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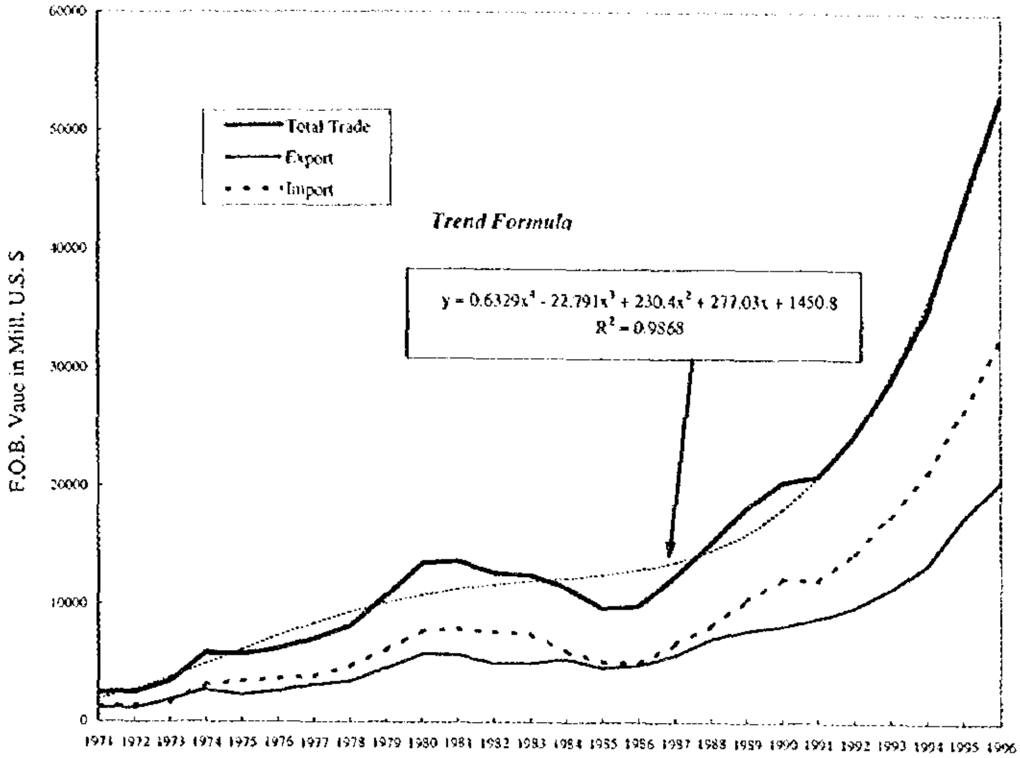
Figures



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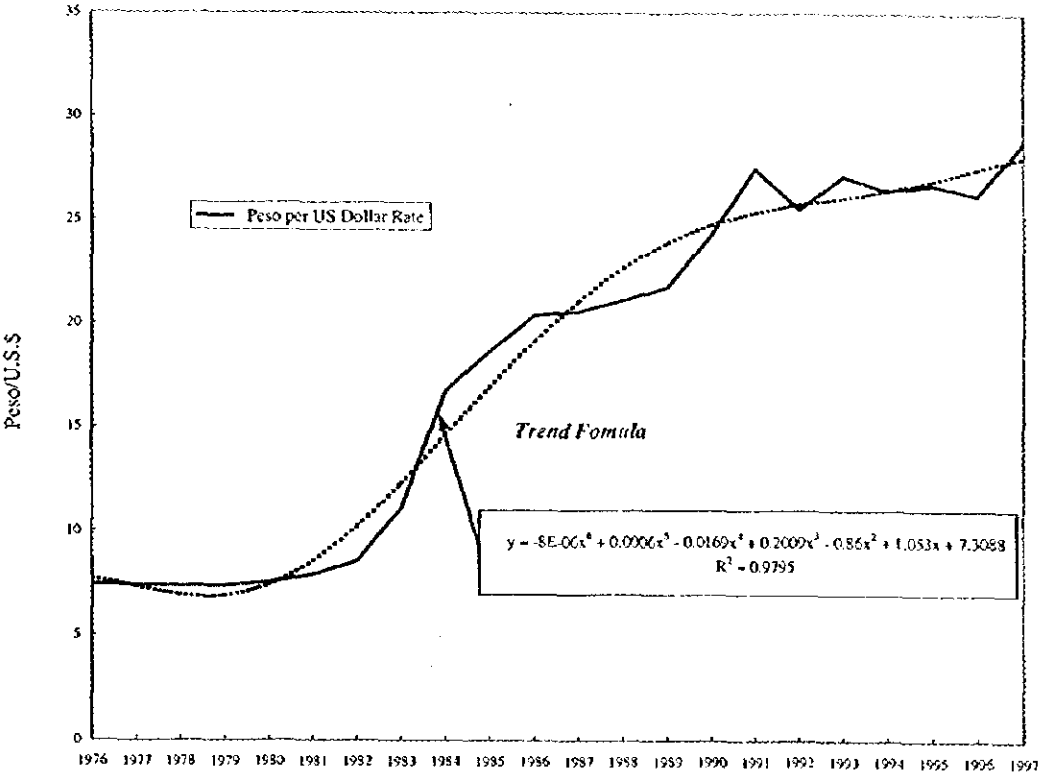

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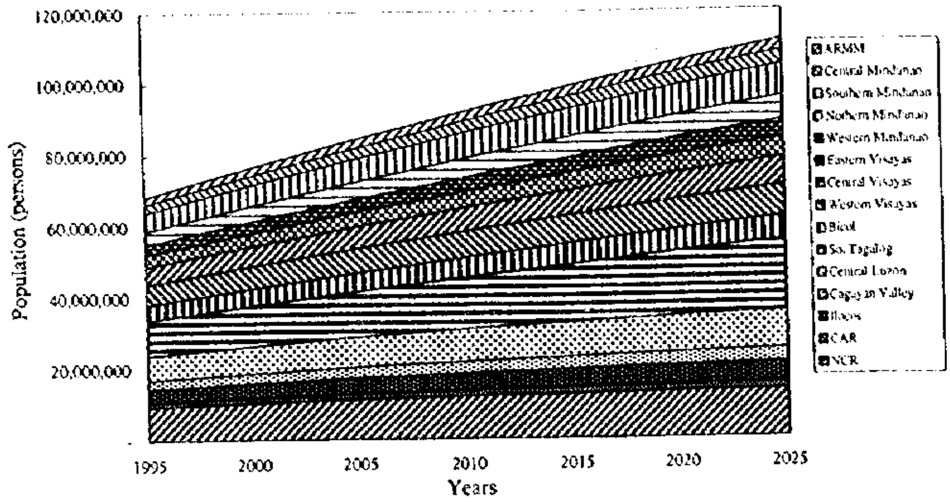

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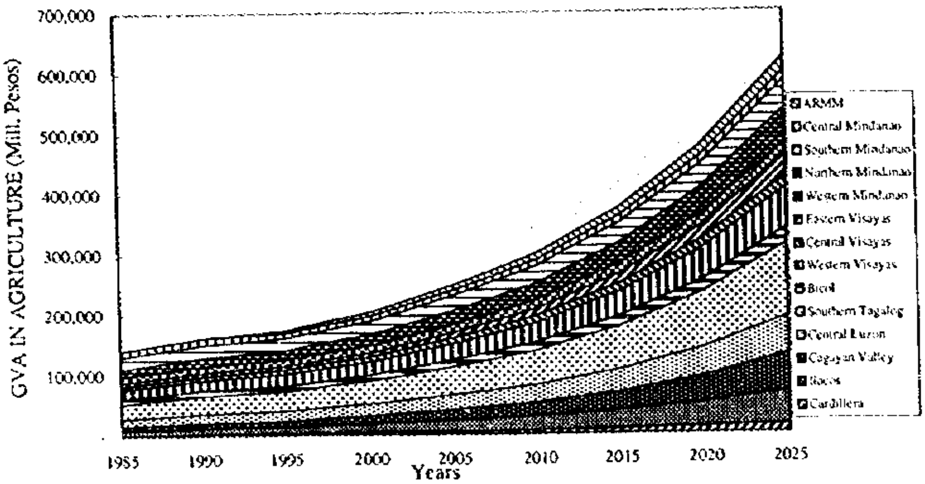

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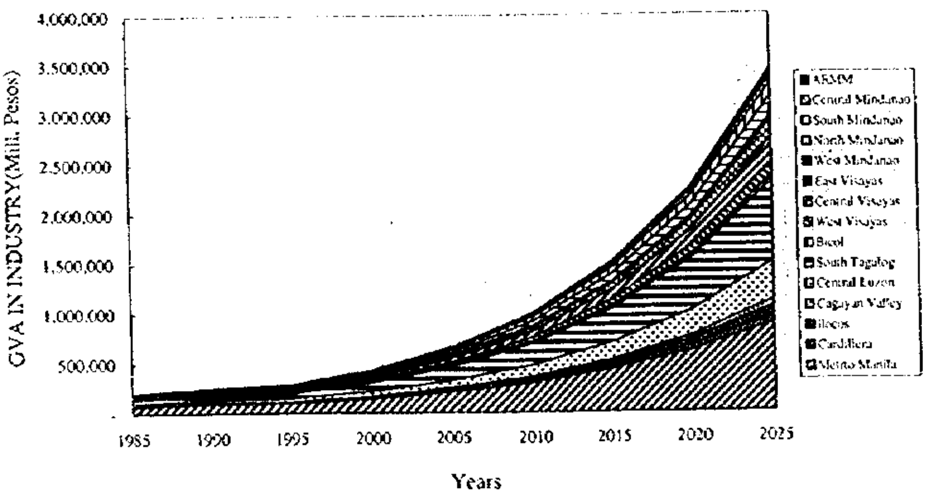

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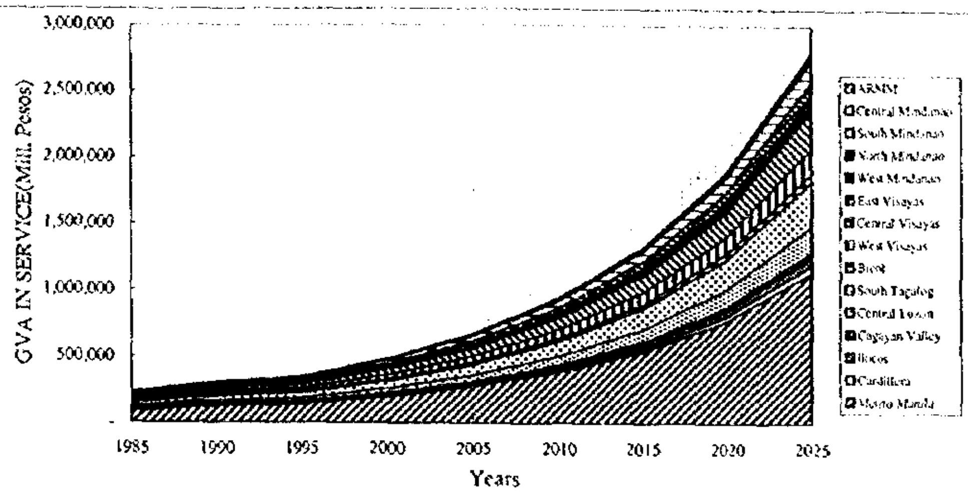

