ANNEX - 3

HYDROLOGY

The Study
on
The Disaster Prevention Plan
for
Severely Affected Areas by the 1993 Disaster
in
The Central Development Region of Nepal

FINAL REPORT

Supporting Report

Annex-3 : Hydrology

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Annex -3 : Hydrology

1. METEOROLOGY

1.1 Available Meteorological and Rainfall Stations

Figure 1.1.1 shows the location of meteorological and rainfall stations in and around the Study Area. There are two study areas, one is Kulekhani, Manhari and Agra river basins in Makwanpur and Dhadin districts located on the south west from Kathmandu, and the other is Marin Khola basin in Sindhuli district on the south east from Kathmandu.

Most of the meteorological and hydrological stations are operated and administrated by the Department of Hydrology and Meteorology (DHM). Every station have ID. No, to indicate the location and serial numbers. In the case of Makwanpur district such as Kulekhani and Manhari river basins, "09" is the aerial code which is provided in prior to serial numbers of ID No.. Similarly, those in Kathmandu valley, Dhadin district, and Upper Trisuli river basins are given "10", and those in Sindhuli district are given "11".

In addition to the stations of DHM, there are some other meteorology and rainfall stations operated by the other departments such as the Department of Soil Conservation (DOSC), Department of Agriculture (DOA), Nepal Electricity Authority (NEA) and so on. Particularly, there are several stations operated by the DOSC and the NEA in Kulekhani watershed, which are highly useful for hydrological analysis.

In and around the Study area, however, most of the stations are rather newly established in 1960s, and there are only about 30 years availability of the record which is not enough to proceed the hydrological analysis. Moreover, most of the record are processed only daily basis and it is difficult to analyse the flood characteristics.

The available data for hourly rainfall is only the one of Tistung station of the DOSC in Kulekhani watershed, which was established in November 1992, though there is only 3 years of hourly rainfall record. The list of available meteorological and rainfall stations for the Study is shown in Table 1.1.1.

1.2 Meteorological Characteristics

Meteorological characteristics in the Study areas are assessed based on the observation record and Daman and Hetauda N.F.I meteorological stations (Id.No.904, 906) for Makwanpur district, and Sindhuli Gadhi meteorological station (Id. No.1107) for Sindhuli district.

1.2.1 Makwanpur District

Daman meteorological station was established in 1965, which is located on the southern part of Kulekhani river basin on the Mahabarat Range at El.2,314 m. Table 1.2.1 shows the Observation record of Daman station from 1987 to 1990 for the air temperature, the relative humidity and the vapour pressure.

The annual average temperature at Daman is about 13℃. The lowest temperature is observed in January or February ranging from 0.3 to 2.4 ℃, and the highest is observed in April to September with around 25℃. In spite that the low latitude of 27°30' north latitude, the negative temperature is observed sometimes in winter due to high altitude, and hailstone is sometimes observed in the rainy season which will severely damages to the agriculture products. Relative humidity is ranging from 44% in dry season to 92% in rainy season. The vapour pressure is observed similar characteristics as relative humidity which ranges from 5.8 mb in dry season to 19.1 mb in rainy season.

Hetauda N.F.I meteorological station was established in 1965, is located south of the Kulekhani and Manhari river basin in inner Siwalik zone. The elevation of the station is at El.474 m, which is about 1,900 m lower than Daman meteorological station. The observation record from 1987 to 1990 is shown in Table 1.2.2.

The annual average temperature at Hetauda is observed at about 23℃, which is 10℃ higher than Daman. The lowest temperature is observed in December or January with about 4 to 5 ℃, and the highest is about 35 to 40℃ in April to Jun. The related humidity is generally high through the year ranging from 60% to 80%.

Concerning the climate of the Project areas in Makwanpur district, it is required to take into account the difference of the altitude between the Project areas and the meteorological stations. For Phedigaon with El.1,800 m and Chisapani with El.2,100 m in altitude, observation record of Daman station will be available, but for Namtar with El.800 m in altitude, the record of Hetauda station will be rather applicable for meteorological assessment.

1.2.2 Sindhuli District

There is no meteorological and rainfall stations in Marin Khola basin in Sindhuli district. Accordingly, the observation record of the nearest meteorological station at Sindhuli Gadhi (ID No.1107) is collected to assess the meteorological characteristics.

Sindhuli Gadhi meteorological station is located on the eastern neibour of Marin Khola basin with an altitude of El.1,463 m. The observed meteorological condition of 1989 and 1990 such as temperature, relative humidity and vapour pressure is shown in Table 1.2.3.

Annual average temperature at Sindhuli is observed at 23 ℃ which is almost same as Hetauda. The lowest temperature is observed in January with 5.0 ℃ and the highest is 35℃ in May. The relative humidity is high ranging from 70% to 90% through the year reflecting the high annual precipitation with more or less 2,700 mm.

1.3 Rainfall Characteristics

Figure 1.3.1 shows the monthly rainfall pattern in the Study area. The monthly rainfall record for Daman and Sindhuli Gadhi are shown in Tables 1.3.1 and 1.3.2. The other monthly data as well as daily rainfall record of Chisapani Gadhi, Daman, Markhu Gaun, Nuwakot, Thankot and Dhunibesi, and hourly rainfall data at Tistung are attached in Data Book.

Figure 1.3.1 clearly indicates the contrast of rainfall amount between rainy season and dry season. Rainy season can be defined from May to September. During the period, about 70 to 80% of annual precipitation is observed in the Study area. This is because of the affect of the monsoon climate, in which the heavy evaporation phenomenum is observed at the Bay of Bengal and Indian Ocean and the thick clouds are produced and transported to the north, which is called as Monsoon climate. On the other hand, the high pressure zone is generally observed in the Eurasian Continent in winter and the dry wind to be observed from the continent to the Indian Ocean through Nepal in dry season.

In April or May, the pre-monsoon rainfall is generally observed in the Study area, in which heavy rainstorm is there in a short time. This is the symptom of the coming monsoon season and the many farmers are to start the cropping the corn and beans assuming the rich in rainfall in the near future. The pre-monsoon with intermitted storm rainfall is generally observed once in 10 days up to end May or middle of June. After then, precipitation is observed almost every day in July and August. In September or October, the post-monsoon climate which is like the pre-monsoon with occasional rainstorm with more or less 10 day interval. From November to March for 5 months, almost no rainfall is observed.

The regional rainfall characteristics in the Study area are assessed based on the collected data. The annual average precipitation in Daman station is about 1,700 mm for 26 years from 1969 to 1994. The highest is in 1973 with 2,426 mm, followed in 1978 with 2,312 mm and 1974 with 2,307 mm. The lowest is in 1994 with 1079 mm, followed in 1982 with 1,258 mm.

Rainfall characteristics in Sindhuli district is also same as Makwanpur district, however, the rainfall amount in monsoon season is much higher than Makwanpur district. The annual average rainfall at Sindhuli Gadhi is about 2,700 mm which is about 1,000 mm more than the Makwanpur district. Another characters is found from Figure 1.3.1 is that the annual rainfall on the southern part of area is generally higher than the northern part of compared Chisapani Gadhi of 2,112 mm with Markhu Gaun with 1,465 mm, as well as Sindhuli Gadhi of 2,680 mm with Nepal Thok of 1,034 mm. This is because of the topographic conditions depending of the location of high mountain range. Those stations which are located on the south of the high mountain range are recorded more rainfall than those on the north of high mountain range so that the direction of monsoon in rainy season flows from the south to the north, and the clouds are trapped by the high mountain range.

2. LOW FLOW ANALYSIS

2.1 Available Data

Figure 2.1.1 shows the location of river stage gauging stations in and around the Study area. There are two river gauging stations in Kulekhani watershed and one in Manahari watershed, however no river gauging station exist in Agra river in Makwanpur as well as in Marin watershed in Sindhuli district. The followings are the list of river gauging stations in and around the Study area:

ID No.	Station Name	River system	District	Elev. (m)	C.A. (km^2)	Established year	Closed year	Data collected period
446.8	Betrawati	Phalankhu	Nuwakot	630	162	Apr.1969	-	1971 - 1985
447	Betrawati	Trisuli	Nuwakot	600	4110	Apr.1967	-	1967 - 1993
448	Tadipul Belkot	Tadi	Nuwakot	475	653	Jun.1968	-	1969 - 1985
465	Manhari	Manhari	Makwanpur	305	427	Jun.1963	-	1963 - 1990
470	Lothar	Lothar	Makwanpur	336	169	Nov.1963	-	1964 - 1990
565	Lamichaur	Kulekhani	Makwanpur	1514	122	Jul.1975	Dec.1978	1976 - 1978
570	Kulekhani	Kulekhani	Makwanpur	1480	126	Dec.1962	Nov.1977	1963 - 1977
589	Pandhera Dobhan	Bagmati	Sarlahi	180	2700	Jan.1979	-	1981 - 1990
590	Karnaiya-Mangalpur	Bagmati	Sarlahi	177	2720	Jun.1964	Oct.1984	1965 - 1978

Among the above river stage gauging stations, two stations are selected for low flow analysis, Manhari and Kulekhani in Makwanpur district, taking into account the selected priority areas for the Disaster Prevention.

The monthly discharge record for the two gauges are shown in Tables 2.1.1 and 2.1.2 respectively. The collected data for the other stations are attached in Data Book.

2.2 Run-off Characteristics

Annual runoff ratio for the two river stage gauging stations are assessed as shown in Table 2.2.1, which is estimated based on annual precipitation at Daman rainfall stations for Manhari river basin and the average rainfall of Daman and Markhu Gaun for Kulekhani river basin. Based on the calculation the annual runoff ratio in Kulekhani and Manhari river basins are almost same with about 70-80%, indicating rather high run-off ratio.

This is assumed that the water holding capacity of the basin are generally low due to steep topography and poor vegetation in the basin. The river flow at the end of dry season is critical condition and the water availability in this period is quite limited.

The monthly duration curves at the above two stations are described in Figure 2.2.1. The Figure also indicate there are big difference in flow in wet season and dry season, and the water storage will be quite effective for maximum utilisation of river flow. The reliable river flow in respective basins are summarised as follows:

Dependable flow	Manhari ($427\ km^2$)	Kulekhani ($126\ km^2$)
50% dependable in Normal Year	$8.36\ m^3/s$	$1.75\ m^3/s$
80% dependable in Normal Year	$4.26\ m^3/s$	$1.15\ m^3/s$
95% dependable in Normal Year	$2.92\ m^3/s$	$0.86\ m^3/s$
50% dependable in Drought Year	$5.78\ m^3/s$	$1.36\ m^3/s$
80% dependable in Drought year	$3.24\ m^3/s$	$0.82\ m^3/s$
95% dependable in Drought year	$1.97\ m^3/s$	$0.48\ m^3/s$

In case of the Study, the suitable dependability would be 95% in normal year or 80% in drought year, as the proposed project is rather small scale in the communities in rural area so that the required reliability for water supply would be rather low compared with the large scale irrigation or water supply project.

2.3 Low Flow Estimation for Community Development

The estimation of water availability for the respective community development shall be as follows;

for Phedigaon and Phatbazar in Kulekhani watershed

Since the community is located in the upper most area of Kulekhani watershed with a catchment area of more or less 5 km^2, the low flow data at Kulekhani gauge with 126 km^2 will not be available. Because, the run-off characteristics in the upper most area is highly depended on the geology, topography and the vegetative conditions and it is usually not in proportion to the runoff at the far downstream area. In case that the low flow availability of the Phedigaon/Phatbazar is estimated based on the run-off at Kulekhani the designed specific discharge will be at 30 litter / sec / km^2, however, it shall not be used for the design purpose. For estimating the available flow at the area, it is better to ask the villagers about the stream conditions in the long term view point.

for Chisapani

Chisapani is also located upper most area of Agra river catchment, and there is no river gauging stations in Agra watershed. In case of Chisapani also, no hydrological approach as to estimate the available water exist, and the detailed field investigation with hearing survey from the villagers will be required. There are some spring sources in the area, on

which the water is observed through the year. The amount of the spring water would be depended on the geological structures in and around the basin.

for Namtar

In the case of Manhari Khola at Namtar, the catchment area at the village is about 60 km^2, which is about 14% of the catchment area at Manhari gauging station site. In the case of Namtar village, it is also difficult to apply the ratio of catchment between Manhari gauging station and Namtar village, however, it can be used as the tentative estimation for preliminary design purpose. In the case of Manhari river, the 80% dependable flow in draught year is estimated at 10 litter / sec / km^2.

