowing debris flow (kN/m^3),

ρ : Density of water flow (kN/m^3),

ϕ : Angle of shear resistance (^{0}),

θ : Average river bed gradient from dam site to the 200 m upstream (^{0}),

6) Stability Analysis

<u>Stability for Overturn</u>

Stability for the overturn was confirmed using following equation:

$$x = \frac{M}{V}$$

$$0 \le x \le b$$

where,

x : Distance between the intersection point of action line of the load resultant and dam bed to upstream end of dam bed (m),

M : Moment of load for the unit width of the section which has the support point at upstream end of the dam bed (kN·m),

V : Total vertical force for the unit width of the section (kN), and

b : Dam bed width (m).

<u>Stability for Sliding</u>

Stability for the sliding was confirmed using formula shown below:

$$F_s \le \frac{f \cdot V}{H}$$

where,

F_s : Safety factor (-) (see table below),

Safety Factor		Dam Height	
		less than 15 m	more than 15 m
Foundation	Sand and Gravel	1.2	1.5
	Rock	1.5	4.0

f : Coefficient of friction (-),

V : Vertical force on the unit width of the cross section (kN), and

H : Horizontal force on the unit width of the cross section (kN).

Stability for Dam Body and Foundation Destruction

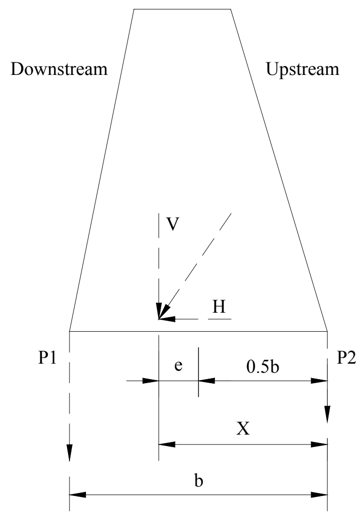
Stability for dam body and foundation destruction was confirmed using following equations.

Vertical stress P_1 at downstream end of the dam body bed (kN/m^2)

$$P_1 = \frac{V}{b}\left(1 + \frac{6e}{b}\right)$$

Vertical stress P_2 at upstream end of the dam body bed (kN/m^2)

$$P_2 = \frac{V}{b}\left(1 - \frac{6e}{b}\right)$$



The distance from center line of the dam body bed and point of action of resultant

$$e = X - \frac{b}{2}$$

$$X = \frac{M_r + M_o}{V}$$

where,

V : Total vertical force for the unit with of the section (kN),

b : Dam body bed width (m),

e : Distance between center line of the dam body and action line of the resultant (m),

X : Distance between intersection point of action line of the resultant and dam body bed and upstream end of the dam body bed (m),

M_r : Resisting moment of the vertical force for the unit width with supporting point at upstream end of the dam body (kN·m), and

M_o : Overturning moment of the horizontal force for the unit width with supporting point at upstream end of the dam body (kN·m)

See Table H.3.23 to H.3.37 and Drawings for the detail.

3.3.3 Slope Protection Works for Hillside

Proposed slope protection works for hillside at Mt. Maimberg consists of two parts. One is hillside foundation works to create acceptable condition for the tree plantation by civil works. The other is hillside seedling and planting works to re-vegetate the slope failure site with some supporting facilities (See Drawings).

(1) Hillside Foundation Works

Since the site was excavated severely by the quarrying activities, soil filling is required to plant the trees on site. To stabilize the filled soil, it is required to provide wall works on the upslope of the site.

Gabion box wall works are recommended, since a lot of cobbles and gravels are found at the lower slope of the slope. Height of gabion wall works will be 2 m in height.

Filling soil should be carefully selected, to create suitable condition for the tree growing.

(2) Hillside Seedling and Planting Works

Bamboo fence works with 30 cm height will be applied on the lower slope of the site. Local material will be used for the construction.

3.3.4 Slope Protection Works for Road

(1) Slope Protection Works for Road at Paleloan

Gabion slope protection works with 3 m height is proposed to prevent further expansion on the slope failure. Standard size of gabion box (1.0 x 2.0 x 0.5 m) will be applied to the facility to simplify the construction works. For the upslope of the gabion protection works, grading works will be applied to keep suitable slope gradient (See Drawings).