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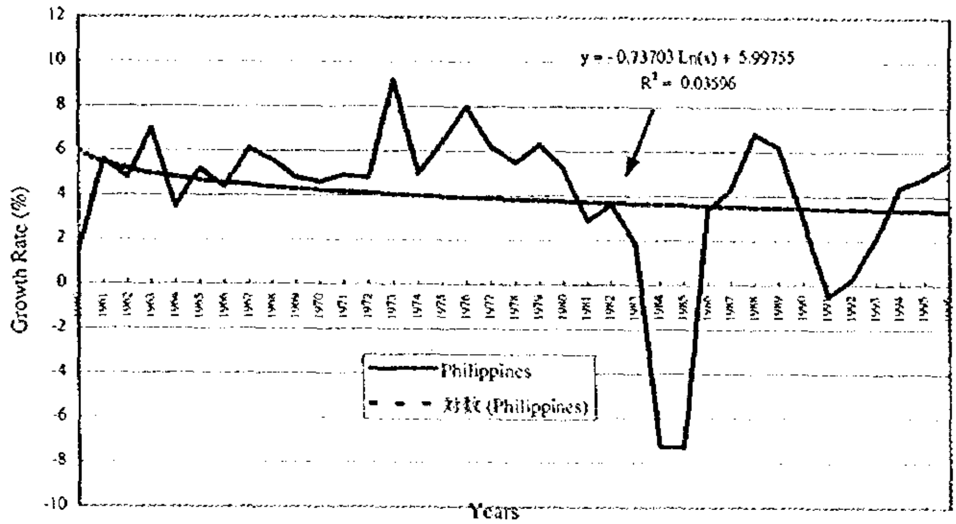

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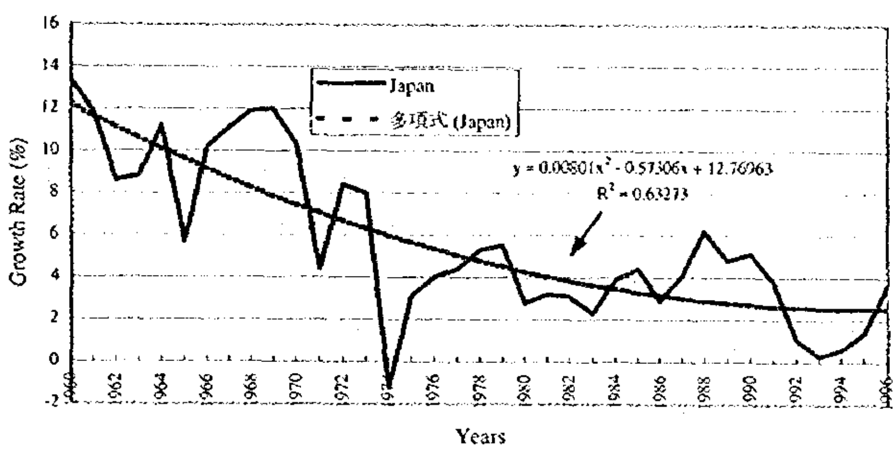

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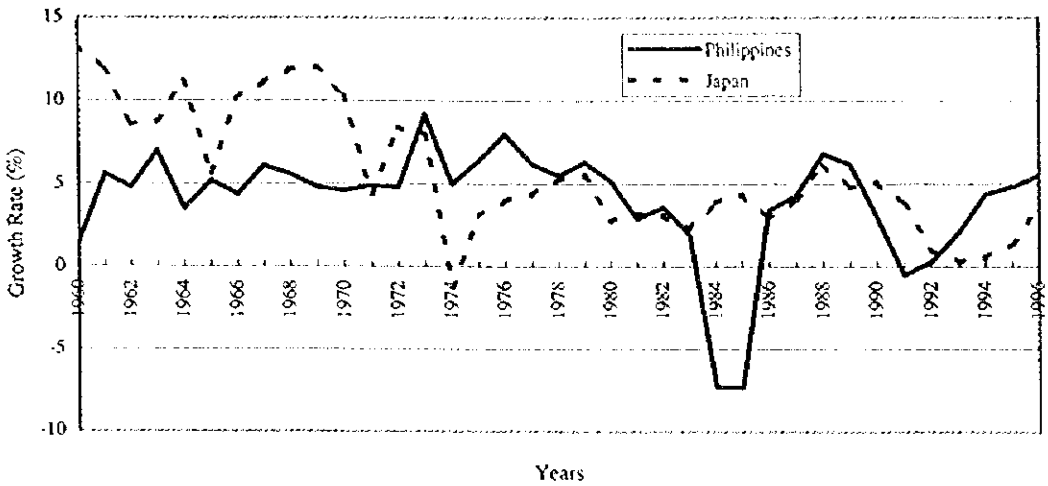

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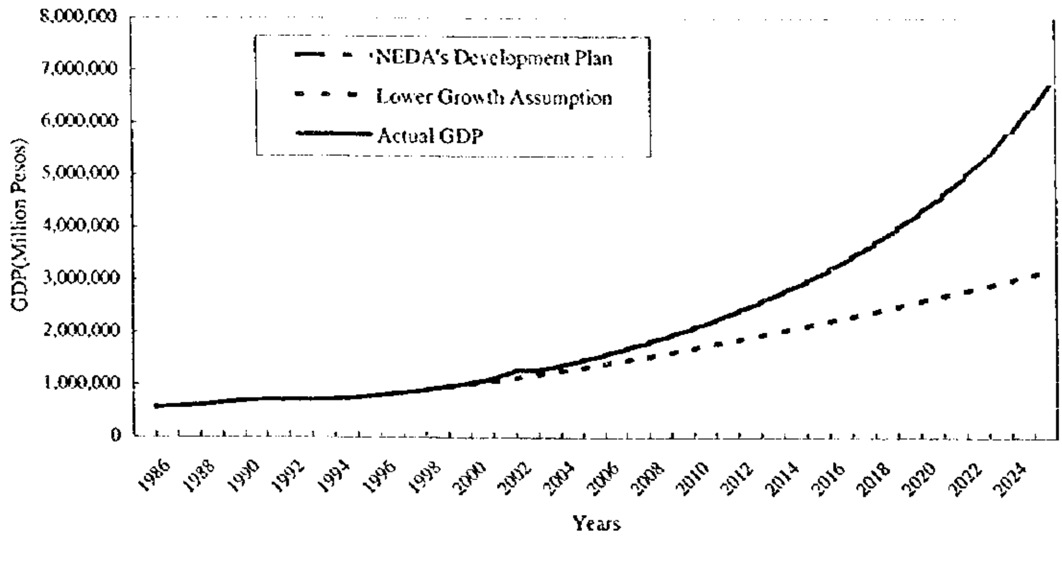

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Part – B

HYDROLOGY

Part – B HYDROLOGY

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Part – B HYDROLOGY

B1 Introduction

B1.1 Overall Study Works Carried Out

The hydrologic investigation of the major river basins involved the following elements:

- classification of each major river basin in terms of climate
- collection of streamflow and rainfall records, and data on flood and sediment
- lowflow analyses
- overall assessment of flood and sedimentation

A detailed description of each of these elements is presented in subsequent sections.

In the first stage field investigation, the hydrological investigation was performed placing a focus on the lowflow analysis. While, in the second stage field investigation, the study of flood and sedimentation was concentratedly carried out.

B1.2 Data Collection

B1.2.1 Rainfall Data Collection

Rainfall data were obtained from PAGASA for 50 synoptic stations. These data include daily rainfall totals as well as monthly and annual summary data. For most of the synoptic stations, daily rainfall data are available for the period 1961 to 1995. Representative rainfall gauging stations were selected for each of the major river basins. In a few basins, rainfall data from sources other than PAGASA were used because they were determined to be more representative of the particular river basin. Other sources of rainfall data included NIA and NPC. The rainfall data were used to validate streamflow records from selected stream gauging stations as described in *Sub-Section B3.2.2*. The locations of the representative rainfall gauging stations are shown in Figures B-2 to B-13.

Frequency analyses were performed using total annual rainfall for each of the 50 PAGASA Synoptic stations. The total annual rainfall values were ranked and fitted to both Log-Pearson III and Gumble distributions presented in Table 2.3-1. The total annual rainfall for the representative stations used in the hydrologic analysis to validate the stream flow data are presented in Tables 2.3-2

B1.2.2 Streamflow Data Collection

Streamflow data were gathered for many of the stations within the study area. Data for a minimum of two stations per study area were gathered. Representative streamflow gauging stations for each major river basin were selected from these as described in *Section B3.2*. Streamflow records were obtained from BRS, NPC, and NIA. Some of the data were in computer format and others were only available in hard copy format.

B1.2.3 Climatological Data

Climatological normal data were acquired from PAGASA for twenty Agromet stations and nineteen Synoptic stations. The data are averaged monthly values for periods ranging from thirteen to twenty-two years. The following parameters are included:

- Rainfall (total annual, mm)
- Temperature (mean monthly, °C)
- relative humidity (mean monthly, %)
- sun duration (total monthly, hours)
- evaporation (total monthly, mm)

Evaporation and sun duration values are only available for the Agromet stations. The data from these stations are presented in tabular form for each of the major river basins in Chapter B4 Lowflow Analysis Results.

B2 Climate and Climate Regions of the Study Area

Four climatological types exist in the Philippines and are characterized as follows:

- Type I - Two pronounced seasons, dry from November to April, wet during the rest of the year
- Type II - No dry season with a very pronounced maximum rainfall period from November to January
- Type III - Seasons not very pronounced, relatively dry from November to April and wet during the rest of the year.
- Type IV - Rainfall more or less distributed throughout the year.

Figure B-1 shows the distribution of these climate regions for the entire study area.

Rainfall intensities in the study area range from very light to heavy and may occur as continuous, intermittent, or showery. Precipitation is influenced by prevailing air streams or monsoons, tropical cyclones, the Intertropical Convergence Zone (ITCZ), topography, fronts, easterly waves, and local thunder storms. The significance of each of these climatic influences varies with the time of year.

Tropical cyclones contribute largely to the rainfall from May to December and produce annual maximum quantities in many locations.

The ITCZ affects precipitation from May to October. It typically appears in the southwestern portion of the archipelago in May and moves north reaching its northernmost position in July or August. It begins moving back southward in August moving south of the Philippines by November and reaching it's southernmost position in January or February. In general convective type precipitation occurs in the ITCZ.

Two major air streams, the Northeast and Southwest monsoons trigger the onset and recession of the rainy season in the Philippines. Depending on location, the Northeast monsoon may begin as early as mid July and end as late as late April. The Southwest monsoon may begin as early as mid April and end as late as early November depending on location. The Southwest monsoons produce more rain than the Northeast monsoons. In general, the eastern coastal areas have marked a rainy season from October to March when the northeast monsoon is dominant. The rainy season for the western coastal areas occurs during the period from June to October when the Southwest monsoon and tropical cyclone seasons are dominant.