3. FLOOD ANALYSIS

3.1 Procedures for Peak Flood Estimation

Estimating the probable peak flood for the respective river structure site is inevitably required for designing purpose of the river structures. The procedures for estimating the peak flood is generally to develop the flood run-off model such as storage function method, unit hydrograph method and so on applying the recorded hourly rainfall and discharge record collected from near by the structure site.

In case of the Study, however, there is no applicable river gauging stations for designing the peak flood discharge. In addition, as most of the rain gauge stations measure only daily basis of rainfall record except Tistung hourly rain gauge station, it is not possible to apply such normal procedures as storage function or unit hydrograph approaches.

In this Study, therefore, the rational method, which utilises the results of daily probable rainfall record nearby the structure area, and converting to the assumed instantaneous flood discharge taking into account the size and the slope of the drainage area as well as the length of the river.

Rational formulae is widely applied for estimating instantaneous flood discharge in the small drainage areas generally within 100 km^2 in mountainous area of which no discharge gauging stations exist. According to the applicable range of rational formula for flood estimation above, all the structure sites in the Study are applicable to the rational formula for peak flood estimation. The detail procedures are mentioned in Sub-section 3.3.2 in the report.

3.2 Estimated Probable Rainfall in the Study Area

Based on the procedures mentioned in Section 3.1 above, the probable rainfall analysis is carried out prior to applying the rational formula. The following rainfall stations are selected to apply the rational formula for respective project area:

(1) For Phedigaon Community Disaster Prevention Plans

Since there is no rain gauge stations in the Phedigaon drainage area, Daman rainfall station is selected to apply the rational formula, which is located on the southern edge of Kulekhani watershed and the distance between Daman and Phedigaon is more or less 10 km without high mountain range. Considering the above, the observation record at Daman rain gauge station can be applied for estimating probable flood for Phedigaon area so that it seems that there is no big differences in rainfall characteristics between Daman and Phedigaon.

(2) For Namtar Community Disaster Prevention Plans

Namtar is located in the upper part of the Manhari Khola, and there is no rain gauge station in the drainage area. However, Daman rainfall station is located just on the edge of catchment boundaries between Kulekhani and Manhari watershed. Considering the above, the observation record at Daman rainfall station is available for estimating instantaneous flood discharge at Namtar.

(3) For Chisapani Community Disaster Prevention Plans

Chisapani is located on the upper most catchment in the Agra river basin. However, there is no rain gauge stations in the basin. Tistung rainfall station is located on the western edge of the Agra basin, but it is not available so that the observation period of Tistung rain gauge station is only 4 years.

The observation record at Daman rainfall station will not be suitable applying for Chisapani. Because, the drainage area of Chisapani is located on the behind of the mountain and there might be different rainfall characteristics between Daman and Chisapani due to the high mountain between them.

However, there is so far no other choice other than applying Daman gauging station for estimating instantaneous flood discharge for Chisapani, and the Study Team finally determined to apply the observation record at Daman rainfall stations.

(4) For Mahadev Besi Bridge Infrastructure Disaster Prevention Plans

Mahadev Besi bridge is located in the downstream end of Agra Khola just upstream of the confluence of Mahesh Khola. The drainage area at the bridge site is 112 km^2.

As mentioned in the above paragraph (3), there are no rainfall stations as well as river gauge stations in the Agra river basin. In case of the Mahadev Besi bridge, the rainfall record at Dhunibesi would be rather applicable than Daman. Because, Dhunibesi is located in shorter distance to the bridge than Daman though the both stations are located on the outside of the Agra river basins. Because of the location of high mountain range and the direction of monsoon in rainy season, the Dhunibesi which is located north of Chandragiri Range with an elevation of more or less 2,500 m. The Agra Khola basin also located on the north of Chandragiri Range but Daman is located on the south. Considering the above, the Study Team determined that the observation record at Dhunibesi rainfall station is applied for estimation of instantaneous flood discharge at Mahadev Besi bridge.

The probable rainfall at Daman and Dhunibesi are accordingly calculated utilising the annual maximum daily rainfall for 26 years for Daman, and for 20 years for Dhunibesi as shown in Table 3.2.1.

The following tables are the results of probability analysis of the point rainfall at Daman and Dhunibesi which applies the two theories of Gumbel and Log Pearson Type III formulae:

Return Period	Daman (mm)		Dhunibesi (mm)	
	Gumbel	Log Pearson Type III	Gumbel	Log Pearson Type III
2	111	102	93	87
5	182	159	135	119
10	229	206	163	146
20	275	258	190	177
30	301	292	205	198
40	319	317	215	213
50	334	338	224	226
80	364	385	241	254
100	378	408	249	269
200	422	489	275	319

For applying the rational formula, Gumbel theory is applied so that the probable rainfall at 20-year return period of the one applied in Gumbel theory indicates rather higher value than the one of Log Pearson Type III in the view of conservative design.

3.3 Estimation of Design Flood Discharge

3.3.1 Conversion from Point Rainfall to Basin Rainfall

Prior to applying rational formula for estimating the instantaneous flood discharge, basin probable rainfall shall be estimated. In this Study, Aerial Reduction Factor (ARF) is applied to convert from point rainfall to basin rainfall as the following procedures:

A popular formula is expressed:

$$R = \sqrt{D} \times \frac{a + b}{\sqrt{A + C}}$$

where
- A : area (km^2)
- D : duration (hr)
- R : rainfall (mm)
- a, b, c : coefficient

Popular formula has been expressed by putting the coefficient

a = 13, b = 10900 and c = 30.9 (Figure 3.3.1)

However, we here introduce formula, because the ARF is assumed to be variant not only of the area but also of the duration time. According to "Highway and Urban Hydrology in the tropics", L.H. Watkins and D. Fiddes (British Library Cataloguing in Publication Data, 1984) the following equation is said to be appropriate, to a small basin.

$$ARF = 1 - 0.038T^{-0.38} A^{0.37}$$

where
- T : duration (hr)
- A : area (km^2)

In this study, we make use of this equation (Figure 3.3.2).

3.3.2 Estimating Design Flood at the Proposed Structure Sites

In the plan formulation for disaster prevention structures mentioned in Annex-2 in the report, design flood was determined to be equivalent to 20-year probable flood. According to the design criteria, 20-year probable instantaneous flood for all the river structure sites are estimated applying the rational formula as the following manners:

$$Q_p = \frac{1}{3.6} f \quad R$$

where
- Q_p : flood peak runoff (m^3/s)
- f : runoff coefficient (f =0.7 assumed)
- R : rainfall intensity within concentration time (mm/h)
- A : catchment area (km^2)

Rainfall intensity within concentration time is estimated by the following formulae.

$$R = \frac{r_t}{T}$$

$$T = \frac{1}{3600} \cdot \frac{L}{W}$$

$$r_t = r_{24}\left(\frac{t}{24}\right)^{\frac{1}{2}}$$

where
- r_t : continuation rainfall intensity within t hours
- T : time of concentration (h)
- W : flood propagation speed (m/s)
- L : length of waterway (m)
- r_{24} : daily rainfall depth (mm/day)

For the computation of concentration time, Kraven's formula was used:

in case of			
	H/L > 1/100	--------	w = 3.5 m/s
	1/200 < H/L < 1/100	--------	w = 3.0 m/s
	H/L < 1/200	--------	w = 2.1 m/s

The results of the design flood estimation are summarised in Table 3.3.1.

Table 1.1.1 List of Meteorological and Rainfall Stations in and around Study Area

	Index No.	Name	Elev. (m)	Observation Items	Established	Collected Data	Collected Period	Source
Makwanpur District (West Area)	904	Chisapani Gadhi	1704	1)Precipitation	May 1956	1) Precipitation (Daily)	9 Jun.1957-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
						2) Precipitation (Monthly)	Jul.1957-Dec.1994	Department of Hydrology and Meteorology Data Book
	905	Daman	2314	1) Precipitation	Sep.1965	1) Precipitation (Daily)	1 Jan.1971-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
				2) Air Temperature		2) Precipitation (Monthly)	Jan.1969-Dec.1994	Department of Hydrology and Meteorology Data Book
				3) Relative Humidity		3) Air Temperature (Monthly)	Jun.1973-Dec.1990	〃
				4) Vapour Pressure		4) Relative Humidity (Monthly)	〃	〃
						5) Vapour Pressure (Monthly)	Jun.1983-Dec.1990	〃
	906	Hetauda N.F.I	474	1) Precipitation	Sep.1965	1) Precipitation (Monthly)	Jan.1967-Dec.1990	Department of Hydrology and Meteorology Data Book
				2) Air Temperature		2) Air Temperature (Monthly)	〃	〃
				3) Relative Humidity		3) Relative Humidity (Monthly)	〃	〃
				4) Vapour Pressure		4) Vapour Pressure (Monthly)	Jan.1983-Dec.1990	〃
	915	Markhu Gaun	1530	1)Precipitation	Dec.1971	1) Precipitation (Daily)	1 Jan.1985-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
						2) Precipitation (Monthly)	Jan.1972-Dec.1994	Department of Hydrology and Meteorology Data Book
	1004	Nuwakot	1004	1) Precipitation	May.1956	1) Precipitation (Daily)	1 Jan.1985-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
				2) Air Temperature		2) Precipitation (Monthly)	Jun.1956-Dec.1994	Department of Hydrology and Meteorology Data Book
				3) Relative Humidity		3) Air Temperature (Monthly)	Jun.1968-Dec.1990	〃
				4) Vapour Pressure		4) Relative Humidity (Monthly)	〃	〃
						5) Vapour Pressure (Monthly)	Jan.1983-Dec.1990	〃
	1015	Thankot	1706	1)Precipitation	Sep.1966	1) Precipitation (Daily)	1 Jan.1985-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
						2) Precipitation (Monthly)	Jan.1967-Dec.1994	Department of Hydrology and Meteorology Data Book
	1022	Godavari	1400	1) Precipitation	Jan.1952	1) Precipitation (Monthly)	Feb.1952-Dec.1990	Department of Hydrology and Meteorology Data Book
				2) Air Temperature		2) Air Temperature (Monthly)	Jan.1971-Dec.1990	〃
				3) Relative Humidity		3) Relative Humidity (Monthly)	Apr.1972-Dec.1990	〃
				4) Vapour Pressure		4) Vapour Pressure (Monthly)	Jan.1983-Dec.1990	〃
	1038	Dhunibesi	1085	1) Precipitation	Apr.1971	1) Precipitation (Daily)	1 Jan.1985-31 Dec.1994	Data Input at Department of Hydrology and Meteorology
				2) Air Temperature		2) Precipitation (Monthly)	Jan.1973-Dec.1994	Department of Hydrology and Meteorology Data Book
				3) Relative Humidity		3) Air Temperature (Monthly)	Jan.1983-Dec.1990	〃
				4) Vapour Pressure		4) Relative Humidity (Monthly)	〃	〃
						5) Vapour Pressure (Monthly)	〃	〃
	DOSC	Tistung		1) Precipitation	Nov.1992	1) Precipitation (Hourly)	16 Nov.1992-31Dec.1995	Department of Soil Conservation
Sindhuli District (East Area)	1107	Sindhuli Gadhi	1463	1) Precipitation	Jun.1955	1) Precipitation (Monthly)	Jul.1955-Dec.1990	Department of Hydrology and Meteorology Data Book
				2) Air Temperature		2) Air Temperature (Monthly)	Mar.1989-Dec.1990	〃
				3) Relative Humidity		3) Relative Humidity (Monthly)	〃	〃
				4) Vapour Pressure		4) Vapour Pressure (Monthly)	〃	〃
	1115	Nepal Thok	757	1) Precipitation	Oct. 1948	1) Precipitation (Monthly)	May 1948-Dec.1990	Department of Hydrology and Meteorology Data Book
	1121	Karmaiya	131	1) Precipitation	Aug.1983	1) Precipitation (Monthly)	Jan.1984-Dec.1990	Department of Hydrology and Meteorology Data Book
				2) Air Temperature		2) Air Temperature (Monthly)	Mar.1984-Dec.1990	〃
				3) Relative Humidity		3) Relative Humidity (Monthly)	〃	〃
				4) Vapour Pressure		4) Vapour Pressure (Monthly)	〃	〃