(2) Slope Protection Works for Road at Eris-3

Grading works will be applied for the site to prevent further expansion of the slope failure. Slope gradient will be changed from

3.3.5 River Bed Protection Works

(1) Spillway

Since the purpose of the river bed protection works is to stabilize the river bed, not to trap the sedimentation, it is recommended to keep the original flow section as a spillway. If the river bed protection works disturbs the original flow section severely, it might be washed away. Another critical point is the width of the crest. If the width were not thick enough, river bed protection works would suffer from the instability problem. For example, the gabion box check dam at Tontimomor is in an unstable condition, since it has only 1 m crest width. Taking this situation into account, the JICA Study Team recommend to provide the river bed protection works, which keeps original flow section as a spillway.

(2) Body

4 m crest width and 1 m height will be applied for the dam body, considering its stability. (See Drawings).

(3) Apron

1) Length

Length of apron was determined by the following empirical formula:

$$L = (1.5\sim 2.0) \cdot (H_1 + h)$$

where,

L : Length of the apron (m),

H_1 : Difference of height between spillway and apron (m), and

h : Overflow depth (m).

As a result of calculation, length of the river bed protection works will be 4 m.

2) Thickness

Thickness of the apron was calculated using the following equation:

$$t = 0.1(0.6H_1 + 3h - 1.0)$$

where,

t : Thickness of the apron (m),

H_1 : Difference of height between spillway and apron (m), and

h : Overflow depth (m).

As a result, two layers of the standard gabion box (0.5 m in height) will be applied for the apron.

(4) Bed Protective Works

Dimension of bed protective works were decided assuming that the structure will have a submerged hydraulic jump (see Drawings)

3.3.6 River Bank Protection Works

The JICA Study Team recommends providing gabion box river bank protection works on the sharp curve section of the River Panasen. The proposed revetment works will have same dimension as the existing revetment works, taking simple construction into account. 5 layers of the standard size gabion boxes (1.0 x 2.0 x 0.5 m) will be provided with 1:1.0 slopes. The height of the revetment is 2.5 m in total (See Drawings).

3.3.7 Implementation Schedule

(1) Basic Considerations

The project implementation plan was formulated based on following considerations:

Rainfall and Suspended Day

Daily Rainfall Depth (mm)	Time to be Suspended (day)
0 - 10	0.0
10 - 30	0.5
30 - 50	1.0
more than 50	2.0

- A manpower construction will be principally introduced for all of the construction works in order to increase the employment opportunity.
- The local consultant will assist the project executing agency in the detail design and construction stages.

(2) Construction Plan

1) Workable Day

Workable day for each of months are estimated based on the daily rainfall record at Tondano meteorological station and national holidays. Time length of suspended days is set for respective intensity of the rainfall as shown in the right. As a result, workable day is estimated as 253 days per year as presented in Table H.3.38.

2) Construction Materials

For the construction works, local construction materials, such as sand, rocks, bamboo etc. will be used as much as possible. Available construction materials in and around the Intensive Area are shown in Figure H.3.26. Moreover, bamboo is broadly available in the area.

3) Basic Method of Works

For the earth works and wet masonry works, manual construction works will be applied, considering the work volume and the practicability in the area. In the manual construction works, the inhabitants may be employed as a common labor, taking their income increment and incentives for the maintenance works into account.

4) Implementation Schedule

The project implementation period for the erosion control facility development was planned at 2 years as shown in Figure H.3.35. It includes the detailed design works and the construction works.

The detailed design works for all the proposed facilities will last 6 months considering the time necessary for the design works and project preparatory works such as land acquisition etc.

The construction works will last 18 months. In the first 6 months, erosion control facilities for the critical land such as i) check dam for debris flow control, ii) river bed protection works, iii) slope protection works for hillside, and iv) slope protection works for road will be constructed, taking their urgencies into account. After completing these works, sediment trap check dams for the potential critical land will be constructed. Moreover, the JICA Study Team planned to construct river bank protection works also in the second year, considering their work volume.