Topographic affects on precipitation have been documented. Previous studies have shown that rainfall increases with elevation up to a certain elevation above which further increases in elevation result in decreased rainfall. Maximum rainfall occurs at intermediate elevations. Where rapid changes in elevation occur a phenomenon known as the "splash effect" significantly influences precipitation. The "splash effect" results when cold air moves downslope from a precipitating cloud and causes the formation of another cloud at a lower elevation.

Fronts affect precipitation in the Philippines in the winter months only. Fronts, coupled with the topographical effects, produce a portion of the rainfall along the eastern coasts and occasionally over the middle and western portions of the islands.

Easterly waves are frequent in the summer and seldom occur during the winter months. They are usually accompanied by precipitation especially along the mountainous, eastern coastal areas.

Thunderstorms may produce a considerable amount of rainfall. However, they typically affect relatively small areas and occur over a relatively short time period.

Diurnal rainfall patterns have been observed to vary from one area to another. In mountainous areas rainfall maxima typically occur at night as a result of converging winds in the valleys. In other areas, convection heating during the day combined with sea-breezes to produce rainfall maximums during the afternoon.

B3 Lowflow Analysis Methodology

B3.1 General

The hydrologic analysis involved the following elements:

- identification of representative stream gauging stations for each major river basin,
- verification of streamflow data using double mass curve analysis,
- flow frequency analysis for the selected representative stream gaging stations using mean annual discharge, and
- selection of drought years based on frequency analysis

The purpose of the hydrologic analysis was to characterize the drought flow conditions of each of the major river basins using streamflow data from representative gauging stations within each basin. The results of the hydrologic analyses are generally applicable to all parts of the respective basins. However, as noted in the analysis results for the individual basins, adjustments will be necessary to account for differences in rainfall at various locations within the basin. Transposing the results of the hydrologic analyses to other locations should be done with prudence. Climate region, annual rainfall-runoff patterns, and annual rainfall totals must be considered. In general, transposing data from one climate region to another should be avoided due to differences in annual rainfall-runoff patterns.

B3.2 Identification of Representative Streamflow Gauging Stations

B3.2.1 Criteria for Selecting Representative Streamflow Gauging Stations

Representative streamflow gauging stations were selected for each of the major river basins. The representative stations were selected based on the following criteria

- Period of available record - Both the length of record and the period covered by the record were considered. When possible, stations with recent records were selected.
- Size of tributary catchment area – The representativeness of streamflow data is dependent on the size of the tributary catchment area relative to the size of the catchment area for which the data are intended to represent. When possible stations with large catchment areas were selected.
- Location of the station within the basin – When possible, representative stations were selected so that the tributary area reasonably represented the general topography and rainfall patterns of the entire basin.
- No upstream flow manipulation – Ideally, stations downstream of features such as lakes, reservoirs, and flow diversion structures were not selected as representative stations. However, limited information on such features was available at the time of station selection.

It was not possible to meet all of these selection criteria with the representative station for every major river basin. In some cases only one of the criteria could be met due to the limited number of gaging stations within the basin.

B3.2.2 Data Validation

The reliability of the data from prospective representative gaging stations was validated by comparison with data from selected rainfall stations and, in some cases, other stream gaging stations. Correlation plots and double mass curve plots were produced for this purpose by plotting the mean annual discharge against the total annual rainfall. Finding long-term streamflow records that produced a smooth double mass curve was not possible for every basin. In some cases streamflow data from adjacent or nearby basins were used. The selected long-term streamflow data were used to perform frequency analyses of the mean annual discharge. The double mass curve plots are shown in Figures B-14 through B-32.

B3.3 Mean Annual Discharge Frequency Analysis

Frequency analyses were performed using streamflow data from the selected representative stations. Mean annual discharge values were used for this analysis. The purpose of the flow frequency analysis was to determine the magnitude of the mean annual mean annual flow for the theoretical 5-, 10-, and 20-year droughts. The values were ranked in ascending order and fitted to the Log Pearson Type III distribution. Annual precipitation patterns vary with location throughout the study area. In western Luzon, for example, the peak of the rainy season occurs in August. In other areas, the peak of the rainy season occurs November through January. For this reason, the cycle used for calculating the mean annual discharge was adjusted to begin at the typical time of peak annual rainfall-runoff for each station. The flow frequency analysis plots for the selected representative stations are presented in Figures B-14 through B-32. The magnitude of the theoretical mean annual streamflow for the 5-, 10-, and 20-year drought return periods were taken from these plots.

B3.4 Drought Year Selection

Based on the theoretical drought year magnitudes identified through the frequency analyses, representative drought years were selected and the daily values for those years were used for a more detailed analysis. Ideally the annual cycle with the mean annual discharge closest to that of the theoretical drought year was selected for this purpose. However, in some cases that was not possible due to missing daily data. In some cases, the year with the next closest mean annual discharge was selected. In other cases, missing streamflow data for the closest year were estimated by converting rainfall data to discharge using the average annual runoff coefficient for the basin. The average annual runoff coefficients were calculated using the total annual rainfall and the total annual runoff depth for the years when both data values were available.

It was intended that the selected drought year cycles begin at the peak of the runoff season and carried through the following dry season. In some cases this required that one or two months of daily data from the prior year be added to the beginning of the drought year data series. The representative drought year hydrographs for each of the selected stream gaging stations are presented in Figures B-14 through B-32. As previously stated, the annual cycle used to perform the frequency analysis was adjusted to begin at the typical peak runoff period. The drought year designation corresponds to the calendar year in which the annual cycle ends. For example, a representative drought year that begins in August 1989 and ends in July 1990 is identified as runoff year 1990. The mean monthly discharges for the representative 5-year draught year which were derived applying the above procedures are summarized Table B-1.

B4 Lowflow Analysis Results

B4.1 Factors Affecting Runoff Condition

The following sections describe the results of the hydrologic analysis for each of the major river basins. It should be noted that these results are the product of a general hydrologic investigation. There are many factors that influence the hydrology of a watershed which were not investigated in detail as part of this study. Human activities within the basins which have influenced the rainfall-runoff relationship include

- diversions for irrigation,
- diversions for municipal and industrial water supply,
- reservoirs
- deforestation, and
- changes land use

The extent to which each of these factors has influenced the hydrology within the individual basins was not assessed as part of this study. However, as can be seen in the double mass curve plots for some of the representative stations, considerable changes in the rainfall-runoff relationships have taken place over the period of record. The annual runoff coefficients for each of the representative stream gaging stations were also calculated. For a few stations, a declining trend in the annual runoff coefficients is detectable.

The effects of upstream diversions are of particular concern when performing low flow analyses. The assumption could be made that any diversions from the system represent water that is already in use or otherwise unavailable for future development. If the diversion quantities are assumed to remain constant there may be no need to quantify them directly. However, it is unlikely that the diversion quantities have remained constant. Also, it may be inappropriate to transpose the streamflow data to other locations without quantifying flow diversions.

Diversions for irrigation were identified in tributary areas of five of the selected representative stream gaging stations. Relevant information regarding these diversions are presented in the following table.

Major River Basin	Selected Stream Gauging Station	Area Trbutary to Stream Gauging Station	Area Irrigated by Diversion
Cagayan River	Pinacanauan River at Tuguegagarao	646 sq kms	880 ha
Pampanga River	Pampanga River at Camba, Arayat	6,487 sq kms	116,508 ha
Amnay-Patrick	Caguray River at Otoyan, Mindoro	136 sq kms	3308 ha
Jalaur River	Jalaur River at Calyan Potatan	1,499 sq kms	144,000 ha
WRR 11	Padada River at Lapulabao	821 sq kms	3,000 ha

The estimated diverted quantities for each of these basins are presented with the hydrologic analysis results in the respective subsections.

The diversions on the Pinacanauan River in the Cagayan River Basin are not considered to be significant based on the diverted quantity relative to the mean annual discharge at the gauging station. Due to lack of streamflow data for the other basins, the data from the stations identified above were used in the frequency analysis and extraction of drought year hydrographs. It may be necessary to make adjustments to the discharge data to account for diverted flows when transposing the data to other locations or when carrying out water balance calculations.

In addition to these artificial influences, changes in climate have been identified as a possible cause of change in hydrology. However, a 1994 NIA report concluded that there was no evidence of significant changes in annual or seasonal rainfall amounts. Also, human error in data collection techniques may have reduced the reliability of the available data in some cases.

Assessing the influence of these factors within the individual basins will be necessary before carrying out any detailed facility design.

The hydrology of the Pampanga and Agno River basins has been significantly affected by the 1991 eruption of Mt. Pinatubo. As a result of the eruption, airfall deposits of ash have caused a reduction in the infiltration rate over the land surface. Also, vegetation was destroyed over large areas. These changes are expected to be short lived. However, in the short term, there will likely be an increase in peak runoff rates and a decrease in base flow for these basin. More significant are the changes in channel geometry within the major drainage courses. All of the rivers draining Mt. Pinatubo have been affected by extreme channel agradation and degradation. In some areas the base levels of the river channels have been raised by as much as three to five meters due to wide spread lahar flow and deposition. The results of the hydrologic analyses for these basins should therefore be interpreted and applied with caution, considering these affects.

The following sections present the results of the hydrologic analyses for each of the major river basins.

B4.2 Laoag River Basin

The 1,355 square kilometer Laoag River Basin is located in northwestern Luzon. It is located in a Type I climate region and is bounded on the north and south by the Ilocos Mountains and on the east by the Cordillera Mountains. The peak runoff season is August and therefore an August to July cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Laoag City are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at MMSU Batac, Ilocos Norte. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	4.4	24.5	73	215	143
February	1.5	25.1	73	207	143
March	1.7	26.5	73	215	177
April	20.1	28.3	73	222	189
May	149.4	29.1	76	209	177
June	349.6	28.6	81	176	138
July	437.6	28	83	173	133
August	573.2	27.6	86	140	109
September	406.3	27.6	85	144	114
October	118.4	27.5	79	188	127
November	31.4	26.8	76	201	135
December	9.7	25.4	73	218	133
Annual	2103.3	27.1	77.6	2306	1717

The BRS gauging station on the Laoag River at Laoag City was chosen as the representative stream gauging station for the basin based of the period of available record for the station. The station is located in the lowermost reach of the basin near the mouth of the river and therefore includes the entire 1355 square kilometer, river basin as the tributary area. The runoff at this station is considered to be representative of the entire river basin. However, some adjustment for differences in rainfall may be necessary when transposing the data to the uppermost, more mountainous portions of the basin. The period of available record for this station is 1959-1977 and 1984-1996 and the records are somewhat fragmentary. Rainfall data from the PAGASA synoptic station at Laoag City were used to validate the data with the double mass curve method. The mean annual discharge for twenty-three August to July annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-14.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	68.16	1989
10-Year	46.75	1966
20-Year	30.11	1973

