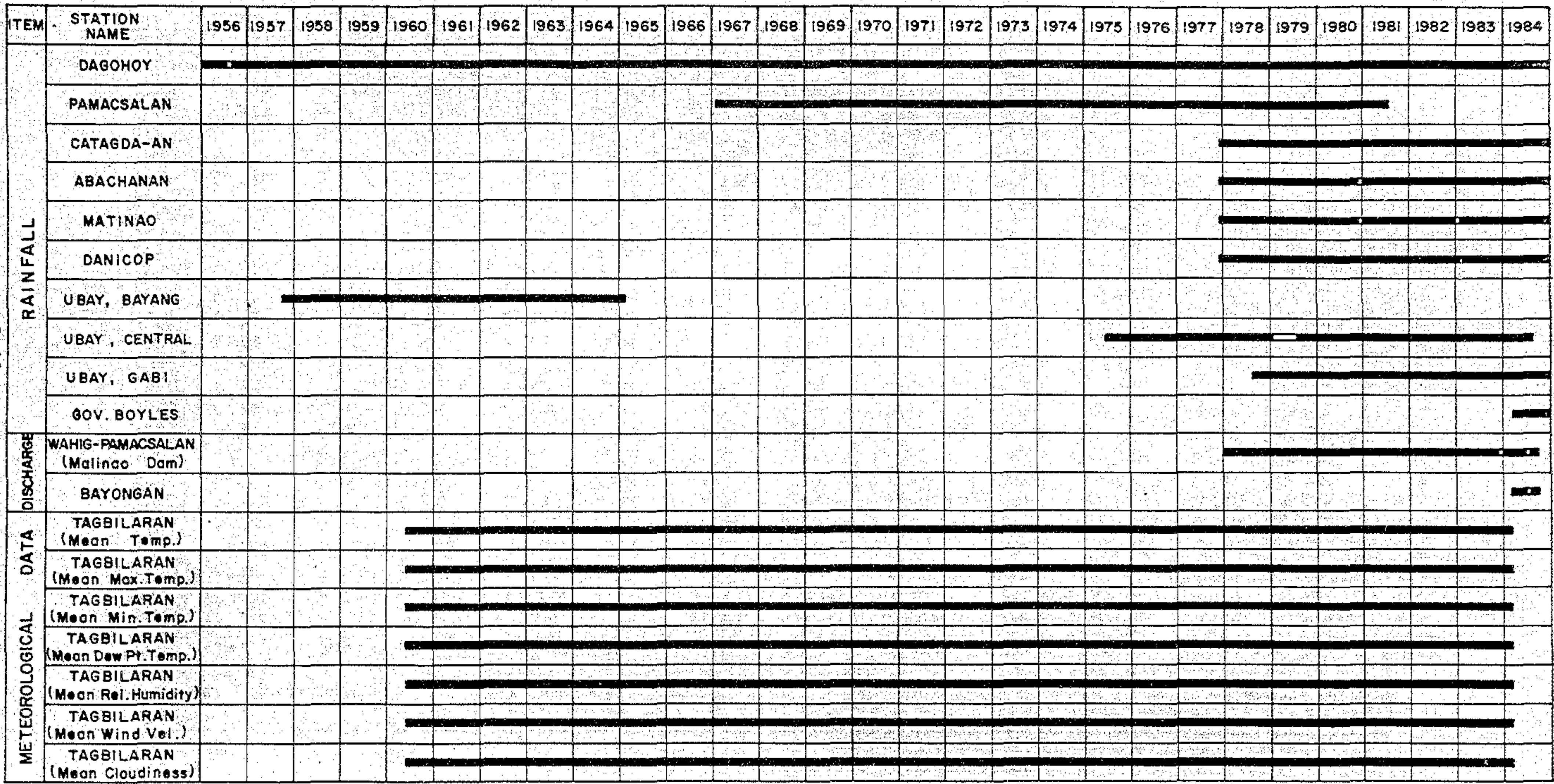
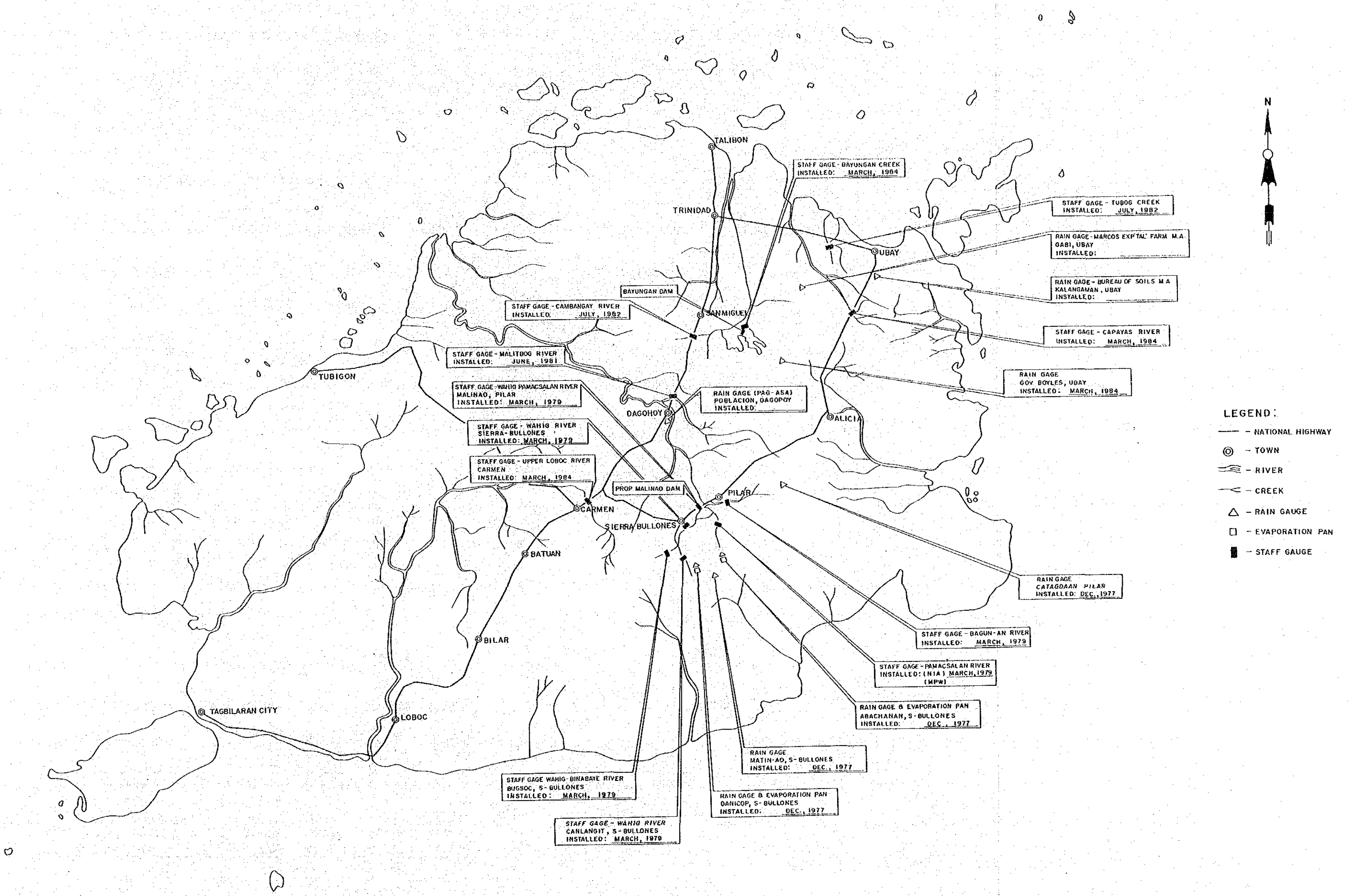
FIGURE BI-2 HISTORIC METEOROLOGICAL AND HYDROLOGICAL RECORDS



NOTE: LOCATION OF ABOVE STATIONS ARE SHOWN IN FIGURE BI-1, ANNEX B.

FIGURE B.I-I METEOROLOGICAL AND HYDROLOGICAL STATION



CHAPTER II RAINFALL DATA AND RAINFALL ANALYSIS

The daily rainfall data were collected and reviewed during the study period. These data are summarized in TABLE B2-1 to TABLE B2-10 and FIGURE B2-1 to FIGURE B2-4.

Observed Years and Annual Rainfall

Station	Observed Years	Annual Rainfall (mm)
Dagohoy	29	2,050
Pamacsalan	15	2,051
Matinao	7	2,355
Abachanan	7	2,042
Danicop	7	2,140
Catagda-an	7	2,018
Ubay Central	10	1,324
Ubay Bayang	9	1,797
Ubay Gabi	7	1,725
Gov. Boyles	1	-

2.1 Correlation Analysis

Correlation analyses among six rainfall stations of Phase I Project (between Dagohoy station and the other five stations) and four stations of Phase II Project were made on the basis of daily, 5-day total, 10-day total and monthly total respectively. The results are shown in the following table.

Correlation Coefficient for Phase I

Station	Daily	5-Day	10-Day	Monthly
Pamacsalan	0.520	0.574	0.671	0.697
Matinao	0.322	0.475	0.516	0.645
Abachanan	0.387	0.598	0.652	0.682
Danicop	0.355	0.544	0.583	0.694
Catagda-an	0.399	0.666	0.682	0.756
Ubay Central	0.215	0.453	0.521	0.535
Ubay Bayang	0.255	0.441	0.504	0.531
Ubay Gabi	0.258	0.473	0.555	0.730

According to the results, the correlation of Dagohoy and other stations is not so good, especially the value on the basis of daily, 5-day total and 10-day total are less than the value on the basis of monthly total. Therefore, it is reasonable to adopt the monthly total value for the correlation of Dagohoy and other stations. The results of analysis for Phase II are shown in FIGURE B2-5 to FIGURE B2-7.

The missing data for each station was complemented by the following method.

(i) The monthly rainfall was complemented by regression equation estimated from correlation analysis.

$$Y = a \cdot x + b \quad \text{(mm/month)}$$

where; Y: the complemented monthly rainfall (mm)
X: the monthly rainfall of Dagohoy station (mm)
a,b: regression coefficient

(ii) The missing daily rainfall was to be estimated by multiplying the daily rainfall of Dagohoy station by the ratio of monthly rainfall.

$$R = R(\text{Dagohoy}) \times \frac{\text{Monthly rainfall of the station}}{\text{Monthly rainfall of Dagohoy station}}$$

where;
R: daily rainfall of the station (mm/day)
R(Dagohoy): daily rainfall of Dagohoy station (mm/day)

The adopted regression equations are shown as follows;

Regression Equation for Phase I

Station	Regression Equation
Pamacsalan	0.686 · X + 56.3
Matinao	0.745 · X + 75.4
Abachanan	0.684 · X + 61.7
Danicop	0.687 · X + 66.3
Catagda-an	0.670 · X + 58.8

where; X: monthly total rainfall of Dagohoy station (mm)

Regression Equation for Phase II

Station	Regression Equation
Ubay Central	$0.352 \cdot X + 53.9$
Ubay Bayang	$0.380 \cdot X + 72.0$
Ubay Gabi	$0.548 \cdot X + 59.6$

All missing daily rainfall data of each station were complemented by using above mentioned regression lines. Therefore, all of the daily rainfall data were prepared from 1956 to 1984 and summarized in the following table.

Annual Rainfall of Each Stations in Phase I

Station	Annual Rainfall Before Complement (mm)	After Complement (mm)
Pamacsalan	2,051	2,067
Matinao	2,355	2,428
Abachanan	2,042	2,144
Danicop	2,140	2,203
Catagda-an	2,018	2,079

Annual Rainfall of Each Station in Phase II

Station	Annual Rainfall Before Complement (mm)	After Complement (mm)
Ubay Central	1,324	1,362
Ubay Bayang	1,797	1,636
Ubay Gabi	1,725	1,837

TABLE B2-1 SUMMARY TABLE OF DAILY RAINFALL DATA AT DAGOHOY STATION

* STATION --- DAGOHOY UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1956	180.6	35.1	118.5	221.7	302.4	171.2	252.1	--	161.0	107.2	201.8	458.2	--
1957	195.4	187.2	101.9	143.4	47.4	310.9	409.7	177.5	134.5	309.3	123.7	91.0	2231.9
1958	131.9	108.3	75.3	104.1	67.0	159.1	252.1	152.1	130.4	72.8	163.9	62.8	1479.8
1959	264.8	84.0	238.7	16.8	89.3	116.8	442.9	207.2	178.0	116.9	128.2	154.7	2038.3
1960	261.0	97.1	56.8	168.9	124.5	285.8	172.7	90.5	244.5	158.1	264.1	154.5	2078.5
1961	179.7	101.9	54.9	106.0	69.1	103.3	410.4	123.1	240.3	395.7	182.2	179.1	2145.7
1962	124.9	291.1	185.7	21.9	132.5	232.1	240.0	297.4	300.3	130.2	390.9	161.3	2508.3
1963	317.0	152.5	221.4	52.8	6.3	47.4	326.9	232.3	288.6	331.8	168.6	75.2	2220.8
1964	139.2	320.2	19.4	80.5	366.5	107.6	206.4	56.4	269.7	179.1	934.3	257.9	2937.2
1965	364.9	171.5	136.4	72.9	9.8	326.6	155.4	173.9	150.1	206.2	122.3	189.2	2079.2
1966	93.0	58.4	29.1	65.6	215.1	61.3	372.3	219.4	106.8	352.5	106.5	187.0	1867.0
1967	436.9	260.7	255.7	49.6	109.3	129.3	147.0	112.6	189.2	145.3	186.9	191.6	2214.1
1968	123.8	51.7	82.7	4.5	3.3	151.7	115.9	110.8	210.3	262.3	399.5	319.9	1836.4
1969	33.0	9.4	81.6	18.6	95.1	151.0	248.7	126.8	164.2	123.1	132.3	228.8	1412.6
1970	78.4	142.2	34.0	20.8	42.2	349.7	263.6	140.5	153.6	388.6	209.1	124.8	1947.5
1971	266.7	49.9	117.5	115.6	248.6	339.5	239.8	179.9	202.6	214.3	330.5	92.3	2397.2
1972	388.7	33.8	97.1	33.2	189.3	207.6	135.6	255.7	284.8	168.2	161.3	147.4	2102.7
1973	33.8	35.0	28.0	5.9	0.7	209.4	194.4	303.0	244.1	158.0	564.0	262.6	2038.9
1974	53.5	278.6	123.9	231.7	109.7	267.5	114.9	105.7	86.0	119.2	304.8	253.2	2048.7
1975	362.9	126.9	94.9	147.8	18.8	228.6	251.9	153.2	263.3	226.0	116.0	172.3	2162.6
1976	298.8	65.7	42.3	12.9	57.9	198.1	144.6	337.7	117.9	47.4	71.9	342.6	1737.8
1977	347.4	296.4	67.1	2.8	170.3	125.9	272.9	283.6	132.2	158.6	201.2	49.8	2108.2
1978	292.1	133.7	29.0	67.3	39.5	333.4	173.3	85.0	218.8	172.1	114.6	192.9	1851.7
1979	128.0	42.2	32.8	71.9	174.4	314.4	228.8	71.1	148.4	126.6	101.9	132.3	1572.8
1980	227.5	310.5	29.7	72.7	65.0	216.5	338.4	714.5	271.5	441.8	194.6	301.3	3184.0
1981	225.1	95.3	59.7	41.1	64.8	77.5	323.4	98.9	192.4	295.9	127.3	428.3	2029.7
1982	83.9	147.2	213.2	7.5	77.7	152.8	152.1	270.8	139.1	269.1	61.5	99.3	1674.2
1983	30.2	9.4	1.3	0.0	6.0	119.1	337.1	148.1	236.1	227.2	131.1	297.8	1543.4
1984	181.1	254.2	157.7	54.9	65.5	62.6	57.3	28.8	281.2	222.4	154.0	418.9	1938.6
MEAN	201.5	136.2	96.1	69.4	102.3	191.6	240.7	187.7	197.9	211.2	218.9	207.8	2049.6

TABLE B2-2 SUMMARY TABLE OF DAILY RAINFALL DATA AT PAMACSALAN STATION

* STATION --- PAMACSALAN

UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1967	--	290.7	221.3	6.1	19.4	151.1	142.0	153.4	89.4	222.4	243.4	392.1	--
1968	227.2	129.7	56.2	0.0	46.8	155.5	192.0	64.0	192.7	109.3	391.1	278.1	1842.6
1969	47.3	16.7	103.1	48.9	85.3	124.9	101.3	214.7	119.0	185.9	142.9	307.2	1497.2
1970	134.0	254.3	61.0	0.0	19.4	390.0	279.7	171.9	94.2	374.0	202.7	160.7	2141.9
1971	305.2	171.0	138.9	91.0	123.4	512.4	206.4	220.0	210.7	266.8	400.5	75.7	2722.0
1972	312.1	63.8	236.3	56.3	249.9	194.1	28.7	169.6	218.5	201.4	131.0	203.5	2065.2
1973	18.5	43.7	19.6	7.6	0.0	249.9	175.3	207.0	333.5	163.1	571.0	239.6	2028.8
1974	99.9	368.2	238.7	138.4	42.2	188.2	116.8	98.1	189.8	246.8	169.1	363.0	2259.2
1975	496.8	155.2	37.3	109.7	15.2	257.9	139.1	46.0	312.2	197.3	61.5	280.8	2109.0
1976	374.9	132.8	62.8	26.4	131.7	218.8	103.6	229.7	141.5	56.1	179.6	222.5	1880.4
1977	219.6	346.3	146.1	0.0	56.3	185.7	104.4	183.4	118.2	139.5	182.9	106.6	1789.0
1978	314.6	150.6	33.2	122.6	183.1	176.5	92.1	122.3	347.9	192.7	97.9	234.2	2067.7
1979	151.8	64.3	237.3	54.7	167.6	431.6	108.6	126.2	134.8	105.4	102.7	159.1	1844.1
1980	256.7	151.2	51.9	64.0	0.0	469.3	226.0	268.6	107.8	224.0	290.9	298.6	2409.0
1981	293.6	115.9	32.0	29.9	17.7	193.5	108.7	--	--	--	--	--	--
MEAN	232.3	163.6	111.7	50.4	77.2	260.0	141.6	162.5	186.4	191.8	226.2	237.3	2050.5

