The Study on Comprehensive Disaster Prevention
around Mayon Volcano

SUPPORTING REPORT (1)

(Part I: Master Plan)

I : Hydrology, Hydraulics / River Planning

SUPPORTING REPORT (1) – I
HYDROLOGY, HYDRAULICS / RIVER PLANNING

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SUPPORTING REPORT (1) – I
HYDROLOGY, HYDRAULICS / RIVER PLANNING

1. METEOROLOGY

1.1 Climate

1.1.1 General

The climate in the Province of Albay is tropical and is generally influenced by monsoons and Pacific trade wind. The western most part of Albay receives only a moderate effect of the Northeast Monsoon, the North Pacific Trade Wind and the Southwest Monsoon with an uniformly distributed but lesser rainfall. The eastern part in which the Study Area is located is not sheltered either from the effect of the Northeast and Southwest Monsoons or from the typhoons and tropical storms.

By the Climatological classification in the Philippines, the eastern part of Albay belongs to Type II climate and the western part belongs to Type IV of which definitions are shown below:

- Type II climate : No dry season with a very pronounced maximum rainfall from November to January.
- Type IV climate : Rainfall more or less evenly distributed throughout the year.

1.1.2 Southwest Monsoon

The Southwest Monsoon which is one of the two major air masses governing the climate of the Province of Albay originates from the Indian Ocean and approaches the area from the southwest and west directions. Because of its origin, the higher elevated area at the center of the province including the clusters of mountain on the east receives a considerable amount of rain during the months of June to October when this monsoon season is dominant.

1.1.3 Northeast Monsoon and the North Pacific Trade Wind

During the months of November to February, another group of air masses (Northeast Monsoon and the North Pacific Trade Wind) pass over and create a great disturbance on almost all parts of the province. Because of its origin and the vulnerability of the area to its effect, a tremendous amount of rain falls over the most exposed portion of the province.

1.1.4 Tropical Cyclones

Typhoons or tropical cyclones as a result of low pressure from the Pacific where they originate, significantly damage crops, properties, and infrastructure, and even cause loss of lives in the province almost every year. Majority of tropical cyclones occur from June to December in the Philippines. Tropical cyclones pass the province westerly or northwesterly. The province is within the regular path of tropical cyclones which generally pass over the archipelago from September to January.

1.1.5 Orographic Effects

Another cause of climate variation in the province is the influence of high mountains particularly Mt. Mayon, Malinao, Masaraga, and other barriers like Mt. Iriga which directly affect the province's ever changing weather. In the event that converging air masses meet this mountain barriers, or where local convection cells are present, considerable rain could occur as a result of orography. These moisture saturated air masses are then condensed by the cooler temperature above, thus, the amount of rainfall on these highly elevated areas is relatively higher than those on the lower area.

1.2 Rainfall

The Study Area is characterized by an indistinct dry season and a very pronounced maximum rainfall period from September to January as shown below.

The long-term mean annual rainfall observed from 1961 to 1995 at Legazpi Station of PAGASA is 3,354mm. From June to October when the Southwest Monsoon is dominant, 42% of annual total rainfall is poured in the area, and 44% from November to February influenced by the Northeast Monsoon and the tropical cyclones. From March to May when the area is not relatively affected by two monsoons and tropical cyclones, 14% of rainfall is poured.

Total number of rainy days per year in Legazpi is measured as 221 days (60%) on average. In two monsoon seasons from July to January, about 3 weeks of rainy day occur in a month, and from February to June, more than 2 weeks of rainy day in a month.

Monthly Rainfall Distribution and No. of Rainy Days in Legazpi

(1961-1995)

Month	Rainfall (mm)	No. of Rainy Days
Jan**	303	21
Feb**	178	15
Mar	154	16
Apr	147	15
May	167	14
Jun *	252	16
Jul *	287	19
Aug *	273	19
Sep *	272	20
Oct *	326	21
Nov**	479	22
Dec**	516	23
Annual	3,354	221

Source : PAGASA, Legazpi City

Note : (**) indicates a month influenced by Southwest Monsoon.

: (*) indicates a month influenced by Northeast Monsoon.

1.3 Tropical Cyclones

Tropical cyclones are categorized into three types, Typhoon, Tropical Storm, and Tropical Depression according to the maximum wind velocity around the center of disturbance.

a) Tropical Depression – maximum wind velocity is less than 63km/h or 17m/s.
b) Tropical Storm – maximum wind velocity ranges from 64 to 117km/h or 18 to 32m/s.
c) Typhoon – maximum wind velocity is more than 118km/h or 33m/s.

The following table, showing the list of tropical cyclones that affected the Bicol Region in the past 10 years, reveals that on average, 8.4 tropical cyclones pass over the region in a year.

List of Tropical Cyclones over Bicol Region (1987-1996)

Year	No. of Cyclone	Strongest Cyclone	Date of Occurrence	Max Wind Speed (Kph)
1987	7	Typhoon Sisang	23-27, November	240
1988	6	Typhoon Asiang	14-18, January	115
1989	7	Typhoon Unsing	18-21, November	90
1990	7	Typhoon Gading	15-18, August	100
1991	9	Tropical Dep. Etang	09-10, July	80
1992	8	Typhoon Seniang	25, November	65
1993	12	Tropical Dep. Huling	07-09, July	90
1994	13	Typhoon Garding	20-22, December	80
1995	10	Typhoon Rosing	01-03 November	137
1996	5	Tropical Storm Gloring	21-24, July	55

Source : PAGASA, Legazpi City

As to the preceding table on tropical cyclone record, years 1993 and 1994 have the greatest number of cyclones registered with 12 and 13, respectively. The strong cyclones occurred frequently in the Bicol Region in the month of November within the ten years period.

1.4 Temperature, Relative Humidity and Wind

The annual mean temperature in Legazpi is 27.1℃ with the maximum reaching 30.7℃, while the minimum is 23.4℃. The coolest month is generally February with the minimum temperature 22.3℃ while the warmest month is March with the maximum temperature 32.4℃.

Humidity varies slightly from 81% during the months of April and May to 85% during the months of September, November and December.