B4.3 Abra River Basin

The 5,125 square kilometer Abra River Basin is located in northwestern Luzon. It drains to the Luzon Sea and is bounded in the east by the Cordillera Mountains. The main stem of the river is oriented in a relatively narrow north-south trending valley. The areas adjacent to the mainstem valley are hilly with numerous small drainage subbasins. The entire basin is located in the Type I climate region and the peak runoff season is typically August. An August to July cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Vigan are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at MMSU, Batac, Ilocos Norte. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	3	25.4	75	111	143
February	2.4	25.7	75	96	143
March	2.1	27.1	76	111	177
April	15	28.6	75	111	189
May	169.5	28.9	78	108	177
June	409.4	27.9	83	88	138
July	556.9	27.3	85	89	133
August	697.9	26.8	86	72	109
September	411.7	27.1	84	72	114
October	130.8	27.3	81	97	127
November	22	27	78	100	135
December	9.5	26.2	76	113	133
Annual	2430	27.1	79.3	1169	1717

The BRS stream gauging station on the Abra River at Bumagcat, Tayum was chosen as the representative gauging station for the basin based on the size of the tributary basin and the period of available record. The area tributary to the station is 2575 square kilometers. Stream flow data from this station are considered to be representative of the entire basin. Some adjustment for rainfall may be necessary when transposing the data to the western portions of the basin in the Cordillera Mountains. The period of available record for this station is 1958-1977 and 1984-1988 and the records are somewhat fragmentary. The more recent data, from 1988 to 1996, are missing from the BRS files. Rainfall data from the PAGASA synoptic station at Vigan were used to validate the streamflow data with the double mass curve method. The mean annual discharge for twenty-one August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-15.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	80.98	1975
10-Year	55.92	1973
20-Year	34.39	1974

B4.4 Cagayan River Basin

The Cagayan River Basin is located in northern Luzon. The basin is characterized by a large central valley oriented north to south. The valley is bound on the east by the Sierra Madre and on the west and south by the Cordillera Mountains. The 25,649 square kilometer basin is the largest river basin in the study area and is located within Type I, Type III and Type IV climate regions. The peak runoff season is typically November. A January to December cycle was used for the frequency analysis and extraction of drought year runoff data. The period of October to December of the previous year was then added to the beginning of the drought year hydrographs.

Climatological normal data from the PAGASA Synoptic station at Tuguegarao are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at ISU, Echague, Isabela. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	23.8	24.1	80	208	2.8
February	11.5	25.2	77	320	3.7
March	24.1	27.3	72	379	5.1
April	45.8	29.3	69	420	5.5
May	125.2	30.1	70	425	5.4
June	158.1	29.7	73	386	4.8
July	210.3	29	75	372	4.6
August	259.6	28.8	76	320	4.1
September	197	28.3	77	322	4.1
October	275.4	27.2	79	255	3.4
November	250.4	25.7	82	223	2.5
December	91	24.3	82	144	2.5
Annual	1672.2	27.4	76.0	314.5	4.0

Long term streamflow records are available for several stations within the basin. However, recent data are only available at a few stations. The BRS gauging station on the Pinacanauan River at Tuguegarao was selected as the representative gauging station for the basin based on its location within the basin, the size of the tributary basin, and the period of available record. The area tributary to the gaging station is 646 square kilometers and includes areas within both Type III and Type IV climate regions. Because the tributary area includes climate regions Type III and Type IV, it is considered to be representative of the basin as a whole. However, some adjustment may be necessary when transposing the data to smaller drainage areas which lie completely within one of the climate region or the extreme western portions of the basins which are located in the Cordillera mountains. Also, there are flow diversions for irrigation upstream of this gaging station. The area irrigated by the diverted flow is 880 hectars and the diverted flow is approximately 3.3 m^3/sec. This quantity should be considered when transposing the data to other locations or when calculating a water balance. The period of available record for this station is 1956-1979 and 1984-1996 and the records are somewhat fragmentary. Rainfall data from the PAGASA synoptic station at Tuguegarao were used to validate the streamflow data. The mean annual discharge for twenty-eight annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-16.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	31.9	1964
10-Year	25.8	1993
20-Year	22.9	1995

B4.5 Abulog River Basin

The 3,372 square kilometer Abulog River Basin is located in the northern most part of Luzon. The upper portions of the basin are located in the Cordillera Mountains. The river valley is confined and very narrow in the upper portions and wide and flat in the lower portions. Although it is a relatively small basin it lies within Types II, III, and IV climate regions. The peak runoff season is typically October and therefore an October to September cycle was used for the frequency analysis and extraction of drought year runoff data.

The following climatological normal data were taken from various sources. The rainfall data were calculated by averaging the mean monthly values for the NPC rain gauging stations at Calanasan, Baliwanan, Mataguise, Lenneng, and Aparri. The temperature values were taken from the PAGASA Agromet station at Aparri. The relative humidity, sun duration and evaporation data were taken from the PAGASA Agromet station at MMSU Batac, Ilocos Norte.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	305	23.4	82	215	143
February	131	24.2	83	207	143
March	103	25.8	82	215	177
April	184	27.6	78	222	189
May	330	28.8	78	209	177
June	434	29	80	176	138
July	473	28.7	81	173	133
August	510	28.4	84	140	109
September	482	28	84	144	114
October	684	26.9	83	188	127
November	740	25.7	82	201	135
December	555	24.1	81	218	133
Annual	4931	27	82	2306	1717

Long term streamflow records are available for several NPC gauging stations in the basin. The NPC station at Bulu was chosen as the representative gauging station for the basin based on its location on the mainstem, the size of the tributary basin and the period of available record. The area tributary to the gaging station is 1609 square kilometers. The period of available record for this station is 1967-1994. The data were obtained from NPC in gauge height format along with discharge measurement data. The discharge measurement data were used to construct a rating curve and convert the gage height data to discharge values. The data are considered to be representative of the entire river basin. However, because most of the basin tributary to the gaging station is in upland or mountainous terrain, some adjustment based on rainfall may be necessary when transposing the data to small areas in the lowland, flat portions of the lower basin. Rainfall data from the NPC station at Calanasan were used to validate the data with the double mass curve method. The mean annual discharge for twenty-four October to September, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-17.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	142.4	1977
10-Year	123.1	1991
20-Year	95.5	1983

B4.6 Agno River Basin

The 5,952 square kilometer Agno River Basin is located in western Luzon. The upper portion of the Basin is in mountainous terrain with a narrow, confined mainstem valley. In the lower reaches the main stem valley is very wide and flat. The hydrology of the lower portion of the basin has been substantially altered as a result of the 1990 eruption of Mt. Pinatubo. Therefore the results of the hydrologic analysis performed as part of this study have limited applicability. Previous study reports have presented more detailed hydrologic analyses of the areas affected by the eruption. The basin is located in a Type I climate region and the peak runoff period is typically in August. Therfore, an August to July annual cycle was used in the frequency analysis and for extraction of the drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Dagupan City are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at Hacienda, Luisita, Tarlac. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (oC)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	7.7	25.8	74	207	140
February	4.3	26.5	73	220	154
March	14.4	28	72	258	198
April	54.6	29.7	72	257	198
May	212.3	29.6	76	224	164
June	373.9	28.8	81	158	129
July	520.2	28.1	84	148	102
August	593	27.7	86	105	81
September	359.9	28	84	157	96
October	174.2	28	81	184	118
November	54	27.4	79	202	120
December	11.2	26.3	77	218	136
Annual	2379.7	27.8	78.3	2337	1636

The BRS stream gauging station on the Ambayoan River at Sta. Maria, Pangasinan was chosen as the representative gauging station for the basin based on the period of available record. The period of available record for this station is 1958-1977 and the records are mostly complete. The area tributary to the gauging station is 281 square kilometers. The station is considered to be representative of the upper, more mountainous portions of the Agno River basin. Some adjustment for rainfall may be necessary when transposing the data to other portions of the basin. Also, for reasons previously stated, caution should be used in applying the hydrologic results to the lower basin. Rainfall data from the PAGASA synoptic station at Dagupan City were used to validate the streamflow data with the double mass curve method. The mean annual discharge for seventeen August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-18.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	14.9	1964
10-Year	12.5	1959
20-Year	10.2	1960

B4.7 Pampanga River Basin

The 9,759 square kilometer Pampanga River Basin is located in western Luzon. With the exception of the extreme eastern portions, the basin is flat lowland. The hydrology of the lower portion of the basin has been substantially altered as a result of the 1990 eruption of Mt. Pinatubo. Therefore the results of the hydrologic analysis performed as part of this study have limited applicability. Previous study reports have presented more detailed hydrologic analyses of the areas affected by the eruption. The basin is located mostly in a Type I climate region and the peak runoff period is typically in August. Therfore, an August to July annual cycle was used for the frequency analysis and for extraction of the drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Cabanatuan are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at CLSU, Munzo,Nueva Ecija. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	8.1	25.7	73	249	177
February	3.4	26.3	71	254	182
March	13.3	27.4	70	278	220
April	21.5	29	68	291	231
May	165.1	29.5	73	247	198
June	286.8	28.6	81	200	141
July	358.4	27.9	84	186	130
August	378.9	27.5	86	154	109
September	315.9	27.7	86	168	117
October	193.1	27.6	82	204	127
November	112.6	27	78	220	138
December	36.9	26.2	75	234	161
Annual	1894.0	27.5	77.3	2684	1931

The BRS stream gauging station on the Pampanga River at Arayat, Camba was chosen as the representative gauging station for the basin based on the size of the tributary basin and the period of available record. The period of available record for this station is 1946-1996. The period between 1976 and 1988 are fragmentary. The area tributary to the gaging station is 6487 square kilometers. The data area considered applicable to the entire river basin. However, for reasons stated previously, caution must used when applying the hydrologic results to other portions of the basin due to the affects of the Mount Pinatubo eruption. Some minor adjustment for rainfall may be necessary when transposing the data to other locations. Also, there are significant diversions for irrigation upstream of the gaging station. The area irrigated by the diverted water is 116,500 hectars. This should be considered when transposing the data to other locations or when calculating a water balance. Rainfall from the PAGASA synoptic station at Cabanatuan were used to validate the streamflow data with the double mass curve method. The mean annual discharges for forty-two August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-19

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	171	1960
10-Year	155	1959
20-Year	143	1956

B4.8 Pasig-Laguna Bay River Basin

The 4,678 square kilometer Pasig-Laguna River Basin is located in Southern Luzon. The basin lies in both a Type I and Type III climate region and includes the Laguna Lake drainage basin as well as other upland areas west of Manila. The peak runoff period is typically in August and therefore an August to July cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Sangley Point are presented below. The period covered by the data is 1971-1995. The evaporation and sun duration data are from the PAGASA Agromet station at NAS, UPLB, Los Banos, Laguna. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	18	26	76	159	109
February	5	26.4	73	196	132
March	5.9	28.1	70	262	183
April	13.9	29.6	69	268	198
May	98.4	29.6	71	238	177
June	273.8	28.7	76	165	132
July	355.8	28.1	79	161	121
August	501.8	27.8	82	139	124
September	288.9	27.9	80	137	111
October	216	27.7	79	145	105
November	103.8	27.3	78	147	99
December	40.7	26.3	77	141	99
Annual	1922.0	27.8	75.8	2157	1589