TABLE B2-3 SUMMARY TABLE OF DAILY RAINFALL DATA AT CATAGDA-AN STATION

* STATION --- CATAGDA-AN UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1977	--	--	--	--	--	--	--	--	--	--	--	--	--
1978	319.2	169.9	45.6	77.8	230.1	240.1	61.5	139.2	439.2	192.6	98.9	218.7	2232.8
1979	135.0	52.3	41.4	67.2	162.9	264.8	71.0	66.2	142.7	148.7	124.5	146.5	1423.2
1980	299.5	198.5	40.4	57.6	73.4	388.0	255.5	357.2	138.6	312.8	245.0	330.2	2696.7
1981	297.4	138.2	33.8	33.5	54.0	160.7	144.8	49.2	209.5	212.8	242.5	358.2	1934.6
1982	120.5	217.3	208.3	43.4	115.5	143.2	173.4	263.3	76.9	192.2	105.3	90.6	1749.9
1983	103.7	13.4	10.8	7.2	4.5	122.0	263.3	221.3	274.7	166.8	146.1	442.3	1776.1
1984	172.3	249.4	106.0	71.9	79.5	90.7	190.6	55.0	445.9	198.1	228.7	424.8	2312.9
MEAN	206.8	148.4	69.5	51.2	102.8	201.4	165.7	164.5	246.8	203.4	170.1	287.3	2018.0

TABLE B2-4 SUMMARY TABLE OF DAILY RAINFALL DATA AT ABACHANAN STATION

* STATION --- ABACHANAN UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1977	--	--	--	--	--	--	--	--	--	--	--	--	--
1978	339.8	160.5	27.0	164.8	73.5	257.4	45.0	146.2	461.1	189.4	133.4	242.5	2240.6
1979	161.5	23.5	49.0	90.5	109.5	417.5	102.5	154.5	114.5	164.5	185.0	168.0	1740.5
1980	237.0	145.0	46.5	53.0	10.0	371.0	208.0	313.0	174.0	221.0	272.0	--	--
1981	372.0	142.5	34.0	49.0	14.0	111.0	146.0	40.0	97.5	267.5	130.5	372.0	1776.0
1982	182.0	212.0	242.5	15.0	63.0	158.5	244.0	222.0	75.5	242.0	109.0	107.0	1872.5
1983	101.5	11.0	14.0	3.0	5.0	100.0	305.5	326.0	316.0	212.5	251.0	303.0	1948.5
1984	168.5	258.5	98.5	44.0	63.0	144.0	154.5	110.0	628.0	204.0	285.0	514.0	2672.0
MEAN	223.2	136.1	73.1	59.9	48.3	222.8	172.2	187.4	266.7	214.4	195.1	284.4	2041.7

TABLE B2-5 SUMMARY TABLE OF DAILY RAINFALL DATA AT MATINAO

* STATION --- MATINAO UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1977	--	--	--	--	--	--	--	--	--	--	--	--	--
1978	368.3	127.0	15.8	77.0	70.9	328.3	150.3	179.6	611.9	354.7	118.6	265.6	2668.0
1979	161.1	32.8	26.3	94.7	240.7	664.8	246.2	212.7	195.3	326.8	116.3	231.4	2549.1
1980	192.8	115.2	46.9	62.4	16.4	437.4	268.9	339.6	168.8	271.4	251.8	--	--
1981	437.1	167.3	78.5	69.1	58.6	195.4	219.0	53.3	275.5	242.4	229.4	347.0	2372.6
1982	234.1	220.6	338.5	1.0	91.4	172.2	276.4	504.7	130.4	149.0	62.1	43.7	2224.1
1983	--	13.0	0.0	5.2	31.0	180.9	519.0	324.6	350.2	205.6	233.2	257.1	--
1984	137.8	235.9	140.9	39.7	22.8	259.1	123.2	12.7	163.6	196.3	172.1	459.2	1963.3
MEAN	255.2	130.3	92.4	49.9	76.0	319.7	257.6	232.5	270.8	249.5	169.1	267.3	2355.4

TABLE B2-6 SUMMARY TABLE OF DAILY RAINFALL DATA AT DANICOP

* STATION --- DANICOP UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1977	--	--	--	--	--	--	--	--	--	--	--	--	--
1978	379.5	164.5	18.7	111.0	31.0	347.2	65.5	127.5	530.8	207.5	101.0	191.0	2275.2
1979	165.0	22.0	51.0	106.0	121.0	478.8	265.5	121.5	152.0	167.0	119.0	166.5	1935.3
1980	227.0	126.5	26.0	62.0	16.0	388.5	182.0	280.0	169.0	222.5	271.5	450.0	2421.0
1981	308.0	118.5	24.0	27.0	92.0	190.0	172.0	45.0	149.0	236.0	157.0	373.0	1891.5
1982	197.0	210.0	245.0	20.0	119.0	158.0	261.0	316.0	112.0	145.0	152.0	90.0	2025.0
1983	72.0	17.0	14.0	4.0	38.0	136.0	484.0	367.0	281.0	210.0	158.0	327.0	2108.0
1984	156.0	233.0	143.0	100.0	71.0	238.0	85.0	123.0	280.0	206.0	222.0	469.0	2326.0
MEAN	214.9	127.4	74.5	61.4	69.7	276.6	216.4	197.1	239.1	199.1	168.6	295.2	2140.3

TABLE B2-7 SUMMARY TABLE OF DAILY RAINFALL DATA AT UBAY CENTRAL

* STATION --- UBAY-CENTRAL UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1975	--	--	--	--	--	--	81.3	32.2	166.3	218.0	73.0	173.4	--
1976	160.5	66.5	27.8	21.6	73.1	150.0	54.7	104.3	127.9	75.7	147.4	145.2	1154.7
1977	147.4	115.3	111.7	9.9	37.3	81.7	151.9	133.9	50.5	154.7	88.3	56.8	1139.4
1978	104.2	83.0	23.2	44.1	57.6	61.3	62.5	106.0	139.3	68.4	46.4	97.2	893.2
1979	29.0	--	--	--	--	--	--	70.6	112.6	149.6	47.5	84.9	--
1980	275.7	316.1	11.9	17.5	23.4	217.1	139.1	121.1	262.9	283.9	51.7	216.0	1936.4
1981	311.8	76.2	115.8	15.0	29.0	128.5	262.0	32.1	24.4	120.7	134.0	171.6	1421.1
1982	35.0	155.6	174.8	0.0	121.8	108.4	266.0	277.6	76.0	163.0	74.0	90.8	1543.0
1983	43.2	4.0	7.4	2.0	0.0	64.9	78.0	208.2	100.0	95.6	230.8	345.0	1179.1
1984	153.2	175.8	81.2	50.0	88.0	80.8	125.8	119.4	--	--	--	--	--
MEAN	140.0	124.1	69.2	20.0	53.8	111.6	135.7	120.5	117.8	147.7	99.2	153.4	1323.8

TABLE B2-8 SUMMARY TABLE OF DAILY RAINFALL DATA AT UBAY BAYANG

* STATION --- UBAY-BAYANG UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1957	--	--	--	--	--	--	--	--	--	38.1	30.5	85.9	--
1958	132.0	119.5	109.2	17.8	--	--	--	10.8	236.0	312.4	266.8	228.6	--
1959	195.8	111.8	95.3	6.3	116.9	47.1	345.5	203.2	200.7	148.6	37.0	54.5	1562.7
1960	120.0	80.0	24.1	--	0.0	61.0	251.5	80.1	147.5	247.2	200.1	136.7	--
1961	144.4	84.8	67.8	88.2	34.3	71.1	216.9	126.9	163.0	274.5	127.1	105.5	1504.5
1962	129.6	248.5	157.1	18.8	211.3	264.1	260.3	285.6	266.8	189.8	280.8	100.6	2413.3
1963	257.4	85.1	140.5	21.6	6.8	115.1	199.6	397.4	138.4	318.5	54.5	58.5	1793.4
1964	53.3	238.4	14.0	64.8	242.6	127.1	247.6	43.5	205.8	183.0	191.7	100.3	1712.1
1965	199.5	231.2	--	10.2	34.2	174.2	140.0	47.2	188.0	91.4	5.1	--	--
MEAN	154.0	149.9	86.9	32.5	92.3	122.8	237.3	149.3	193.3	200.4	132.6	108.8	1797.2

TABLE B2-9 SUMMARY TABLE OF DAILY RAINFALL DATA AT UBAY GABI

* STATION --- UBAY-GABI UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1978	--	--	--	--	--	--	--	--	310.9	190.8	199.7	265.8	--
1979	111.5	31.3	19.4	43.5	194.4	270.0	144.7	137.1	238.5	114.3	141.3	120.9	1566.9
1980	293.4	120.3	11.5	37.8	103.6	246.1	197.9	292.1	199.3	402.4	145.3	270.1	2319.8
1981	252.4	60.5	71.4	15.9	134.6	74.6	130.4	17.0	141.2	180.0	120.6	220.3	1418.9
1982	95.4	106.5	263.4	28.0	136.4	169.8	290.7	251.7	84.8	223.9	65.7	89.5	1805.8
1983	49.3	9.3	5.3	10.2	2.3	115.3	302.4	288.3	150.8	196.0	169.6	213.7	1512.5
1984	164.5	181.9	61.2	77.7	35.2	131.4	249.2	54.4	--	197.9	127.5	323.0	--
MEAN	161.1	85.0	72.0	35.5	101.1	167.9	219.2	173.4	187.6	215.0	138.5	214.8	1724.8

TABLE B2-10 SUMMARY TABLE OF DAILY RAINFALL DATA AT GOV. BOYLES

* STATION --- GOV.BOYLES UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1984	--	--	--	422.0	85.7	143.7	119.6	55.9	--	106.0	128.9	178.1	--
1985	299.7	--	--	--	--	--	--	--	--	--	--	--	--
MEAN	299.7	--	--	422.0	85.7	143.7	119.6	55.9	--	106.0	128.9	178.1	--

FIGURE B2-1 MONTHLY MEAN RAINFALL AT SIX STATIONS IN PHASE I AREA

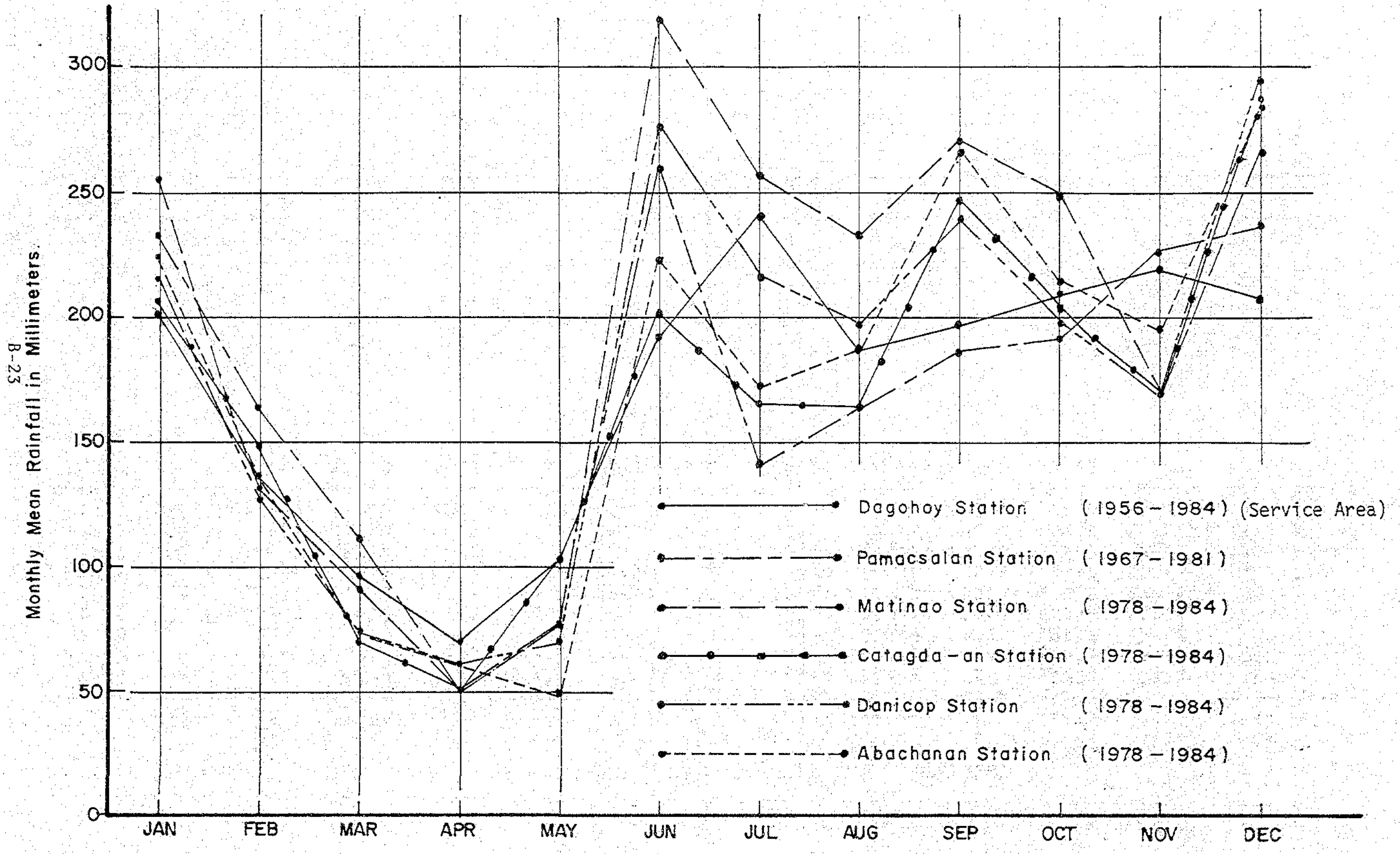
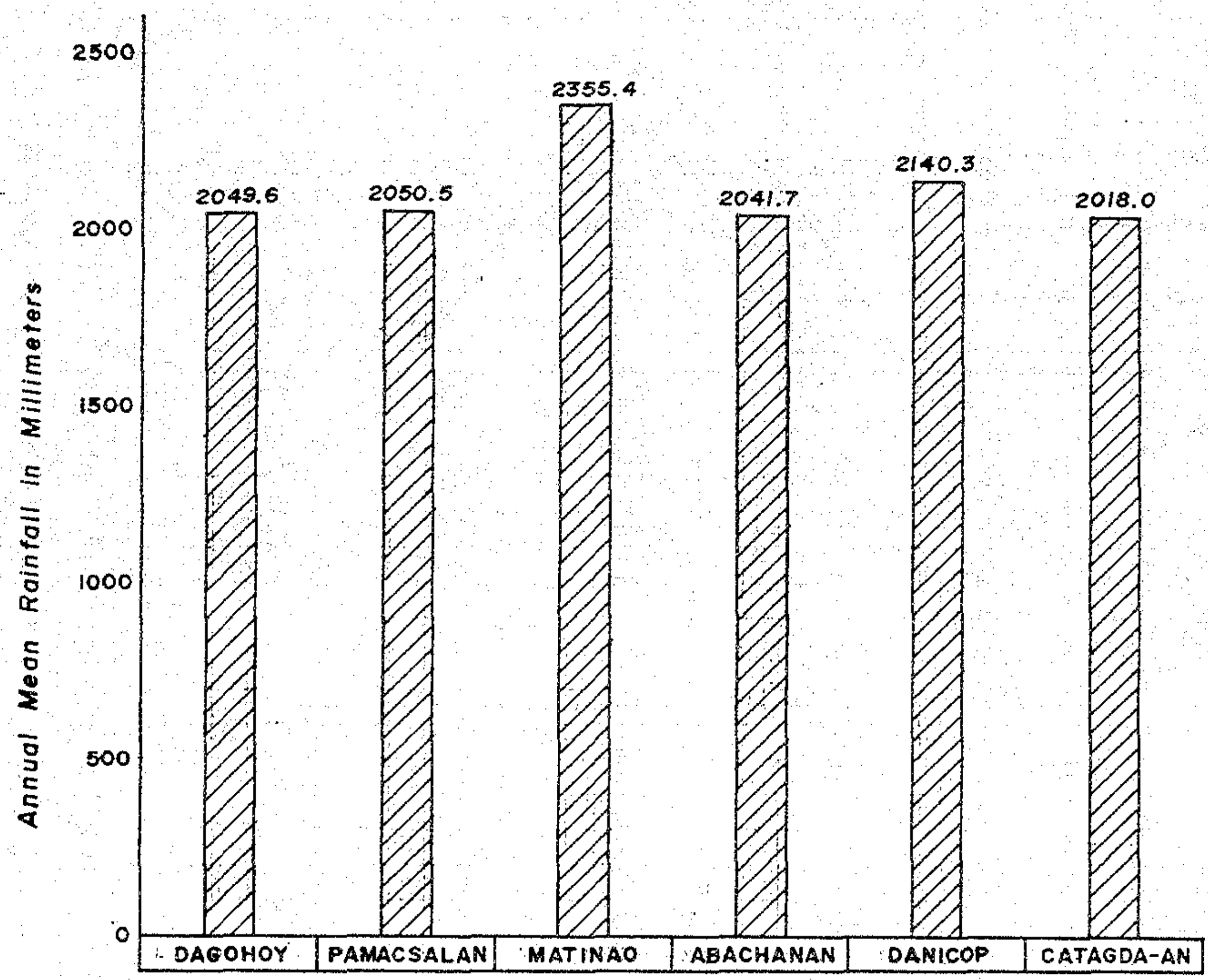


FIGURE B2-2 ANNUAL MEAN RAINFALL AT SIX STATIONS IN PHASE I AREA



STATIONS	OBSERVED PERIOD
1. DAGOHOY	1956 - 1984
2. PAMACSALAN	1967 - 1981
3. MATINAO	1978 - 1984
4. ABACHANAN	1978 - 1984
5. DANICOP	1978 - 1984
6. CATAGDA-AN	1978 - 1984