3.3.8 Cost Estimate

(1) Basic Assumption

The construction cost consists of direct construction cost, engineering services and physical and price contingencies. Following basic consideration and assumption are made for estimate the project cost:

- The exchange rate used in the cost estimate is:
  US$ 1.00 = Rp. 9,100 = \ 115
  as of December 2000.
- Construction works will be executed full contract basis through competitive bidding. The contractor himself will provide the construction machinery and equipment required for construction. Thus, depreciation cost of machinery and equipment are considered in the estimate of construction unit rates.

- The unit rates of the works are divided into the foreign and local currency portions. Respective currency portions include the following costs:

Demarcation of Local and Foreign Currency

Local currency portion:	Local labor cost, Cost of local material, Machinery cost, Inland transportation cost, etc.
Foreign currency portion:	Foreign labor cost, Cost of imported materials, Machinery cost, etc.

- The unit rates of the works are estimated at the December 2000 price on the basis of the current price prevailing in North Sulawesi and data obtained from standard price list of several government agencies and similar projects.
- Materials and equipment is provided firstly installed by the Project and is maintained and replaced by the Government of Indonesia later.
- Engineering service is provided by the Project with the administration support from the Government of Indonesia in the project implementation period. For the project running period, only administration support from the Government of Indonesia is applied.
- The project running cost to be financed by the Government of Indonesia and communities after the completion of the project activities, are not included in the project cost.

(2) Capital Cost

1) Direct Construction Cost

Direct construction cost can be obtained by multiplying construction unit rate and work quantity. Construction unit rates for the major works were calculated based on the local production rate of the works as much as possible. The data of local production rate of the works were collected from Regional Irrigation Office and District Forest Service. Work quantities were preliminary estimated with feasibility study level accuracy (See Table H.3.39 to H.3.43).

2) Indirect Construction Cost

Indirect construction cost was assumed as a 20 % of the direct construction cost.

3) Maintenance Equipment Cost

One pick-up track and one jeep will be procured by the project for the operation and maintenance (See Table H.3.44).

4) Land Acquisition Cost

The land acquisition cost required for the erosion control facilities is estimate based on the present land use. The unit cost is referred to the data obtained from District Forest Service.

5) Engineering Services Cost

Local consultant team will organize the detail design and construction supervision with the cooperation of Ministry of Forestry (See Table H.3.45).

6) Physical Contingency

The physical contingency is estimated at 10% of the direct construction cost.

7) Capital Cost of the Erosion Control Facility Development

Total capital cost for the erosion control facility development was estimated at Rp. 7,170 million with 10% of physical contingency as shown in Table H.3.46. However, price contingency was not included here, since it will be added separately to the total capital cost of the project (See Appendix-J Section 4.2.7).

8) Annual Disbursement Schedule

The annual disbursement schedule for the project implementation shown in Table H.3.47 is prepared based on the implementation schedule presented in Figure H.3.35.

(3) Running Cost

1) Maintenance Cost

Annual maintenance cost for the erosion control facilities is estimated at 0.5% of direct construction cost of the erosion control facilities (See Table H.3.48).

2) Replacement Cost

Vehicles that will be used for the maintenance of erosion control facilities will require replacement during the proposed 60 years project life (See Table H.3.49).

3.4 Recommendation

By the research on erosion and sedimentation, following activities are recommended to implement.

(1) Erosion

In the study area, judging from field observation and analysis, there is no critical land. However, potential critical lands are found in the middle and northern part of the Study

Area, and in the Intensive Area. To reduce soil loss and to increase produce, extension of agroforestry must meet the necessity of local population. Addition to it, applying proper soil conservation measures is recommendable for sustainable land use.

(2) Torrent and Slope Erosion

There are problems in the rivers and hillside, leading loss of property and production. High floods erode agricultural lands along rivers and transportation is disturbed by slope failures caused by heavy rainfall. Aggressive exploitation on steep lands causes large amount of sediment transport. It is recommended to take structural measures against these incidents. Construction of minimum numbers of structures for river protection works, slope protection works, and check dams at the most critical sites is recommended.