Streamflow records are available for several stations within the basin. However in most cases either the tributary basin is very small, the station is tidally influenced or it is located downstream of Laguna Lake. The BRS stream gauging station on the Panaysayan River at Gen Trias was selected as the representative gauging station because the flows are neither attenuated by Laguna Lake nor tidally influenced. The period of available record for this station is 1957-1995 and the records are somewhat fragmentary. The size of the tributary basin is 30 square kilometers which is relatively small. The data are considered marginally representative of the Pasig Laguna River Basin due to the size of the tributary drainage basin. Rainfall data from the PAGASA synoptic station at Sangley Point were used to validate the streamflow data with the double mass curve method. The mean annual discharge for twenty-seven August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-20

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	0.57	1986
10-Year	0.49	1960
20-Year	0.45	1995

B4.9 Amnay-Patrick River Basin

The 993 square kilometer Amnay-Patrick River Basin is located in western Mindoro Island. The basin is located in a Type I climate region and is mountainous in the upper portions and very flat and swampy in the lower portions. The peak runoff period is August and therefore an August to July cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at San Jose are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at NAS, UPLB, Los Banos, Laguna. These evaporation and sun duration data are considered reasonably representative of the Amnay-Patrick river basin. The seasonal patterns are similar, for the two areas as are the mean annual temperatures and the percent relative humidity. However, the annual rainfall in the Amnay-Patrick Basin is approximately 30 percent higher than that of the Laguna area.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	3.9	27.4	69	159	109
February	6.6	27.6	67	196	132
March	11.7	28.9	66	262	183
April	20.1	29.6	68	268	198
May	107.7	29.4	74	238	177
June	427.9	28.2	82	165	132
July	496.1	27.3	85	161	121
August	497.2	27.3	86	139	124
September	414	27.2	87	137	111
October	264.8	27.5	84	145	105
November	117.4	27.9	77	147	99
December	52.7	27.6	73	141	99
Annual	2420	28	77	2157	1589

No long term stream flow records are available for the Amnay Patrick River. However, BRS has established a few gaging stations in recent years on Mindoro and NPC maintained a few stations for short periods of time in the past. BRS streamflow data from the Caguray River which is located south of the Amnay-Patrick basin were used for the hydrologic analysis. The area tributary to the station is 136 square kilometers and the period of available streamflow records is from 1956 to 1969. This river basin was selected because it is considered to have rainfall/runoff patterns similar to the Amnay-Patrick River Basin. The other gauging stations with at least 10 years of record are located in eastern Mindoro which lies within a Type III climate region. The data for the Caguray River are considered to be more representative of western Mindoro Island. However, there are diversions for irrigation upstream of the station. The area irrigated by the diverted flow is 3,308 hectars and the quantity diverted is approximately 6.4 m^3/sec. The PAGASA rainfall station at San Jose should be the most representative of the rainfall within the Caguray River Basin. However the data from that station are only available beginning in 1979. For that reason the rainfall data from the PAGASA synoptic stations at San Jose, Coron, Romblon, and Cuyo were compared using the double mass curve method and it was concluded that there was reasonable correlation between the total annual rainfall at these stations. The rainfall data from the Romblon station were used to validate the Caguray River flow data with the double mass curve method. As shown in Figure B-21 the relationship between the data sets is not perfect. However, due to the lack of better streamflow data, the Caguray data were used in the hydrologic analysis. The mean annual discharges for ten August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	8.4	1967
10-Year	6.4	1966
20-Year	4.9	1968

B4.10 Bicol River Basin

The 3,771 square kilometer Bicol River Basin is located in the southern most portion of Luzon Island. The eastern basin boundary is formed by a series of five volcanoes and the western boundary is a low non-contiguous ridge adjacent to the Ragay Gulf/Burias Pass coast line. Most of the basin is flat lowland. There are swampy areas and two large lakes in the basin. Type II, Type III and Type IV climate regions are all represented in that basin although the majority of the basin is in a Type IV region. The peak runoff period is typically in November and December. A January to December cycle was used for the frequency analysis and extraction of drought year runoff data. November and December of the previous years were then added to the beginning of the drought year hydrographs.

Climatological normal data from the PAGASA Agromet Station at CSAC, Pili, Camarines Sur are presented below. The period covered by the data is 1975-1990. Because sun duration data are not available from the Pili station, those data are from the Agromet station at Parapoto, Milanao, Albay. Based on a comparison of evaporation data for the Parapoto and Pili stations, the sun duration data for the Parapoto station are probably lower than the actual values within the Bicol River Basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	87.6	25.3	84	122	130
February	58	25.5	85	150	137
March	47	26.6	81	185	189
April	68.2	27.9	78	209	201
May	127.5	28.8	78	235	195
June	229.6	28.4	82	160	159
July	271.1	27.9	86	158	149
August	203.8	28	85	138	149
September	255.8	27.7	86	123	129
October	294.6	27.3	86	147	127
November	306	26.7	86	118	108
December	203.8	25.8	85	94	121
Annual	2153.0	27.2	83.5	1838	1794

The BRS stream gauging station at Balza on the Quinali River was selected as the representative stream gauging station based on its location within the basin and the availablity of data for recent years. Data from most other stations located within the basin either cover a short time period or are very fragmented. The other stations with long term data are tidally influenced or located downstream of one of the two large lakes in the basin. The area tributary to the Balza gauging station is 172 square kilometers and the period of available record is 1980 through 1995. The data are considered to be representative of the entire basin. However, some adjustment for rainfall may be necessary when transposing the data to other locations within the basin. Rainfall data from the PAGASA synoptic station at Legaspi City were used to validate the streamflow data by the double mass curve method. As can be seen in Figure B-22 the rainfall-runoff correlation is not ideal. The mean annual discharges for twelve January to December, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-22.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	22.8	1982
10-Year	18.4	1984
20-Year	15.1	1983

B4.11 Catanduanes Island

There are no major river basins located on Catanduanes Island. However, the hydrologic analysis was carried out for the island in the same manner as for the Major River Basins. The entire island lies in a Type III climate region and the topography is mountainous. The peak runoff period is typically in December.

Climatological normal data from the PAGASA Synoptic station at Virac are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at Parapoto, Malinao, Albay. These data are considered to be reasonably representative of Catanduanes Island. However, the mean annual precipitation at the Parapoto, Virac Radar and Virac Synoptic stations are 4106 mm, 3523 mm, and 2766 mm respectively. The reason for the difference in the reported values for the two Virac stations was not determined.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	191.7	25.6	80	122	90
February	99.3	25.7	79	150	112
March	99.9	26.3	78	185	136
April	107.7	27.2	79	209	156
May	158.4	27.9	80	235	174
June	241.7	28	81	160	138
July	235.1	27.7	82	158	155
August	163.5	27.9	81	138	155
September	236	27.6	82	123	132
October	348.3	27.1	84	147	130
November	439.5	26.8	83	118	90
December	444.9	26.1	83	94	81
Annual	2766	27	81	1838	1549

The BRS gauging station on the Payo River at San Miguel was chosen as the representative stream gauging station for the Island based on the period of available record. The period of available record for this station is 1954-1977 and 1983-1995 and the records are somewhat fragmentary. The area tributary to the station is 29 square kilometers. These data are considered to be representative of the entire island. Rainfall data from the PAGASA radar station at Virac were used to validate the streamflow data with the double mass curve method. For that reason those data points were adjusted using the rainfall data and the average annual runoff coefficient for the previous years. The mean annual discharges for twenty-four January to December annual cycles were used in the frequency analysis. Mean daily flows for December of the previous year were added to the beginning of the drought year hydrographs. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	2.11	1983
10-Year	1.53	1987
20-Year	1.04	1992

B4.12 Masbate Island

Masbate is located in a Type III climate region. No stream flow data were obtained for the island. Therefore no hydrologic analysis was carried out. The results of the hydrologic analysis for the Panay River Basin described in the following section are considered reasonably applicable to the island based on the similarity in climate. However, the geology of Masbate Island is somewhat different than that of the Panay River Basin. For that reason, judgement should be used when transposing the Panay River hydrologic results to Masbate.

B4.13 Panay River Basin

The 1,843 square kilometer Panay River Basin is located in northern Panay Island in Central Visayas. Most of the basin is flat lowland bordered on the east and west by upland. The basin is located in a Type III climate region and the peak runoff season is November.

Climatological normal data from the PAGASA Synoptic station at Roxas City are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at PSPC, Mambusao, Capiz. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	96.5	26.3	81	115	112
February	42.2	26.4	80	186	106
March	46.7	27.2	79	269	149
April	51.1	28.5	77	282	165
May	124.4	29	77	235	152
June	244.9	28.4	81	164	117
July	264.9	28	82	169	127
August	230.2	28.1	82	157	121
September	230.3	28	82	146	126
October	297.2	27.7	82	155	127
November	249.9	27.5	82	145	117
December	147.1	26.9	82	169	115
Annual	2025.4	27.7	80.6	2192	1534

The BRS gauging station on the Panay River at Tacas, Cuartero was chosen as the representative stream gauging station for the basin based on the size of the tributary basin, the location within the basin and the period of available record. The area tributary to the gaging station is 880 square kilometers. The portions of the tributary basin located in upland areas and lowland areas are approximately 600 square kilometers and 280 square kilometers, respectively. These data are considered to be representative of the entire river basin. However, adjustments for rainfall may be necessary when transposing the data to small basins in the lowlands. The period of available record for this station is 1956-1969, 1973-1979 and 1984-1995. The records are mostly complete for these periods. Rainfall data from the PAGASA synoptic station at Roxas City were used to validate the streamflow data with the double mass curve method. As shown in Figure B-23, the runoff data for the later years did not produce a linear double mass curve. The reason for this could not be determined. The mean annual discharges for twenty-seven January to December, annual cycles were used in the frequency analysis. The representative drought years were selected based on this annual cycle. November and December from the previous years were then added to the beginning of the drought year hydrographs. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	45.6	1987
10-Year	42.6	1961
20-Year	41.1	1963

B4.14 Jalaur River Basin

The 1,503 square kilometer Jalaur River Basin is located in southern Panay Island. The basin drains to Iloilo Strait and is mostly lowland bordered by mountains on the west side. The basin lies in both Type I and Type III climate regions. The peak runoff season is typically October and November and therefore an October to September cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Iloilo City are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at PSPC, Mambusao, Capiz. Although the Mambusao station is located in the Panay River basin, these data are considered to be representative of the Jalaur River basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	39.4	26.2	82	115	112
February	23.9	26.6	80	186	106
March	29.6	27.6	75	269	149
April	50.9	28.9	73	282	165
May	118.2	29.1	76	235	152
June	303.8	28.2	82	164	117
July	340.4	27.6	84	169	127
August	383.6	27.5	84	157	121
September	285.6	27.6	84	146	126
October	268.3	27.6	84	155	127
November	176.2	27.5	84	145	117
December	84.6	26.8	83	169	115
Annual	2104.5	27.6	80.9	2192	1534