Monthly distribution of temperature and humidity in Legazpi is shown below:

Monthly Temperature and Relative Humidity in Legazpi (1961-1995)

Month	Max Temp (°C)	Min Temp (°C)	Ave Temp (°C)	RH (%)
Jan	28.7	22.4	25.5	84
Feb	29.1	22.3	25.7	82
Mar	30.1	22.9	26.5	82
Apr	31.3	23.8	27.6	81
May	32.4	24.4	28.4	81
Jun	32.3	24.2	28.3	82
Jul	31.6	23.9	27.8	84
Aug	31.6	24.0	27.8	83
Sep	31.5	23.8	27.6	85
Oct	31.1	23.4	27.2	84
Nov	30.2	23.4	26.8	85
Dec	29.1	23.0	26.0	85
Annual Mean	30.7	23.4	27.1	83

Source : PAGASA, Legazpi City

The province is generally influenced by monsoons and Pacific trade air current. Therefore, the highest wind speed is always associated with typhoons and is experienced from June to November. The Northeast Monsoon (Amihan) is from October to February and the Southwest Monsoon (Habagat) is from May to September and the prevailing wind is northeast in the region as shown below.

Monthly Prevailing Wind Direction in Legazpi

(1961-1995)

Month	Wind Direction
Jan	Northeast
Feb	Northeast
Mar	Northeast
Apr	Northeast
May	Northeast
Jun	Southwest
Jul	Southwest
Aug	Southwest
Sep	Southwest
Oct	Northeast
Nov	Northeast
Dec	Northeast
Annual Mean	Northeast

Source : PAGASA, Legazpi City

1.5 Meteorological Observation

1.5.1 Rainfall

There are presently five rainfall gauging stations of PAGASA in and around the Study Area as shown below. Rainfall station at Guinobatan was closed in 1983. Location of existing rainfall gauging stations is shown in Figure I 1.1.

The rainfall observation is conducted on a daily basis with an ordinary collector type rain gauge. Only Legazpi station, however, facilitates an automatic recorder measuring the shorter duration than one-day. However, only three hour rainfall is recorded four times per day such as 2 p.m., 8 p.m., 2 a.m. and 8 a.m.

The recorded data of all the rainfall stations are sent to the Climate Data Section, Climatology and Agrometeorology Branch, PAGASA for compilation. The daily rainfall graph of the automatic recorder at Legazpi station is sent to the same section of PAGASA, but no records are compiled for the shorter duration than 3-hour. The rainfall graph is conveyed from the Climate Data Section to the Hydrometeorological Investigations and Special Studies Section, Flood Forecasting Branch, PAGASA for further analysis of rainfall intensity-duration-frequency. The past rainfall graphs are filed by the Hydrometeorological Investigations and Special Studies Section.

Existing Rainfall Gauging Stations of PAGASA in the Study Area

Station No.	Station Name	Years of Record	Type of Station
444	Legazpi City	1951-Present	Agromet
501	BPI Exp. Stn. Buang, Cross., Tabaco	1981-Present	OR
506	Malama, Ligao	1971-Present	OC
512	San Ramon, Tabaco	1971-Present	OR
513	Sto Domingo	1966-Present	OR

Source : Climate Data Section, PAGASA, Quezon City.
Note : (Agromet) means Agrometeorological Station.
: (OR) means Official Rain Station.

The mean annual rainfall in the Study Area ranges from 2,000 mm to 4,000 mm. The western part of the Mayon Volcano which situates in the inland area has lower amount of rainfall than the eastern part facing to the Pacific. This is due to sheltering effects of the surrounding hills and mountains.

The recorded maximum rainfalls (1980-1997) in the Study Area for the duration of 1-day, 1-month and 1-year are 685 mm at Buang, Tabaco in October 1985, 2,220 mm at Sto Domingo in December 1995 and 6,328 mm at Buang, Tabaco in 1993, respectively. The maximum rainfall records in the Study Area are summarized below.

Maximum Rainfall Records in the Study Area (mm)

	Legazpi City (1980-97)	Sto Domingo (1980-97)	Buang Tabaco (1982-94)	San Ramon Tabaco (1986-95)	Malama Ligao (1980-97)
Daily Max Rainfall	315	392	685	226	100
Monthly Max Rainfall	1649	2220	2003	1287	877
Annual Max Rainfall	4727	6217	6328	4398	3154
Mean Annual Rainfall	3312	3976	5132	2962	1784

Source : Climate Data Section, PAGASA, Quezon City.

Note : Malama station is located south of Ligao and out of the Study Area.

Five automatic rain gauges with a telemetering system were installed in the south slope of the Mayon Volcano in 1996 provided by JICA. Hourly rainfall data are to be sent on a real time basis to the office of the OCD in Legazpi. Since 1998, this real time rainfall observation system has been out of order because of malfunction of relay station. And, real time data recorded at five stations measured from 1996 to 1998 are presently missing as of February 1999.

The early recovery of the data acquisition by the telemetering system and the data compilation at the OCD is highly required.

1.5.2 Problems Encountered and Needs for Solution

The management of flood control and sabo works within the Study Area depends highly on the adequacy and accuracy of relevant meteorological data. Thus, the implementation of an efficient data collection system is crucial to disaster prevention.

Hourly and sometimes even minutely rainfall data are important in the analysis and interpretation of flood and debris flow in the Study Area. As such, a comprehensive rainfall station network with a automatic recorder is needed in the Study Area to provide the necessary information.

At present, there are five existing stations (Only one station is furnished with an automatic recorder.) within the Study Area, most of which are located on the flat lands. It is required to establish additional rainfall stations for levelled areas and for rolling/mountainous areas in order to obtain a more accurate picture of the areal variation of rainfall and its intensity.

1.6 Meteorological Data

The meteorological data collected during the First Work in the Philippines are shown below:

Meteorological Data Collected

Title	Organization	Note
1. Daily Rainfall Records - Legazpi (1980 – 1997) - Sto Domingo (1980 – 1997) - Buang (1981 – 1995) - San Ramon (1981 – 1997) - Malama (1988 – 1997)	PAGASA Climate Data Section, Climatology and Agrometeorology Branch	Computer Outputs from Data Base.
2. Tropical Cyclone Values In the Philippines	PAGASA Weather Branch	From 1980 to 1997
3. Rainfall Intensity Duration Frequency Data at Legazpi	PAGASA, Flood Forecasting Branch	Based on 40 years of record (1951 – 1990)
4. Climatological Normals at Legazpi	PAGASA, Legazpi	Period : 1961 – 1995
5. List of Rainfall Stations of PAGASA	PAGASA, Legazpi	

1.7 Meteorological Analysis

1.7.1 Probable 1-Day Point Rainfall

The probable 1-day point rainfall was previously estimated by the Master Plan in 1981. The estimate was made by the comparisons of different calculation methods such as Iwai, Hazen and Gumbel. The largest values for higher return periods were adopted.