(3) Floods

Around Lake Tondano, flooding occurs in Tondano town and paddy areas around the lake. To reduce flood damage around the lake, regulation of land use and fixation of lake area and appropriate operation of hydropower station are necessary.

To reduce flood damage in Manado of the lower reaches of Tondano River, establishment of land use regulation along the river and its enforcement are necessary along with engineering corrective measures.

(4) Water Quality of Lake Tondano

Dense settlements and intensive use of agriculture land around Lake Tondano result in the status of 'eutrophic.' However, it is unclear what is the major pollutant of eutrophic. It is necessary to clarify the sources causing eutrophication and to evaluate their contribution to eutrophication. To improve the condition of Tondano Lake, it is recommended to specify pollutants and take suitable corrective measures to remove the pollutant.

(5) Monitoring

Tondano Lake has very important role in the region, as the biggest water source. However, data explaining present condition of the lake are limited. For proper management of the lake and its watershed, collecting scientific data by monitoring is recommended to analyze the status of erosion, water quality, and water balance of the lake.

CHAPTER 4 SIMILAR STUDIES/PROJECTS

4.1 The Watershed Management Technology Development Project in South Sulawesi

(1) Current Status:

Operation and Monitoring Stage

(2) Objectives:

Development and improvement of technique of hydrological observation and analysis, soil conservation, silviculture, nursery, and machinery operation which are suitable to physical and socio-economic conditions in South Sulawesi, and training to personnel for its dissemination.

(3) Project Description:

In Indonesia, forest areas have been largely decreased mainly due to expansion of farm lands, tree cutting, and grazing. As a result, critical lands have increased, and thus severe soil erosion, flood and water shortage have frequently occurred at downstream area of watershed. In order to avoid such deterioration in natural environment, the Government of Indonesia (GOI) has given a priority to afforestation of critical lands to conserve and preserve forest, soil, and water resources in his forest policy. In this regard, GOI has prepared a plan of establishing a Watershed Management Technology Center at 6 regions, which have been demarcated based on natural and land use conditions. To fulfill the plan, GOI requested the Government of Japan (GOJ) to extend a technical assistance for Sulawesi in 1985. In reply to this request, GOJ has started the Watershed Management Technology Development Project. The Project area extends over about 8,500 ha of upstream area of Jeneberang River, and administratively belongs to Malino village, Gantara district, Gowa Regency. In the Project, the technology transfer has been performed for GOI staff through lecture and on-the-job training. The fields of technology transfer performed have been hydrology, soil conservation, silviculture, nursery and machinery.

(4) Major issues:

In connection with these technology transfer, the Project has provided various works such as grading work, retaining wall work, simple terracing work, covering work, water channel work, planting work, and slope seedling work. In addition, bridges and access road have been also constructed. These works are generally in good conditions although wooden bridge has been damaged and access road has been deteriorated.

According to the head of a Watershed Management Technology Center, this road will be paved with asphalt in the next year.

It should be noted that a cooperation was established on November 14, 1999 in the Project area, to make seedling, nursery preparation, etc. The cooperation consists of a head, a secretary, a treasurer, a marketing manager and 155 members. Member fees are Rp. 10,000 at enrollment time and Rp. 2,500 per month. A regular meeting is held once a month, say 5th of every month. In the meeting, discussions have been made for many matters such as how to find seeds and how to cultivate seedlings. In the recent meeting, discussions have been conducted for how to find financial source for capital in a short term, and how to train members, how to build an office, how to buy agricultural and estate tools in a long term. The head of cooperation presents some major problems envisaged at present. These are lack of capital, less number of guidance by relevant agency, and no approval on application of registration by the Department of Cooperation so far. It is urgently necessary that the relevant agency shall support the cooperation so as to settle such problems.

4.2 Limboto-Bolango-Bone Basin Water Management Master Plan

(1) Current Status:

Planning Stage

(2) Objectives:

The Plan aims at (a) provision of a central planning and coordination instrument for the application of integrated approach to water management, (b) guidance for the optimal basin management, (c) grouping of viable water resources development schemes, and (d) formulation of a phased development plan for single and multi-purpose water resources projects.