The BRS gauging station on the Jalaur River at Calyan, Potatan was chosen as the representative stream gauging station for the basin based on the size of the tributary basin and the period of available record. The area tributary to the gaging station is 1499 square kilometers. The period of available record for this station is 1957-1971, 1974-1978 and 1984-1995. These records are mostly complete. Rainfall data form the PAGASA synoptic station at Iloilo were used to validate the streamflow data. As can be seen in Figure B-24 the runoff from the earlier years produces a different double mass curve alignment than the data from the later years. This is likely the result of increases in flow diversions for irrigation upstream of the gaging station in recent years. The estimated quantity of diverted flow is 21 m3/sec and the area irrigated is 144,000 hectars. Hydrologic analyses were also carried out for the station at Simsiman on the Jalaur River with the expectation that since this station is located upstream of significant diversions, the data would be more representative of the rainfall/runoff relationship within the basin. However, the double mass curve plot of the

Simsiman station streamflow data versus rainfall data look very similar to the double mass curve for the Calyan station. The runoff for the more recent years are noticably lower relative to the rainfall. Data from the Calyan station were used for the frequency analysis and drought year extraction. Only the data from 1974 through 1995 were used in the frequency analysis. The data from this station are considered to be representative of the entire river basin. However adjustments may be necessary based on rainfall when transposing the data to basins which lie completely within one of the climate regions. Also, upstream flow diversions must be considered when transposing the data or when calculating a water balance. The mean annual discharge for fifteen October to September, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	22.7	1995
10-Year	15.8	1992
20-Year	10.7	1993

B4.15 Ilog-Hilabangan River Basin

The 1,945 square kilometer Ilog-Hilabangan River Basin is located in Negros Orientals. The Ilog River Basin lies mostly within a Type I climate region and is relatively flat with the boundaries formed by more hilly areas. The Hilabangan River Basin lies mostly in a Type III climate region and is a relatively small basin with a higher percentage of upland areas. The peak runoff period typically occurs in August and therefore an August to July cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Damaguete City are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at La Granja, La Carolta, Negros Occidental and are considered to be marginally representative of the Ilog-Hilabangan River Basin. The seasonal rainfall patterns for the two stations are different as are the magnitudes of the mean annual rainfall.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	78.5	26.8	81	171	112
February	52	26.8	81	176	123
March	45.3	27.5	79	210	167
April	40.6	28.5	77	223	162
May	65.6	28.9	77	212	140
June	107.8	28.5	78	146	99
July	118.3	28	80	153	96
August	105.8	28.2	79	150	105
September	135.6	28.1	79	128	93
October	157.6	27.9	80	158	99
November	137.8	27.8	80	169	93
December	97	27.4	81	179	105
Annual	1141.9	27.9	79.3	2074	1395

The BRS gauging station on the Ilog River at Pandan, Orong was chosen as the representative stream gauging station based on the period of available record. The records for the other stations within the basin are very short term and fragmented. The area tributary to the Pandan Orong station is 346 square kilometers and the period of available record for the station is 1956-1979. The records are mostly complete. The data are considered representative of the entire Ilog River Basin. Adjustment for rainfall may be necessary when transposing the data the Hilabangan drainage basin. Rainfall data from the PAGASA synoptic station at Dumaguete City were used to validate the flow data with the double mass curve method. The mean annual discharge for twenty-one August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-25.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	48.7	1978
10-Year	41.9	1958
20-Year	36.8	1977

B4.16 Cebu Island

The northern portion of Cebu Island is located in a Type IV climate region and the southern portion is in a Type III climate region. The peak runoff period typically occurs in October or November depending on location. A November to October cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Mactan are presented below. The period covered by the data is 1972-1995. The evaporation and sun duration data are from the PAGASA Agromet station at La Granja, La Carlota, Negros Occidental and these data are considered to be marginally representative of Cebu Island. Other possible data stations which could be used to obtain sun duration and evaporation data are the Tacloban and Visca Agromet stations located on Leyte Island.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	104	26.8	81	171	112
February	68.2	27	79	176	123
March	56.1	27.7	77	210	167
April	43.4	28.8	75	223	162
May	72	29.4	76	212	140
June	182.1	28.7	79	146	99
July	191.7	28.2	80	153	96
August	146.5	28.4	78	150	105
September	176.9	28.3	80	128	93
October	183.5	28.1	81	158	99
November	148.9	27.9	81	169	93
December	130.9	27.2	81	179	105
Annual	1504.2	28.0	79.0	2074	1395

Relatively little long term streamflow data are available for Cebu. DPWH operated gauging stations on the Carcar and the Pitogo Rivers until the mid 1970's. NPC operated at least one station in the 1970's and 1980's. The Carcar River data were selected as the representative data for the Island based on the period of available record. The period of available record is 1955 to 1974 and the records are almost complete. The area tributary to the gaging station is 31 square kilometers. These data are considered representative of Cebu Island. However, because of the varied geology on the island and varied seasonal rainfall patterns, caution should be used when transposing the data to other locations on the Island. Also, some adjustment for rainfall may be necessary when transposing the data. Rainfall data from the PAGASA station at Lahug were used to validate the streamflow data with the double mass curve method. The mean annual discharge for thirty November to October, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	0.19	1990
10-Year	0.13	1970
20-Year	0.08	1992

B4.17 Bohol Island

Bohol Island is Located in a Type IV climate region. The peak runoff period is typically in January and therefore a January to December cycle was used for the frequency analysis and extraction of the drought year hydrographs.

Climatological normal data from the PAGASA Synoptic station at Tagbilaran are presented below. The period covered by the data is 1961-1995. The evaporation data are from the PAGASA Agromet station at Visca, Baybay, Leyte. The closest station with sun duration data is the PAGASA Agromet station in Saba, Basin Tacloban, Leyte. Neither the evaporation nor the sun duration data are considered to be very representative of Bohol Island because the average annual rainfall for the Leyte stations is almost twice that of the Tagbilaran Station in Bohol.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	100.2	26.3	82	118	78
February	69.4	26.4	82	148	81
March	69.7	26.9	79	192	118
April	65.1	27.9	78	222	126
May	76.4	28.5	79	209	130
June	122.1	28.3	81	129	96
July	118.6	28.1	81	127	81
August	108.4	28.4	80	144	99
September	130	28.2	81	119	93
October	171.6	27.8	84	136	87
November	183.2	27.4	85	128	69
December	118	26.9	84	126	71
Annual	1333	28	81	1796	1129

Very little long term streamflow data are available for Bohol Island. The NIA station on the Wahig-Pamacsalan River at Pilar was selected as the representative stream gaging station due lack of longer term data and based on the size of the tributary basin. The period of available record is 1978 to 1989 and the records are almost complete. The area tributary to the station is 141 square kilometers. These data are considered to be representative of the entire island. Some adjustment for rainfall may be necessary when transposing the data to other locations. Rainfall data from the PAGASA synoptic station at Tagbilaran were used to validate the streamflow data with the double mass curve method. The mean annual discharge for twelve January to December, annual cycles were used for the frequency analysis. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	3.7	1988
10-Year	3.1	1987
20-Year	2.6	1979

B4.18 Leyte Island

Leyte Island is located mostly in a Type IV climate region. The peak runoff period is typically in January. Therefore a January to December cycle was used for the frequency analysis.

Climatological normal data from the PAGASA Synoptic station at Tacloban are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at Saba, Basin Tacloban. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	272.5	25.8	85	118	81
February	198.7	25.9	84	148	95
March	145.2	26.6	82	192	130
April	117.6	27.6	81	222	129
May	136.1	28.2	82	209	133
June	157	28.1	82	129	108
July	172.6	27.8	82	127	105
August	143.4	28	81	144	115
September	161	27.9	82	119	102
October	189.7	27.7	84	136	96
November	280.2	27.1	86	128	81
December	323.8	26.4	86	126	78
Annual	2298	27	83	1796	1253

The BRS stream gauging station on the Daguitan River at Burauen was selected as the representative station for the island based on the size of the tributary basin and the period of available record. The size of the tributary basin is 135 square kilometers and the period of record is 1957 to 1996. The records are fragmentary. These data are considered representative of the entire island. However some adjustment for rainfall may be necessary when transposing the data to other basins on the island. Rainfall data from the PAGASA synoptic station at Tacloban were used to validate the streamflow data with the double mass curve method. The mean annual discharge for twenty-two January to December, annual cycles were used in the frequency analysis. November and December of the previous years were added to the beginning of the selected drought year hydrographs. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	8.1	1975
10-Year	6.7	1974
20-Year	5.6	1973

B4.19 Samar Island

Samar Island is located in both Type II and Type III climate regions. The peak runoff period is typically December. A January to December cycle was used for the hydrologic analysis and extraction of drought year hydrographs.

Climatological normal data from the PAGASA Synoptic station at Catarman are presented below. The period covered by the data is 1961-1995. The evaporation and sun duration data are from the PAGASA Agromet station at Catarman. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	425.1	25.4	86	100	109
February	231.3	25.5	84	121	112
March	183.8	26	83	164	149
April	134.8	27	83	203	153
May	138.7	28	82	205	152
June	194.2	28.1	84	155	126
July	210.7	27.8	83	157	136
August	149.1	28.2	82	153	146
September	202.7	27.8	84	132	126
October	324.5	27.2	86	139	112
November	511.3	26.5	88	119	84
December	539.2	25.9	88	110	84
Annual	3245	27	84	1757	1488

The BRS stream gauging station on the Tenane River at Wright was selected as the representative station for the Island based on the size of the tributary basin and the period of available record. The period of available record is 1959 to 1980 and the records are somewhat fragmentary. The area tributary to the gaging station is 346 square kilometers. The data are considered representative of most of Samar Island. However some adjustment for rainfall will be necessary when transposing the data to other basins on the island. Rainfall data from the PAGASA synoptic station at Catarman were used to validate the streamflow data with the double mass curve method. The mean annual discharge for twenty-six January to December, annual cycles were used in the frequency analysis. December of the previous year was added to the beginning of the drought year hydrographs. The results of the frequency analysis and the representative drought years are as follows.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	16.5	1972
10-Year	14.4	1973
20-Year	12.6	1969

B4.20 Agusan River Basin

The 10,921 square kilometer River Basin is located in northwestern Mindanao Island. The basin lies in both Type I and Type II climate regions. The interior of the basin is relatively flat surrounded by high mountains on the south, east and west. The peak runoff period is typically January and February and therefore a January to December cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Butuan are presented below. The period covered by the data is 1981-1995. There are no available evaporation and sun duration data from within the basin. Data from the Agromet station in at CMU, Musuan, Bukidnon which is located in the river basin adjacent to west are available. However, because of differences in climate, these data are not considered applicable to the Agusan Basin. Based on climate pattern, the data from the Agromet station at Catarman, Samar are probably more applicable to the Agusan Basin. The total annual rainfall at the Catarman station is considerably higher (68%). However, the annual rainfall pattern, mean temperature and relative humidity are more similar to those of the Agusan basin than are those of the Bukidnon station.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	301.7	25.9	88	100	109
February	197.4	26.2	85	121	112
March	135.9	26.9	83	164	149
April	101.3	27.9	81	203	153
May	110.8	28.6	81	205	152
June	132.1	28.2	82	155	126
July	159.9	27.7	84	157	136
August	101.5	28	81	153	146
September	143.6	27.9	82	132	126
October	195.1	27.6	84	139	112
November	175.9	27.1	86	119	84
December	223.6	26.4	87	110	84
Annual	1979	27	84	1757	1488