The latest estimate of the probable 1-day point rainfall by the Study was made using 42 years of records (1956-1997) observed at Legazpi. The following five methods are applied to the estimate.

- Two Parameters Log Normal Distribution(LN2)
- Three Parameters Log Normal Distribution (LN3)
- Type I Extremal Distribution (T1E)
- Pearson Type III Distribution (PT3)
- Log Pearson Type III Distribution (LP3)

The results of the calculation and the average values of five distributions are adopted to the Study as shown in the following tables.

Results of Frequency Analysis on 1-Day Maximum Rainfall at Legazpi

Return Period (yr)	LN2	LN3	T1E	PT3	LP3	AVE.
2	178	176	181	168	177	176
5	252	249	263	242	248	251
10	302	300	318	299	298	303
20	351	352	371	358	349	356
50	415	421	438	439	418	426
100	465	476	489	501	474	481

The table below showing both values estimated by the Restudy in 1983 and the present study in 1999 reveals that the latter estimates are much lower than the former ones by 4 to 20%.

Probable 1-Day Rainfall (mm) at Legazpi

Return Period (year)	Restudy in 1983 (1956 - 1981)	Present Study in 1999 (1956 - 1997)	Difference (%)
2	176	176	0.0
5	261	251	-3.8
10	328	303	-7.6
20	401	356	-11.2
50	510	426	-16.4
100	602	481	-20.1

The resultant value of 1-day maximum rainfall for each rainfall station is summarized below.

Results of Frequency Analysis on 1-Day Maximum Rainfall

Return Period (yr)	Legazpi	Guinobatan	Buang	San Ramon	Sto Domingo
2	176	162	194	110	174
5	251	230	335	166	227
10	303	274	451	208	262
20	356	316	581	252	297
50	426	368	785	316	344
100	481	407	975	369	379

1.7.2 Probable Rainfall Intensity-Duration Relation

Also, 50-yr probable rainfall intensity-duration relations are compared between the values estimated by the Restudy and the present study as shown below:

50-yr Probable Rainfall Intensity-Duration Relation at Legazpi

Duration (hr)	I_{50}(mm/hr) Restudy in 1983 (1970 – 1981)	I_{50}(mm/hr) Present Study in 1999 (1951 – 1990)	Difference (%)
6	50.3	56.2	11.7
12	26.4	34.4	30.3
18	18.4	-	-
24	17.2	18.7	8.7

Note : Both of the above intensity-duration relations were obtained from PAGASA.

The latest estimates using longer records than those of the Restudy are much larger than those of the Restudy by 9 to 30%. The latest data are used for the Study.

Adopted Probable Rainfall Intensity-Duration Relation at Legazpi

Return Period (yr)	20 (min)	30 (min)	45 (min)	60 (min)	80 (min)	100 (min)	120 (min)	150 (min)
2	95.1	78.4	62.7	52.4	45.5	40.4	36.8	32.3
5	136.8	113.2	90.8	76.6	67.5	60.6	55.3	48.8
10	164.4	136.2	109.5	92.7	82.1	74.0	67.6	59.6
20	191.1	158.2	127.5	108.1	96.1	86.8	79.3	70.1
50	225.3	186.8	150.7	128.0	114.2	103.4	94.6	83.6
100	251.1	208.2	168.0	143.0	127.9	115.9	106.0	93.8

Note : Rainfall intensity values for short duration are only shown here for the Study.

1.7.3 Probable Basin Average Rainfall

The average depth of rainfall for a given duration in a given area generally tends to decrease conversely with increasing of area. This relation is usually derived from the isohyetal map with a given duration. However, as the available data are inadequate to construct the isohyetal map, Horton's formula is employed for the present study and it is expressed in the form of

$$P = Po \times \exp(-kA^n)$$

where,

P : average depth of basin rainfall (in.)

Po : largest rainfall amount in the basin area (in.)

A : basin area ($mile^2$)
k, n : constants

Po, k and n are assumed below on the basis of the final results of the Restudy in 1983 since no new findings regarding this matter are obtained for the present study.

Po : 1.5 times of the rainfall of the representative station in the basin to be studied. But, no elevation adjustment is made for Buang rainfall station since it is located at high altitude (approximately EL. 250m)
k : 0.1
n : 0.33

The calculated probable basin average 1-day rainfall for each river is shown below and the process of calculation is shown in detail in the previous tables.

Probable Basin Average 1-Day Maximum Rainfall

Unit: (mm)

River Name	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Yawa	195	278	336	394	472	533
Pawa-Burabod	229	326	394	463	554	626
Budiao	229	327	394	463	554	626
Anuling	227	323	390	458	548	619
Quirangay	209	296	353	407	474	524
Tumpa	213	303	361	416	485	536
Maninila	215	305	363	419	488	540
Masarawag	207	294	351	404	471	521
Ogsong	191	271	322	372	433	479
Nasisi	177	252	300	346	403	445
Buang	172	297	400	515	696	865
Quinali (B)	112	169	212	256	322	375
San Vicente	141	213	267	324	406	474
Arimbay	236	308	356	403	467	514
Padang	226	295	341	386	447	493
Basud	219	286	330	374	433	477
Bulawan	218	284	328	372	431	475

2. HYDROLOGY

2.1 Hydrological Observation

2.1.1 Water Level and Discharge

The streamflow observation network in the Study Area is inappropriate in terms of its number of stations and measurement method.

Presently, there exist only two stream gauging stations in the Study Area as shown below. No automatic water level recorders are applied to the measurements. Two stations with only a staff gauge are located in Ogsong and Malinao rivers. Nasisi and Yawa gauging stations were closed in 1985 and 1993, respectively. Location of water level gauging stations is shown in Figure I 1.1.

The measurement of water level by a staff gauge (three times per day at 7 a.m., 12 p.m., and 6 p.m.) is conducted by near-by resident assigned as a gauge keeper. In case of flood, the observers are instructed by DPWH that the maximum high water level and its time of occurrence are checked.