Table 1.2.1 Meteorological Summary in Daman

LOCATION	: DAMAN	LAT.	: 27° 36' N
INDEX NO.	: 0905	LONG.	: 85° 05' E
DISTRICT	: MAKWANPUR	ELEV.	: 2314 m. amsl

(1987)

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb	
	Mean			Absolute extreme		Number of Days		Observed at			
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥ 30°	Min. ≤ 0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST
JAN	14.0	1.9	8.0	17.3 28	0.0 1	0	4	52	78	5.8	7.5
FEB	14.8	3.8	9.3	17.0 19	-0.2 4	0	2	62	63 a	7.3	8.4 a
MAR	15.5	5.5	10.5	19.6 30	3.0 2	0	0	65	82 a	9.3	10.3 a
APR	20.1	9.1	14.6	24.4 8	7.0 28	0	0	62	64	11.4	11.2
MAY	20.8	10.9	15.9	24.4 21	5.0 4	0	0	54	58	10.6	10.7
JUN	21.9 a	14.5 a	18.2 a	23.8 14a	12.7 12a	0 a	0 a	80 a	80 a	16.9 a	16.9 a
JUL	20.8	14.7	17.8	22.5 29	12.3 28	0	0	89	91	18.6	19.1
AUG	21.1	14.2	17.7	23.2 21	13 17	0	0	90	90	17.7	17.7
SEP	22.2	14	18.1	23.5 17	12.4 29	0	0	90	88	17.6	18.4
OCT	19.9a	9.9a	14.9a	22.2 9a	7.0 29a	0 a	0 a	76 a	76 a	13.0 a	14.0 a
NOV	17.9	4.6	11.3	21.5 9	2.0 25	0	0	61	79	9.7	11.2
DEC	13.3a	2.8	8.1b	19.0 1b	-1.6 17	0 b	2	70	67 f	8.5	8.1 f
YEAR	18.5	8.8	13.7	24.4 APR	-1.6 DEC	0	8	71	76	12.2	12.8

(1988)

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb	
	Mean			Absolute extreme		Number of Days		Observed at			
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥ 30°	Min. ≤ 0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST
JAN	12.7	1.4	7.0	16.0 1	0.0 18	0	2	74	73	8.2	7.6
FEB	14.0	3.3	8.6	16.4 4	0.2 24	0	0	68	74	8.4	9.4
MAR	15.8	4.8	10.3	18.6 6	3.0 20	0	0	69	71 a	8.8	9.5 a
APR	19.9 a	9.7	14.8 a	24.0 6a	7.0 1	0 a	0	50	57	9.2	10.6
MAY	20.6	11.8	16.2	23.8 30	9.0 5	0	0	72	72 a	14.4	14.1 a
JUN	21.0	13.4	17.2	23.3 23	10.2 5	0	0	87	87	17.4	17.9
JUL	20.9 a	14.6 a	17.8 a	22.4 1a	12.6 17a	0 a	0 a	89	88	18.3	19.1
AUG	20.9	14.4	17.7	23.3 8	13.0 15	0	0	90	89 a	18.4	18.9 a
SEP	21.7	13.6	17.7	24.3 15	11.3 16	0	0	85	86	17.3	18.1
OCT	20.4	11.2	15.8	23.0 2	8.3 16	0	0	75	74 a	14.6	13.1 a
NOV	16.6	5.2	10.9	19.6 18	2.5 27	0	0	76	75	11.4	10.5
DEC	13.0 a	2.9	8.0 a	17.2 3a	0.0 26	0 a	1	70	80	8.4	9.5
YEAR	18.1	8.8	13.5	24.3 SEP	0.0 JAN	0	3	75	77	12.9	13.2

(1989)

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb	
	Mean			Absolute extreme		Number of Days		Observed at			
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥ 30°	Min. ≤ 0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST
JAN	10.1 b	0.3	5.2 b	13.4 31b	-4.0 8	0 b	12	67	75	6.2	6.6
FEB	12.5 b	2.8	7.7 b	15.5 26	-0.3 19	0 b	6	60	53	6.6	6.0
MAR	14.1 i	3.4	8.8 i	17.6 9i	-0.3 21	0 i	6	61	55 a	7.1	6.8 a
APR	19.2 f	8.5	13.9 f	22.8 25f	4.0 11	0 f	0	44	50	7.9	8.6
MAY	21.5 b	12.1	16.8 b	25.3 6b	8.0 14	0 b	0	79	78	15.8	15.4
JUN	21.3 a	13.1 a	17.2 a	23.0 11a	11.0 3a	0 a	0 a	83 a	81 a	16.5 a	16.1 a
JUL	21.1 a	14	17.5 a	24.2 23a	12.3 15	0 a	0	91	88	18.4	18.3
AUG	21.1 b	13.4 a	17.3 b	23.3 15b	12.2 27a	0 b	0 a	92	87	18.8	17.7
SEP	20.2 c	12.9 c	16.5 c	23.0 10c	11.0 22	0 c	0	90	91 a	17.3	16.8 a
OCT	21.0	9.8	15.4	22.6 10	5.0 30	0	0	72	87	13.9	16.0
NOV	15.0 a	4.2	9.6 a	19.6 1a	1.0 29	0 a	0	71 a	85	9.4 a	10.5
DEC	13.4	1.8	7.6	18.6 10	-0.2 28	0	9	60	69	6.6	7.8
YEAR	17.6	8	12.8	25.3 MAY	-4.0 JAN	0	33	73	75	12.0	12.2

(1990)

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb	
	Mean			Absolute extreme		Number of Days		Observed at			
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥ 30°	Min. ≤ 0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST
JAN	13.7 b	3.2	8.5 b	16.3 25b	-1.1 10	0 b	8	52	57	6.4	7.2
FEB	11.0 d	2.4	6.7 d	14.3 4d	0.1 24	0 d	0	77	73	7.7	7.5
MAR	13.6 a	2.9	8.3 a	18 22a	0.8 5	0 a	0	72	73	8.6	8.6
APR	18.4	7.9 a	13.2 a	21.8 25	2.4 4a	0	0 a	63 a	71 a	10.9 a	11.2 a
MAY	19.7 b	10.8	15.3 b	22.5 16b	6.0 1	0 b	0	80	80	14.5	15.2
JUN	21.9 b	14.0	18.0 b	23.6 17b	12.2 10	0 b	0	82	83	16.8	18.9
JUL	21.2	14.0	17.6	23.5 2	8.4 9	0	0	91	89	18.0	18.4
AUG	21.9 e	13.7	17.8 e	24.5 31e	12.8 24	0 e	0	85	86	17.9	18.7
SEP	21.3	13.0	17.2	24.4 2	10.0 27	0	0	89	86	17.0	17.2
OCT	19.6 b	8.4	14.0 b	22.0 7b	4.8 28	0 b	0	78	80 a	13.7	13.1 a
NOV	17.9 c	5.6	11.8 c	20.5 16c	2.0 26	0 c	0	68	67	10.2	10.2
DEC	14.1 a	2.4 a	8.3 a	16.3 17a	0.1 31a	0 a	0 a	62 a	65 a	7.8 a	7.9 a
YEAR	17.9	8.2	13.0	24.5 AUG	-1.1 JAN	0	8	75	76	12.5	12.8

NOTICE
1) SOURCE: CLIMATOLOGICAL RECORDS OF NEPAL 1987-1990 , DEPARTMENT OF HYDROLOGY AND METEOROLOGY , JUNE 1995
2) MISSING NUMBER OF DAYS: a=1; b=2; c=3; d=4; e=5; f=6; g=7; h=8; i=9; j=10

Table 1.2.2 Meteorological Summary in Hetauda N.F.I

LOCATION : HETAUDA N.F.I.
INDEX NO. : 0906
DISTRICT : MAKWANPUR

LAT. : 27° 25' N
LONG. : 85° 03' E
ELEV. : 474m. amsl

(1987)

Month	AIR TEMPERATURE °C Mean Max.	Mean Min.	Mean Daily	Absolute extreme Max. & Date	Absolute extreme Min. & Date	Number of Days Max. ≥ 30°	Number of Days Min. ≤ 0°	RELATIVE HUMIDITY % Observed at 8:45 NST	RELATIVE HUMIDITY % Observed at 17:45 NST	VAPOUR PRESSURE mb Observed at 8:45 NST	VAPOUR PRESSURE mb Observed at 17:45 NST
JAN	22.6	8.5 a	15.6 a	25.2 30.0	5.2 1 a	0	0 a	90	79	12.5	15.7
FEB	25.5	10.6	18.0	28.9 25.0	7.4 3	0	0	79	65	13.8	15.9
MAR	28.6	14.5	21.6	32.7 31.0	9.8 1	10	0	74	68	17.4	21.8
APR	32.9	18.2	25.6	36.0 3.0	13.0 12	26	0	70	68 a	22.7	28.6 a
MAY	33.9	20.4	27.2	38.5 24.0	15.4 4	24	0	59	51	21.7	21.6
JUN	33.3 a	24.5 a	28.9 a	35.7 19 a	21.8 2 a	28 a	0 a	75 a	70 a	29.1 a	29.5 a
JUL	30.1	24.2	27.2	33.0 18.0	22.2 25	19	0	87	88	30.1	31.1
AUG	30.1	23.5	26.8	35.2 19.0	20.2 8	21	0	87	85	29.5	30.0
SEP	30.7	23.3	27.0	32.4 17.0	20.8 10	24	0	85	86	29.6	31.2
OCT	28.7	19.1	23.9	31.2 1.0	13.4 20	9	0	81	82	23.5	26.6
NOV	27.3	13.1	20.2	29.0 8.0	10.2 12	0	0	81	82 b	18.7	21.4 b
DEC	24.0	10.1	17.0	26.8 1.0	6.4 28	0	0	87	77 b	14.8	17.2 b
YEAR	29.0	17.5	23.3	38.5 MAY	5.2 JAN	161	0	79	75	21.9	24.2

(1988)

Month	AIR TEMPERATURE °C Mean Max.	Mean Min.	Mean Daily	Absolute extreme Max. & Date	Absolute extreme Min. & Date	Number of Days Max. ≥ 30°	Number of Days Min. ≤ 0°	RELATIVE HUMIDITY % Observed at 8:45 NST	RELATIVE HUMIDITY % Observed at 17:45 NST	VAPOUR PRESSURE mb Observed at 8:45 NST	VAPOUR PRESSURE mb Observed at 17:45 NST
JAN	22.7	8.3	15.5	23.7 2	4.2 9	0	0	88 a	73	12.6 a	14.5
FEB	25.4	10.9	18.2	28 28	8.4 4	0	0	81	64	14	15.7
MAR	28.3 a	14.2 a	21.3 a	32.7 26 a	9.8 3 a	7 a	0 a	67 a	54 a	15.2 a	15.9 a
APR	32.7	18.3	25.5	37.2 6	12.2 11	25	0	65	64 a	21.4	24.7 a
MAY	32.2	22	27.1	35.5 10	18.2 14	29	0	75	70 a	26.3	27.7 a
JUN	31.0	23.4	27.2	33.8 4	19.6 5	23	0	79	76 a	28.1	29.4 a
JUL	30.8	24.5	27.7	33.2 17	22.5 2	24	0	85	85 a	30.3	30.8 a
AUG	30.3	23.9	27.1	33.2 3	22.0 29	21	0	87	88 a	30	30.4 a
SEP	31	23.2	27.1	33 20	20.2 16	24	0	83	82	28.7	29.6
OCT	29.9	19	24.5	32.0 2	16 30	18	0	78	82	23.9	26.4
NOV	27.5	11.6 b	19.5 b	29 2	8.6 26 b	0	0 b	69 b	66 b	15.5 b	17 b
DEC	24.0 a	10.4	17.2 a	26.4 2 a	8.2 29	0 a	0	87	71	14.7	15.5
YEAR	28.8	17.5	23.2	37.2 APR	4.2 JAN	171	0	79	73	21.7	23.1

(1989)