FIGURE B2-3 MONTHLY MEAN RAINFALL AT THREE STATIONS IN PHASE II AREA

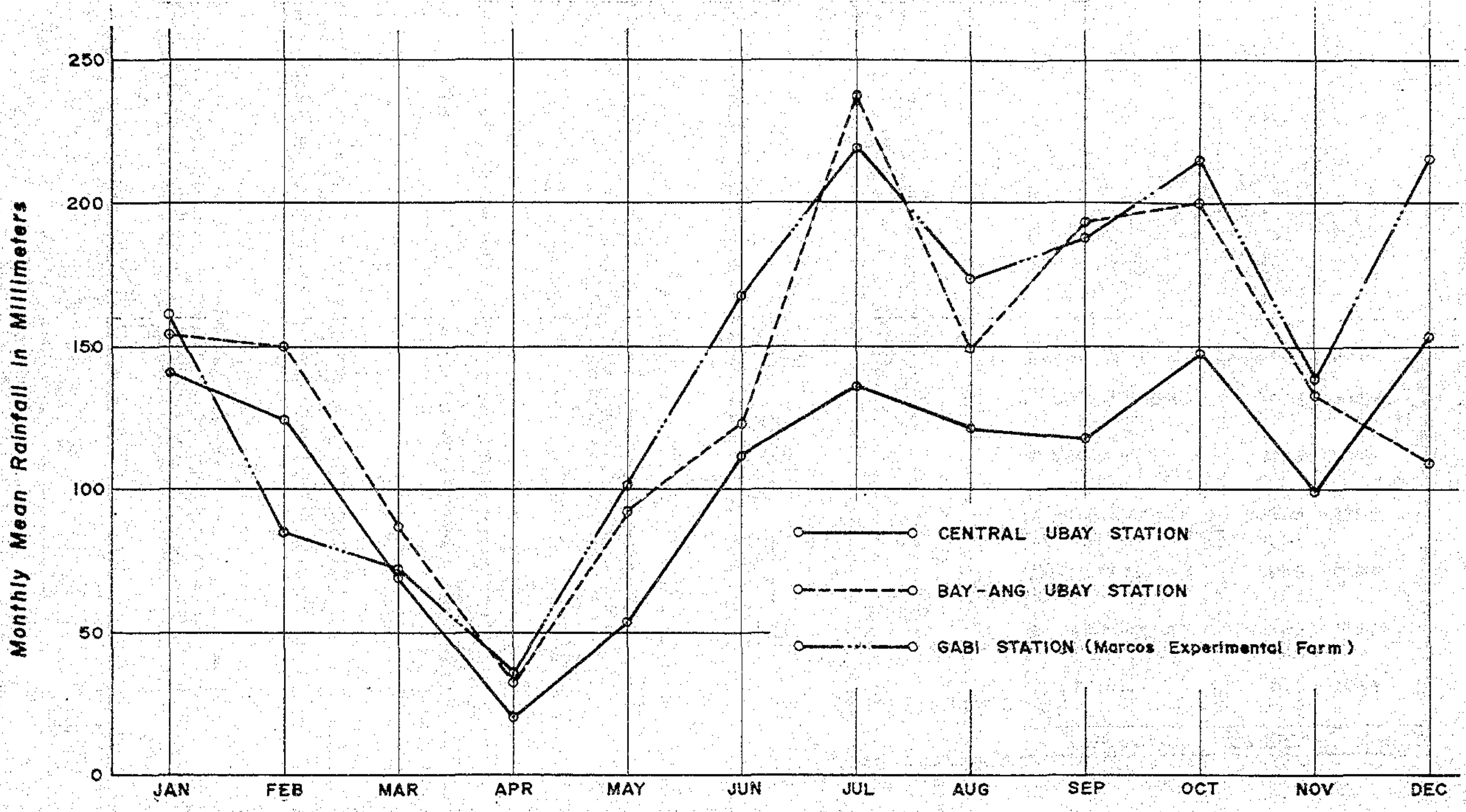


FIGURE B2-4 ANNUAL MEAN RAINFALL AT THREE STATIONS IN PHASE II AREA

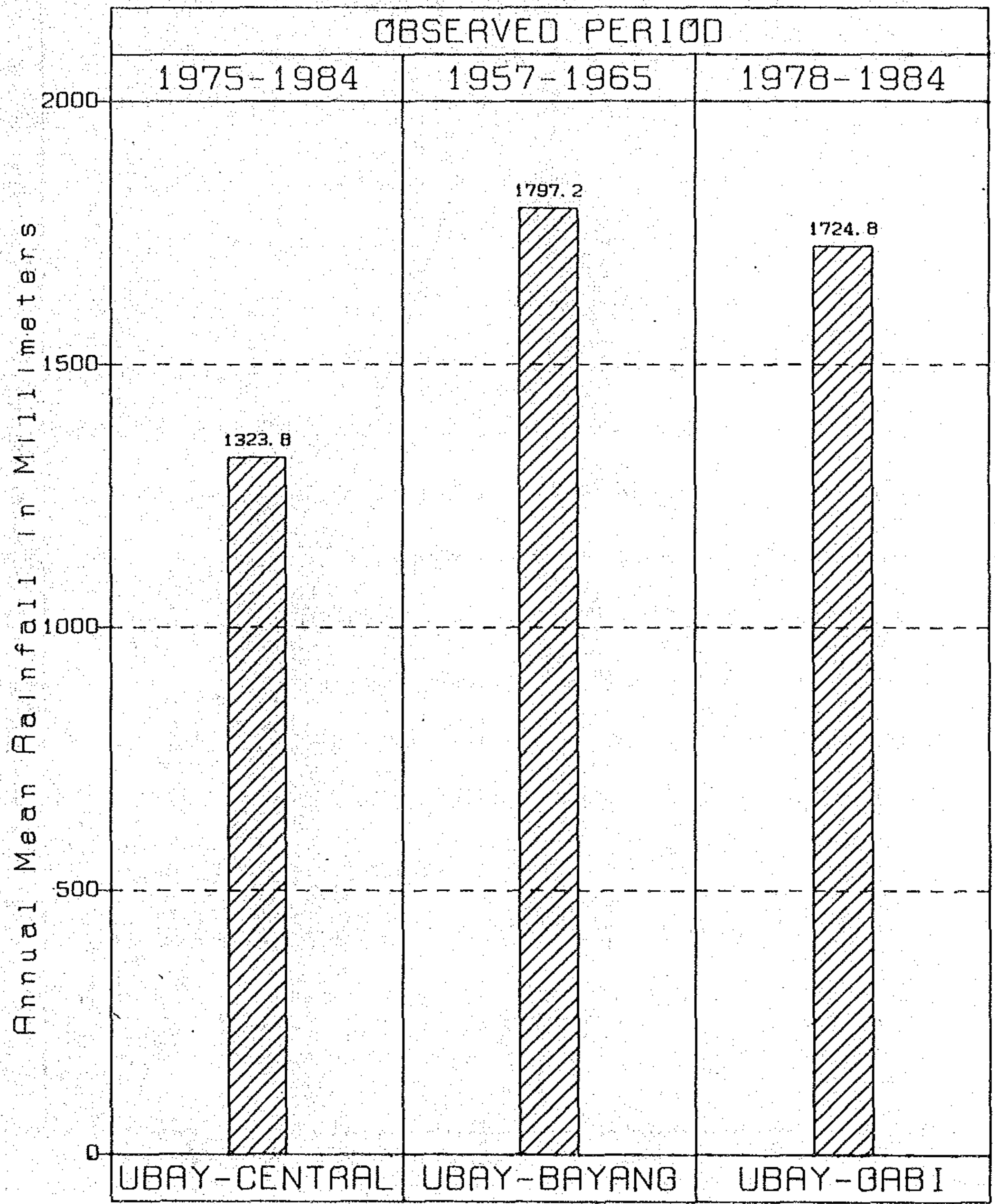


FIGURE B2-5 CORRELATION ANALYSIS BETWEEN DAGOHOY STATION AND CENTRAL UBAY STATION

MONTHLY BASE

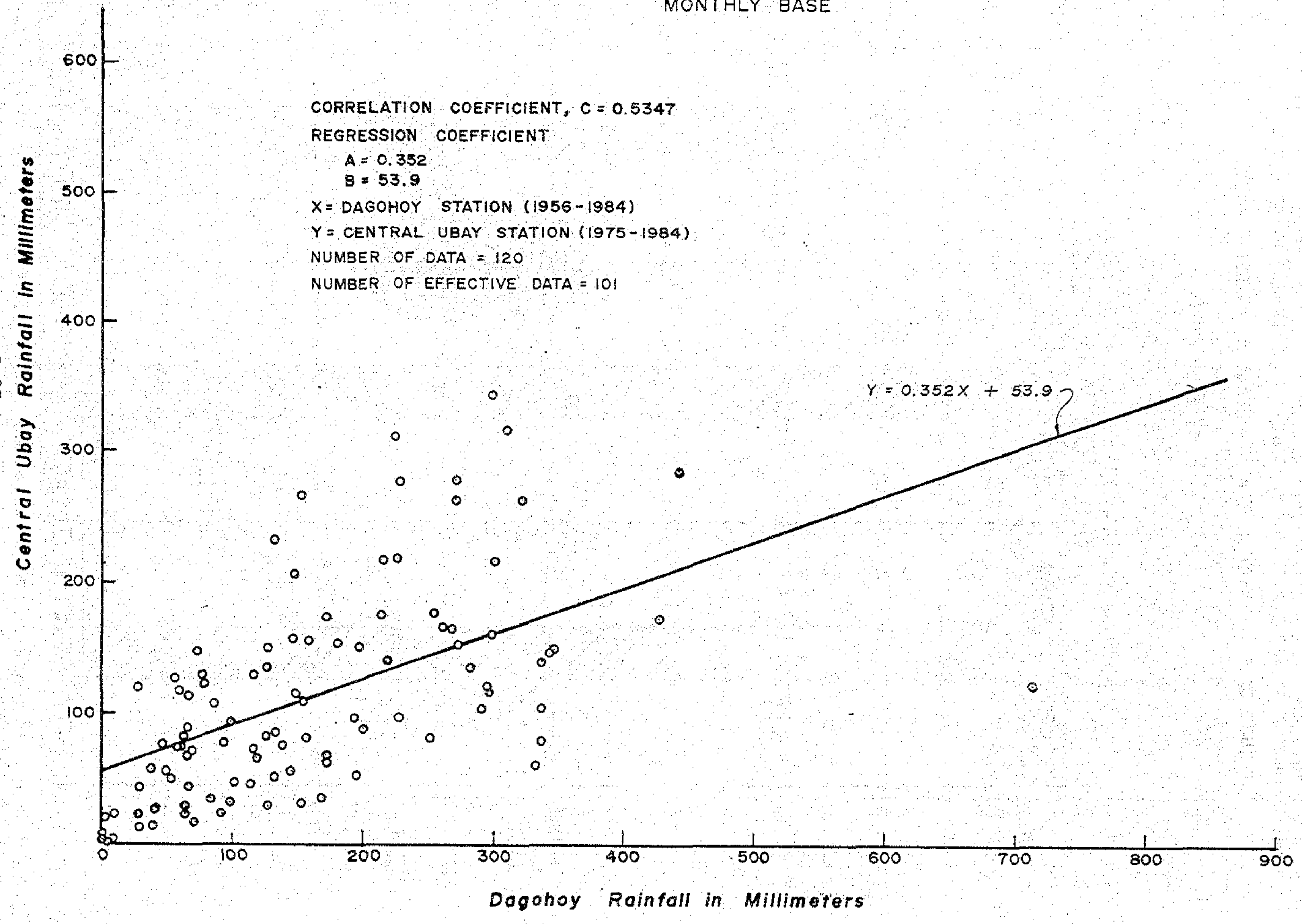


FIGURE B2-6 CORRELATION ANALYSIS BETWEEN DAGOHOY STATION AND BAY-ANG UBAY STATION

MONTHLY BASE

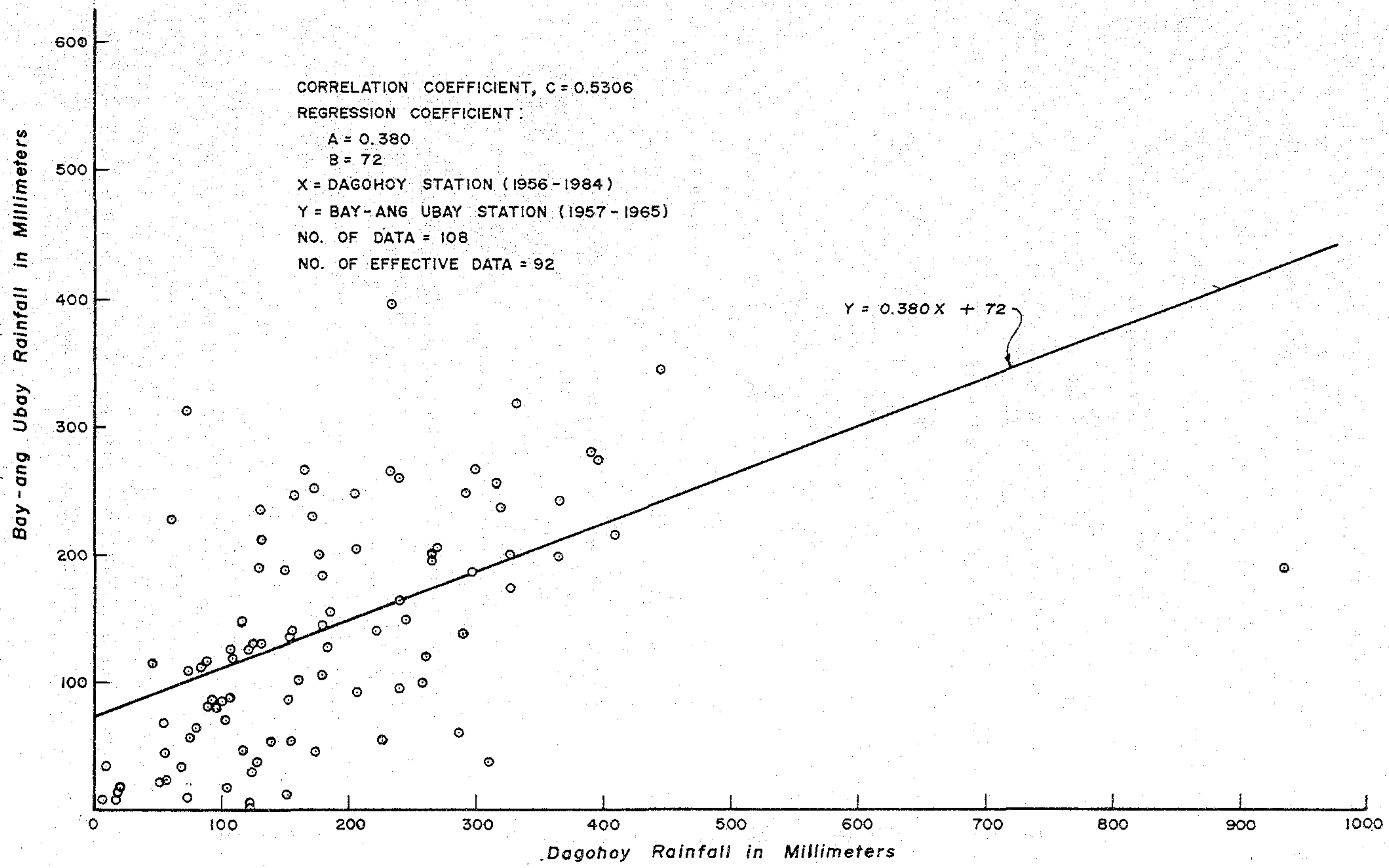
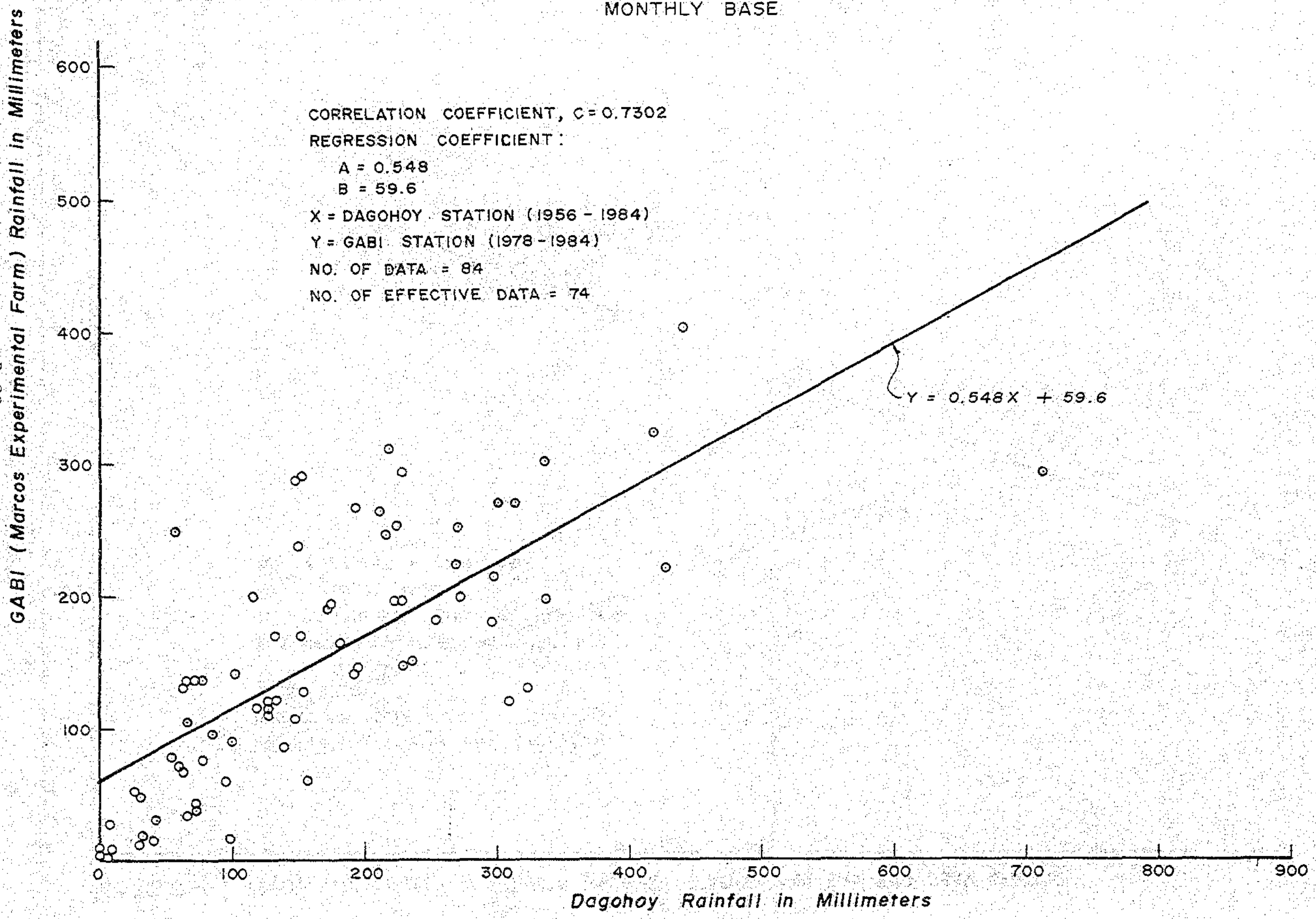


FIGURE B2-7 CORRELATION ANALYSIS BETWEEN DAGOHOY STATION AND GABI STATION

MONTHLY BASE



2.2 Areal Rainfall

2.2.1 Phase I Project

There are five rain gauge stations in the catchment area of the Malinao reservoir as mentioned above. The areal rainfall of the catchment area was estimated by the Thiesen polygon method to use for the runoff analysis. The missing daily rainfall of each five rain gauge stations was prepared by using regression line. The occupied area of each station and the ratio are shown in the following table.