The water level records are sent to the Bureau of Research and Standards (BRS), DPWH in Quezon City for compilation through the Hydrological Observation Section, DPWH Region V. The BRS conducts the conversion of water levels to runoffs and to check and define rating curves for each station by the latest discharge measurement records which are conducted once a month by the Hydrological Observation Section, DPWH Region V.

Water Level Gauging Stations of DPWH in the Study Area

Name of Station	River	Record Available
Yawa *	Yawa	1980-1988
Ogsong **	Ogsong	1982-1990
Nasisi *	Nasisi	1951-1985
Malinao **	Quinali (B)	1980-1988

Source : Bureau of Research and Standards (BRS), DPWH, Quezon City.
Note : (*) means an abandoned station.
(**) means an existing station.

The inspection of regular discharge and water level measurements at the existing stream gauging station of DPWH was carried out on 10 February 1999. The results of inspection are summarized below:

Results of Discharge Measurement Inspection

Item of Inspection	Note of Evaluation
Station name and location	Ogsong in the middle reaches of the Ogsong river.
Condition of staff gauge	The flow is almost uniform. The staff gauge covers from low to high water regimes.
Observation method	Measured by three observers properly following the standard method. By wading. The adequate equipment is used. Mechanical current meter is used.
Observation interval	Once a month.
Accessibility to the staff gauge	Fair in normal flow conditions. Incapable to reach to the staff gauge in case of flood.

The relocation of the staff gauge to the accessible site is highly recommended to make gauge reading possible in case of floods.

The staff gauge at Malinao stream gauging station is installed at the right abutment of the bridge. Therefore, the observation of high water level can be done in any flow conditions.

2.1.2 Sedimentation

The suspended load samplings at Ogsong and Malinao gauging stations are also carried out once a month by the Hydrological Observation Section, DPWH Region V and the samples are sent to the BRS for analysis and compilation.

The results of analysis have been filed at BRS since 1994 as shown below:

Suspended Load Sampling at DPWH Water Level Stations

Name of Station	Years of Record
Ogsong	1994-1998
Malinao	1994-1998

Source : Bureau of Research and Standards (BRS), DPWH, Quezon City.

No discharge measurements were undertaken at the time of sampling. The highest and the lowest values of concentration (ppm) are summarized below.

Highest and Lowest Sediment Concentrations

Gauging Station	Highest Value (ppm)	Lowest Value (ppm)
Ogsong	176.6	5.2
Malinao	245.3	6.9

2.1.3 Problems Encountered and Needs for Solution

The management of flood control and sabo works within the Study Area depends highly on the adequacy and accuracy of relevant hydrological data. Thus, the implementation of an efficient data collection system is crucial in the disaster prevention.

Streamflow discharge measurements are the only direct means of quantifying the amounts and degree of flood and debris flow. As such, the installation, operation and proper maintenance of the instruments for flow measurement are priority considerations in flood control and sabo planning.

Within the Study Area, there are only two stream gauging stations, both of which are measured by a staff gauge. Thus, the required numbers of automatic stream gauging station should be installed to acquire more accurate information and monitor the flood and debris flows of major rivers and tributaries.

2.2 Hydrological Data

The hydrological data collected during the First Work in the Philippines are summarized below:

Hydrological Data Collected

Title	Organization	Note
1. Daily Water Level & Discharge Data - Yawa (1980 – 88) - Ogsong (1982 – 90) - Nasisi (1980 – 85) - Malinao (1980 – 88)	BRS, DPWH	With discharge rating curves.
2. Suspended Load Records - Ogsong - Malinao	BRS, DPWH	From 1994 – 1998.

No hourly flood hydrographs and instantaneous flood peaks at the above stations were available from DPWH, Region V and BRS. No suspended load records for high water regime were obtained, either.

The other data and reference books collected during the First Work in the Philippines are shown below:

Other Collected Data

Title	Organization	Note
1. Re-study of Mayon Volcano Sabo and Flood Control Project, Supporting Report I, II and III, March 1983, JICA	DPWH, Region V	The latest Master Plan report.
2. Philippine Water Resources Summary Data, Volume 1, Streamflow and Lake or River Stage, NWRC, Jan 1980	NWRC	
3. Philippine Water Resources Summary Data, Volume 2, Streamflow and Lake or River Stage, BRS, DPWH, Jun 1991	BRS, DPWH	
4. Philippines Water Data 1980-1983 Surface Water Records no.22 BRS, DPWH, Feb 1993	BRS, DPWH	

2.3 Water Level and Flow Measurements

2.3.1 Introduction

The conduct of the Survey on Water Level and Flow Velocity Measurements is one important direct method of obtaining information related to the river flow conditions in the Study Area. The results of the survey will be vital in evaluating the past flow records and estimating the flood hydrographs of the rivers around the Mayon Volcano. The survey was undertaken from January to February 1999.

2.3.2 Objective

The objective of this survey is to examine the river flow conditions at the disaster prone rivers where no measurements of water level and flow velocity have been undertaken except for the Yawa, Ogsong, Nasisi, and Quinali (B).

2.3.3 Scope of Work

(1) Location of measurements

The water level and flow velocity measurements are carried out at the following 17 rivers.

Water Level and Flow Velocity Measurements

River system	River
Yawa River System	Yawa
	Pawa-Burabod
	Budiao
	Anuling
Quinali (A) River System (Upstream of the Bicol river)	Quirangay
	Tumpa
	Maninila
	Masarawag
	Ogsong
	Nasisi
Quinali (B) River System	Buang
	Quinali (B)
	San Vicente
Arimbay River System	Arimbay
Padang River System	Padang
Basud River System	Basud
Bulawan River System	Bulawan

(2) Measurements of flow velocity

Flow velocity measurement is made by current meter. The measuring points are at 20% and 80% of water depth from water surface in a vertical section. In case water depth is less than 70cm, flow velocity is measured at 60% of the depth from the water surface. Water depths and flow velocities in a section are measured with proper interval at the site.

(3) Recording of measurement results

The following items are precisely recorded on the standard form.

- Date of measurement
- Name of observers
- Weather and wind conditions
- Time of the commencement and end of measurement
- Water level of manual water level gauge installed by the Contractor at the commencement and end of measurement,
- Water depths and flow velocities by measuring lines

(4) Numbers of measurement

Numbers of measurement are four times per each river. In total, 68 (4 x 17 = 68) measurements are to be carried out.