Month	AIR TEMPERATURE °C Mean Max.	Mean Min.	Mean Daily	Absolute extreme Max. & Date	Absolute extreme Min. & Date	Number of Days Max. ≥ 30°	Number of Days Min. ≤ 0°	RELATIVE HUMIDITY % Observed at 8:45 NST	RELATIVE HUMIDITY % Observed at 17:45 NST	VAPOUR PRESSURE mb Observed at 8:45 NST	VAPOUR PRESSURE mb Observed at 17:45 NST
JAN	20.7	7.4 b	14.1 b	23.6 1	5.0 15 b	0	0 b	91 b	68 b	11.7 b	12.4 b
FEB	23.5	7.8	15.7	30 28	4.6 16	1	0	75	54 a	11.5	11.5 a
MAR	28.7	13.1	20.9	33 23	8 3	9	0	62	45 a	13.8	13.3 a
APR	34.3	15.7	25.0	38 24	12.0 3	30	0	56	24	11.7	10.9
MAY	33.8	21.5 a	27.7 a	40.2 7	14.8 9 a	28	0 a	63 a	56	22.7 a	21.2
JUN	31.8	23.7	27.8	35.2 9	21.4 4	26	0	79 a	77 a	28.9 a	29.2 a
JUL	29.8	23.7	26.8	34 22	21 30	18	0	88	85 b	29.3	30.3 b
AUG	31.5	23.6	27.6	34 3	21.6 1	29	0	81	84	29.2	29.4
SEP	30.0	22.9	26.5	33.4 10	21.2 29	17	0	86	85 b	28.5	29.1 b
OCT	29.9	18.4	24.2	31.6 15	10.6 31	17	0	77	79	23.2	25.5
NOV	25.7	11.6	18.7	28.2 1	9.0 8	0	0	80 a	76	16.1 a	18
DEC	22.5	7.8	15.2	25 1	4.4 31	0	0	86	73	12.5	13.9
YEAR	28.5	16.4	22.5	40.2 MAY	4.4 DEC	175	0	75	67	19.9	20.4

(1990)

Month	AIR TEMPERATURE °C Mean Max.	Mean Min.	Mean Daily	Absolute extreme Max. & Date	Absolute extreme Min. & Date	Number of Days Max. ≥ 30°	Number of Days Min. ≤ 0°	RELATIVE HUMIDITY % Observed at 8:45 NST	RELATIVE HUMIDITY % Observed at 17:45 NST	VAPOUR PRESSURE mb Observed at 8:45 NST	VAPOUR PRESSURE mb Observed at 17:45 NST
JAN	23.6	8.3	16	26.6 21	4 4	0	0	91	71	12.9	15
FEB	23.2	10.1	16.7	26.8 9	7.2 2	0	0	82	67	13.6	14.3
MAR	27.1	13.2	20.2	32.2 20	8.2 5	7	0	67	62	15	17.2
APR	31.5	17.4	24.5	34.5 16	12 2	23	0	65	61	19.8	22.4
MAY	31.9	21.3	26.6	34.8 30	16.6 21	27	0	77	75	26.8	29.1
JUN	33	24.3	28.7	35.5 8	19.6 7	30	0	84	86	32.7	35.8
JUL	30.8	24.4	27.6	33 2	23 20	24	0	88	88	31.3	32.6
AUG	31.9	24	28	34.6 20	22.2 28	27	0	83	87 a	30.1	32.5 a
SEP	30.7	23.1	26.9	34 1	20.4 25	26	0	85	89	29.3	31.7
OCT	29.1 a	17.4	23.3 a	34.0 7 a	11.2 28	10 a	0	83	91	24	27.5
NOV	28.4	12.8	20.6	30.6 11	8.6 30	6	0	78 a	78	18.1 a	21
DEC	24.4	8.9	16.7	26 2	6.8 25	0	0	89	82	14.8	18.2
YEAR	28.8	17.1	23.0	35.5 JUN	4 JAN	180	0	81	78	22.4	24.8

NOTICE
1) SOURCE: CLIMATOLOGICAL RECORDS OF NEPAL 1987-1990, DEPARTMENT OF HYDROLOGY AND METEOROLOGY, JUNE 1995
2) MISSING NUMBER OF DAYS: a=1; b=2; c=3; d=4; e=5; f=6; g=7; h=8; i=9; j=10

Table 1.2.3 Meteorological Summary in Sindhuli Gadhi

(1989)

LOCATION : SINDHULI GADHI
INDEX NO. : 1107
DISTRICT : SINDHULI

LATITUDE : 27° 17' N
LONGITUDE : 85° 58 'E
ELEVATION : 1463 m. amsl

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb		PRECIPITATION mm						
	Mean			Absolute extreme		Number of days		Observed at				Total	Maximum in 24 hrs & Date	Number of rainy days				
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥30°	Min. ≤0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST			≥ 1.0	1.0 to 9.9	10.0 to 24.9	25.0 to 49.9	50.0 to 99.9	≥ 100
JAN												22	17 / 9	2	1	1	0	0	0
FEB												39	21 / 21	3	1	2	0	0	0
MAR	28.3 d	8.5 d	18.4 d	32.5 23 d	4.0 19 d	9 d	0 d	85 e	78 g	19.8 e	23.5 g	11	11 / 15	1	0	1	0	0	0
APR	33.2 b	8.3 b	20.8 b	37.5 19 b	1 14 b	26 b	0 b	78 c	79 e	26.8 c	35.0 c	0	0 / 0	0	0	0	0	0	0
MAY	32.7 a	6.9 b	19.8 b	39.1 7 a	10.0 25 b	24 a	0 b	82 a	83 a	29.2 a	32.4 a	143	39 / 26	8	4	1	3	0	0
JUN	31.1 s	15.3 m	23.2 s	34.0 11 s	7.0 2 m	7 s	0 m	89 n	93 t	32.2 n	33.4 t	356	90 / 20	13	4	4	3	2	0
JUL	29.8 q	22.4 p	26.1 q	32.0 22 q	13.0 30 p	9 q	0 p	93 m	95 q	32.0 m	31.7 q	490	82 / 13	16	3	5	5	3	0
AUG	30.6 b	23.2 b	26.9 b	33.0 3 b	21.0 1 b	27 b	0	88 a	92 a	31.6 a	31.7 a	286	49 / 20	21	10	7	4	0	0
SEP	29 d	22.2 d	25.6 d	32.0 10 d	20.0 29 d	14 d	0	91 c	92 c	28.9 c	29.5 c	379	52 / 24	23	10	7	5	1	0
OCT	30.1 b	19.4 b	24.8 b	32.0 5 b	14.1 31 b	20 b	0	84 a	82 a	24.7 a	27.0 a	65	28 / 13	8	6	1	1	0	0
NOV	27.2	13.1	20.2	31.1 3	10.0 30	10	0	88 a	89 a	17.4 a	23.3 a	0	0 / 0	0	0	0	0	0	0
DEC	22.8 a	9.2 a	16.0 a	25.0 6 a	6.0 30 a	0 a	0 a	85 a	87 a	12.7 a	16.4 a	0	0 / 0	0	0	0	0	0	0
YEAR												1788	90 / JUN	95	39	29	21	6	0

NOTICE 1) SOURCE: CLIMATOLOGICAL RECORDS OF NEPAL 1987-1990, DEPARTMENT OF HYDROLOGY AND METEOROLOGY, JUNE 1995
2) MISSING NUMBER OF DAYS: a=1; b=2; c=3; d=4; e=5; f=6; g=7; h=8; i=9; j=10; k=11; l=12; m=13; n=14; o=15; p=16; q=17; r=18; s=19; t=20; u=21; v=22; w=23; x=24; y=25; z=26

(1990)

LOCATION : SINDHULI GADHI
INDEX NO. : 1107
DISTRICT : SINDHULI

LATITUDE : 27° 17' N
LONGITUDE : 85° 58 'E
ELEVATION : 1463 m. amsl

Month	AIR TEMPERATURE °C							RELATIVE HUMIDITY %		VAPOUR PRESSURE mb		PRECIPITATION mm						
	Mean			Absolute extreme		Number of days		Observed at				Total	Maximum in 24 hrs & Date	Number of rainy days				
	Max.	Min.	Daily	Max. & Date	Min. & Date	Max. ≥30°	Min. ≤0°	8:45 NST	17:45 NST	8:45 NST	17:45 NST			≥ 1.0	1.0 to 9.9	10.0 to 24.9	25.0 to 49.9	50.0 to 99.9	≥ 100
JAN	23.4 a	9.8 a	16.6 a	27.4 27 a	5.0 2 a	0 a	0 a	88 a	89 b	13.1 a	17.4 b	0	0 / 0	0	0	0	0	0	0
FEB	23.2	12.2 d	17.7 d	27.0 9	10.0 6 d	0	0	84	78	13.5	16.1	32	11 / 11	5	4	1	0	0	0
MAR	26.5	15.0 a	20.8 a	31.2 20	11.0 6 a	6	0 a	77	71	16.2	18.5	21	15 / 24	2	1	1	0	0	0
APR	30.1	18.4 a	24.3 a	34.2 18	14.2 1 a	17	0 a	75	71	22.9	23.7	109	41 / 15	6	2	2	2	0	0
MAY	30.8 g	21.1 m	26.0 m	35.0 16 g	19.2 2 m	19 g	0 m	80 f	83 g	26.9 f	29.3 g								
JUN	31.6 b	23.5 a	27.6 b	33.2 8 b	21.0 9 a	28 b	0 a	86 a	87 e	32.5 a	33.3 e	406	133 / 26	20	7	9	3	0	1
JUL	30.1 p	23.6 p	26.9 p	32.0 22 p	23.0 24 p	10 p	0 p	91 p	91 q	31.4 p	32.9 q								
AUG	31.1	23.4	27.3	34.0 20	22.0 7	28	0	89	91	33.4	32.7	550	136 / 27	18	6	5	3	3	1
SEP	30.4	22.2	26.3	33.3 1	20.6 28	23	0	87	87	28.7	30.1	415	80 / 25	23	11	7	2	3	0
OCT	29.4	17.7	23.6	33 7	13 25	15	0	84	87 a	22.6	26.3 a	245	64 / 2	12	6	2	2	2	0
NOV	28.0 n	13.3 l	20.7 n	31.0 13 n	10.0 30 l	2 n	0 l	81 l	86 x	17.9 l	18.9 x								
DEC	24.8	10.3	17.5	29.0 17	8.2 24	0	0	84	88	13.1	17.7	0	0 / 0	0	0	0	0	0	0
YEAR	28.3	17.6	23.0	35.0 MAY	5.0 JAN	148	0	84	84	22.5	24.8								

NOTICE 1) SOURCE: CLIMATOLOGICAL RECORDS OF NEPAL 1987-1990, DEPARTMENT OF HYDROLOGY AND METEOROLOGY, JUNE 1995
2) MISSING NUMBER OF DAYS: a=1; b=2; c=3; d=4; e=5; f=6; g=7; h=8; i=9; j=10; k=11; l=12; m=13; n=14; o=15; p=16; q=17; r=18; s=19; t=20; u=21; v=22; w=23; x=24; y=25; z=26

Table 1.3.1 Monthly Precipitation Summary in Daman (mm)