Station	Area (sq.km)	Ratio	Annual Mean Rainfall (mm)
Pamacsalan	30.1	0.216	2,067
Matinao	15.8	0.114	2,428
Abachanan	23.4	0.169	2,144
Danicop	42.5	0.306	2,203
Catagda-an	27.0	0.195	2,079
Total	138.8	1.000	

The areal rainfall from 1956 to 1984 is shown in TABLE B2-11. According to the result, the annual mean rainfall is 2,165 mm.

2.2.2 Phase II Project

There are three rain gauge stations in the Phase II service area of 5,300 ha, that is Ubay Central, Ubay Bayang and Ubay Gabi stations. These rainfall data are necessary to estimate the effective rainfall for irrigation water requirements in the Phase II service areas.

On the other hand, it is not enough to estimate the weighted rainfall for the areal rainfall. Therefore, the average rainfall of the three stations was adopted for the areal rainfall of Phase II service area. The monthly rainfall from 1956 to 1984 is shown in TABLE B2-12. According to the result, the annual mean rainfall is 1,612 mm.

TABLE B2-11 ESTIMATED AREAL RAINFALL IN CATCHMENT AREA IN WAHIG RIVER

* STATION---AREAL RAINFALL

UNIT ; MM

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1956	---	---	---	---	---	---	---	---	173.8	137.1	202.0	378.9	----
1957	197.6	192.1	133.4	161.8	95.6	277.2	345.5	185.4	155.7	276.2	148.3	125.9	2294.7
1958	154.0	137.6	114.9	134.6	109.1	172.6	236.6	168.0	152.9	113.1	175.9	106.1	1775.4
1959	245.6	120.9	227.5	74.5	124.4	143.3	368.5	205.9	185.6	143.4	151.2	169.5	2160.3
1960	242.9	129.9	102.1	179.4	148.8	260.0	182.0	125.6	231.5	171.9	245.0	169.4	2188.5
1961	186.8	133.4	100.7	136.1	110.7	134.0	345.7	148.0	228.6	335.9	188.4	186.5	2234.8
1962	149.1	263.7	191.0	78.1	154.3	223.0	228.3	268.0	269.9	153.0	332.3	174.0	2484.7
1963	281.6	168.0	215.5	99.3	67.2	95.5	288.4	223.2	262.0	291.8	179.5	115.0	2287.0
1964	159.0	283.8	76.3	118.3	315.8	137.3	205.6	102.0	249.0	186.5	707.2	240.8	2781.6
1965	314.7	180.9	156.9	113.1	69.7	288.3	170.0	182.9	166.8	205.2	147.2	193.3	2189.0
1966	127.1	103.2	83.1	108.1	211.4	105.3	319.3	214.4	136.6	306.1	136.4	191.7	2042.7
1967	364.4	254.6	237.0	78.9	114.0	153.5	161.0	144.7	172.3	177.4	204.4	239.2	2301.4
1968	166.9	106.8	107.7	53.3	62.6	166.4	155.1	124.5	206.4	216.2	351.5	284.2	2001.6
1969	78.9	59.5	117.1	71.5	120.6	159.7	207.3	165.7	165.3	157.6	153.2	240.8	1697.2
1970	122.1	182.9	82.2	62.1	77.9	324.3	253.7	164.0	154.3	341.8	207.7	153.2	2126.2
1971	261.0	114.8	144.5	133.0	211.9	345.3	225.2	195.5	206.0	224.4	316.2	117.1	2494.9
1972	328.6	82.7	154.3	81.0	207.2	205.2	130.4	225.9	252.2	185.4	166.2	174.5	2193.6
1973	73.0	79.2	70.3	55.6	51.1	218.0	193.8	259.5	255.0	171.6	479.3	244.4	2150.8
1974	101.2	281.2	169.4	206.1	119.1	236.0	138.5	129.4	138.1	168.5	252.2	266.3	2206.0
1975	354.5	153.2	110.2	154.6	64.3	230.2	217.0	143.6	260.7	215.9	127.0	204.6	2235.8
1976	293.4	114.9	87.4	63.3	110.4	205.1	151.7	283.1	145.0	88.5	128.5	284.3	1955.6
1977	286.4	286.0	118.6	52.3	155.1	159.0	221.1	243.8	148.0	166.7	199.2	149.5	2185.7
1978	345.9	157.6	28.2	112.3	114.5	272.2	76.5	137.8	470.6	215.2	107.4	222.8	2261.0
1979	155.3	38.6	86.3	83.6	150.9	437.9	163.8	128.0	145.3	168.0	127.4	168.5	1853.6
1980	245.3	147.7	40.2	60.2	22.7	408.3	220.2	305.0	150.8	245.6	268.4	346.0	2460.4
1981	328.4	131.3	35.4	37.5	51.7	172.4	153.8	63.0	174.9	242.4	174.3	361.9	1927.0
1982	165.8	201.4	239.0	30.5	103.8	157.7	221.1	295.3	109.5	191.9	113.8	95.1	1924.9
1983	87.0	24.7	21.1	3.7	29.9	132.8	372.3	281.5	279.9	202.0	177.4	323.1	1935.4
1984	164.4	240.2	132.6	76.8	72.5	166.0	124.1	84.8	351.2	203.7	215.7	439.8	2271.8
MEAN	213.6	156.1	120.8	93.6	116.0	213.8	217.0	185.7	206.8	203.6	220.1	219.5	2165.1

TABLE B2-12 ESTIMATED AREAL RAINFALL IN PHASE II SERVICE AREA

* STATION --- SERVICE-AREA UNIT ; mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1956	138.9	76.8	112.5	156.5	190.5	135.1	169.3	--	130.5	107.5	148.0	257.4	--
1957	145.3	141.9	105.3	123.1	81.9	194.1	236.6	137.4	119.5	143.4	85.1	94.1	1607.7
1958	121.6	110.2	96.9	74.7	90.4	129.8	169.3	86.9	155.6	163.8	175.9	132.7	1507.8
1959	182.7	100.3	141.2	45.0	103.7	88.4	285.9	167.6	158.1	122.4	88.7	102.3	1586.3
1960	156.3	93.5	63.0	133.8	75.3	143.9	173.4	91.8	160.1	167.6	183.7	129.6	1572.0
1961	139.6	96.5	76.9	98.9	69.9	92.3	232.9	117.0	164.4	248.0	134.8	126.6	1597.8
1962	118.5	208.1	145.9	50.7	148.1	195.7	196.7	222.1	216.8	140.0	248.5	119.6	2010.7
1963	218.9	111.9	151.1	60.8	42.0	90.3	202.2	240.1	170.7	243.6	106.4	80.2	1718.2
1964	97.6	213.3	48.3	83.4	228.7	112.4	182.1	69.2	187.5	152.6	382.2	148.5	1905.8
1965	213.6	166.4	120.3	63.2	52.2	193.9	131.1	105.8	145.5	130.2	75.9	142.6	1540.7
1966	101.7	86.5	74.3	89.8	153.5	87.9	220.8	155.5	107.5	212.2	107.2	141.7	1538.6
1967	248.3	173.1	170.8	83.0	108.5	117.0	124.5	109.8	142.6	124.1	141.8	143.5	1687.0
1968	114.7	84.0	97.3	63.8	63.2	126.9	111.4	109.4	151.4	173.8	232.2	198.4	1526.5
1969	76.0	65.8	96.7	69.7	102.5	126.4	168.1	115.6	132.1	114.4	118.3	159.3	1344.9
1970	95.2	122.6	76.3	70.7	79.8	211.0	174.3	121.6	127.5	227.3	151.1	115.3	1572.7
1971	175.7	82.9	112.0	111.2	167.7	206.4	164.0	138.5	148.6	153.4	202.5	101.2	1764.1
1972	228.0	76.4	103.2	76.0	142.7	150.5	119.6	171.1	183.3	133.8	130.5	124.9	1640.0
1973	76.3	76.8	73.9	64.3	62.1	151.1	145.3	190.9	165.7	129.4	302.5	173.5	1611.8
1974	84.9	180.5	114.7	160.7	108.8	175.9	110.8	106.9	98.4	112.6	191.9	169.8	1615.9
1975	216.9	116.1	102.3	125.3	69.8	158.9	148.9	102.2	180.5	186.6	103.9	155.0	1666.4
1976	189.6	86.4	66.3	55.1	86.3	155.3	106.8	183.1	123.0	83.8	115.3	198.4	1449.4
1977	200.4	174.0	101.9	48.1	108.9	110.1	179.0	176.1	101.6	144.5	135.7	78.2	1558.5
1978	169.0	113.0	60.7	79.4	75.2	167.4	118.3	105.3	201.8	132.4	120.8	169.5	1512.8
1979	87.2	62.6	56.6	74.1	149.3	208.5	146.0	102.2	159.8	128.0	100.2	109.5	1384.0
1980	242.6	208.8	35.5	51.8	74.6	206.1	179.1	252.2	212.4	308.8	114.3	224.3	2110.5
1981	240.6	82.0	94.1	39.5	86.7	101.5	196.1	53.1	103.6	161.7	124.9	209.2	1493.0
1982	78.3	129.7	196.9	34.3	119.9	136.2	228.8	234.5	95.1	186.9	78.5	96.9	1616.0
1983	58.7	29.6	28.4	4.2	25.6	99.1	193.6	208.1	137.5	150.1	173.9	248.1	1356.9
1984	152.8	175.5	91.5	73.6	73.1	102.9	156.2	85.3	181.6	162.3	122.3	251.9	1629.0
MEAN	150.7	118.8	97.1	78.1	101.4	144.0	171.4	141.4	150.4	160.2	151.6	151.8	1611.6

CHAPTER III HYDROLOGICAL DATA AND RUNOFF ANALYSIS

The runoff observation has been continuing for the three water resources, i.e. the Wahig-Pamacsalan river, the Bayongan river and the Bayang river. The staff gauges have been installed at each station, and observation of water level has been made twice a day. The observation period of each station is as follows.

River	Reservoir	Installed Year
Wahig-Panacsalan	Malinao	1978
Bayongan	Bayongan	1984
Bayang	Capayas	1984

Meanwhile, the discharge measurements have been continuing since the staff gauges were installed. The number of the measurements is as follows.

River	Number of Measurements	Available Data
Wahig-Panacsalan	48	48
Bayongan	8	4
Bayang	8	8

The discharge measurement data are not sufficient to make the rating curve for estimation of river flow except the Wahig-Pamacsalan river. Therefore, the runoff analysis for three water sources was made by different methods, that is, one is the method by verification with observed discharge and the other is method by estimation with average runoff coefficient.

3.1 Rating Curve of Wahig River

The rating curve of the Wahig river at the proposed Malinao damsite was prepared by using the discharge measurement data observed at the national highway bridge in Poblacion Pilar. There are 48 points of measurement data presented in TABLE B3-1 and the correlation coefficients between staff gauge reading and discharge measurements are as follows;

Actual Discharge Measurements

Year	Number of Observation	Correlation Coefficient
1978	6	0.982
1979	9	0.978
1980	6	0.999
1981	8	0.988
1982	12	0.912
1983	1	-
1984	6	0.979
Total	48	0.907

But, most of data were measured in the lower stage of water level (less than one meter). Accordingly, the rating curve was prepared by the following rule;

- The lower stage curve will be made by discharge measurement data.
- The higher stage curve (higher than one meter) will be made by using the Manning formula.

3.1.1 Lower Stage Curve

The correlation coefficient between staff gauge reading and discharge is 0.907 as mentioned above. It can be recognized that there is no meaning on the statistics. The exponential regrassion equation of the rating curve for the lower stage was obtained as follows;

$$Q = 18.877 \cdot H^{4.051}$$

where; Q: runoff discharge (cu.m/sec)
H: gauge reading (m)

The above mentioned equation was applied to estimate the lower stage discharge by using daily gauge reading from 0 m to 0.955 m. The obtained rating curve for the lower stage is shown in FIGURE B3-1.

3.1.2 Higher Stage Curve

The cross section, profile and roughness coefficient are necessary to estimate the discharge flow of the higher stage water by using the Manning formula. There is a surveyed cross section at the gauging station under the national highway bridge as shown in FIGURE B3-2, but there is no profile in the neighborhood of the gauging station. Additionally, there are not observed data for the roughness coefficient. Therefore, the river bed slope was estimated at 1/300 by using the topographic map. The roughness coefficient was decided at 0.045, considering the conditions of river bed and vegetation of river.

The Manning formula is expressed as follows.

$$V = \frac{1}{n} R^{2/3} I^{1/2}$$

where; V: velocity of flow (m/sec)

R: hydraulic mean depth (m)

$R = A/P$ A: flow area (sq.m)

P: wetted perimeter (m)

I: energy gradient

Therefore, the discharge of flow can be calculated as follows;

$$Q = A V$$

where; Q: discharge of flow (cu.m/sec)

A: flow area (sq.m)

V: velocity of flow (m/sec)

The rating curve at a higher stage was calculated by using above-mentioned equation and the results are shown in TABLE B3-2.

3.1.3 Compounded Rating Curve

The two rating curves, i.e., the lower stage curve and higher stage curve, was compounded at gauge high of 0.955 m. It is a point of intersection for two rating curves. The compounded rating

TABLE B3-1 DISCHARGE MEASUREMENT DATA OF WAHIG-PAMACSALAN RIVER

Year	Month	Gauge Readings (m)	Discharge (cu.m/s)	Year	Month	Gauge Readings (m)	Discharge (cu.m/s)
1978	Feb.	0.60	1.55	1982	Jan.	0.59	2.79
	Mar.	0.64	2.29		Feb.	0.66	2.69
	May	0.62	1.96		Mar.	0.59	3.32
	Jul.	0.64	2.60		Apr.	0.48	1.53
	Aug.	0.54	0.96		May	0.49	1.13
	Nov.	0.57	1.39		Jun.	0.45	1.38
					Jul.	0.71	5.90
1979	Jan.	0.56	1.40		Aug.	0.63	2.91
	Mar.	0.49	0.44		Sep.	0.50	1.14
	Apr.	0.48	0.39		Oct.	0.58	2.44
	Jun.	0.57	1.66		Nov.	0.57	1.99
	Jul.	0.68	3.86		Dec.	0.48	1.02
	Sep.	0.53	1.20				
	Oct.	0.74	6.37	1983	Jul.	0.65	4.02
	Nov.	0.55	1.40				
	Dec.	0.62	2.60	1984	Mar.	0.50	1.93
					Apr.	0.58	2.48
1980	Feb.	0.89	15.87		May	0.44	0.85
	Mar.	0.53	1.15		Jun.	0.39	0.75
	Apr.	0.46	0.57		Jul.	0.42	0.84
	Jun.	0.50	0.86		Oct.	0.57	2.36
	Sep.	0.70	4.09				
	Nov.	0.78	8.53				
1981	Apr.	0.47	0.98				
	May	0.44	0.56				
	Jun.	0.54	1.59				
	Jul.	0.58	2.36				
	Aug.	0.42	0.53				
	Sep.	0.58	2.96				
	Oct.	0.73	5.82				
	Nov.	0.61	3.18				

TABLE B3-2 RATING CURVE AT HIGHER STAGE

Gauge Readings (m)	Discharge (cu.m/s)	Gauge Readings (m)	Discharge (cu.m/s)
0.955	15.67	2.00	90.28
1.00	17.71	2.05	95.10
1.05	20.09	2.10	100.01
1.10	22.61	2.15	105.03
1.15	25.26	2.20	110.16
1.20	28.04	2.25	115.40
1.25	30.95	2.30	120.75
1.30	34.05	2.35	126.21
1.35	37.28	2.40	131.78
1.40	40.63	2.45	137.48
1.45	44.11	2.50	143.31
1.50	47.73	2.55	149.26
1.55	51.46	2.60	155.31
1.60	55.32	2.65	161.47
1.65	59.29	2.70	167.74
1.70	63.37	2.75	174.11
1.75	67.57	2.80	180.63
1.80	71.89	2.85	187.25
1.85	76.31	2.90	193.98
1.90	80.85	2.95	220.82
1.95	85.51	3.00	207.76