2.3.4 Results of the Survey

(1) Date of measurements

The date of the measurements is shown below:

Date of Measurements

Measurements	Date	Weather Condition
1st	07-08 January 1999	Fair
2nd	14-15 January 1999	Rainy
3rd	28-29 January 1999	Cloudy
4th	04-05 February 1999	Fair/Cloudy

(2) Results of measurements

a) The second measurement was able to undertake in high flow condition of the rivers. Therefore, the measurements could cover from low to high regimes of the rivers.
b) The maximum discharge was measured to be 156 m^3/s at the Quinali (B) on 14 January 1999. The minimum discharge was obtained at the Maninila ($Q=0.044m^3/s$) on 4 February 1999.
c) The high velocity values more than 1.0m/s were obtained at the Nasisi, Buang, Basud, and Bulawan even in low flow conditions, reflecting their steep river slope.

2.4 Hydrological Analysis

2.4.1 Runoff Coefficient

No data on the runoff coefficient of flood runoff are available in the Study Area. Japanese Standard indicates the following runoff coefficients for Sabo and river planning depending on the ground conditions.

Runoff Coefficients of Japanese Standard

Ground Condition	Runoff Coefficient
Field, Farm	0.6
Paddy Field	0.7
Mountainous Area	0.7

As the Study Area was thought to be mainly composed of mountainous area and paddy field, the runoff coefficient of 0.7 for the Rational Formula was adopted to the Master Plan in 1981.

This Study also adopts the runoff coefficient of 0.7 for the Rational Formula method on flood peak runoff estimate since no data of hourly rainfall and runoff hydrograph are obtained for the present study.

2.4.2 Flood Concentration Time

The flood concentration time is given by the summation of the time required for flood to flow out into the river course from the farthest point in the basin and the time required for flood to run down through the river course up to the point under consideration.

Various empirical formulas have been proposed for the estimation of flood concentration time. Among them, Kraven's formula is simple and applicable for the calculation of both times defined above. It is therefore adopted for this Study.

Kraven gave the following empirical values on the flood velocity depending on the river bed slope.

Flood Velocity After Kraven

River Bed Slope	> 1/100	1/100 - 1/200	< 1/200
Flood Velocity (m/sec)	3.5	3.0	2.1

Finally, the flood concentration time can be calculated by the following equation.

$$T = L/60W$$

where,

T : time of flood concentration (min)

L : length of river course from the farthest point in the basin to the point under consideration (m)

W : flood velocity after Kraven (m/s)

Results of the calculation of flood concentration time in 17 rivers are shown below.

Flood Concentration Time

River Basin	Drainage Area (km^2)	Flood Concentration Time (min)
Yawa	74.4	96
Pawa-Burabod	7.6	55
Budiao	7.5	56
Anuling	9.4	49
Quirangay	9.3	46
Tumpa	5.7	37
Maninila	4.9	51
Masarawag	10.5	58
Ogsong	38.1	128
Nasisi	84.2	117
Buang	4.5	39
Quinali (B)	157.8	178
San Vicente	9.9	63
Arimbay	2.6	25
Padang	7.6	44
Basud	14.0	52
Bulawan	15.4	55

2.4.3 Probable Flood Peak Discharges

(1) Review of previous study

Rational Formula was employed for the calculation of probable flood peak discharges by previous the Master Plan. The results of calculation for 50-yr flood are shown below.

50-Year Probable Flood Peak Discharges Estimated by JICA Master Plan (1981)

River System	River	Q (m^3/s)	Specific Discharge ($m^3/s/km^2$)
Yawa River System	Yawa	2,140	28.8
	Pawa-Burabod	300	39.5
	Budiao	290	38.7
	Anuling	370	39.4
Quinali (A) River System	Quirangay	280	30.1
	Tumpa	180	31.6
	Maninila	150	30.6
	Masarawag	300	28.6
	Ogsong	770	20.2
	Nasisi	1,660	19.7
Quinali (B) River System	Buang	140	31.1
	Quinali (B)	2,380	15.1
	San Vicente	270	27.3
Arimbay River System	Arimbay	-	-
Padang River System	Padang	-	-
Basud River System	Basud	360	25.7
Bulawan River System	Bulawan	390	25.3

Based on the data availability in the Study Area, rational method is used again for the present study since no improvement of data acquisition has been made after the Master Plan in 1981.

(2) Representative rainfall station

The representative rainfall station is determined for each basin, which defines the meteorological conditions of the basin. In general, the station having the long and reliable record is selected as a representative one. In the Study Area, five stations of Legazpi, Guinobatan, Buang, San Ramon and Sto Domingo which are located around the Mayon Volcano are qualified. The Study Area therefore is divided into five sections around the Mayon Volcano as shown below.

Representative Rainfall Station

River Basin	Representative Station
Yawa	Legazpi
Pawa-Burabod	Legazpi
Budiao	Legazpi
Anuling	Legazpi
Quirangay	Guinobatan
Tumpa	Guinobatan
Maninila	Guinobatan
Masarawag	Guinobatan
Ogsong	Guinobatan
Nasisi	Guinobatan
Buang	Buang
Quinali (B)	San Ramon
San Vicente	San Ramon
Arimbay	Sto Domingo
Padang	Sto Domingo
Basud	Sto Domingo
Bulawan	Sto Domingo

(3) Probable flood peak runoff

Rational formula is employed for the calculation of probable flood peak runoff. It is expressed in the form of

$$Q = 1/3.6 \times C \times I \times A$$

where,

Q : flood peak discharge (m^3/s)

A : drainage area (km^2)

C : runoff coefficient (=0.7)

I : rainfall intensity for the duration equal to the flood concentration time (mm/hr)

Results of calculation are summarized below and the process of calculation is shown in detail in the previous tables.