NAME OF SITE : DAMAN
STATION No. : 905
EST.DATE : Sep. 1965
DISTRICT : MAKWANPUR

LATITUDE : 27° 36' N
LONGITUDE : 85° 05' E
ELEVATION : 2314m
ZONE : NARAYANI

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MAXIMUM IN 24HRS.	DATE
1969	0	0	35	47	172	259	303	380	222	9	2	0	1428	47.5	20.Aug
1970	14	25	12	111	116	284	382	167	121	23	6	0	1259	58.6	26.Jul
1971	9	7	38	224	184	583	191	349	67	61	4	0	1717	121.6	29.Jun
1972	2	69	26	20	80	362	958	161	304	83	20	0	2085	128.2	28.Jul
1973	73	47	47	39	189	618	266	281	599	248	19	0	2426	104.0	16.Jun
1974	0	27	41	54	163	185	503	655	601	70	0	8	2307	181.7	2.Sep
1975	36	21	11	64	202	284	848	304	370	19	0	0	2159	156.0	27.Jul
1976	53	10	0	67	218	533	536	296	212	4	0	0	1929	168.0	10.Jun
1977	4	20	35	196	186	230	272	316	114	54	46	56	1529	76.8	20.Jun
1978	0	36	80	180	189	271	828	340	238	150	0	0	2312	233.5	16.Jul
1979	0	39	2	148	53	230	655	467	132	37	18	75	1856	207.5	21.Aug
1980	1	14	45	11	142	434	-	-	165	40	0	4	-	-	-
1981	43	0	51	103	100	179	224	353	325	0	39	0	1417	120.5	29.Sep
1982	22	19	56	64	144	190	234	285	235	2	7	0	1258	59.0	6.Jul
1983	27	1	25	116	253	158	417	259	266	110	0	15	1647	110.5	17.Jul
1984	20	20	11	72	127	170	460	253	470	48	0	7	1658	90.5	16.Sep
1985	0	0	0	39	360	197	519	353	405	179	0	83	2135	96.5	5.Sep
1986	0	29	10	169	262	353	352	531	339	74	0	77	2196	151.0	27.Aug
1987	3	41	49	18	119	162	681	410	159	19	0	16	1676	124.5	20.Oct
1988	0	26	96	60	204	338	330	360	157	15	19	92	1695	61.5	8.Sep
1989	73	21	23	8	231	167	449	155	240	1	0	0	1367	76.0	6.Jul
1990	0	115	102	90	226	257	623	391	253	27	0	0	2084	100.8	14.Jul
1991	0	16	39	94	88	291	312	415	174	0	0	0	1428	69.0	28.Aug
1992	0	16	0	80	159	214	347	274	122	56	15	4	1286	55.0	24.Jul
1993	18	27	26	119	126	315	693	404	176	20	9	0	1932	373.2	20.Jul
1994	36	30	38	19	98	247	189	217	201	0	0	4	1079	74.5	26.Jun
AVERAGE	17	26	34	88	170	283	463	335	260	52	8	17	1755	-	-
EXTREME	73	115	102	224	360	618	958	655	601	248	46	92	2426	373.2	20.Jul.'93

SOURCE: DATA BOOK BY DEPARTMENT OF HYDROLOGY AND METEOROLOGY (1969-1990),
INPUT DATA AT DEPARTMENT OF HYDROLOGY AND METEOROLOGY (1991-1994)

Table 1.3.2 Monthly Precipitation Summary in Sindhuli Gadhi (mm)

NAME OF SITE	: SINDHULI GADHI	LATITUDE	: 27° 17' N
STATION No.	: 1107	LONGITUDE	: 85° 58' E
EST.DATE	: Oct. 1971	ELEVATION	: 1364m
DISTRICT	: SINDHULI	ZONE	: JANAKPUR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MAXIMUM IN 24HRS.	DATE
1955	-	-	-	-	-	-	652	414	174	47	0	0	-	-	-
1956	0	12	0	26	91	422	598	617	297	7	12	11	2093	66.0	4.Sep
1957	22	0	0	4	168	304	522	452	135	165	0	48	1820	132.1	6.Aug
1958	89	0	0	144	274	142	559	1006	333	125	0	5	2676	142.2	24.Aug
1959	107	0	51	234	212	341	321	395	297	145	94	0	2196	126.1	23.Aug
1960	0	0	83	0	384	357	553	537	526	42	0	0	2481	161.2	27.Aug
1961	0	32	112	38	139	679	210	633	247	279	0	40	2408	146.0	3.Jun
1962	215	43	127	104	222	880	377	624	394	12	0	0	2999	235.0	27.Jun
1963	2	0	26	98	180	630	424	408	216	143	85	0	2212	157.0	29.Jun
1964	0	0	0	192	89	241	907	457	388	105	0	0	2379	155.2	22.Aug
1965	0	0	52	47	39	257	655	1215	243	162	22	0	2690	306.0	7.Aug
1966	56	12	1	4	256	504	894	1151	258	5	0	0	3141	286.4	2.Jul
1967	0	0	94	114	86	366	955	360	157	0	54	0	2186	216.6	9.Jul
1968	78	0	29	41	0	650	497	550	87	39	0	0	1972	222.0	1.Jun
1969	2	3	56	90	115	405	407	505	248	64	0	0	1894	112.0	18.Aug
1970	22	50	16	46	164	360	1356	799	431	49	0	0	3295	291.2	14.Jul
1971	0	55	213	232	360	798	681	471	269	64	29	0	3172	202.0	11.Jun
1972	0	45	32	39	212	525	718	274	536	91	15	0	2487	90.0	29.Jul
1973	45	11	24	65	229	264	532	295	256	160	32	0	1913	185.0	18.Jul
1974	20	0	38	71	279	311	869	539	596	116	2	32	2873	206.0	2.Sep
1975	18	29	16	70	81	299	842	326	686	223	0	0	2590	150.0	4.Oct
1976	100	8	0	258	260	602	562	647	529	364	0	0	3330	242.0	22.Sep
1977	10	12	68	308	195	179	698	443	151	88	37	65	2254	66.0	30.Jul
1978	40	20	99	369	252	594	588	434	456	128	14	0	2994	130.0	23.Apr
1979	22	41	7	94	99	552	846	752	452	200	44	17	3126	165.0	20.Aug
1980	0	14	38	8	402	504	810	514	989	225	0	0	3504	300.0	9.Sep
1981	30	6	43	193	311	390	602	820	538	6	6	0	2945	302.0	29.Sep
1982	6	9	45	106	86	570	585	624	504	98	62	10	2705	135.0	17.Jun
1983	36	0	34	65	275	161	1210	347	590	186	0	15	2919	188.0	5.Jul
1984	31	8	16	61	306	603	948	628	1005	100	0	0	3706	342.0	16.Sep
1985	7	9	11	31	209	460	867	883	818	182	19	72	3568	208.0	24.Aug
1986	0	14	0	90	270	706	435	588	479	85	8	42	2717	178.0	30.Jun
1987	0	40	83	47	49	358	868	718	622	287	37	9	3114	172.0	19.Oct
1988	0	16	51	61	344	521	812	691	298	150	12	34	2989	110.0	24.Jul
1989	22	39	11	0	141	356	490	286	379	65	0	0	1788	89.5	20.Jun
1990	0	32	21	109	-	406	-	550	415	245	-	0	-	-	-
AVERAGE	29	15	43	99	199	450	682	588	424	122	17	12	2680	-	-
EXTREME	215	55	213	369	402	880	1356	1215	1005	364	94	72	3706	342.0	16.Sep.'84

Table 2.1.1 Discharge Summary in Manhari Station (1/4)

NAME OF SITE	MANHARI	LATITUDE	27° 33′ 00″ N
STATION No.	465	LONGITUDE	84° 48′ 10″ E
EST.DATE	13 JUN. 1963	ELEVATION	305m
NAME OF RIVER	MANHARI	CA. AREA	427km²

MAXIMUM MONTHLY AND YEARLY DISCHARGES (m³/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	5.6	4.4	3.4	7.0	5.4	23.0	50.0	46.6	55.6	43.4	13.6	7.4	55.6
1964	5.5	4.3	3.4	3.7	7.9	11.5	81.3	51.0	43.5	23.5	11.6	7.5	81.3
1965	5.6	4.7	3.5	11.6	4.9	28.8	320.0	400.0	51.0	31.6	26.0	9.9	400.0
1966	8.2	7.4	5.1	3.7	6.4	20.8	87.6	463.0	120.0	27.0	13.8	9.8	463.0
1967	7.3	4.7	13.4	12.2	8.6	175.0	425.0	148.0	108.0	29.7	9.8	7.6	425.0
1968	15.0	7.2	7.2	7.9	8.3	29.0	180.0	223.0	66.8	78.0	16.5	9.4	223.0
1969	6.7	5.0	9.4	4.3	7.7	16.5	41.2	215.0	61.6	31.6	12.3	7.5	215.0
1970	5.5	5.5	26.0	18.0	9.5	39.6	494.0	64.0	54.4	17.5	9.2	7.9	494.0
1971	7.0	6.2	6.7	9.8	13.7	220.0	56.0	98.6	86.6	45.0	19.5	8.9	220.0
1972	5.9	4.9	4.2	3.6	4.9	35.6	168.0	117.0	83.0	23.9	16.2	9.8	168.0
1973	8.3	13.4	8.3	3.5	12.0	112.0	64.0	51.0	56.8	54.4	14.0	7.5	112.0
1974	6.0	4.2	5.5	6.5	12.5	61.6	108.0	522.0	662.0	74.7	14.2	8.8	662.0
1975	6.6	6.1	4.1	4.4	15.7	69.5	510.0	148.0	154.0	50.0	18.0	12.6	510.0
1976	8.6	5.7	3.4	18.0	68.0	134.0	226.0	112.0	91.1	33.0	13.0	8.2	226.0
1977	5.5	7.9	3.6	9.2	15.4	27.0	50.2	152.0	34.5	20.9	23.6	11.0	152.0
1978	6.4	8.9	18.7	17.4	9.4	57.2	244.0	72.4	66.7	56.8	51.3	9.5	244.0
1979	6.7	9.0	4.6	7.0	3.3	31.0	101.0	400.0	146.0	27.4	13.4	16.0	400.0
1980	6.1	6.1	5.2	8.6	16.0	47.4	46.1	54.5	77.0	14.0	8.7	6.9	77.0
1981	6.9	5.4	6.0	17.0	11.8	24.4	144.0	211.0	132.0	36.0	12.0	8.1	211.0
1982	5.2	4.9	5.5	3.4	10.6	10.6	84.4	52.0	313.0	43.2	21.6	11.8	313.0
1983	9.4	5.8	5.0	6.2	19.4	17.2	250.0	90.0	128.0	51.2	11.4	6.9	250.0
1984	6.9	3.8	3.2	4.4	5.4	21.6	116.0	64.0	343.0	28.0	10.1	5.6	343.0
1985	4.8	4.3	3.6	3.4	9.8	7.7	34.3	60.8	140.0	144.0	16.1	12.0	144.0
1986	8.1	17.2	7.8	70.4	72.0	132.0	98.0	430.0	301.0	41.2	13.0	6.0	430.0
1987	5.0	3.6	14.6	6.0	6.2	25.1	205.0	298.0	176.0	136.0	12.2	14.6	298.0
1988	11.4	8.4	28.6	8.7	17.9	14.6	43.4	46.7	106.0	16.2	16.2	10.6	106.0
1989	23.3	8.7	9.8	15.4	14.6	60.4	98.0	39.0	435.0	22.4	5.2	2.8	435.0
1990	1.7	1.8	2.5	1.8	5.5	50.0	113.0	261.0	98.0	64.7	17.0	7.6	261.0
AVERAGE	7.5	6.4	7.9	10.5	14.4	53.7	158.5	174.7	149.7	45.2	15.7	9.0	282.8
EXTREME	23.3	17.2	28.6	70.4	72.0	220.0	510.0	522.0	662.0	144.0	51.3	16.0	662.0

Table 2.1.1 Discharge Summary in Manhari Station (2/4)

NAME OF SITE	MANHARI	LATITUDE	27° 33′ 00″ N
STATION No.	465	LONGITUDE	84° 48′ 10″ E
EST.DATE	13 JUN. 1963	ELEVATION	305m
NAME OF RIVER	MANHARI	CA. AREA	427km²