FIGURE B3-1 GAGE HEIGHT-DISCHARGE CURVE

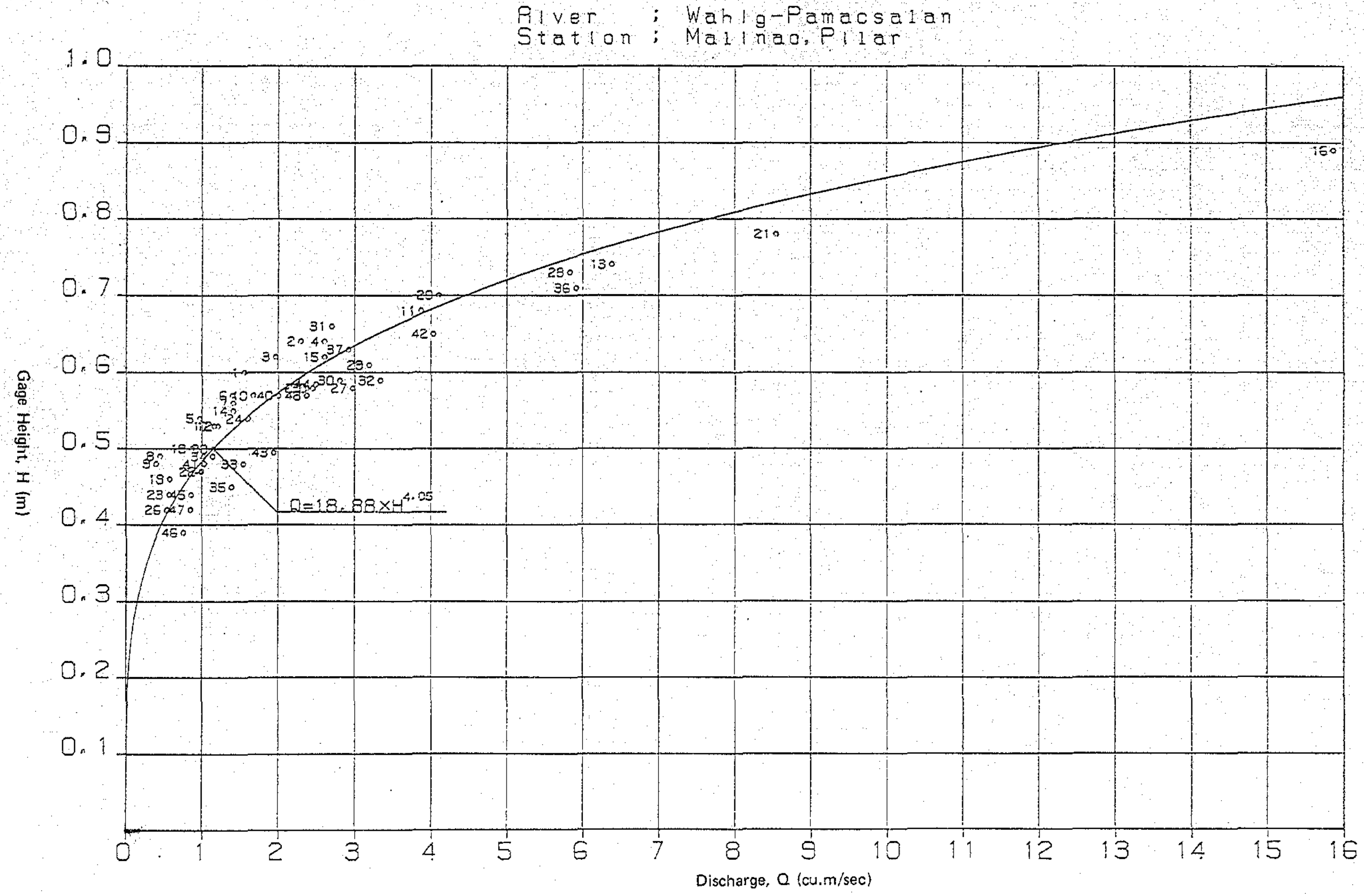


FIGURE B3–2 CROSS SECTION OF WAHIG RIVER AT NATIONAL HIGHWAY BRIDGE

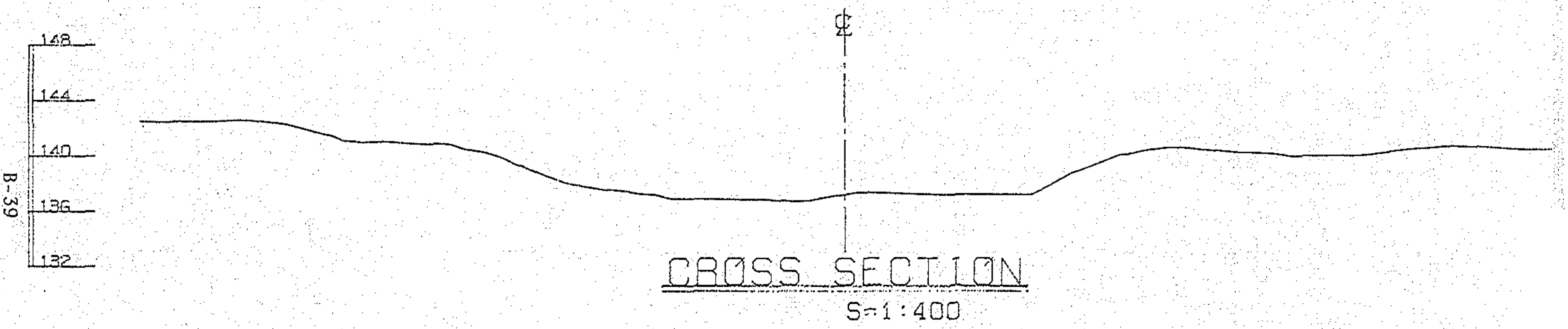
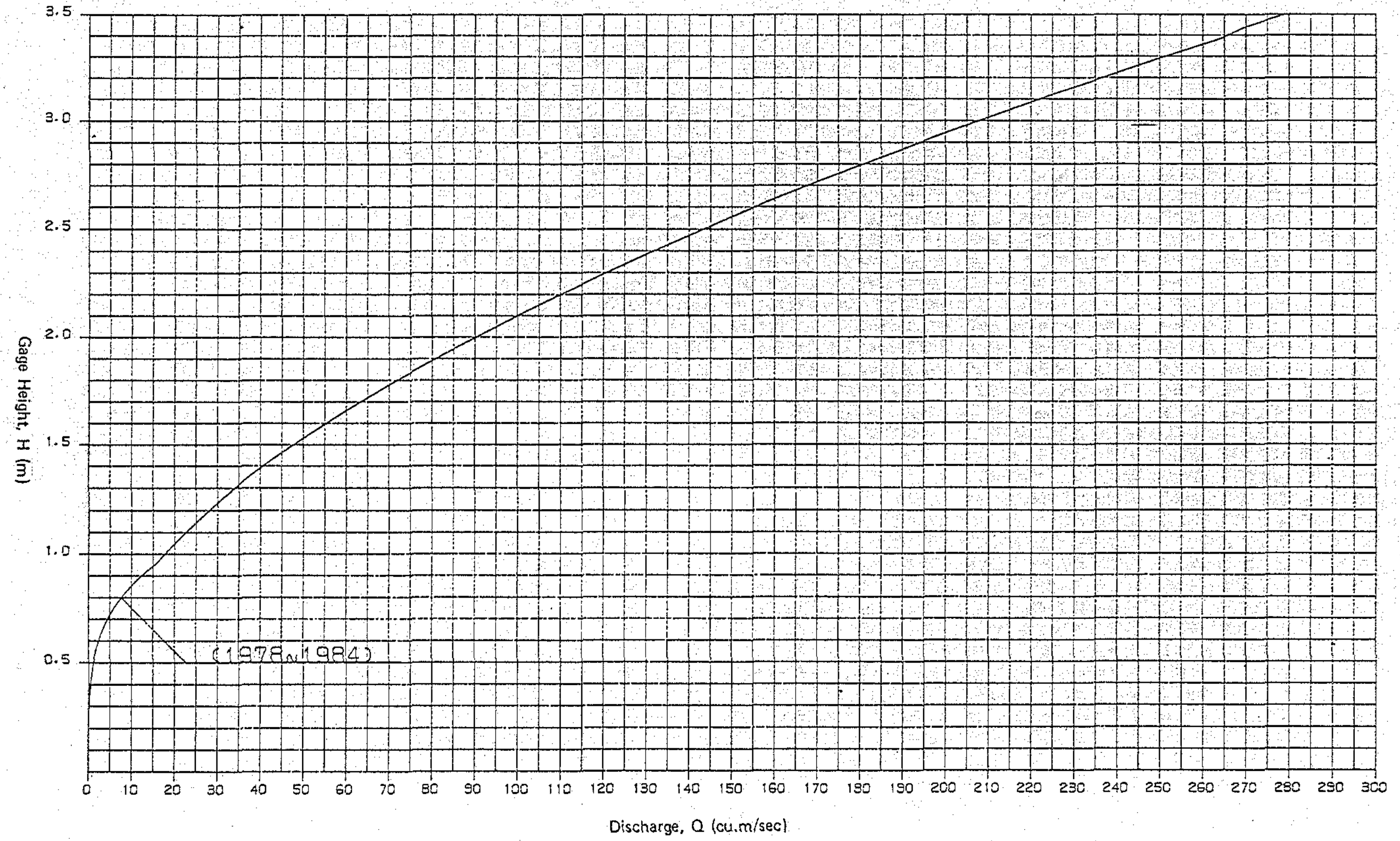


FIGURE B3-3 RATING CURVE AT MALINAO DAMSITE

River ; Wahig-Pamacsalan
Station ; Malinao, Pilar

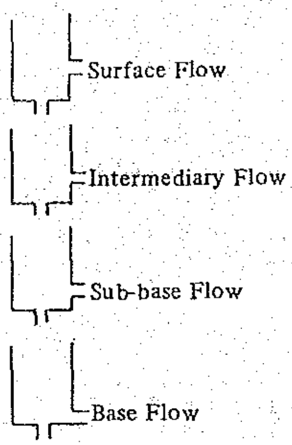


curve, in other words the rating curve of the Wahig-Pamacsalan river at the Malinao damsite, is shown in FIGURE B3-3.

3.2 Runoff Analysis for Wahig-Pamacsalan River

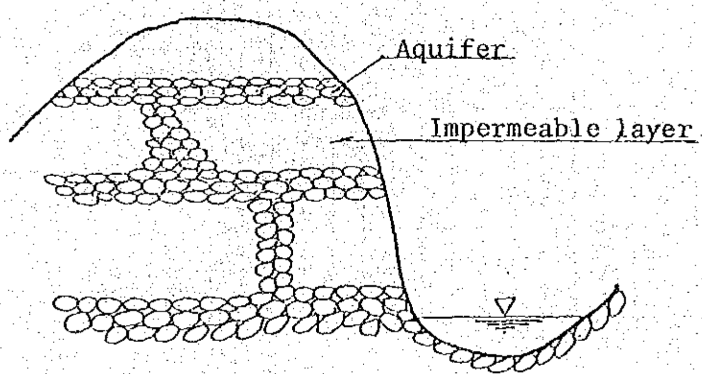
The discharge records of the Wahig-Pamacsalan river are available at the national highway bridge which is the immediate downstream of the proposed Malinao damsite during 7 years from 1978 to 1984.

The hydrological analysis should be made based on the long-term reliable records. The conceptual model for conversion of rainfall into runoff was adopted to synthesize the discharge of the Wahig-Pamacsalan river. The tank-model method, which was introduced by Dr. M. Sugawara in 1956, uses the conceptual use of simple mechanism consisting of linear reservoir (tank) with several holes. In this model, the rainfall pours into the top tank and then, the water will be supplied to the other tank including secondary tank from the bottom hold of the upper tank.



A part of the stored water in the each tank will be discharged to outside from side holes, and the other part will be transferred to a lower tank. The sum of discharge from side holes of each tank indicate the runoff discharge. It can be considered that the model will be met with the structure for the aquifer of the catchment area as shown below.

Conceptual Figure for Runoff Discharge



The rainfall becomes river flow, percolating to underground continuously and discharging from each aquifer. The discharge from side holes, which are located in each tank will be met with runoff each aquifer as shown in the above figure and the transfer of stored water from bottom hole to the lower tank will be met with percolation from each aquifer to lower aquifer. When the tank-model method is corresponded to the component of runoff mechanism, it can be considered that the top tank is met with surface flow, the secondary tank is met with intermediary flow and the third and fourth tanks are met with base flow.

The percolation from bottom hole of the lowest tank indicates the ground water or percolation to another catchment area, therefore, it can not return as surface flow in self catchment area.

The evapotranspiration will be considered at the uppermost tank and secondary tank additionally to the runoff discharge and percolation.

3.2.1 Establishment of the Tank Model

In the case of the Wahig-Pamacsalan river, the dimension of the model was determined by verification based on the actually observed rainfall and runoff between 1978 to 1984. The dimension was determined by try-and-error method comparing to the result and actual data. The determined coefficient of the model is shown in FIGURE B3-4.

The runoff coefficients of actual observed data and analysis are calculated as shown in the following table.

		Observed Data		Estimated Result	
Year	Areal Rainfall (mm)	Runoff Discharge (mm)	Runoff Coefficient	Runoff Discharge (mm)	Runoff Coefficient
1978	2,261.0	1,249.6	- 1/	1,037.7	0.456
1979	1,853.6	733.9	0.396	723.4	0.390
1980	2,460.6	1,280.1	- 2/	1,014.2	0.412
1981	1,927.0	1,045.5	0.543	927.5	0.481
1982	1,924.9	840.4	0.437	763.3	0.397
1983	1,935.4	734.4	0.381	795.5	0.413
1984	2,271.8	1,220.9	0.537	967.9	0.426
Average	2,090.6	915.0 3/	0.438 3/	888.9	0.425

Note: 1/ Missing data in December
2/ Missing data in December
3/ Average except Two year of 1978 and 1980

According to the result, since it was difficult to adjust the actual observed discharge and estimated discharge on the daily and monthly bases, in this case, the coefficient of model was determined on the basis of annual runoff discharge. Especially, since the surplus water of the Phase I Project area will be supplied to the Phase II Project area as available main water the resource, it should be considered that the runoff discharge of Phase I area will be not overestimated. Therefore, it is much better to decide the coefficient of tank-model on the basis of the annual discharge in the dry year.

According to the above table, since the runoff discharge in the dry year of 1979 and 1983 is close to the observed discharge, the assumed model is adopted as final proposed model.

3.2.2 Estimation of Runoff Discharge

The daily runoff discharge of the Wahig-Pamacsalan river was estimated for the period of 28 years from 1956 to 1984 by applying the areal rainfall to the determined tank-model. The estimated runoff discharge is summarized on the annual basis as shown in TABLE B3-3 and on the monthly basis in TABLE B3-4.

According to the result, the annual mean runoff discharge for 28 years is about 117 MCM, and the annual mean runoff coefficient is about 0.39. Additionally, the monthly mean runoff pattern is similar to the monthly mean rainfall pattern as shown in FIGURE B3-5. Therefore, it can be considered that the analysis is reasonable.

TABLE B3-3 ESTIMATED ANNUAL RUNOFF OF WAHIG-PAMACSALAN RIVER

Year	Annual Rinfall (mm)	Annual Runoff (mm)	(MCM)	Runoff Coefficient
1956[1/]	891.8	364.3	50.6	0.408
1957	2,294.7	973.1	135.1	0.424
1958	1,775.4	571.4	79.3	0.322
1959	2,160.3	699.8	97.1	0.324
1960	2,188.5	797.0	110.6	0.364
1961	2,234.8	766.5	106.4	0.343
1962	2,484.7	967.0	134.2	0.389
1963	2,287.0	973.4	135.1	0.426
1964	2,781.6	1,136.2	157.7	0.408
1965	2,189.0	865.5	120.1	0.395
1966	2,042.7	685.4	95.1	0.336
1967	2,301.4	910.4	126.4	0.396
1968	2,001.6	755.4	104.8	0.377
1969	1,697.2	572.0	79.4	0.337
1970	2,126.2	797.6	110.7	0.375
1971	2,494.9	985.5	136.8	0.395
1972	2,193.6	910.8	126.4	0.415
1973	2,150.8	894.7	124.2	0.416
1974	2,206.0	830.1	115.2	0.376
1975	2,235.8	872.6	121.1	0.390
1976	1,955.6	734.3	101.9	0.375
1977	2,185.7	799.3	110.9	0.366
1978	2,261.0	955.8	132.7	0.423
1979	1,853.6	709.1	98.4	0.383
1980	2,460.4	1,011.2	140.4	0.411
1981	1,927.0	926.9	128.7	0.481
1982	1,924.9	763.2	105.9	0.396
1983	1,935.4	799.5	111.0	0.413
1984	2,271.8	967.9	134.3	0.426
Average	2,165.1	844.0	117.1	0.391