Probable Flood Peak Runoff Estimated by Rational Formula

Unit: (m^3/s)

River Name	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Yawa	716	978	1163	1353	1604	1802
Pawa-Burabod	116	154	181	210	247	276
Budiao	113	150	177	205	241	270
Anuling	152	201	237	274	322	361
Quirangay	143	189	219	248	284	311
Tumpa	103	135	157	177	203	222
Maninila	73	97	113	128	146	161
Masarawag	140	185	215	244	280	307
Ogsong	308	421	495	565	654	720
Nasisi	663	906	1066	1217	1406	1549
Buang	64	102	133	168	224	275
Quinali (B)	619	908	1127	1359	1694	1971
San Vicente	86	121	148	177	219	254
Arimbay	63	76	86	95	108	118
Padang	131	158	177	198	225	246
Basud	212	257	289	322	368	401
Bulawan	223	272	306	341	389	425

3. CHARACTERISTICS OF RIVERS

3.1 River Systems

The river systems to be studied are the following three major rivers and four small streams which originate from the slope of the Mayon Volcano.

a) Yawa River System
b) Quinali (A) River System
c) Quinali (B) River System
d) Arimbay River System
e) Padang River System
f) Basud River System
g) Bulawan River System

The three major rivers, Yawa, Quinali (A), and Quinali (B) are comprised of several tributaries to be studied separately as shown below:

River Systems and Rivers to be Studied

River System	River	Catchment Area (km^2)	River Length (km)	Elevation of Basin (MMSL)	Average River Bed Slope
Yawa River System	Yawa	74.4	17.3	4-2,400	0.0030-0.181
	Pawa-Burabod	7.6	11.6	10-2,400	0.207
	Budiao	7.5	11.8	20-2,400	0.202
	Anuling	9.4	10.2	85-2,400	0.226
Quinali (A) River System	Quirangay	9.3	9.8	110-2,400	0.235
	Tumpa	5.7	7.8	95-525	0.055
	Maninila	4.9	10.7	94-2,400	0.217
	Masarawag	10.5	12.2	68-2,400	0.191
	Ogsong	38.1	21.4	38-1,070	0.0029-0.135
	Nasisi	84.2	20.9	38-2,400	0.0041-0.151
Quinali (B) River System	Buang	4.5	8.3	240-2,400	0.262
	Quinali (B)	157.8	31.1	0-1,548	0.0030-0.092
	San Vicente	9.9	13.3	20-2,400	0.180
Arimbay River System	Arimbay	2.6	5.3	0-300	0.057
Padang River System	Padang	7.6	9.3	0-2,400	0.259
Basud River System	Basud	14.0	11.0	0-2,400	0.218
Bulawan River System	Bulawan	15.4	11.5	90-2,400	0.201

Note : MMSL means meters above mean sea level.

The other small rivers, Arimbay, Padang, Basud, and Bulawan which are located east or southeast of Mayon Volcano are treated as an independent river system.

Therefore, in total, there are 17 rivers to be studied for the Study on Comprehensive Disaster Prevention around Mayon Volcano.

3.2 Description of Rivers to be Studied

(1) Yawa River System

The Yawa river gathers three streams (shown in the previous table) on the southern to southeastern slope of Mayon Volcano and other small tributaries from the southern hills. It flows mostly in an easterly direction along the Legazpi Airport passing under the Yawa bridge and pouring finally into the Poliqui Bay of Albay Gulf, at the north of Legazpi City.

The three streams are the Anuling river, the Budiao river and the Pawa-Burabod river from the west to the east.

The river bed of the Yawa river consists of gravel and boulder in its middle reaches.

(2) Quinali (A) River System

The Quinali (A) river, gathering many streams originating from the southern to western slope of Mayon Volcano, flows generally in a westerly or northwesterly direction and finally pours into the Lake Batu.

Six rivers to be studied, Quirangay, Tumpa, Maninila, Masarawag, Ogsong, and Nasisi rivers, are located in the upstream reaches of the Quinali (A) main river course.

(3) Quinali (B) River System

The Quinali (B) river originates from the western to northwestern slope of the Mayon Volcano and gathers several tributaries from Mayon Volcano, Mt. Masaraga and Mt. Malinao. It covers the Malinao Plain, Malinao and San Vicente and passes under the Balza bridge near the river mouth.

The Buang river situates in the uppermost reaches of the Quinali (B) river and originates from the northwestern slope of the Mayon Volcano.

The San Vicente river originates from the northern slope of the Mayon Volcano and joins the lower reaches of Quinali (B) river near Malinao.

(4) River Systems in Eastern and Southeastern Slope

There are several independent rivers originating from the Mayon Volcano and flowing into the Albay Gulf and Tabaco Bay between the Yawa river system and Quinali (B) river system.

Among them, the following four rivers are selected to be the ones within the scope of study.

- Arimbay river
  The Arimbay river originates from the southeastern slope of the Mayon Volcano. The catchment area is relatively small.
- Padang river
  The Padang river situates north of the Arimbay river. The river is heavily devastated. The Padang river shares the possibility of the river piracy events by the debris flow with the Pawa-Burabod river.

- Basud river

  The Basud river is one of the most devastated river similar to the Pawa-Burabod river.
- Bulawan river

  The Bulawan river flows through a narrow gorge in its middle reaches and forms a flat plain in the lower reaches where the enormous sediment is deposited.

The river course changes towards east and then towards northeast after passing the National Highway and flows into the Tabaco Bay with a steep river bed slope.

The following river characteristics around the Mayon Volcano are briefly summarized below.

a) Shape of river channel
b) Bank erosion
c) Flood plain
d) Main land use
e) Community to be affected by flood
f) Existing dikes
g) Existing bridges

Characteristics of Rivers around Mayon Volcano

River	Shape of River Channel	Bank Erosion	Flood Plain	Main Land Use	Community to be Affected by flood	Existing Dikes	Existing Bridges
Yawa	Straight channel trained by past shortcut works	Only observed near Bogtong Barangay	None Almost confined by existing dikes	Mostly paddy fields	Bogtong Barangay	(R) 3,850m (L) 1,400m Partially damaged	Yawa Bridge (under construction) Mali Bago Bridge and one spillway type bridge
Pawa-Burabod	Braided	Heavily	500m upstream from confluence to Yawa river	(R) Mainly devastated (L) Residential area	Bonga	(R) 1,100m (L) 3,000m Good condition	None
Budiao	Straight	Heavily	500m upstream from confluence to Yawa river	Paddy and coconut field	Kilnar	(R) 500m (L) 2,550m Good condition	None
Anuling	Straight	Heavily	1,000m upstream from confluence to Yawa river	Paddy and coconut field	Budiao	(R) 850m (L) 570m Partially damaged	None
Quirangay	Rather straight	Heavily in mountain slope	Lower reaches near confluence to Quinali (A) river caused by backwater from Quinali (A) river	Mostly paddy fields	Barangays near confluence to Quinali (A) river	No dikes	Camalig Bridge for National Road