MINIMUM MONTHLY AND YEARLY DISCHARGES (m³/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	4.3	3.5	3.0	2.8	1.9	1.8	5.9	18.2	16.2	12.2	7.2	5.5	1.8
1964	4.3	3.3	2.9	2.5	1.9	1.8	5.9	23.5	24.5	11.6	7.5	5.6	1.8
1965	4.3	3.7	3.0	2.6	1.8	1.8	10.6	21.0	26.6	15.4	9.9	6.9	1.8
1966	5.1	4.5	3.7	2.8	2.5	2.2	16.3	23.5	24.9	13.3	9.4	6.8	2.2
1967	4.7	3.4	3.1	2.5	1.6	1.3	7.3	28.5	29.7	10.4	7.3	5.8	1.3
1968	5.1	3.5	2.6	2.0	1.7	5.6	16.0	12.3	15.9	15.9	9.4	6.7	1.7
1969	4.7	3.4	3.1	2.6	2.2	3.9	6.7	17.1	32.4	12.8	7.5	5.5	2.2
1970	4.3	3.2	3.7	5.8	3.0	3.5	9.8	26.8	19.0	9.2	7.2	7.0	3.0
1971	6.5	5.8	5.3	3.0	4.3	5.3	28.6	40.0	25.5	14.0	9.8	5.7	3.0
1972	4.4	3.7	2.9	2.6	2.5	2.5	7.3	25.3	21.8	15.5	9.8	6.0	2.5
1973	4.5	3.5	3.0	2.3	2.8	3.0	24.2	22.4	23.0	14.5	7.5	5.0	2.3
1974	4.5	3.7	3.1	3.9	3.4	3.7	38.0	32.4	26.5	14.6	8.8	6.1	3.1
1975	4.9	4.0	3.5	3.2	3.2	3.1	12.8	31.0	47.4	18.0	12.6	6.6	3.1
1976	5.2	3.4	2.0	2.0	2.0	7.8	37.0	34.0	29.0	13.0	8.2	5.8	2.0
1977	4.3	3.3	2.8	3.6	3.3	3.3	15.4	28.0	20.0	12.0	7.7	6.0	2.8
1978	4.8	4.0	3.6	3.3	4.8	5.7	20.0	31.0	30.0	15.5	9.5	6.7	3.3
1979	5.3	4.6	3.3	3.1	2.5	2.3	9.0	36.0	28.6	13.4	9.4	6.1	2.3
1980	4.3	3.4	2.3	1.8	3.9	3.4	7.8	23.0	14.0	8.7	6.9	5.8	1.8
1981	5.6	4.8	4.4	4.6	4.6	3.4	8.4	23.0	23.0	12.0	8.1	5.2	3.4
1982	4.2	3.6	2.8	2.6	2.2	3.9	6.2	16.0	20.0	21.6	12.6	7.0	2.2
1983	5.4	4.6	4.2	3.0	4.2	1.2	12.6	35.8	51.2	11.4	6.9	5.0	1.2
1984	3.8	2.6	2.4	2.4	2.4	2.8	5.8	20.5	28.0	10.1	5.6	4.8	2.4
1985	4.3	3.5	3.3	3.3	3.3	4.1	6.1	16.1	37.2	17.2	8.7	6.6	3.3
1986	5.6	5.2	4.6	4.4	52.8	4.8	28.8	68.8	19.7	8.4	5.7	5.0	4.4
1987	3.4	3.0	3.1	3.1	3.4	3.3	13.0	96.0	68.8	6.8	7.0	11.4	3.0
1988	8.4	7.6	6.2	6.8	8.2	7.3	7.6	17.9	13.8	11.4	8.7	8.2	6.2
1989	8.2	7.9	7.9	8.2	9.8	14.6	17.0	18.8	9.0	5.2	2.8	1.7	1.7
1990	1.1	1.0	0.9	0.8	0.8	5.0	8.4	6.8	31.2	17.9	7.6	5.5	0.8
AVERAGE	4.8	4.0	3.4	3.3	5.0	4.0	14.0	28.3	27.0	12.9	8.2	6.1	2.5
EXTREME	1.1	1.0	0.9	0.8	0.8	1.2	5.8	6.8	9.0	5.2	2.8	1.7	0.8

Table 2.1.1 Discharge Summary in Manhari Station (3/4)

NAME OF SITE	MANHARI	LATITUDE	27° 33′ 00″ N
STATION No.	465	LONGITUDE	84° 48′ 10″ E
EST.DATE	13 JUN. 1963	ELEVATION	305m
NAME OF RIVER	MANHARI	CA. AREA	427km²

MEAN MONTHLY AND YEARLY DISCHARGES (m³/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	4.8	3.9	3.2	3.4	3.3	6.0	19.0	31.8	26.0	18.3	9.5	6.3	11.3
1964	4.7	3.8	3.1	2.9	3.9	5.1	24.8	33.8	30.6	16.2	9.5	6.5	12.1
1965	5.0	4.0	3.2	3.9	2.7	11.5	41.0	128.0	42.1	20.1	13.1	8.3	23.6
1966	6.0	5.2	4.2	3.2	3.2	5.8	27.0	89.3	45.3	18.6	11.8	7.8	18.9
1967	5.9	4.1	4.5	4.8	3.1	21.7	90.7	72.5	66.8	17.1	8.4	6.7	25.5
1968	6.3	4.4	3.6	2.7	3.5	13.2	35.8	49.2	29.9	32.9	12.3	7.9	16.8
1969	5.7	4.1	3.9	3.5	3.8	7.1	23.2	60.6	46.4	19.5	10.1	6.5	16.2
1970	5.0	3.9	11.5	11.7	4.5	12.2	56.2	47.0	41.0	11.4	8.1	7.3	18.3
1971	6.7	6.1	5.7	5.6	8.4	34.7	34.6	70.3	55.8	21.7	14.6	6.9	22.6
1972	5.3	4.4	3.4	2.8	2.7	6.7	55.8	52.5	34.9	19.3	12.2	7.3	17.3
1973	5.5	4.4	4.0	2.7	4.3	32.8	42.7	31.6	35.8	21.5	10.5	6.1	16.8
1974	4.7	4.0	3.7	4.4	5.5	17.8	55.1	77.4	92.5	26.5	11.2	7.2	25.8
1975	5.5	4.6	3.8	3.5	4.6	14.2	69.9	56.6	77.6	29.4	14.4	9.2	24.4
1976	6.1	4.6	2.7	3.6	8.8	39.8	71.2	48.7	49.0	19.1	10.3	6.9	22.6
1977	5.0	4.2	3.0	5.4	6.2	6.9	28.3	48.2	25.6	16.7	10.4	6.9	13.9
1978	5.5	4.6	4.5	5.4	6.4	20.2	62.4	49.0	39.1	24.7	13.4	8.3	20.3
1979	5.8	5.3	3.9	3.9	2.9	7.7	40.5	91.9	59.6	20.2	11.3	8.2	21.8
1980	5.4	4.2	3.7	2.4	8.6	12.0	23.7	32.9	19.7	11.1	7.7	6.2	11.5
1981	5.8	5.2	4.7	6.6	5.6	7.5	19.1	55.9	49.9	19.6	10.0	6.3	16.3
1982	4.7	4.2	3.5	2.8	3.8	7.3	26.5	29.2	52.0	31.9	16.3	9.1	15.9
1983	6.4	5.1	4.4	3.8	8.8	4.3	43.7	57.5	67.4	23.2	8.8	5.7	19.9
1984	4.7	3.1	2.7	2.9	3.4	7.7	26.5	34.4	71.5	14.5	7.4	5.1	15.3
1985	4.5	3.9	3.4	3.3	4.0	4.8	18.3	31.7	63.5	38.5	11.5	8.0	16.3
1986	6.3	6.0	5.0	38.8	57.7	36.4	50.9	105.0	64.2	19.0	7.3	5.5	33.5
1987	4.3	3.3	4.2	4.4	4.1	10.2	76.7	179.0	99.9	37.5	8.1	12.6	37.0
1988	10.0	7.8	7.9	7.9	11.4	10.6	14.2	23.6	22.8	13.9	11.4	8.8	12.5
1989	9.9	8.3	8.4	12.8	11.8	21.9	38.8	25.0	59.1	9.7	3.8	2.1	17.6
1990	1.4	1.2	1.1	0.9	2.1	10.4	52.7	38.0	54.7	38.4	11.0	6.5	18.2
AVERAGE	5.6	4.6	4.3	5.7	7.1	14.2	41.8	59.0	50.8	21.8	10.5	7.1	19.4

Table 2.1.1 Discharge Summary in Manhari Station (4/4)

NAME OF SITE	MANHARI	LATITUDE	27° 33′ 00″ N
STATION No.	465	LONGITUDE	84° 48′ 10″ E
EST.DATE	13 JUN. 1963	ELEVATION	305m
NAME OF RIVER	MANHARI	CA. AREA	427km²

EXTREME DISCHARGES

MAXIMUM INSTANTANEOUS			MIMIMUM INSTANTANEOUS		
DISCHARGE (m³/s)	GAUGE HEIGHT (m)	DATE	DISCHARGE (m³/s)	GAUGE HEIGHT (m)	DATE
59	1.74	13 Jul. 1963	1.79	0.58	31 Dec. 1963
118	1.95	20 Jul. 1964	1.81	0.36	11 Jun. 1964
800	3.50	7 Jul. 1965	1.80	0.28	14 Jun. 1965
1000	4.75	27 Aug. 1966	2.17	0.39	13 Jun. 1966
696	3.70	10 Jul. 1967	1.02	0.36	31 Dec. 1967
292	2.64	28 Aug. 1968	1.52	0.18	13 May. 1968
228	2.42	15 Aug. 1969	2.22	0.70	24 May. 1969
1450	5.60	16 Jul. 1970	2.80	0.59	15 May. 1970
1050	4.70	13 Jun. 1971	2.96	0.58	15 Apr. 1971
262	2.41	28 Jul. 1972	2.46	0.18	13 Jun. 1972
256	2.52	24 Jun. 1973	2.00	0.80	20 Apr. 1973
850	4.20	2 Sep. 1974	3.11	0.73	22 Mar. 1974
910	4.35	28 Jul. 1975	3.24	0.32	1 May. 1975
335	2.70	2 Jul. 1976	2.00	0.68	30 May. 1976
180	1.95	16 Aug. 1977	2.80	0.42	26 Mar. 1977
360	2.80	16 Jul. 1978	3.32	0.53	12 Apr. 1978
970	4.50	21 Aug. 1979	2.30	0.44	7 Jun. 1979
97	1.51	1 Sep. 1980	1.75	0.67	18 Apr. 1980
310	2.70	20 Aug. 1981	3.40	0.56	17 Jun. 1981
610	3.60	19 Sep. 1982	2.24	0.72	13 May. 1982
280	2.60	17 Jul. 1983	1.20	1.00	22 Jun. 1983
1440	5.58	17 Sep. 1984	2.40	0.92	21 May. 1984
280	2.60	5 Sep. 1985	3.27	0.37	14 May. 1985
700	-	27 Aug. 1986	4.40	-	2 Apr. 1986
310	-	8 Jul. 1987	2.95	-	23 Feb. 1987
168	-	8 Sep. 1988	6.20	-	15 Mar. 1988
460	-	8 Sep. 1989	1.66	-	31 Dec. 1989
301	-	27 Aug. 1990	0.70	-	6 Apr. 1990

Table 2.1.2 Discharge Summary in Kulekhani Station (1/2)

NAME OF SITE	KULEKHANI	LATITUDE	27° 39′ 40″ N
STATION No.	570	LONGITUDE	85° 17′ 50″ E
EST.DATE	1 DEC. 1962	ELEVATION	1480m
NAME OF RIVER	KULEKHANI KHOLA	CA. AREA	126km²

MAXIMUM MONTHLY AND YEARLY DISCHARGES (m³/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	1.6	1.2	2.4	2.0	6.9	1.9	22.2	21.9	23.0	8.1	2.5	1.9	23.0
1964	1.6	1.5	1.3	1.5	2.4	5.3	32.4	19.7	42.9	8.1	2.4	1.6	42.9
1965	1.4	1.4	1.6	5.1	1.8	29.8	139.0	67.4	9.4	4.4	6.6	2.0	139.0
1966	2.7	2.4	1.3	0.9	6.4	5.7	77.5	123.0	44.8	4.4	2.4	2.0	123.0
1967	1.2	1.1	2.4	3.3	1.8	46.5	126.0	26.0	7.6	4.2	2.6	1.8	126.0
1968	2.7	1.8	9.2	5.5	3.6	7.4	32.0	15.1	3.8	73.2	2.7	1.8	73.2
1969	1.7	1.0	1.9	8.3	1.8	3.6	9.2	22.0	7.1	2.7	1.3	0.9	22.0
1970	1.4	1.2	1.4	1.8	1.3	20.1	218.0	20.5	7.9	4.6	2.5	1.8	218.0
1971	1.2	1.1	1.1	7.7	3.1	173.0	12.0	19.7	9.9	30.8	2.4	2.0	173.0
1972	1.8	2.4	2.4	1.7	1.8	46.8	115.0	15.6	38.0	7.6	2.8	1.9	115.0
1973	2.6	2.9	9.8	3.7	2.1	68.4	16.5	18.3	52.4	46.8	10.0	4.4	68.4
1974	2.0	1.8	2.1	2.0	2.3	7.0	23.3	162.0	154.0	4.8	2.5	1.6	162.0
1975	1.7	1.5	1.0	1.6	5.0	14.3	108.0	42.4	47.2	8.5	3.0	1.9	108.0
1976	3.9	1.4	1.1	1.8	2.7	49.6	21.8	21.3	7.7	2.9	1.9	1.6	49.6
1977	1.4	1.4	1.3	2.4	3.1	6.9	6.0	7.2	3.2	2.1	2.0	4.2	7.2
EXTREME	3.9	2.9	9.8	8.3	6.9	173.0	218.0	162.0	154.0	73.2	10.0	4.4	218.0