The BRS gauging station on the Agusan River at Kalaw Bridge was selected as the representative stream gauging station for the basin based on the size of the tributary basin, and the period of available record. The area tributary to the gaging station is 1355 square kilometers. The period of available record for this station is 1958-1967 and 1978-1996. With the exception of the later years, the records are very fragmentary. The records are considered to be representative of the entire river basin. However, adjustment for rainfall may be necessary when transposing the data to other locations especially to smaller subbasins located in the lowland areas. Rainfall data from the PAGASA synoptic station at Butuan were used to validate the stream flow data with the double mass curve method. The mean annual discharge for seventeen January to December, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-27.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	59.3	1960
10-Year	47.6	1966
20-Year	38.2	1992

B4.21 Tagaloan River Basin

The 1,704 square kilometer Tagaloan River Basin is located in Northern Mindanao Island. The basin is bounded by the Katanglad mountains to the south and Mount Tago to the east. The basin lies within a Type III climate region. The peak runoff period is typically October and therefore an October to September cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Cagayan de Oro are presented below. The period covered by the data is 1961-1995. The closest station for which evaporation and sun duration data are available is the PAGASA Agromet Station at MSU, Marawi City. These data are considered to be reasonably representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	97.3	26.4	83	104	93
February	65.1	26.4	81	110	98
March	47	27.1	78	113	105
April	37	28	76	140	120
May	88.2	28.7	77	130	105
June	209.2	28.2	80	86	84
July	211.4	27.9	79	108	96
August	207.6	28.1	79	107	96
September	207.4	27.9	80	96	96
October	187	27.8	80	118	93
November	124.9	27.5	81	108	87
December	94.5	26.9	82	114	81
Annual	1577	28	80	1333	1155

The NPC stream gauging station at Pina-auan was chosen as the representative gauging station for the basin based on the tributary area and the period of available record. The period of available record for this station is 1975-1990 and the records are complete. The area tributary to the gaging station is 533 square kilometers. These data are considered representative of the entire river basin. Rainfall data from the PAGASA synoptic station at Cagayan De Oro were used to validate the streamflow data with the double mass curve method. The mean annual discharge for fifteen October to September, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-28.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	23.5	1988
10-Year	21.9	1985
20-Year	20.5	1990

B4.22 Cagayan De Oro River Basin

The 1,521 square kilometer Cagayan De Oro River Basin is located in northern Mindanao Island. The basin is bounded on the south by the Kalatungan Mountains, on the east by the Katanglad Mountains and on the west by an unidentified mountain range. The entire basin is located in a Type III climate region. The peak runoff period is typically October and therefore an October to September cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Synoptic station at Cagayan de Oro are presented below. The period covered by the data is 1961-1995. The closest station for which evaporation and sun duration data are available is the PAGASA Agromet Station at MSU, Marawi City. These data are considered to be reasonably representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	97.3	26.4	83	104	93
February	65.1	26.4	81	110	98
March	47	27.1	78	113	105
April	37	28	76	140	120
May	88.2	28.7	77	130	105
June	209.2	28.2	80	86	84
July	211.4	27.9	79	108	96
August	207.6	28.1	79	107	96
September	207.4	27.9	80	96	96
October	187	27.8	80	118	93
November	124.9	27.5	81	108	87
December	94.5	26.9	82	114	81
Annual	1577	28	80	1333	1155

The NPC stream gaging station at Uguiaban was chosen as the representative gauging station for the basin based on the size and location of the tributary basin, and the period of available record. The period of available record for this station is 1954-1989 and the records are complete. The area tributary to the gaging station is 532 square kilometers. The data from this station are considered representative of the entire river basin. Some adjustment for rainfall may be necessary when transposing the data to other locations, especially in the mountainous portions of the upper basin. Rainfall data from the PAGASA synoptic station at Cagayan De Oro were used to validate the stream flow data with the double mass curve method. The mean annual discharge for thirty-five October to September, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-29.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	47.8	1987
10-Year	44.8	1983
20-Year	42.4	1988

B4.23 Davao, Tagum-Libuganon and Buayan-Malungun River Basins

The Davao and Tagum-Libuganon River Basins are located in Davao del Norte. The basin areas are 1,623 and 3,064 square kilometers respectively. Both basins are relatively mountainous in the upper reaches and flatter in the lower main stem valleys. Also, both of the basins are located in a Type IV climate region and the peak runoff period is typically in August.

Climatological normal data from the PAGASA Synoptic station at Davao are presented below. The period covered by the data is 1961-1995. Evaporation and sun duration data from the

PAGASA Agromet station at PCA, Bago Oshiro, Davao Del Norte are also presented.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	110.5	26.7	81	149	136
February	105	26.8	80	147	137
March	84.9	27.5	79	226	167
April	148.3	28.2	78	224	171
May	190.7	28.2	80	189	152
June	193.9	27.6	82	149	117
July	156.3	27.3	82	163	124
August	180.4	27.4	82	161	121
September	183.8	27.6	81	147	135
October	165.4	27.7	81	167	121
November	131.1	27.6	81	159	129
December	99.5	27.1	81	170	133
Annual	1749.8	27.5	80.7	2050	1644

Limited streamflow data are available for these river basins. However, relatively long term BRS data are available for the Padada River Basin which is located south of the Davao River. The period of available record for the Padada River is 1949 to 1978 and the records are mostly complete. The area tributary to the station is 821 square kilometers. To determine the applicability of the Padada River data to the Davao and Tagum-Libuganon Basins, it was necessary to compare precipitation data at the different locations. Rainfall data from the PAGASA synoptic stations at Davao and General Santos City were compared using a double mass curve analysis. The Padada River basin is roughly halfway between these two stations. Through that analysis it is concluded that there is good correlation between rainfall patterns at the two stations. There is a considerable difference in the magnitude of the total annual rainfall between the two stations. However, that difference in magnitude appears to be consistent from year to year. Next the mean annual discharges from the Padada River were compared with the total annual rainfall data from the PAGASA station at Davao using a double mass curve analysis. Based on the results of that analysis, the streamflow data are considered to be representative of the of Davao and Tagum-Libuganon River Basins. However, there are significant diversions for irrigation upstream of the Padada gauging station. The estimated diverted quantity is 3.9 m^3/sec and the irrigated area is 3,000 hectars. This should be considered when transposing the data to other locations or when calculating a water balance. Some adjustment for rainfall will also be necessary when transposing the streamflow data to the Davao and Tagum-Libuganon basins. The mean annual discharge for twenty-six August to July, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other results are shown in Figure B-30.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	13.8	1956
10-Year	11.5	1960
20-Year	9.5	1958

The 1,434 square kilometer Buayan-Malungun River Basin is located in South Cotabato, north of General Santos City. The basin is bounded to the west by the Quezon Mountains, to the Southeast by the Kioto Mountains, and to the northeast by the Tangbulan Mountains. The basin is located within a Type IV climate region and the peak runoff period is typically in August. Therefore an August to July annual cycle was used for the frequency analysis and extraction of the drought year hydrographs.

Climatological normal data from the PAGASA Synoptic station at General Santos City are presented below. The period cover by the data is 1961-1995. Sun duration and evaporation data are not available for the basin. The closest station with sun duration and evaporation data is the PAGASA Agromet station located in PCA, Bago Oshiro, Davao Del Norte. Those data are also presented below although they are not considered to be especially representative of the Buayan-Malungun River Basin due to differences in mean annual rainfall, temperature and relative humidity. The values from the Bago station should be increased by some percentage when transposing the data to the Buayan-Malungun basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	72.4	27.4	77	149	136
February	67.2	27.6	76	147	137
March	43.8	28.1	75	226	167
April	52.4	28.4	76	224	171
May	73.6	28	80	189	152
June	118.3	27.1	82	149	117
July	102.2	26.7	83	163	124
August	82.1	26.8	82	161	121
September	89.8	27	82	147	135
October	104	27.3	81	167	121
November	83.8	27.5	80	159	129
December	70	27.5	79	170	133
Annual	959.6	27.5	79.4	2050	1644

B4.24 Agus River basin

The Agus River Basin is located in northwestern Mindanao and is the outlet for Lake Lanao. The Lake is surrounded by mountains and the entire basin lies within a Type III climate region. The peak runoff period is typically June and July. Therefore, a June to May cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Agromet station at MSU, Marawi City, Lanao Del Sur are presented below. The period covered by the data is 1969-1990. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	122.4	22	89	104	93
February	85.4	21.9	87	110	98
March	78.5	23	84	113	105
April	74	23.4	82	140	120
May	139.8	23.8	83	130	105
June	179.8	23.4	84	86	84
July	175.5	23.2	85	108	96
August	158.4	23.3	85	107	96
September	201.2	23.4	85	96	96
October	174.2	23.2	85	118	93
November	130.6	22.8	86	108	87
December	102.3	22.4	88	114	81
Annual	1622	23	85	1333	1155

NPC stream gauging stations are located at several of the hydroelectric stations on the Agus River. The records for those stations were not used for the hydrologic analysis because of the attenuation effects of the lake. Lake inflow data were obtained from NPC and used for the hydrologic analysis. The total drainage basin tributary to the Lake is 1681 square kilometers and the period of the available inflow data is 1948 through 1997. The records obtained at the time of this report preparation were mean monthly flow data. These data are considered representative of the entire Agus River Basin. Rainfall data from the NPC rainfall station at Masiu were used to validate the Lake inflow data with the double mass curve method. The mean annual inflow for forty-eight June to May, annual cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. The daily data for the drought years could not be obtained prior to completion of this report. Other hydrologic results are presented in Figure B-31.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	78.1	1986
10-Year	69.5	1990
20-Year	62.	1993

B4.25 Mindanao River Basin

The 23,169 square kilometer Mindanao River Basin is located in central and south Mindanao Island. There are several tributary rivers within the basin. In general the tributary main stem rivers are located in broad, relatively flat low-lying valleys which are surrounded by high mountains. Most of the Mindanao River basin is in a type III climate region. Runoff in the basin is fairly evenly distributed throughout the year although there are typically, slightly higher flows during the period form June to October. A January to December cycle was used for the frequency analysis and extraction of drought year runoff data.

Climatological normal data from the PAGASA Agromet station at USM, Kabacan, North Cotabato are presented below. The period covered by the data is 1969-1988. These data are considered to be representative of the entire river basin.