Note: Average; from 1957 to 1984
1/ ; from September to December

FIGURE B3-4 ESTIMATED RUNOFF DISCHARGE OF WAHIG-PAMACSALAN RIVER

* STATION --- WAHIG-PAMACSALAN

UNIT ; MCM

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1956	-	-	-	-	-	-	-	-	-	9.35	12.13	20.94	
1957	15.61	13.00	7.56	11.44	5.53	14.17	21.84	8.84	7.63	16.59	7.48	5.36	135.07
1958	6.81	7.04	5.43	7.89	4.52	7.13	12.20	6.65	5.59	5.50	6.06	4.50	79.31
1959	11.66	5.66	9.17	3.53	4.20	3.54	20.82	10.44	7.62	6.19	6.45	7.86	97.13
1960	12.87	7.11	5.18	9.83	7.84	13.74	7.59	7.93	11.07	7.04	13.25	7.18	110.63
1961	9.37	7.79	4.53	4.34	5.27	6.25	16.34	8.25	10.09	17.50	8.33	8.35	106.39
1962	7.73	13.64	11.59	5.21	3.47	14.77	13.19	14.10	15.24	6.54	19.76	8.96	134.22
1963	18.39	9.90	12.40	7.78	4.22	5.44	10.66	15.25	14.26	19.41	11.60	5.79	135.10
1964	7.10	16.05	4.85	4.24	12.67	7.81	10.01	5.62	12.15	8.82	51.38	17.00	157.70
1965	19.98	8.84	10.07	5.71	4.49	15.71	10.06	8.55	7.15	13.02	5.44	11.12	120.14
1966	6.00	3.82	5.63	3.35	10.86	4.33	14.29	9.46	7.75	15.61	6.12	7.92	95.13
1967	21.18	13.83	17.53	4.59	4.63	9.12	9.26	6.31	8.25	7.78	9.47	14.42	126.37
1968	7.57	4.97	4.91	3.11	3.22	6.34	7.67	6.01	10.77	10.96	22.27	17.03	104.85
1969	5.28	3.33	7.30	4.29	5.62	5.12	10.22	6.71	6.49	6.42	6.48	12.14	79.40
1970	5.63	9.01	3.98	3.25	4.06	13.83	16.37	8.26	6.72	16.52	13.15	9.94	110.71
1971	12.14	7.74	7.00	4.28	12.95	19.30	13.85	8.57	10.37	14.90	18.80	6.91	136.79
1972	19.08	5.42	9.72	4.53	10.46	9.54	12.30	9.15	12.67	10.92	9.93	12.69	126.42
1973	6.03	4.00	4.04	2.63	3.43	9.02	9.18	10.51	11.46	16.73	30.64	16.51	124.18
1974	7.03	18.23	9.36	8.37	6.83	10.30	6.94	5.61	6.41	8.17	13.28	14.70	115.22
1975	22.06	10.39	7.10	7.30	3.89	9.77	11.29	8.49	13.65	10.59	6.06	10.55	121.12
1976	16.40	7.63	5.62	3.42	4.62	9.27	5.03	17.23	7.98	4.13	5.70	14.88	101.93
1977	14.74	19.84	7.55	3.35	5.95	6.82	10.61	11.25	7.27	7.94	7.97	7.67	110.95
1978	21.59	9.18	3.25	5.45	5.51	14.35	4.61	5.17	28.08	16.05	7.48	11.93	132.66
1979	8.34	3.22	4.71	4.63	7.41	20.74	14.33	5.25	7.64	6.89	6.56	8.70	98.42
1980	12.30	10.53	3.44	3.63	2.59	19.02	16.22	17.28	8.42	14.52	15.36	17.04	140.35
1981	29.73	9.01	4.86	4.61	3.55	7.81	8.12	3.73	7.63	14.10	8.84	26.66	128.65
1982	8.51	11.49	12.50	4.73	6.09	7.81	12.12	16.36	5.42	9.96	5.47	5.46	105.93
1983	4.81	2.33	2.50	1.84	1.77	5.18	19.35	16.58	12.65	16.60	8.11	19.23	110.97
1984	11.14	13.72	9.80	5.36	5.11	7.70	6.53	4.22	20.67	12.49	11.76	25.86	134.35
TOTAL	12.47	9.17	7.20	5.09	5.74	10.14	11.82	9.35	10.40	11.42	12.25	12.32	117.15

FIGURE B3-4 COEFFICIENT OF TANK MODEL

(Unit: mm)

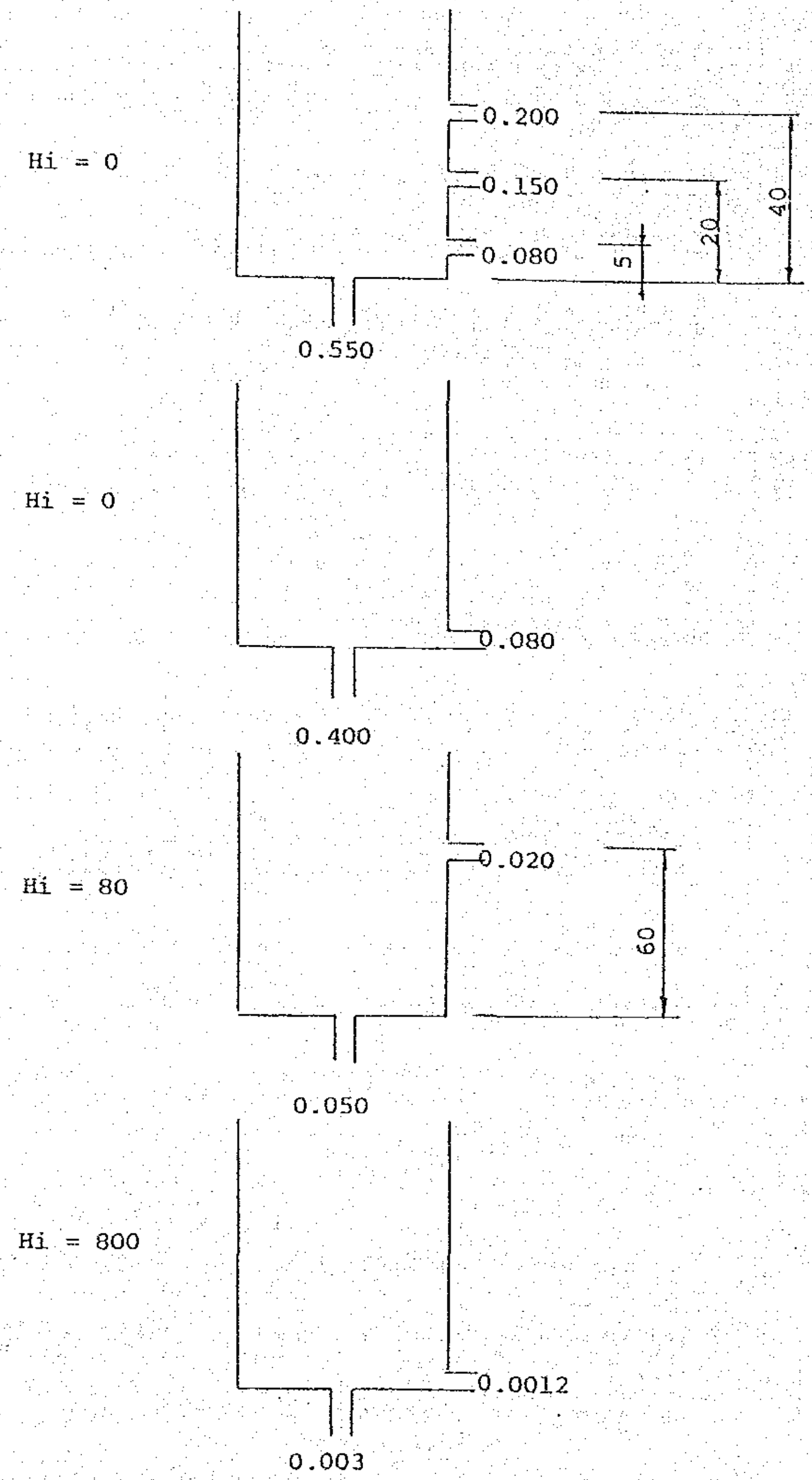
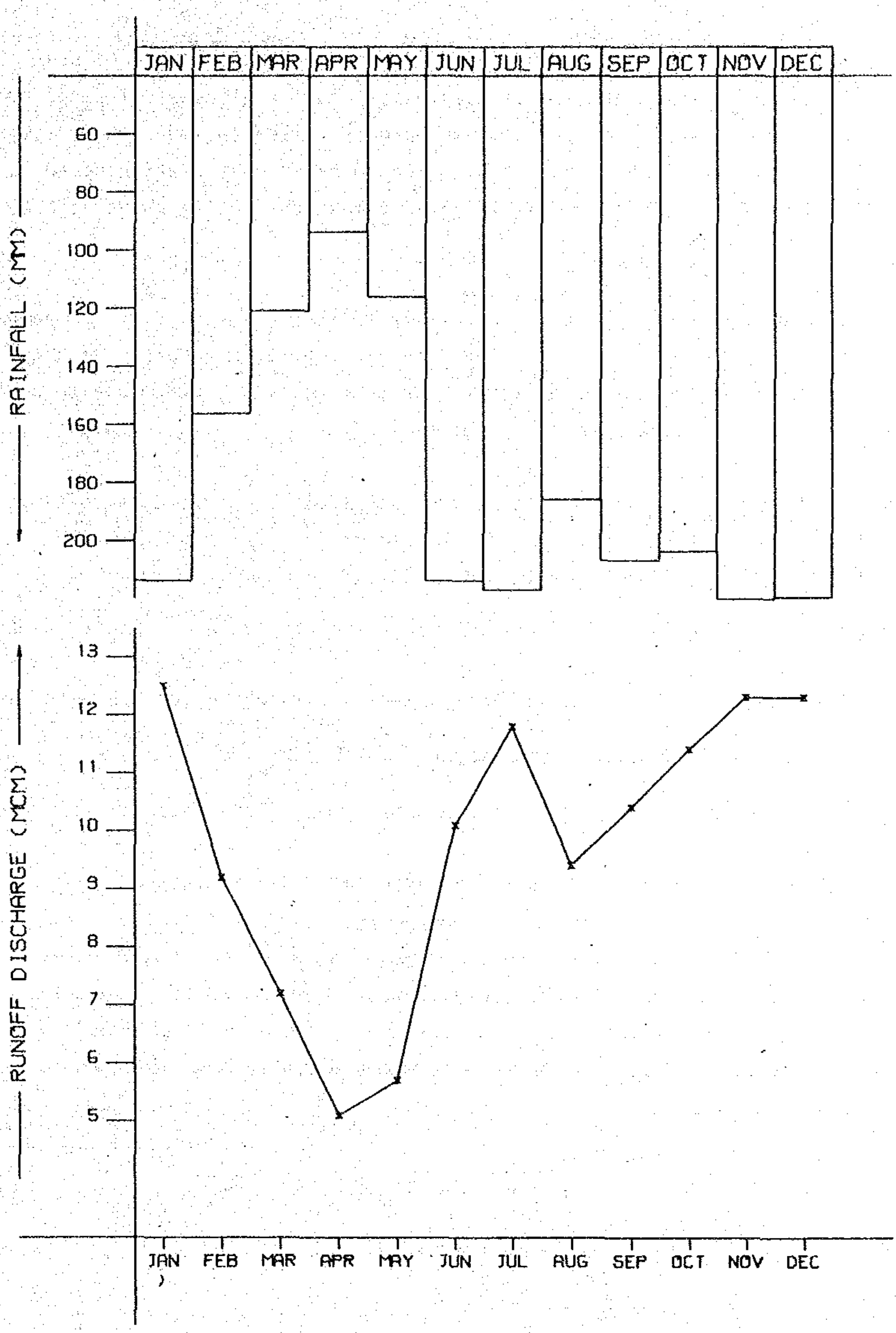


FIGURE B3-5 RAINFALL AND RUNOFF PATTERN FOR PHASE I AREA



3.3 Runoff Analysis for Phase II Project

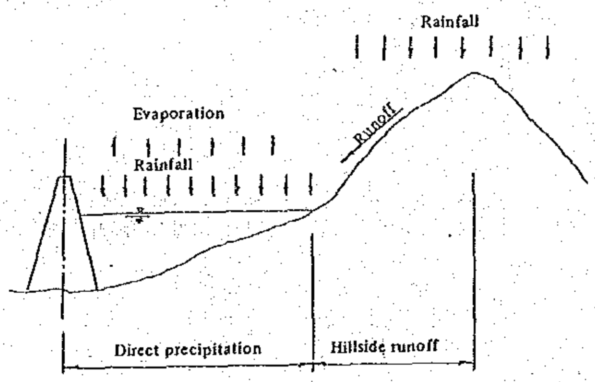
The discharge measurement data and staff gauge reading data are essential to analyze the runoff discharge. However, the staff gauge of the Bayongan river and Capayas river were installed in 1984, thus, eight times of discharge measurements have been made at each station up to 1985, and there are few available data to make the rating curve because of no flow or few flow.

Generally speaking, it is necessary to make a rating curve based on more than 20 points of observation data distributed moderately as the data of the Wahig-Pamacsalan river. Therefore, it is impossible to apply the analytical method for the estimation of runoff discharge.

It is very dangerous to make the analysis using poor data, because it is not reliable for the result of estimation. The simple method, as mentioned below, will be adopted to estimate the runoff discharge for above-mentioned reasons. The catchment areas and full water surface areas, after construction of dams, will become as follow;

Reservoir	Catchment Area (sq.km)	Full Water Surface Area (sq.km)
Bayongan	11.2	2.8
Capayas	13.1	0.6
Malinao	138.8	1.4

It is clear that the ratio of the catchment area and full water surface area is greater than that of the Malinao reservoir. In this case, it should be considered that the runoff mechanism would be separated into direct inflow to reservoir and hillside runoff as illustrated below.



The direct precipitation contributes to the inflow into the reservoir directly, and on the other hand, the evaporation loss from reservoir surface should be considered. Therefore, the reservoir inflow by direct precipitation can be estimated by the following equation;

In (direct) = (P - Evap) x (Water surface)/1,000

where;	In :	reservoir inflow (cu.m)
	P :	precipitation (mm/day)
	Evap. :	evaporation (mm/day)
	water surface:	mean water surface between full water and low water level (sq.m)

The rainfall on the hilly or mountainous area contributes to the runoff discharge by some ratio, which is generally called as runoff coefficient. Therefore, if there were actual observed data for the runoff coefficient, it will be easy to estimate the hillside runoff. Unfortunately, there are no observation data for Phase II area at all, thus the annual mean runoff coefficient of the Malinao reservoir was adopted for the calculation of runoff discharge. The hillside runoff can be estimated by the following equation;

In (indirect) = P · C · Ar/1,000

where;	In:	runoff discharge (cu.m)
	P :	precipitation (mm/day)
	C :	runoff coefficient of 0.4
	Ar:	residual catchment area (sq.m)

The water surface is mean area between full water and low water level for safety. The water surface and residual catchment area were estimated as follow;

Reservoir	Water Surface (sq.km)	Residual Catchment Area (sq.km)
Bayongan	1.85	9.35
Capayas	0.40	12.70

The total inflow from the catchment area will be integrated by direct and indirect inflows which were already mentioned.

3.3.1 Rainfall Data for Runoff Analysis

Both catchment areas of the Bayongan and Capayas dams are located in the elevation of 50 m to 150 m above sea level, which is a similar elevation of the Dagohoy station, and additionally, there is no rain gauge station except Gov. Boyles station which was installed in 1984.

The rainfall data at Gov. Boyles have been observed during only nine months, April to December in 1984. It is not sufficient for observation data to consider the correlation analysis between the Dagohoy station and Gov. Boyles station. Accordingly, the rainfall data at the Dagohoy station were adopted as the areal rainfall for the both catchment areas.

3.3.2 Runoff Analysis

The runoff discharges from both catchment areas were estimated by applying the rainfall data to the above-mentioned rule. The summary table of monthly runoff discharge for both catchment areas is shown in TABLE B3-5, TABLE B3-6 and FIGURE B3-6. The result of computation is summarized as follows.

Item	Bayongan (MCM)	Capayas (MCM)
Annual mean runoff	10.3	11.0
Annual maximum runoff	16.4	17.2
Annual minimum runoff	6.9	7.5

TABLE B3-5 ESTIMATED DISCHARGE FOR BAYONGAN RESERVOIR

UNIT ; MCM

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1956	0.925	0.157	0.550	1.077	1.540	0.842	1.260	0.0	0.812	0.494	1.031	2.366	11.054
1957	0.956	0.952	0.490	0.740	0.210	1.598	2.103	0.859	0.668	1.619	0.607	0.412	11.214
1958	0.624	0.522	0.348	0.515	0.304	0.771	1.276	0.720	0.644	0.342	0.788	0.282	7.136
1959	1.364	0.400	1.210	0.063	0.397	0.551	2.291	1.049	0.867	0.552	0.619	0.761	10.124
1960	1.332	0.455	0.249	0.862	0.625	1.453	0.852	0.418	1.273	0.777	1.334	0.757	10.387
1961	0.863	0.469	0.230	0.491	0.297	0.494	2.126	0.599	1.236	2.052	0.920	0.888	10.665
1962	0.595	1.485	0.895	0.100	0.675	1.120	1.184	1.508	1.529	0.599	2.066	0.778	12.534
1963	1.598	0.763	1.078	0.272	0.024	0.215	1.661	1.140	1.475	1.696	0.830	0.352	11.104
1964	0.666	1.630	0.074	0.348	1.863	0.490	1.041	0.256	1.388	0.873	5.046	1.330	15.005
1965	1.884	0.855	0.683	0.319	0.037	1.680	0.768	0.852	0.737	1.050	0.576	0.915	10.356
1966	0.411	0.263	0.120	0.303	1.083	0.282	1.916	1.089	0.512	1.809	0.503	0.919	9.210
1967	2.271	1.331	1.308	0.230	0.557	0.657	0.712	0.544	0.948	0.721	0.911	0.979	11.169
1968	0.560	0.230	0.373	0.017	0.012	0.735	0.582	0.540	1.086	1.337	2.137	1.650	9.259
1969	0.124	0.036	0.415	0.072	0.478	0.738	1.267	0.608	0.798	0.602	0.624	1.179	6.941
1970	0.361	0.671	0.138	0.078	0.193	1.812	1.318	0.711	0.773	2.004	1.062	0.587	9.708
1971	1.329	0.223	0.563	0.582	1.225	1.700	1.211	0.872	1.012	1.082	1.675	0.430	11.904
1972	2.012	0.144	0.469	0.133	0.946	1.030	0.706	1.260	1.420	0.846	0.778	0.753	10.497
1973	0.163	0.148	0.113	0.022	0.003	1.021	0.963	1.528	1.207	0.831	2.955	1.347	10.301
1974	0.229	1.445	0.594	1.111	0.483	1.393	0.565	0.497	0.388	0.551	1.572	1.291	10.119
1975	1.864	0.639	0.477	0.690	0.079	1.159	1.319	0.781	1.352	1.125	0.542	0.847	10.874
1976	1.521	0.320	0.197	0.049	0.255	0.989	0.690	1.761	0.596	0.215	0.343	1.791	8.727
1977	1.823	1.476	0.311	0.011	0.830	0.620	1.380	1.457	0.660	0.825	1.005	0.251	10.649
1978	1.529	0.695	0.141	0.321	0.169	1.747	0.868	0.392	1.106	0.833	0.577	0.972	9.350
1979	0.606	0.186	0.148	0.342	0.892	1.628	1.161	0.338	0.744	0.617	0.505	0.632	7.799
1980	1.121	1.654	0.124	0.314	0.313	1.035	1.768	3.789	1.421	2.329	0.953	1.552	16.373
1981	1.158	0.455	0.294	0.198	0.325	0.376	1.659	0.502	1.008	1.510	0.633	2.286	10.404
1982	0.396	0.723	1.089	0.028	0.370	0.779	0.767	1.399	0.697	1.363	0.296	0.497	8.404
1983	0.114	0.036	0.005	0.0	0.022	0.590	1.707	0.738	1.243	1.171	0.663	1.554	7.843
1984	0.888	1.300	0.772	0.238	0.344	0.310	0.288	0.131	1.503	1.150	0.792	2.218	9.934
MEAN	1.010	0.678	0.464	0.328	0.502	0.959	1.221	0.941	1.004	1.068	1.115	1.054	10.285