MINIMUM MONTHLY AND YEARLY DISCHARGES (m³/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	1.1	1.0	0.9	0.8	0.8	0.8	1.0	5.1	3.7	2.4	1.9	1.6	0.8
1964	1.4	1.3	0.6	0.6	0.8	0.9	2.3	5.5	10.2	2.4	1.6	1.4	0.6
1965	1.3	1.2	1.1	1.2	1.3	1.2	3.2	6.4	3.8	2.7	2.0	1.5	1.1
1966	1.4	1.2	1.1	0.5	0.5	0.4	2.9	5.4	4.2	2.4	1.9	1.4	0.4
1967	1.0	0.8	0.5	0.5	0.3	0.2	1.6	3.3	4.4	2.7	1.9	1.5	0.2
1968	1.4	1.3	1.0	0.7	0.6	1.0	2.1	4.0	1.9	1.8	1.8	1.3	0.6
1969	1.0	0.8	0.7	0.4	0.4	0.5	0.8	2.6	2.7	1.3	0.9	0.8	0.4
1970	0.8	0.6	0.5	0.3	0.3	0.4	1.0	5.6	4.4	2.5	1.8	1.2	0.3
1971	1.1	1.1	1.1	1.1	1.7	1.7	2.7	2.8	2.7	2.4	2.0	1.8	1.1
1972	1.7	1.6	1.5	1.2	1.2	1.1	2.1	2.9	2.6	2.3	1.9	1.3	1.1
1973	1.2	1.0	1.0	0.8	1.0	0.9	3.7	5.2	5.2	4.6	3.2	1.8	0.8
1974	1.5	1.2	1.0	0.9	0.8	0.6	1.7	3.9	5.0	2.5	1.7	1.4	0.6
1975	1.2	1.0	0.8	0.7	0.7	0.5	2.3	5.4	5.8	3.0	1.9	1.4	0.5
1976	1.3	1.1	0.9	0.8	0.7	1.5	3.0	3.1	2.9	1.9	1.6	1.3	0.7
1977	1.3	1.2	0.9	1.1	1.1	0.8	1.9	2.3	1.9	1.6	1.5	1.4	0.8
EXTREME	0.8	0.6	0.5	0.3	0.3	0.2	0.8	2.3	1.9	1.3	0.9	0.8	0.2

Table 2.1.2 Discharge Summary in Kulekhani Station (2/2)

NAME OF SITE	KULEKHANI	LATITUDE	27° 39′ 40″ N
STATION No.	570	LONGITUDE	85° 17′ 50″ E
EST.DATE	1 DEC. 1962	ELEVATION	1480m
NAME OF RIVER	KULEKHANI KHOLA	CA. AREA	126km^2

MEAN MONTHLY AND YEARLY DISCHARGES (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1963	1.2	1.1	1.1	1.2	1.7	1.1	6.6	7.6	5.8	3.5	2.2	1.8	2.9
1964	1.5	1.4	1.2	0.9	1.3	2.2	7.2	12.1	15.2	4.5	1.8	1.5	4.2
1965	1.3	1.3	1.2	1.8	1.5	3.7	17.2	18.4	5.7	3.2	2.9	1.8	5.0
1966	1.6	1.5	1.2	0.7	1.1	1.1	10.4	20.8	10.3	3.3	2.2	1.7	4.7
1967	1.1	0.9	0.9	1.0	0.7	4.5	11.8	6.9	5.7	3.4	2.3	1.7	3.4
1968	1.7	1.5	1.6	1.2	1.1	2.5	5.7	6.3	2.6	7.1	2.3	1.5	2.9
1969	1.2	0.9	0.9	0.9	1.0	0.9	3.1	6.9	4.2	1.9	1.1	0.8	2.0
1970	0.8	0.7	0.6	0.6	0.6	3.4	21.5	9.0	5.3	3.3	2.2	1.5	4.1
1971	1.2	1.1	1.1	2.0	2.1	21.6	5.2	7.7	4.3	3.8	2.2	1.9	4.5
1972	1.7	1.8	1.6	1.4	1.4	4.5	26.3	5.6	7.9	3.2	2.2	1.6	4.9
1973	1.4	1.2	1.6	1.0	1.3	10.2	7.3	8.0	9.5	9.5	5.1	2.7	4.9
1974	1.6	1.3	1.1	1.2	1.3	1.7	7.2	15.6	20.6	3.5	2.0	1.5	4.9
1975	1.3	1.2	0.9	0.8	1.1	2.1	14.8	11.0	11.7	4.7	2.4	1.7	4.5
1976	1.5	1.3	1.0	1.1	1.4	8.0	6.0	4.8	3.9	2.3	1.8	1.5	2.9
1977	1.3	1.2	1.1	1.4	1.6	1.6	3.2	3.5	2.3	1.8	1.6	1.6	1.8
AVERAGE	1.3	1.2	1.1	1.1	1.3	4.6	10.2	9.6	7.7	3.9	2.3	1.6	3.8

EXTREME DISCHARGES

MAXIMUM INSTANTANEOUS			MIMIMUM INSTANTANEOUS		
DISCHARGE (m^3/s)	GAUGE HEIGHT (m)	DATE	DISCHARGE (m^3/s)	GAUGE HEIGHT (m)	DATE
40	1.60	29 SEP. 1963	0.73	0.90	14 MAY. 1963
148	2.71	15 JUL. 1964	0.20	0.44	8 APR. 1964
304	4.20	7 JUL. 1965	1.10	0.64	28 MAR. 1965
202	3.25	24 AUG. 1966	0.28	0.21	12 JUN. 1966
277	3.95	10 JUL. 1967	0.11	0.18	4 JUN. 1967
141	2.63	4 OCT. 1968	0.55	0.35	31 MAY. 1968
33	1.31	21 AUG. 1969	0.34	0.32	26 MAY. 1969
571	5.35	16 JUL. 1970	0.20	0.30	31 MAY. 1970
305	5.24	13 JUN. 1971	1.05	0.93	5 APR. 1971
251	4.56	24 JUL. 1972	1.08	0.95	12 JUN. 1972
100	2.67	17 JUN. 1973	0.75	0.87	22 APR. 1973
236	4.38	30 AUG. 1974	0.62	0.99	4 JUN. 1974
143	3.21	27 JUL. 1975	0.51	0.52	10 JUN. 1975
148	3.28	10 JUN. 1976	0.74	0.58	30 MAY. 1976
8.6	0.98	17 AUG. 1977	0.84	0.22	14 JUN. 1977

Table 2.2.1 Assumed Annual Run-off Ratio in Makwanpur District

	Rainfall at Daman (mm)	Rainfall at Markhu Gaun (mm)	Manhari		Kulekhani	
			Depth (mm)	Run-off Ratio (%)	Depth (mm)	Run-off Ratio (%)
1969	1428	-	1196	84%	583	-
1970	1259	-	1352	107%	1214	-
1971	1717	-	1669	97%	1289	-
1972	2085	1473	1278	61%	1507	85%
1973	2426	1865	1241	51%	-	-
1974	2307	1829	1905	83%	-	-
1975	2159	1866	1802	83%	-	-
1976	1929	1706	1669	87%	-	-
1977	1529	1369	1027	67%	-	-
1978	2312	1689	1499	65%	-	-
1979	1856	1080	1610	87%	-	-
1980	-	-	849	-	-	-
1981	1417	1028	1204	85%	-	-
1982	1258	1115	1174	93%	-	-
1983	1647	1462	1470	89%	-	-
1984	1658	1498	1130	68%	956	61%
1985	2135	1928	1204	56%	1289	63%
1986	2196	1758	2474	113%	1299	66%
1987	1676	1503	2733	163%	1201	76%
1988	1695	1344	923	54%	1019	67%
1989	1367	1143	1300	95%	911	73%
1990	2084	1455	1344	65%	1114	63%
1991	1428	1017	-	-	773	63%
1992	1286	983	-	-	463	41%
1993	1932	1937	-	-	1114	58%
Average	1816	1685	1457	84%	1126	69%

Note: 1) Depth of Kulekhani from 1969 to 1972 is calculated by discharge date from O&M Manual, Kulekhani hydropower Project, July 1982.
2) Depth of Kulekhani from 1984 to 1993 is calculated by discharge data that is estimated by KDPP from the recorded R.W.L. power generation and spillout.
3) Run-off ratio of Manhari is calculated by rainfall data of Daman.
4) Run-off ratio of Kulekhani is calculated by average rainfall data of Daman and Markhu Gaun.

Table 3.2.1 Annual Maximum Daily Rainfall in Daman and Dhunibesi

Year	Daman		Dhunibesi	
	Precipitation (mm/day)	Date	Precipitation (mm/day)	Date
1969	47.5	20-Aug	-	-
1970	58.6	26-Jul	-	-
1971	121.6	29-Jun	-	-
1972	128.2	28-Jul	-	-
1973	104.0	16-Jun	-	-
1974	181.7	2-Sep	-	-
1975	156.0	27-Jul	74.0	1-Jul
1976	168.0	10-Jun	84.0	25-Aug
1977	76.8	20-Jun	63.0	20-Jun
1978	233.5	16-Jul	111.0	16-Jul
1979	207.5	21-Aug	93.0	21-Aug
1980	-	-	62.0	9-Jun
1981	120.5	29-Sep	128.0	29-Sep
1982	59.0	6-Jul	85.0	27-Aug
1983	110.5	17-Jul	212.0	6-May
1984	90.5	16-Sep	66.0	8-Jul
1985	96.5	5-Sep	70.0	28-Jul
1986	151.0	27-Aug	109.0	27-Jun
1987	124.5	20-Oct	84.0	23-Jun
1988	61.5	8-Sep	124.7	26-Aug
1989	76.0	6-Jul	80.6	26-Jun
1990	100.8	14-Jul	86.5	27-Aug
1991	69.0	28-Aug	-	-
1992	55.0	24-Jul	92.5	13-Sep
1993	373.2	20-Jul	194.0	20-Jul
1994	74.5	26-Jun	88.3	17-Jun