Month	Rainfall (mm)	Temp. (°C)	% Rel. Humidity	Sun Dur. (hours)	Evap. (mm)
January	80.7	27.1	86	115	124
February	88.7	27.3	84	128	132
March	74.1	28	82	135	167
April	81.6	28.7	82	153	165
May	169.3	28.6	86	148	149
June	215.7	28	88	104	129
July	176.3	27.5	89	96	136
August	134.4	27.6	88	97	143
September	152.8	27.8	87	105	135
October	155.2	27.9	86	128	140
November	140.1	27.5	88	127	120
December	76.1	27.3	89	130	112
Annual	1545	28	86	1466	1651

There are several BRS stream gauging stations within the basin. However data from recent years are not available at many of the stations. The stations located in the lower portion of the basin which have long term data, are affected by tide. NPC operates several station on the Pulangi River, one of the major tributaries to the Mindanao river. Data for the Pulangi No.4 station are available for the period 1953 to 1981 and 1986 to 1992. The data are almost complete. The area tributary to the gaging station is 3,100 square kilometers. These data are considered representative of the Mindanao River Basin based on the location and size of the tributary area. However, adjustments for precipitation will be necessary when transposing the data to other locations. Rainfall data from the NPC rainfall station at Linabo were used to validate the Pulangi No. 4 stream flow data using a double mass curve analysis. The mean annual discharge for thirty-six January to December cycles were used in the frequency analysis. The results of the frequency analysis and the representative drought years are as follows. Other hydrologic results are presented in Figure B-32.

Return Period	Mean Annual Discharge (m^3/sec)	Representative Drought Year
5-Year	114.2	1973
10-Year	105.2	1968
20-Year	93.5	1991

B5 Flood Analysis

B5.1 Purpose

The purpose of the flood flow analysis was to characterize the estimated probable maximum floods calculated in previous studies in a manner that would allow for transposition of those data to other location or other basins. Limited data are available for the study area.

B5.2 Data Collection

The data used in this study were obtained through reviewing previous study reports including pre-feasibility, feasibility, definite design, and project rehabilitation reports. The flood flow data used in the evaluation were in the form of estimated Probable Maximum Flood (PMF) or 10,000-year return period flows. Generally these flow values are calculated for the purpose of determining the required spillway capacity of proposed dams. Various methods were used in the previous studies to calculate the peak flows. In some cases frequency analyses of the peak annual discharges were performed and the 10,000-year event was estimated based on the results. In other cases hydrologic models were used to simulate the runoff generated during the probable maximum precipitation (PMP) event. The relative magnitudes of the PMF and the 10,000-year event are identified differently in the various study reports. In some cases the PMF is defined as some percentage of the 10,000-year event. In other reports the 10,000-year event is defined as some percentage of the PMF.

The values of PMF and 10,000-year probable flood which were derived through the previous studies on the major water resources development projects in the Philippines are presented in Table B-2.

Numerous methods have been developed for calculating the design flow of a spillway. The results obtained with the different methods vary. The method used and the safety factors employed are based on the type of project and the level of protection required. For example, the design capacity of a spillway for an earth dam may be more conservative (higher) than that of a concrete dam because of the potential catastrophic results of overtopping an earth dam.

B5.3 Methodology

The peak runoff rates obtained from the previous study reports were converted to specific discharge for the respective drainage areas. Plots were then made of the specific discharge values versus drainage area. It has been shown in many previous studies in the Philippines and in other part of the world that specific discharge of a basin decreases as drainage area increases.

To represent the magnitudes of the PMF and 10,000 year probable floods which were derived through the previous studies on the major water resources development projects, the following Creager's formula was used:

$$Qp = 46 \times C \times A^{\alpha}$$
$$\alpha = 0.894 \times A^{-0.048} - 1$$

where, C : Creager's coefficient (Creager's C value)
A : Catchment area in mile^2

Qp : Specific discharge in $feet^3/sec/mile^2$

It is accepted that the above Creager's C values of the design floods for the different river basins become almost equal regardless of their catchment areas, provided that the basin characteristics affecting the flood occurrence that include the rainfall amount and intensity, topography, geology, vegetation, etc. are quite similar one another. In Japan, the regional envelope curves are developed using the modified Creager's curves. As for the river basins where the runoff data are not sufficiently available, the design floods are derived through the envelope curves.

Three data groups were formed; for Luzon, Visayas, and Mindanao. The data for Luzon and Mindanao were further separated by climate region. Plots were made for each of the data groups as presented in Figure B-33.

B5.4 Results and Discussion

Numerous plots were made and all of them show a decrease in specific discharge with increase in drainage area. Unlike the sediment data, the runoff data are not as scattered based on location, climate region or annual rainfall. It is supposed that the magnitude of the peak runoff events that occur in a particular basin may not be directly related to the total annual rainfall or annual distribution of rainfall within that particular basin. Usually, the extremely large peak discharges occur in the Philippines as a typhoon by-passes over the catchment. From this aspect, it is foreseen that the magnitudes of the peak discharges in Luzon and Visayas would be larger than those in Mindanao.

The data plots are presented in Figure B-33. In general, all of the plots show the expected trend of decreasing specific discharge with increasing drainage area. However, due to the low number of data points and the scattered positions, developing envelope curves was not possible. Instead, the Creager's curve was worked out using the average one of the Creager's C values corresponding to the PMF and 10,000-year probable flood for the respective regions. The Creager's C values derived by means of the aforesaid formula are shown in the following table:

Location	Creager's C value
Luzon Island	158
Luzon Climate Type I	138
Luzon Climate Type III	159
Luzon Climate Type IV	181
Visayas	196
Mindanao (all)	102
Mindanao Climate Type III	112
Mindanao Climate Type IV	92

Using the Creager's C values to transpose peak flow data from one basin to another must be done with prudence. The intended use of the peak flow estimate is of primary importance. As previously described the safety factors and allowable margins of error may vary depending on the application of the estimate.

It should be noted that other methods could be used to characterize peak runoff events within the study area. In one previous study the historical peak flows for the entire area were plotted against the drainage areas of the respective basins. These data are very scattered as shown in Figure B-33.

B6 Sediment Yield Analysis

B6.1 Purpose

The purpose of the sediment yield study was to characterize the sediment yield data collected in previous studies in a manner that would allow for transposition of those data to other location or other basins. Limited, reliable sediment data are available for the study area.

B6.2 Data Collection

The data used in this study were obtained through reviewing previous study reports including pre-feasibility, feasibility, definite design, and project rehabilitation reports. Perhaps the best long term sediment yield data available for the study area were obtained from studies of deposition in the Magat and Ambuklao Reservoirs. Those data have been widely applied throughout the study area in subsequent studies and planning efforts. Stream sediment data collected in the Jalaur River Basin have also been widely applied to other basins.

In many of the studies reviewed, basin sediment yield estimates were based on data collected in other basins. For example the sediment yield estimates reported in the Panay River Flood Control Plan were transposed from the data collected as part of the Jalaur Multi-purpose Project Feasibility Study. Since the Jalaur data were included in the data analysis the estimated Panay data were not included in the analysis. Similarly, the sediment yield data for many of the studies in Mindanao were estimated based on data collected in other areas; some as far away as northern Luzon Island. In these cases the estimated Mindanao data were not represented in the analysis.

It should also be noted that in some cases data collection and reporting techniques may have resulted in erratic or, perhaps, erroneous values. Due to the lack of data and information on data collection methods, the reliability of the data could not be confirmed. However, based on the description of methods used for the sediment inventories of the Magat and Ambuklao Reservoirs, these data are considered to be reliable.

B6.3 Methodology

The sediment data were first used to calculate the specific sediment discharge or specific sediment yield of the basins in which the data were collected. This was accomplished by calculating the sediment yield per unit area of the basin (q). These values were then plotted against the respective drainage basin areas. The objective was to identify trends in the data plots. It has been shown in many previous studies in the Philippines and in other part of the world that the sediment yield of a basin is related to the magnitude of the peak runoff rates within the basin and as the peak runoff rate increases, the sediment yield also increases. Also the sediment yield per unit area decreases as the drainage area increases. This may be due to the fact that peak runoff rates per unit area decrease with increasing drainage area.

When the data points follow some general plotting trend, envelope curves can be generated. The envelope curves generally characterize the upper, lower or intermediate boundaries of the data. Equations for these curves can then be generated and used to transpose the data to other locations or other basins. The basic requirement of using the envelope curve technique is that the plotted data show some distinct trend. It is difficult to develop enveloping curves when there are too few data points or when the data points are too scattered. However, if there is a general trend in the data, it may still be possible to develop an intermediate representative curve or a line-of-best-fit. Such is the case with the data used in this analysis.

As is discussed in the next section, the plotted data were somewhat scattered and did not always show the expected trends. Specifically, when the data for the entire study area were plotted they did not show a decrease in sediment yield per unit area as drainage area increased. This is likely due to the variation in basin characteristics and rainfall/runoff patterns in the individual basins. It was therefore necessary to group the data and make adjustments to account for differences in location, climate region and basin characteristics. Three data groups were formed for Luzon, Visayas, and Mindanao. However, the Luzon data still did not show a decrease in sediment yield per unit area with increased drainage area. Hence, the average sediment yield expressed in $m^3/km^2/year$ was calculated for each of Luzon, Visayas and Mindanao to indicate the general sediment yield.

B6.4 Results and Discussion

Numerous plots were made attempting to characterize trends in the sediment yield data. Variations in sediment yield per unit area from basin to basin reflect the variations in characteristics of the individual basins including size, slope, vegetative cover, soil types and rainfall intensity.

Although the data for the entire study area are plotted on a log-log paper, there was no distinguishable trend. Subsequently, the plots were made for the data grouped by location, i.e. Luzon, Visayas, Mindanao. These plots show the expected trend of decreasing sediment yield per unit area with increasing drainage area except for Luzon. However, due to the low number of data points and the scattered positions, developing envelope curves was not possible. Instead, each plot is shown with a representative trendline as well as the average sediment yield. The equations for these trendlines and the average sediment yield are presented on the plots as well as in the following table.

Location	*Equation of Trendline*	Average Sediment Yield ($m^3/km^2/year$)
Luzon	-	868
Visayas	$q = 5693.7x^{-0.276}$	1,093
Mindanao	$q = 1670x^{-0.1592}$	662

In these equations q is the annual specific sediment discharge ($m^3/km^2/yr$) and x is the drainage area (km^2). The above table slows a general tendency that the denudation rates in Luzon and Visayas are larger than those in Mindanao. In general, the denudation rate in certain basin increases as the basin development is accelerated. Therefore, it is necessary to take into consideration the sufficient allowance for the dead storage capacity in planning a storage type dam. Besides, it is essential to contemplate and implement the basin conservation plan so as to enable the sustainable operation of the planned reservoir.

Using the equations to transpose sediment yield data from one basin to another must be done with prudence. The scattered nature of the sediment data for Luzon Island is a reflection of differences in climate and basin characteristics as previously described. It is likely also a reflection of disturbances within the various basins caused by natural events or human activity. Natural events such as landslides and debris flows and human activities such as mining, logging and earth clearing for agriculture can significantly influence the sediment production within a particular basin. These types of sediment sources within a particular basin should be characterized before transposing sediment data from one basin to another.