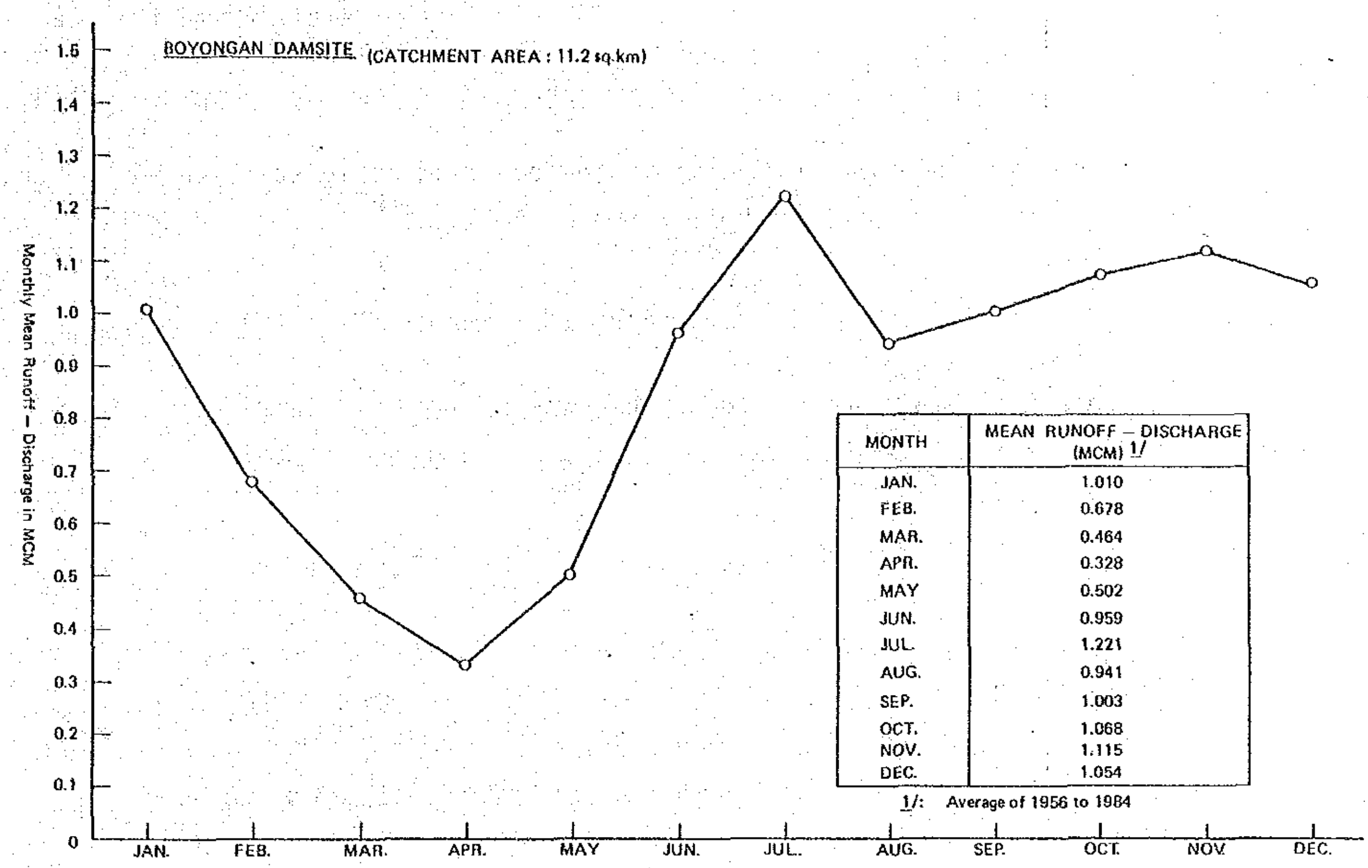
TABLE B3-6 ESTIMATED RUNOFF DISCHARGE FOR CAPAYAS RESERVOIR

UNIT ; MCM

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1956	0.973	0.183	0.624	1.181	1.626	0.914	1.350	0.0	0.864	0.564	1.085	2.471	11.835
1957	1.043	1.006	0.541	0.773	0.248	1.674	2.206	0.944	0.719	1.673	0.660	0.478	11.965
1958	0.698	0.576	0.397	0.556	0.352	0.846	1.354	0.806	0.697	0.385	0.870	0.328	7.865
1959	1.427	0.445	1.282	0.085	0.467	0.618	2.389	1.112	0.948	0.619	0.681	0.825	10.898
1960	1.404	0.513	0.296	0.909	0.667	1.536	0.923	0.477	1.321	0.843	1.417	0.824	11.130
1961	0.954	0.538	0.284	0.559	0.359	0.548	2.215	0.656	1.296	2.136	0.978	0.958	11.481
1962	0.663	1.566	0.987	0.115	0.712	1.234	1.281	1.598	1.614	0.686	2.118	0.857	13.431
1963	1.700	0.816	1.179	0.285	0.032	0.249	1.757	1.240	1.553	1.785	0.900	0.398	11.894
1964	0.739	1.721	0.099	0.418	1.970	0.565	1.107	0.296	1.453	0.953	5.087	1.391	15.799
1965	1.967	0.918	0.730	0.381	0.050	1.759	0.830	0.927	0.802	1.109	0.647	1.006	11.126
1966	0.486	0.306	0.151	0.345	1.154	0.323	2.005	1.173	0.567	1.898	0.564	0.998	9.970
1967	2.359	1.402	1.376	0.261	0.588	0.695	0.781	0.598	1.013	0.777	0.996	1.031	11.877
1968	0.650	0.270	0.434	0.023	0.017	0.808	0.621	0.590	1.133	1.411	2.171	1.724	9.852
1969	0.168	0.048	0.439	0.095	0.510	0.805	1.337	0.673	0.875	0.656	0.700	1.232	7.538
1970	0.413	0.753	0.174	0.105	0.223	1.887	1.411	0.754	0.823	2.095	1.124	0.660	10.422
1971	1.428	0.261	0.623	0.620	1.328	1.819	1.287	0.958	1.085	1.150	1.775	0.487	12.821
1972	2.097	0.175	0.516	0.171	1.014	1.110	0.732	1.364	1.524	0.902	0.857	0.792	11.254
1973	0.180	0.181	0.144	0.031	0.004	1.116	1.038	1.625	1.304	0.855	3.050	1.414	10.942
1974	0.278	1.503	0.658	1.230	0.573	1.446	0.614	0.559	0.452	0.628	1.643	1.362	10.946
1975	1.954	0.681	0.509	0.781	0.097	1.228	1.362	0.824	1.418	1.210	0.612	0.919	11.595
1976	1.605	0.350	0.223	0.066	0.302	1.060	0.768	1.825	0.632	0.249	0.381	1.852	9.313
1977	1.880	1.586	0.354	0.015	0.907	0.672	1.465	1.528	0.709	0.856	1.077	0.267	11.316
1978	1.579	0.722	0.155	0.357	0.206	1.803	0.928	0.448	1.175	0.916	0.615	1.035	9.939
1979	0.678	0.220	0.173	0.381	0.938	1.696	1.229	0.377	0.794	0.674	0.544	0.703	8.407
1980	1.215	1.686	0.154	0.378	0.345	1.150	1.829	3.875	1.468	2.394	1.038	1.623	17.155
1981	1.213	0.506	0.319	0.219	0.348	0.413	1.741	0.531	1.041	1.591	0.681	2.326	10.929
1982	0.445	0.786	1.147	0.038	0.412	0.822	0.815	1.461	0.746	1.445	0.326	0.532	8.975
1983	0.154	0.048	0.007	0.0	0.030	0.636	1.810	0.793	1.279	1.225	0.704	1.609	8.295
1984	0.966	1.367	0.841	0.286	0.355	0.335	0.307	0.152	1.527	1.200	0.830	2.271	10.437
MEAN	1.080	0.729	0.511	0.368	0.546	1.026	1.293	1.006	1.063	1.134	1.177	1.116	10.985

FIGURE B3-6 ESTIMATED MONTHLY MEAN RUNOFF DISCHARGE

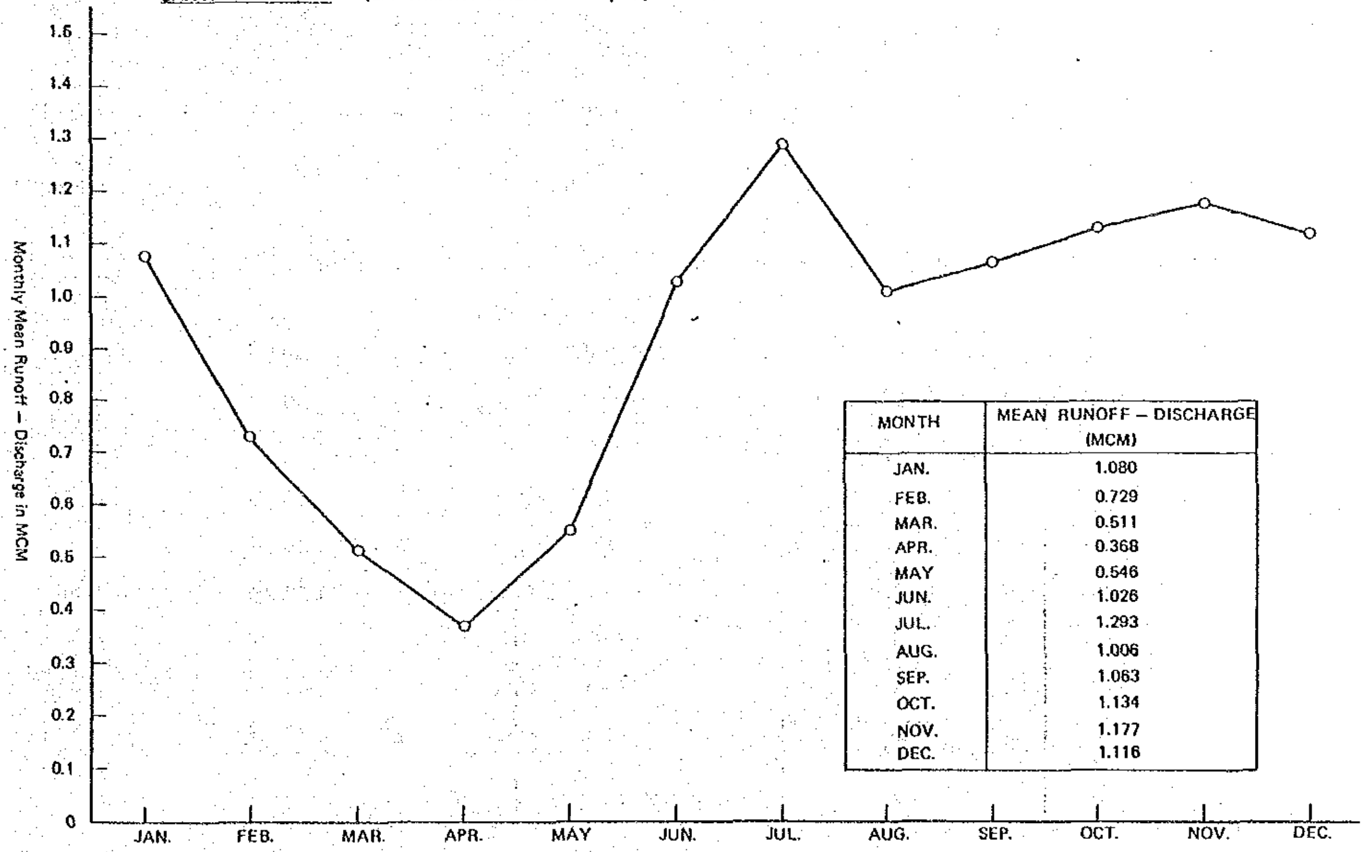
BOYONGAN DAMSITE (CATCHMENT AREA : 11.2 sq.km)



MONTH	MEAN RUNOFF – DISCHARGE (MCM) 1/
JAN.	1.010
FEB.	0.678
MAR.	0.464
APR.	0.328
MAY	0.502
JUN.	0.959
JUL.	1.221
AUG.	0.941
SEP.	1.003
OCT.	1.068
NOV.	1.115
DEC.	1.054

1/: Average of 1956 to 1984

CAPAYAS DAMSITE (CATCHMENT AREA : 13.1 sq.km)



MONTH	MEAN RUNOFF – DISCHARGE (MCM)
JAN.	1.080
FEB.	0.729
MAR.	0.511
APR.	0.368
MAY	0.546
JUN.	1.026
JUL.	1.293
AUG.	1.006
SEP.	1.063
OCT.	1.134
NOV.	1.177
DEC.	1.116

CHAPTER IV FLOOD ANALYSIS

There are three methods to approach the flood analysis based on the past flood data in the Bohol Island as follows;

- The estimation by probable rainfall based on long term observed rainfall.
- The estimation by traces of the past flood.
- The estimation by probable maximum precipitation (PMP).

4.1 Probable Rainfall

It is only the Dagohoy station that has reliable data to meet the analysis of the probable rainfall in Bohol Island, because another stations have not been observed continuously for a long period. There are 28 year data at the Dagohoy station since 1956. The maximum daily rainfall in each year is shown as follows;

Maximum Daily Rainfall in Each Year for Dagohoy Station (Period : 1957 - 1984)

Year	Month	Day	Rainfall (mm)	Year	Month	Day	Rainfall (mm)
1957	Feb.	1	124.5	1971	Oct.	20	95.3
1958	Jul.	8	100.1	1972	Dec.	3	103.4
1959	Jan.	8	96.3	1973	Nov.	18	174.1
1960	Apr.	21	88.9	1974	Feb.	12	148.6
1961	Jul.	3	69.8	1975	Aug.	21	94.0
1962	Nov.	27	150.4	1976	Jan.	23	100.8
1963	Nov.	9	81.8	1977	Jan.	26	102.9
1964	Nov.	19	513.3	1978	Jan.	2	114.3
1965	Jan.	10	86.4	1979	May	11	80.5
1966	Oct.	10	70.3	1980	Oct.	4	84.6
1967	Mar.	8	73.6	1981	Dec.	1	103.9
1968	Dec.	2	159.2	1982	Aug.	17	114.9
1969	Mar.	8	59.6	1983	Oct.	20	61.0
1970	Oct.	27	76.2	1984	Sep.	2	127.8

The stochastic analysis for the daily rainfall was made by using above data, and the result is summarized as follows.

Return Periods (year)	Probable Rainfall (mm/day)
5	144.1
10	174.6
50	247.6
100	281.1
200	316.0
500	364.6
1,000	403.5

In general, the daily rainfall for designing the spillway capacity should meet those rainfall corresponding to the 1,000-years return period, thus, the daily rainfall of 403.5 mm is adopted as design rainfall in the project.

4.1.1 Rational Method

The Rational Method can be expressed as follows by applying the assumptions of runoff coefficient and mean intensity of precipitation within the time of concentration of flood.

$$Q = 0.2778 \cdot f \cdot \gamma t \cdot A$$

where, Q: peak flood discharge in cu.m/sec

f: runoff coefficient 0.9

A: catchment area in sq.km

γt: mean intensity of precipitation within time of concentration of flood, which is expressed as follows;

$$t = \frac{R_{24}}{24} \left(\frac{24}{T} \right)^{0.6}$$

R_{24} : design rainfall of 403.5 mm/day

T : time of concentration of flood in hr, which is expressed as follows;

$$T = 150 \quad A^{0.22} \quad \gamma t^{-0.35} = 0.8 \text{ hr}$$

Accordingly, the mean intensity of precipitation within time of concentration of each probable rainfall can be calculated as follows;

$$\gamma t = \frac{403.5}{24} \cdot \left(\frac{24}{0.8} \right)^{0.6} = 130 \text{ mm/hr}$$

The design flood of spillway based on probable rainfall would be calculated as follows;

Dam	Catchment Area (sq.km)	Design Flood (cu.m/sec)	Specific Runoff Discharge (cu.m/sq.km)
Bayongan	11.2	364	32.5
Capayas	14.6	475	32.5

4.2 Traces of Past Flood

It is only available at the Loboc hydropower station in which the traces of the past flood are observed correctly. The two big floods had occured in the Bohol Island, since it has been constructed, and those detailed data can be shown as follows;

Item	The 1st	The 2nd
Date of Occurrence	Nov. 22, 1964	Sep. 2, 1984
Highest Flood Level (1) (on the wall of Intake)	WL 27.6 m	WL 25.8 m
Elevation of the top of weir (2)	EL 20.7 m	EL 20.7 m
Overflow Head, H = (1) - (2)	6.90 m	5.10 m
Top Length of the Weir (L)	58.3 m	58.3 m
Computed Discharge ($Q = 2.1 \cdot L \cdot H^{3/2}$)	2,219 cu.m/sec	1,410 cu.m/sec
Catchment Area	583 sq.km	583 sq.km
Specific Runoff, q = Q/A	3.81 (cu.m/s/sq.km)	2.42 (cu.m/s/sq.km)

Accordingly, the design flood of spillway based on the traces of the past flood is 2,219 cu.m/sec, equivalant to the specific runoff of 3.81 cu.m/sec/sq.km.

4.3 Probable Maximum Precipitation (PMP)

It is only available at the Tagbiralan station that has climatic data to estimate the PMP such as dew point.