(3) Study Description:

The Plan was prepared by Sub-Dinas Pengairan PU and Canadian Executing Agency under the financial assistance of CIDA, based on the results of the master plan study for the Limboto-Bolango-Bone Basin. The study was performed from April 1993 to March 1999, in such 5 phases as (a) integrated watershed management and development studies, (b) socio-economic studies, (c) water resource engineering, (d) consultation and review meetings, and (e) preparation of the Plan.

(4) Major Issues:

As the result of the master plan study, the following 6 development components have been worked out; (a) improve institutional framework, (b) protect and conserve water resources, (c) improve use of existing water resources infrastructure, (d) meet water requirement, (e) contribute to meeting energy requirement, and (f) reduce urban and agricultural flood damages.

Of these 6 development components, the component of "protect and conserve water resources" would be similar to the Study for Critical Land and Protection Forest Rehabilitation at Tondano Watershed. This component is further divided into 9 initiatives. These are (a) environment management, (b) upper and middle watershed rehabilitation, (c) sediment monitoring, (d) Lake Limboto management plan, (e) demarcation of Lake Limboto buffer zone, (f) regulation of Lake Limboto water levels, (g) dredging of Lake Limboto, (h) fisheries management, and (i) sanitation measures. In particular, the "upper and middle watershed management plan" initiative suggests substantial countermeasures against areas with critical slopes and critical soils, and also excessive shifting cultivation and overgrazing, aiming to improve long term economic sustainability, improve water quality, to reduce soil erosion, reduce sedimentation in downstream areas, increase base river flows, and reduce flash flooding. The proposed major countermeasures are reforestation, social re-greening program, establishing of buffer zone, dryland agriculture, and strengthening of forestry extension services.

4.3 North Sulawesi Water Resources Management Plan

(1) Current Status:

Planning Stage

(2) Objectives:

The objectives of the Plan are to (a) strengthen the planning and design section and senior managers of provincial water resources, (b) put in place the beginnings of a management process able to implement the plan, and (c) prepare a water resources management plan.

(3) Study Description:

The study area is about 27,500 km^2 of whole the North Sulawesi Province. The study was performed from 1996 to 1999.

The Plan was prepared by the Provincial Water Resources Services (Sub-Dinas Pengairan) and the Canadian Executing Agency through the North Sulawesi Water

Resources Institutional Development Project (P3SU) under the financial assistance of CIDA. The Plan included a more in-depth perspective based on field investigation and data validation, organization of 4 public consultation meetings with the community and government authorities in each kabupaten (district): Gorontaro, Bolaang, Mongondow, Minahasa, and Sangihe Talud, and a comprehensive and integrated approach including environmental, social, economic, women in development/gender impacts, and cost and disbursement schedules.

(4) Major Issues:

As the result of the master plan study, major issues on the watershed of Tondano River including Lake Tondano are as follows:

1) Overview

The Tondano watershed is envisaged with higher competition for land and water resources. The Tondano watershed presents relatively good land management with irrigated and upland dryland system. Farmers in the watershed actively use soil conservation techniques, as a result of cultural traditions rather than through extension.

2) Watershed condition

The Tondano watershed is in good condition. Sounding upland agricultural systems have generally replaced logging.

3) Upper Watersheds

The Plan mentions that the northern and eastern parts of the Tondano watershed with average 41% to 60% slope, are given the following land use, since these areas have a critically high potential for soil erosion:

- Tree crops with groundcover or perennial crops. Close cover crops including annual crops if terraced,
- Agroforestry, tree crops if not permanent vegetative cover, and
- Forestry.

4) Critical land

The Plan states that the eastern part of the Tondano watershed are designated as a critical land judging from rainfall erosivity, inherent soil erodibility, land form (slope:length, shape, magnitude, vegetative potential), and land management (land use, cultivation methods, etc), following the data prepared by the Ministry of Forestry in 1991.

5) Flood risks

The outlet area of Lake Tondano where paddy fields extend, and around estuary area of Tondano River are categorized as flood risk areas in Tondano watershed, because of increased lake levels to maximize hydropower generation and insufficient flow capacity of Tondano River, respectively.