River	Shape of River Channel	Bank Erosion	Flood Plain	Main Land Use	Community to be Affected by flood	Existing Dikes	Existing Bridges
Tumpa	Rather straight	Heavily in mountain slope	Lower reaches near confluence to Quinali (A) river caused by backwater from Quinali (A) river	Mostly paddy fields	Barangays near confluence to Quinali (A) river	No dikes	One bridge for National Road
Maninila	Rather straight	Heavily in mountain slope	Lower reaches near confluence to Quinali (A) river caused by backwater from Quinali (A) river	Mostly paddy fields	Barangays near confluence to Quinali (A) river	No dikes	Travesia Bridge for National Road
Masarawag	Rather straight	Heavily in mountain slope	Lower reaches near confluence to Quinali (A) river caused by backwater from Quinali (A) river	Mostly paddy fields	Barangays near confluence to Quinali (A) river	(R) 30m (L) 560m Good condition	One bridge for National Road and one railway bridge
Ogsong	Meandering	Not observed	Widely spread along meandering river channel	Mostly paddy fields	South of Ligao Municipality	(R) 1160m (L) 100m Good condition	Three bridges
Nasisi	Meandering	Heavily in middle reaches near Nasisi Barangay	Widely spread along meandering river channel	Mostly paddy fields	North of Ligao Municipality	(R) 350m (L) 350m Good condition	Four spillway and four bridges
Buang	Rather straight	Heavily in mountain slope	Not observed	Forest	None	(R) 450m (L) 450m Partially damaged	Buang Bridge and one spillway bridge
Quinali (B)	Heavily meandering	Heavily along river course causing river channel shift	Widely spread along meandering river channel	Mostly paddy fields	Malinao Municipality	(R) 800m (L) 50m Good condition	Quinali Bridge and Bailey bridge
San Vicente	Rather straight	Heavily in mountain slope	Widely spread along river channel	Mostly paddy fields	Tabaco and Malinao Municipality	(R) 1050m (L) 1020m Partially damaged	San Vicente Bridge and one bridge downstream
Arimbay	Rather straight	Slightly in mountain slope	Not observed	Paddy and coconut field	None	(R) 250m (L) 150m near National Road Good condition	One spillway for National Road
Padang	Rather straight	Heavily in mountain slope	Not observed	Paddy and coconut field	None	(R) 570m (L) 970m near National Road Partially damaged	One spillway for National Road
Basud	Rather straight	Heavily in mountain slope	Not observed	Paddy and coconut field	None	No dikes	One spillway for National Road
Bulawan	Rather straight but braided in downstream	Heavily in mountain slope	Widely spread along braided downstream channels	Paddy and coconut field	None	No dikes	One Bridge for National Road

3.3 Rivers and Municipalities

The administrative borders are drawn in the Study Area and the relation between the river and municipalities involved is briefly shown below.

River Basins and Municipalities

River System	River	Upper Reach	Middle Reach	Lower Reach
Yawa River System	Yawa	Daraga	Daraga	Legazpi
	Pawa-Burabod	Daraga Legazpi	Legazpi	Legazpi
	Budiao	Daraga	Daraga	Daraga
	Anuling	Camalig Daraga	Daraga	Daraga
Quinali (A) River System	Quirangay	Camalig	Camalig	Camalig
	Tumpa	Camalig	Camalig	Camalig
	Maninila	Camalig	Guinobatan	Guinobatan
	Masarawag	Guinobatan	Guinobatan	Guinobatan
	Ogsong	Guinobatan	Ligao	Ligao
	Nasisi	Ligao Guinobatan	Ligao	Ligao
Quinali (B) River System	Buang	Tabaco	Tabaco	Tabaco
	Quinali (B)	Ligao Tabaco Malinao	Tabaco Malinao	Malinao
	San Vicente	Tabaco	Tabaco	Malinao
Arimbay River System	Arimbay	Legazpi	Legazpi	Legazpi
Padang River System	Padang	Legazpi	Legazpi	Legazpi
Basud River System	Basud	Sto Domingo	Sto Domingo	Sto Domingo
Bulawan River System	Bulawan	Malilipot	Malilipot	Malilipot

Note : No rigorous definition of river reaches is made for above description.

3.4 River Capacity and Flood Inundation

3.4.1 River Capacity

The bank-full flow capacity of 17 rivers is roughly estimated by uniform flow analysis. Location of the cross section for the rivers is the lowest portion of the river. Results of the analysis are summarized below.

Flow Capacity of Rivers

Unit : (m^3/s)

River System	River	Q (existing)	Location
Yawa River System	Yawa	1250	Yawa Bridge
	Pawa-Burabod	180	Confluence to the Yawa River
	Budiao	300	Confluence to the Yawa River
	Anuling	220	Confluence to the Yawa River
Quinali (A) River System	Quirangay	250	National Road
	Tumpa	540	National Road
	Maninila	360	National Road
	Masarawag	1260	National Road
	Ogsong	270	National Road
	Nasisi	630	National Road
Quinali (B) River System	Buang	4950	National Road
	Quinali (B)	850	National Road
	San Vicente	790	National Road
Arimbay River System	Arimbay	71	National Road
Padang River System	Padang	163	National Road
Basud River System	Basud	31	National Road
Bulawan River System	Bulawan	3260	National Road

Note : Flow capacity is calculated by "with-bridge" condition.

3.4.2 Flood Inundation

Flood inundation in the Study Area is analyzed by the flood inundation records for the past cyclones and non-uniform flow analysis to estimate probable flood inundation area, depth and duration.

Flood inundation records

Flood inundation records caused by the past major cyclones are reviewed and evaluated for the present Study. Available flood inundation maps are limited and only obtained from the previous Master Plan Study in 1981. By the present Study, the maximum flood water levels are obtained at several cross sections in the seventeen rivers to check the locations prone to be flooded, and interviews with local residents near the river were undertaken if and when the inundation occurred.

Flood inundation maps obtained from the previous Master Plan are as follows and shown in Figures I 3.1 and I 3.2.