4.3.1 Historical Storm

The storms rainfall heavier than 100 mm/day is shown in the following table;

Date	Daily Rainfall (mm)
Nov. 19, 1964	513.3 1/
Oct. 20, 1971	158.1
Nov. 19, 1964	140.5
Nov. 19, 1968	125.3
Jan. 2, 1978	116.9
Apr. 25, 1974	115.5
Nov. 11, 1980	112.0
Dec. 3, 1972	107.7
Oct. 14, 1974	107.0
Jun. 5, 1969	103.6

Note: 1/: The biggest daily rainfall at the Dagohoy station.

4.3.2 Estimation of Precipitable Water for Each Storm

The estimation of the dew point was made based on the temperature and vapor pressure by using the FIGURE B4-1 and the precipitable water was calculated based on the above dew point by using FIGURE B4-2. The result is shown in TABLE B4-1.

4.3.3 Adjustment Factor and PMP

According to the result of the precipitable water, the maximum precipitable water can be obtained at 85 mm/day. The Probable Maximum Precipitation (MPM) is generally estimated as follows;

$$Pmax = Pac \cdot Fa$$

where, Pmax : probable maximum precipitation,
Pac : areal average value of precipitation during the storm,
Fa : adjustment factor,

$$= \frac{\text{precipitable water at maximum dew point of the zone}}{\text{precipitable water at the representative dew point of the storm}}$$

According to the result shown in TABLE B4-2, the adjustment factor and PMP will be calculated as follows;

Date	Rainfall (mm)	Precipitable Water (mm)	Maximum Precipitable W. (mm)	Adjustment Factor	PMP (mm)
Nov. 19, 1964	140.5	61	85	1.39	195
Nov. 19, 1968	125.3	62	85	1.37	172
Jan. 2, 1978	116.9	57	85	1.49	174
Apr. 25, 1974	115.5	75	85	1.13	131
Oct. 14, 1974	107.0	76	85	1.12	120
Jun. 5, 1969	103.6	85	85	1.00	104

The PMP is obtained at 195 mm which is calculated by the storm on Nov. 19, 1964.

4.3.4 Probable Maximum Flood (PMF)

It can be observed that the Probable Maximum Flood will be small as shown below, because the PMP is less than probable rainfall which was obtained by statistical method.

PMP : 195.0 mm/day

Stochastic rainfall
in 1,000 years return period : 403.5 mm/day

TABLE B4-1 PRECIPITABLE WATER ABOVE SEA LEVEL

Date	Rainfall (mm)	Maximum Temperature (C°)	Minimum Temperature (C°)	Maximum R. Humidity (%)	Minimum R. Humidity (%)	Average Dew Point (C°)	Precipitable Water (mm)
Oct. 20, 1971	158.1	27.8	22.2	-	-	-	-
Nov. 19, 1964	140.5	26.6	21.1	95	80	21.8	61
Nov. 19, 1968	125.3	26.7	18.9	99	90	22.0	62
Jan. 2, 1978	116.9	26.1	18.8	98	80	20.8	57
Apr. 25, 1974	115.5	30.5	21.5	98	81	24.2	75
Nov. 11, 1980	112.0	32.7	22.7	-	-	-	-
Dec. 3, 1972	107.7	26.1	22.1	-	-	-	-
Oct. 14, 1974	107.0	32.0	23.5	99	68	24.3	76
Jun. 5, 1969	103.6	33.9	22.9	98	66	25.3	85

FIGURE B4-1 VARIATION OF VAPOUR PRESSURE WITH TEMPERATURE AT PERCENTAGES OF SATURATION

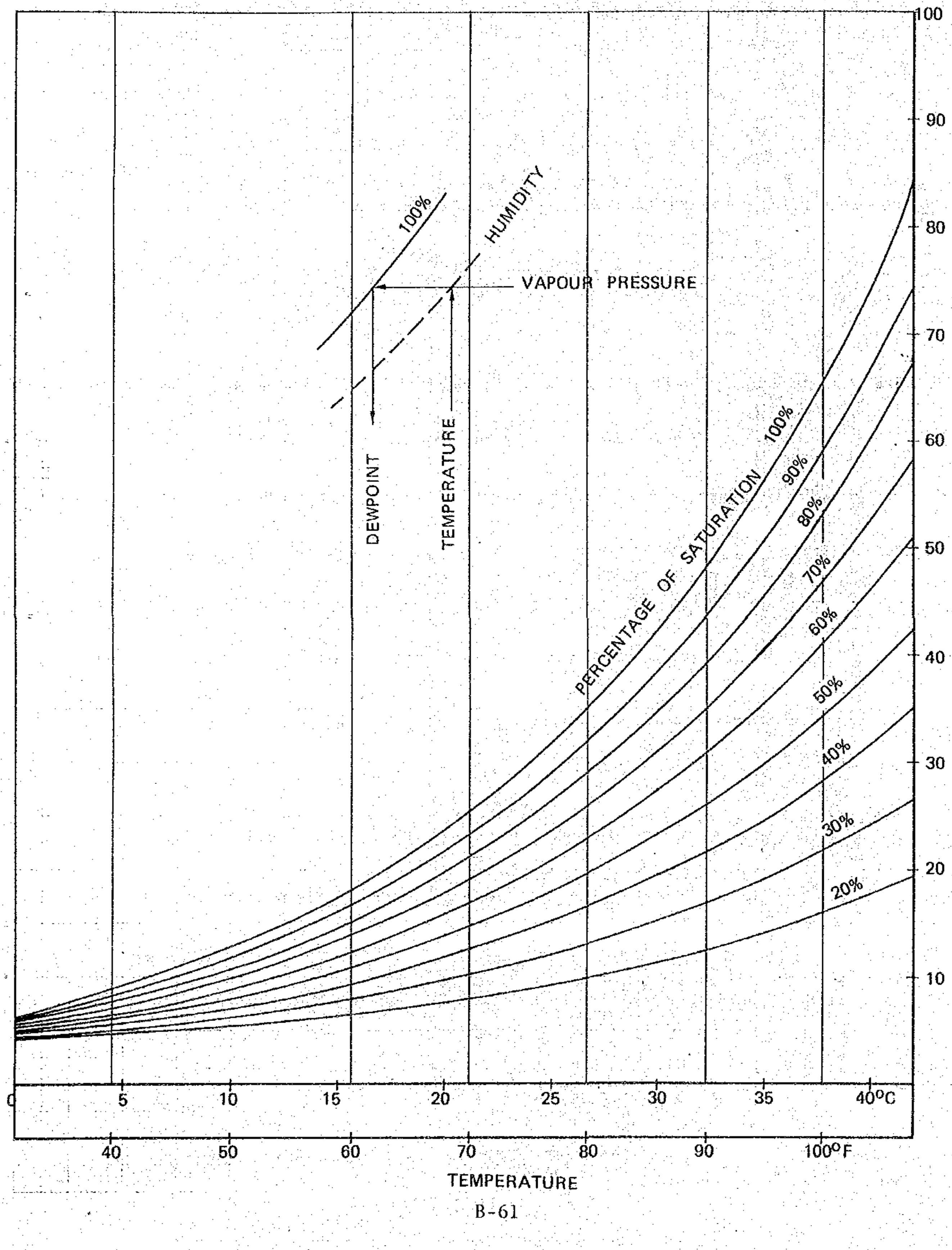


FIGURE B4-2 NOMOGRAM FOR PRECIPITABLE MOISTURE IN ATMOSPHERIC MASS BETWEEN 1,000 MB SURFACE AND VARIOUS ALTITUDE

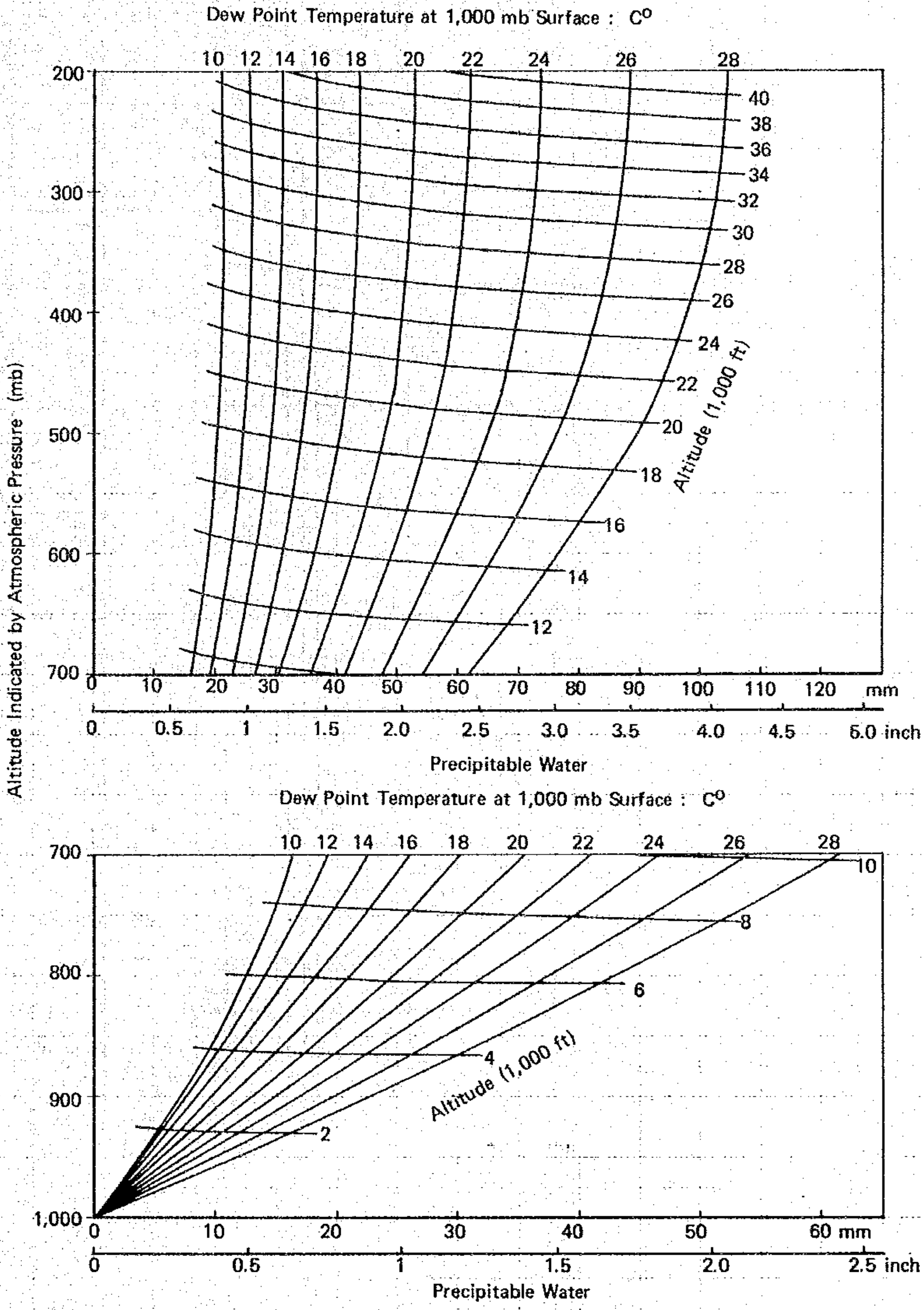
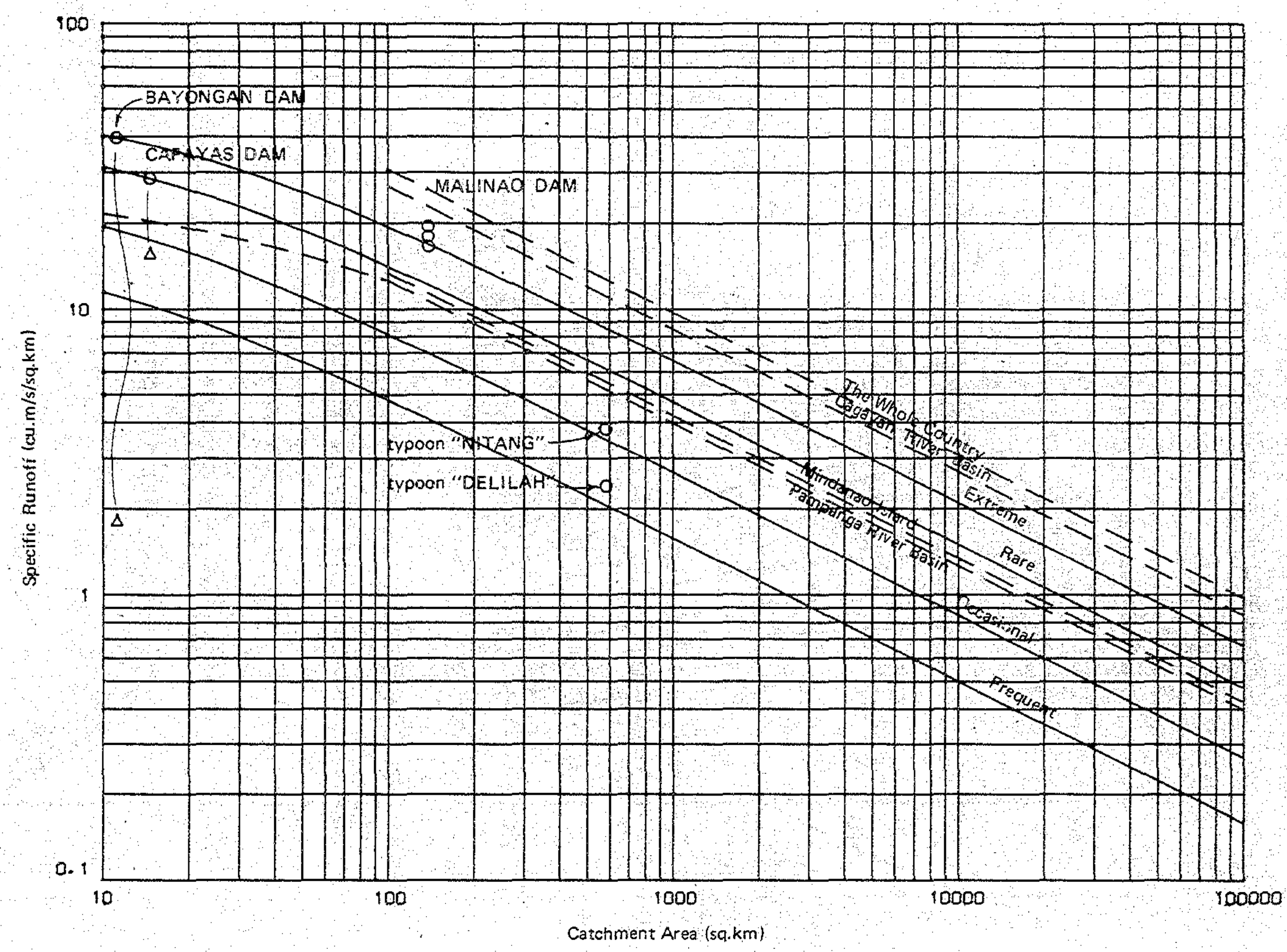


FIGURE B4–3 SPECIFIC RUNOFF ON SPILLWAY DESIGN



ANNEX C. GEOLOGY AND CONSTRUCTION MATERIALS

ANNEX C GEOLOGY AND CONSTRUCTION MATERIALS

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CHAPTER I INTRODUCTION

The feasibility study of Phase II was required urgently and requested to the Japanese government by Philippine government as the main canal of Phase I project is to be constructed taking into consideration surplus water conveyance to Phase II project.

A reconnaissance surface geological mapping covering the damsites and the reservoir areas was initiated by the feasibility study team. The investigation of bore holes drilled at the two damsites and reservoir areas was carried out to establish the depth of the over-burden layer, weathered rock layer and fresh rock layer. Test pits were excavated, sampled and tested to assess the usability of the construction materials at the two damsites.

CHAPTER II GEOGRAPHY

2.1 General

Bohol island is in the Central Visayas. It is approximately covering an area of 3,932 square kilometers. It is bounded on the north by the Camotes Sea, and on the south by the Mindanao Sea.

Bohol is a broad southward plunging syncline with the major axis trending northeast-southwest. At the northern-central and southern portion of the island, undulating to high rolling sedimentary and calcareous hills and plains covers approximately 70 percent of the island.

The famous chocolate hills in Carmen, karst plain in Cortez, high rolling hills and ridges in Sevilla, Anda Peninsula, Sangungan Mountain and undulating sedimentary rocks from Buenavista to San Miguel are some of the formation that dominates the lithologic units. Extensive conglomerate occurs at Tubigon, pure limestone in Balilihane, limy shale in Batuan. Limestone of different ages exhibits karstic topography and are sometimes structurally arranged by NE-SW faults. Sierra Bullones limestone at Mount Mayama reached a height of 827 meters. Low rolling diorite, metamorphic and ultrabasic hills are sometimes associated with high and steep volcanic hills, covering approximately 25 percent of the island, which are exposed in the northeastern and northwestern part of the island. Agglomerate rises as plateau at the central part of the island. Gently rolling metamorphic hills in Ubay are overlain by high steep andesitic to basic Malibalibod Hills.

Main rivers like the Abatan, Loboc, Panapanan and Cacotatan dissect the limy shale and sandstone formation along its lithologic contact and beddings.

Generally, the island is vegetated with cogon, shrubs and coconuts except in the extensive limestone areas that are thickly vegetated with forest trees.

The coast is fairly regular and smooth and usually fringed with coral reefs. Broad alluvial deposits along Talibon to Ubay coast typify the initial stage of an emerging coast line.

2.2 Project Area

The topography of the project area is characterized by rolling to hilly surface undulation which is characterized by extensive sequence of sedimentary formation mainly siltstone, mudstone and sandstone. The beddings are sub-horizontally stratified in the area giving way to formation of plateaus at varying elevation in some places. The boundary of the area is well defined as per observation of sudden change of topography, northeastern volcanics on the east and diorite bodies on the west and karstic limestone on the south. Outcropping on the eastern flank are the igneous rocks characterized by higher elevation and steep to high hills. Drainage in the area is dendritic to radial in pattern.