4.4 Field Trip to Sulawesi Rainfed Agricultural Development Project in Gorontalo District

(1) Purpose of Field Trip

The JICA Study Team together with Mr. Komar, head of BRLKT, carried out a field trip to Sulawesi Rainfed Agricultural Development Project in Gorontalo district for 3 days from November 19 to November 21, 2000, aiming to inspect the rehabilitation works executed, and to reflect the inspection results upon the preparation of watershed conservation plan for the Intensive Area.

(2) Project Description

The rainfed agricultural land occupies about 2/3 of agricultural land in Indonesia, and also brings up more than 2/3 of population in rural area. The people are mostly obliged to be below poverty line due to less income caused by low productivity of the land. But, such rainfed agricultural land would have a high potential on food production increase if proper technical and financial supports are provided. The Project was thus formulated in consideration of the following objectives to develop rainfed agricultural land:

- Raising of upland productivity in the upstream area of watershed;
- Raising of welfare and job opportunity for communities in rural area;
- Increasing of farmers' income;
- Minimizing of poverty and improving of women participants; and
- Protecting and rehabilitating of critical land in the upstream area of watershed.

In order to attain these objectives, the Project provides the following supports:

- Development of estate crops farm (23,000 ha), food crops (20,200 ha) and livestock;
- Re-greening (8,000 ha) and soil conservation (52,000 ha);
- Incentive to farmers who involved in development of estate crops farm, re-greening and soil conservation;
- Assistance of food production and marketing;
- Construction of village roads (33 km) and rehabilitation of existing roads (95 km);

- Supply of water pumps for 40 villages;
- Construction of check dams (20 nos.);
- Community participants development;
- Institutional development; and
- Provision of consultant services supporting for project management.

The Project covers all Sulawesi. In the North Sulawesi, the Project area extends over 5 Sub-districts of Limboto, Telaga, Batuudaa, Tibawa and Tapa located in catchment area of Lake Limboto.

The Project will be implemented for 5 years from 1996 to 2002 under co-finance of ADB and GOI. The forestry works executed by 1998/99 under the Project are listed as follows:

1) 1997/98

- Plantation of 3,000 ha (ADB)

2) 1998/99

- Seeds supply (ADB)
- Land certification (ADB)
- Plantation (GOI)
- Technical guidance, monitoring, and working evaluation (GOI)

(3) Findings

The catchment area of Lake Limboto has been extensively deforested by slash and burn cultivation, and now is characterized by significant degradation of upland area. It has brought about severe sedimentation in the lake. According to the "Limboto-Bolango-Bone Basin Water Management Master Plan, March 1999", Lake Limboto is the remnant of a lagoon connecting with the sea through the Bolongo-Bone estuary called presently. The lagoon was disconnected from the sea by tectonic activity and became fresh lake. The sedimentation process in the lake was accelerated by deforestation since 1940s. Records showed that the maximum water depth of the lake would be 14 m in 1934, but had reduced to 2.5 m by 1972. The lake seems to be lifeless, which is further worse than Lake Tondano.

General View of Lake Limboto

For the critical land inspected, an alley cropping system is applied in cooperation with three district offices of forestry, estate crops and agriculture, aiming to mitigate soil erosion. However, the applied green belt in the alley cropping system is too small in width to lead to effective prevention of surface soil runoff. At least, 1-m width is required for such a green belt.

Through site inspection, it has been deepened that proper farming practice has been essential for soil conservation. Improper farming practice would create infertile land and lead to abandonment of land, which eventually result in encroachment into forest area due to lack of farming land. It can be seen in places that the upper portion is presently cultivated, but the lower portion is abandoned due to occurrence of infertile soil as result of severe sheet soil erosion. In order to prevent such improper farming practice, it is indispensable to strengthen the extension services.

Severe Soil Erosion with Surface Runoff in Limboto Watershed

Soil is a key factor for soil erosion. Silty clay is observed at the sites inspected. As silty clay has low infiltration rate, runoff flows over soil surface. In fact, it has been observed that runoff has brought about severe sheet soil erosion when heavy rains has occurred during site inspection.