- Inundation area by flood caused by Typhoon "Pepang" on September 17-18, 1979
- Inundation area by flood caused by Typhoon "Daling" on June 28 to July 2, 1981

Flood inundation prone rivers are summarized below, based on the flood inundation records.

Flood Inundation Prone Rivers

River System	River	Location
Yawa River System	Yawa	Almost none (river capacity is sufficient)
	Pawa-Burabod	Almost none (river capacity is sufficient)
	Budiao	Almost none (river capacity is sufficient)
	Anuling	Almost none (river capacity is sufficient)
Quinali (A) River System	Quirangay	Occasionally flooded by back-water effects from Quinali (A) river (downstream of national road)
	Tumpa	Occasionally flooded by back-water effects from Quinali (A) river (downstream of national road)
	Maninila	Occasionally flooded by back-water effects from Quinali (A) river (downstream of national road)
	Masarawag	Occasionally flooded by back-water effects from Quinali (A) river (downstream of national road)
	Ogsong	Occasionally flooded by insufficient flow capacity of Ogsong River but Ligao city proper is not affected by floods
	Nasisi	Occasionally flooded by insufficient flow capacity of Nasisi River but Ligao city proper is not affected by floods
Quinali (B) River System	Buang	None (river capacity is sufficient)
	Quinali (B)	Occasionally flooded by insufficient flow capacity of Quinali (A) River
	San Vicente	Occasionally flooded by insufficient flow capacity of San Vicente River and Malinao is often affected by floods
Arimbay River System	Arimbay	None (river capacity is sufficient)
Padang River System	Padang	Almost none (river capacity is sufficient)
Basud River System	Basud	None (river capacity is sufficient)
Bulawan River System	Bulawan	Almost none except for the bladed river portion between national road and river mouth

(2) Probable flood inundation

Probable flood inundation (including area, depth and duration) is roughly estimated by non-uniform flow analysis, topography (such as contour line and river system) and land use (such as road network and irrigation system) of the probable flood plain in the catchment area as shown in Figures I 3.3 to I 3.5.

Probable Flood Inundation in Proposed Rivers

River Name	Probable Flood	Inundation Period (day)	Inundation Depth (m)
Yawa	50	1	1.0
	20	1	0.3
Sto Vicente	50	2	1.0
	20	1	0.3
	10	1	0.3
	5	1	0.3
	2	1	0.3
Quinali (B)	50	2	1.0
	20	1	0.3
	10	1	0.3
	5	1	0.3
Nasisi	50	3	1.2
	20	1	0.5
	10	1	0.5
	5	1	0.5
Ogsong	50	3	1.2
	20	1	0.5
	10	1	0.5
	5	1	0.5
	2	1	0.5

(3) Flood inundation in Legazpi City

Flood inundation records in Legazpi City are obtained from Engineer's Office of Legazpi City.

The map of flood prone areas in Legazpi City (Fig. I 3.6) shows areas regularly flooded and areas occasionally flooded. The flood prone areas are summarized below.

a) Low-lying area along the Tibu river
b) Low-lying area along the Macabalo river
c) City center in the Legazpi Port District

The central area of the Albay District is not seriously affected by flood inundation.

Probable flood inundation (including area, depth and duration) is roughly estimated by non-uniform flow analysis, topography (such as contour line and river system) and land use (such as road network and irrigation system) of the probable flood plain in the catchment area.

Probable Flood Inundation in Legazpi

River Name	Probable Flood	Inundation Period (day)	Inundation Depth (m)
Macabalo	10	2.5	2.0
	5	2	1.5
	2	1	1.0
Tibu	10	2.5	2.0
	5	2	1.5
	2	1	1.0

4. Water Supply System

4.1 Present Water Supply Facilities

Water in the province is presently supplied by level 3 gravity-fed water supply, level 3 pressure-pumped water supply, reservoir and water supply trunk lines. Level 3 water supply system is defined as an individual household faucet system under the supervision of LWUA, Local Water Utility Agency in the area. The existing water supply in the province is summarized below:

Existing Level 3 Water Supply System in the Province of Albay

Municipality	Type of Water Supply	Responsible Agency	No. of Serving Household
Bacacay	Gravity-fed	Bacacay Water District (BWAD)	782
Camalig	Gravity-fed	Camalig Water District (CWAD)	781
Daraga	Gravity-fed	Daraga Water District(DWAD)	2124
Legazpi	Gravity-fed	Legazpi City Water District(LCWD)	3845
Ligao-Oas	Pressure Pumped	Ligao-Oas Water District(LWAD)	2444
Tabaco	Gravity-fed	Tabaco Water District(TWAD)	4039

Source: PPDO/PLUC-TWG, 1996. Note: Year for no. of serving household is not known.

The coverage of Level 3 water supply system in the province is estimated to be about 39% of the total municipalities , which seems to be inadequate.

4.2 Sources of Water

Groundwater and springs are major sources of water supply system in the province. In the case of LCWD, existing water sources are briefed below:

Sources of Water for LCWD in 1998

Type of Water Sources	Location	Name of Barangay
Springs	Kapungolan	Buyuan
	7 Springs	Buyuan
	Ayala	Buyuan
	Aperin	Buyuan
Deepwells	6 at Bonga	Bonga
	4 at Mabinit	Mabini

Source : LCWD, Legazpi

The locations of the water sources for the LCWD and DWAD are mostly concentrated at the radius of about 8km from the crater of the Mayon Volcano as shown in Figure I 4.1.

Primary treatment is undertaken by chlorination for bacteriological treatment. Total service connection in Legazpi is 9,531 in December 1998. About 90% of total service connection is for domestic and government use, and 10% for commercial and industrial.

4.3 Rehabilitation and Expansion Plan

To increase the services and the number of population being served, several water supply plans were proposed by local water supply agency in the area. The proposed facilities for water supply are intended to attain increased coverage of Level 3 water systems in urban centers of municipalities and in areas expected to have special economic roles as in Legazpi City.

In Legazpi City, a rehabilitation and expansion plan is proposed by the Legazpi City Water District (LCWD) to upgrade the present water supply facilities and to expand the system (including additional 21 deep-wells) up to 82 – 90% coverage level in the city.

Feasibility Study was completed in 1998. And its implementation program (by BOT) is under consideration by LCMD. The project, comprising Phase 1 for rehabilitation and Phase 2 for expansion, will take about 25 years.