Source: Climatological Records of Nepal, Department of Hydrology and Meteorology

Table 3.3.1 Calculation of Peak Flood Discharge by Rational Formula

Area	River Name	Site	Length of Waterway (km)	Catchment Area (km²)	Altitude (m)	Altitude Difference with Upstream End (m)	Avarage Gradient	Flood Propagation Speed (m/s)	Time of Concentration (hour)	Adopted Rainfall Station	Daily Rainfall Depth in 20-year Probability (mm)	Continuation Rainfall Intensity within Time of Concentration (mm)	Areal Reduction Factor <ARF>	Rainfall Intensity within Concentration Time with ARF (mm/h)	Design Flood Discharge (20-Year Peak Flood) (m³/s)
Phedigaon/Phatbazar	Palung Khola	Confluence with Gharti Khola (Except Garti Khola Basin)	4.12	5.94	1794	691	1/6.0 (16.8%)	3.5	0.33	Daman	275	32.1	0.89	87.1	100.6
		Palung Bazar (Abandoned Bridge;Pa-1)	3.87	5.90	1760	725	1/5.3 (18.7%)	3.5	0.31	Daman	275	31.1	0.89	89.7	102.9
		Confluence of Palung & Dhungakate & Bhottekoria Khola	2.50	3.57	1765	720	1/3.5 (28.8%)	3.5	0.20	Daman	275	25.0	0.89	111.8	77.6
	Bhottekoria khola	Downstream End	2.00	1.40	1797	403	1/5.0 (20.2%)	3.5	0.16	Daman	275	22.4	0.91	128.7	35.0
		Outlet to Alluvial Fan	1.70	1.33	1827	373	1/4.6 (21.9%)	3.5	0.13	Daman	275	20.6	0.91	139.0	35.9
		Bh-1	1.15	0.94	1877	298	1/3.9 (25.9%)	3.5	0.09	Daman	275	17.0	0.91	168.7	30.8
		Bh-2	0.80	0.38	1960	215	1/3.7 (26.9%)	3.5	0.06	Daman	275	14.1	0.92	205.9	15.2
		Bh-3	0.65	0.27	1927	188	1/3.5 (28.9%)	3.5	0.05	Daman	275	12.7	0.93	229.3	12.0
		Bh-4	0.48	0.05	1846	229	1/2.1 (47.7%)	3.5	0.04	Daman	275	11.0	0.96	275.1	2.7
		Bh-5	0.70	0.08	1865	250	1/2.8 (35.7%)	3.5	0.06	Daman	275	13.2	0.96	227.5	3.5
		Bh-6	0.45	0.06	1913	282	1/1.6 (62.7%)	3.5	0.04	Daman	275	10.6	0.95	282.9	3.3
	Dhungakate Khola	Downstream End	2.50	1.20	1719	766	1/3.3 (30.6%)	3.5	0.20	Daman	275	25.0	0.92	116.5	27.2
		Outlet to Alluvial Fan	1.67	0.66	1898	587	1/2.8 (35.1%)	3.5	0.13	Daman	275	20.4	0.93	143.4	18.4
		Dh-1	1.13	0.28	2010	475	1/2.4 (42.0%)	3.5	0.09	Daman	275	16.8	0.94	176.3	9.6
		Dh-2	1.00	0.27	2055	430	1/2.3 (43.0%)	3.5	0.08	Daman	275	15.8	0.94	187.0	9.8
		Dh-3	0.43	0.09	1980	165	1/2.6 (38.4%)	3.5	0.03	Daman	275	10.4	0.94	286.8	5.0
		Dh-4	0.55	0.12	2000	275	1/2.0 (50.0%)	3.5	0.04	Daman	275	11.7	0.94	253.4	5.9
		Dh-5	0.53	0.06	2120	205	1/2.6 (38.7%)	3.5	0.04	Daman	275	11.5	0.96	261.5	3.1
		Dh-6	0.70	0.09	2135	265	1/2.6 (37.9%)	3.5	0.06	Daman	275	13.2	0.95	227.0	4.0
		Dh-7	0.75	0.05	2135	350	1/2.1 (46.7%)	3.5	0.06	Daman	275	13.7	0.96	221.7	2.2
	Ghatte Khola	Downstream End	2.00	0.97	1804	506	1/4.0 (25.3%)	3.5	0.16	Daman	275	22.4	0.92	130.2	24.6
		Outlet to Alluvial Fan	1.45	0.76	1872	438	1/3.3 (30.2%)	3.5	0.12	Daman	275	19.0	0.92	152.6	22.5
		Gh-1	1.20	0.20	1935	465	1/2.6 (38.8%)	3.5	0.10	Daman	275	17.3	0.95	172.6	6.7
		Gh-2	0.80	0.16	2020	370	1/2.2 (46.3%)	3.5	0.06	Daman	275	14.1	0.95	210.5	6.5
		Gh-3	0.58	0.11	2055	255	1/2.3 (44.0%)	3.5	0.05	Daman	275	12.0	0.95	247.5	5.3
Namtar/Tilar	Manhari Khola	Confluence with Chyau Khola	10.42	27.48	910	1699	1/6.1 (16.3%)	3.5	0.83	Daman	275	51.0	0.86	53.1	283.9
		Confluence with Mahabir Khola	10.48	34.74	910	1699	1/6.2 (16.2%)	3.5	0.83	Daman	275	51.2	0.85	52.2	352.8
		Check Dam D1 (Na-1)	11.86	36.09	856	1645	1/7.2 (13.9%)	3.5	0.94	Daman	275	54.5	0.85	49.4	346.5
		Check Dam D2 (Na-2)	12.67	36.55	839	1662	1/7.6 (13.1%)	3.5	1.01	Daman	275	56.3	0.86	47.9	340.7
		Confluence with Dhobi Khola	13.05	38.80	832	1669	1/7.8 (12.8%)	3.5	1.04	Daman	275	57.1	0.85	47.2	355.7
		Suspension Bridge	14.17	43.00	798	1702	1/8.3 (12.0%)	3.5	1.12	Daman	275	59.5	0.85	45.2	377.9
		Confluence with Gorduwa Khola	14.80	47.53	779	1721	1/8.6 (11.6%)	3.5	1.17	Daman	275	60.8	0.85	44.1	407.3
	Chyau Khola	Downstream End	7.88	8.80	910	1630	1/4.8 (20.7%)	3.5	0.63	Daman	275	44.4	0.90	63.8	109.1
	Mahabir Khola	Downstream End	8.58	7.26	910	1450	1/5.9 (16.9%)	3.5	0.68	Daman	275	46.3	0.91	61.8	87.2
	Dhobi Khola	Downstream End	2.50	2.36	832	588	1/4.3 (23.5%)	3.5	0.20	Daman	275	25.0	0.90	113.9	52.2
	Khade Khola	Downstream End	3.75	2.42	793	627	1/6.0 (16.7%)	3.5	0.30	Daman	275	30.6	0.92	94.3	44.4
	Syarse Khola	Downstream End	4.00	4.61	793	1047	1/3.8 (26.2%)	3.5	0.32	Daman	275	31.6	0.90	89.3	80.1
	Gorduwa Khola	Downstream End	5.56	5.80	779	1201	1/4.6 (21.6%)	3.5	0.44	Daman	275	37.3	0.90	76.1	85.8
Chisapani	Chisapani Khola	No.1 Check Dam (Ch-1)	1.18	0.39	2100	350	1/3.4 (29.7%)	3.5	0.09	Daman	275	17.2	0.93	171.3	13.0
		No.3 Check Dam (Ch-3)	1.70	0.66	1890	560	1/3.0 (32.9%)	3.5	0.13	Daman	275	20.6	0.93	142.2	18.2
		No.4 Check Dam (Ch-4)	1.80	0.67	1855	595	1/3.0 (33.1%)	3.5	0.14	Daman	275	21.2	0.93	138.3	18.0
		Ch-5	1.00	0.16	1890	435	1/2.3 (43.5%)	3.5	0.08	Daman	275	15.8	0.95	189.2	5.9
Mahadev Besi Bridge	Agra Khola	Confluence with Mahesh Khola (Include Mahesh Khola Basin)	21.74	213.60	590	1810	1/12.0 (8.3%)	3.5	1.73	Dhunibesi	190	50.9	0.78	22.9	950.7
		Downstream End	21.74	112.00	590	1810	1/12.0 (8.3%)	3.5	1.73	Dhunibesi	190	50.9	0.82	24.3	529.2
		Confluence with Mel Khola	14.28	85.29	770	1630	1/8.8 (11.4%)	3.5	1.13	Dhunibesi	190	41.3	0.81	29.6	490.7
		Confluence with Chalti Khola	9.78	42.29	930	1470	1/6.7 (15.0%)	3.5	0.78	Dhunibesi	190	34.2	0.83	36.7	301.5
	Mahesh Khola	Downstream End	18.88	101.60	590	1810	1/10.4 (9.6%)	3.5	1.50	Dhunibesi	190	47.5	0.82	26.0	513.2
	Charti Khola	Downstream End	7.53	12.85	930	1290	1/5.8 (17.1%)	3.5	0.60	Dhunibesi	190	30.0	0.88	44.2	110.5
	Mel Khola	Downstream End	12.33	37.77	770	1370	1/9.0 (11.1%)	3.5	0.98	Dhunibesi	190	38.4	0.85	33.4	245.6
	Khani Khola	Downstream End	9.78	29.44	930	1270	1/7.7 (13.0%)	3.5	0.78	Dhunibesi	190	34.2	0.85	37.6	215.1

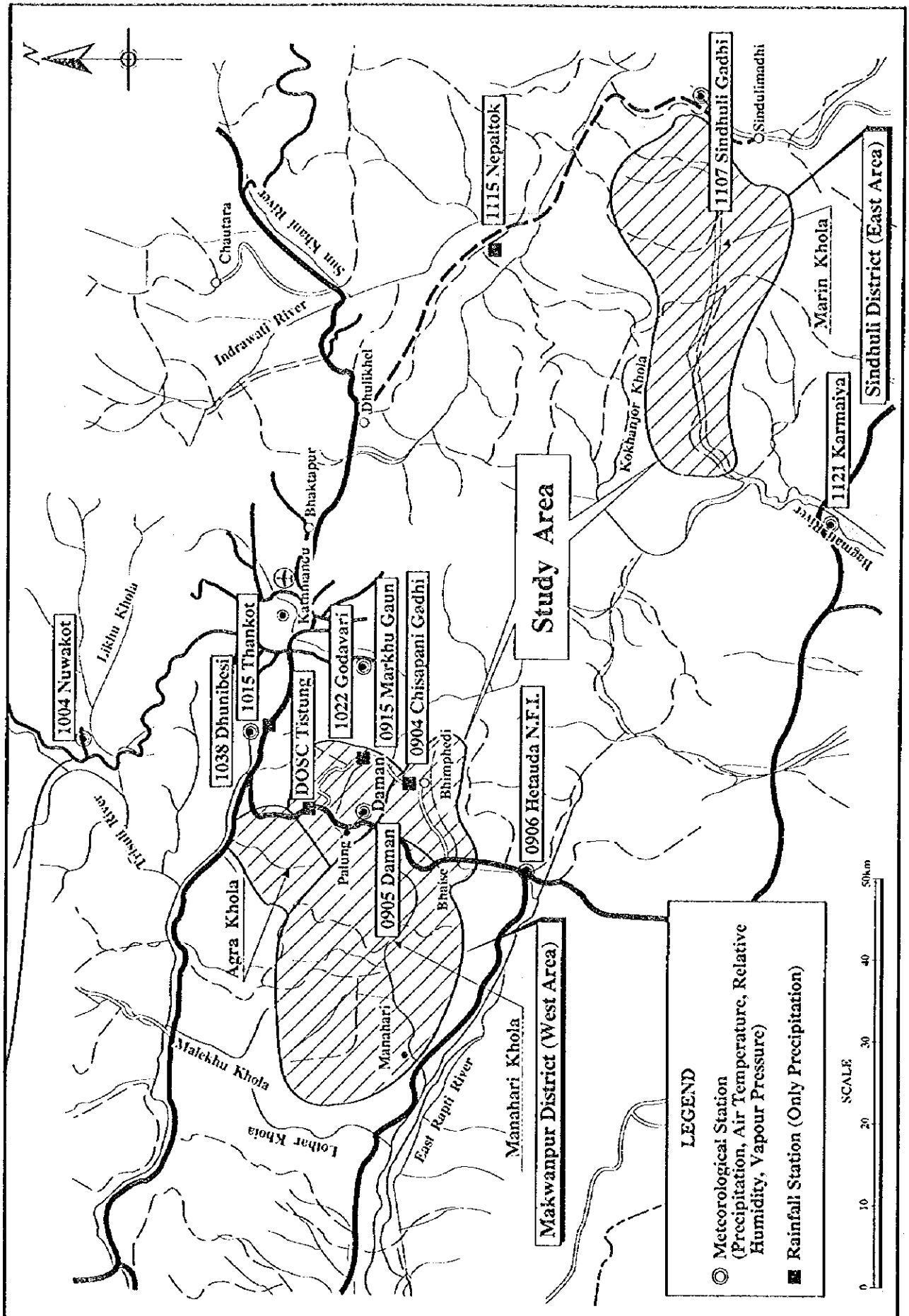

Figure 1.1.1 Location Map of Meteorological and Rainfall Stations

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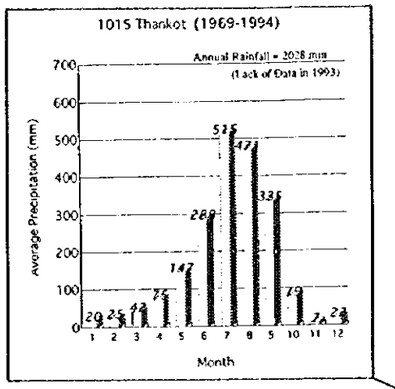

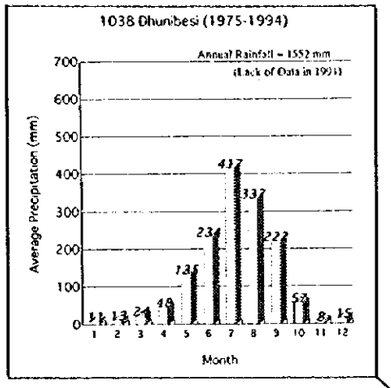

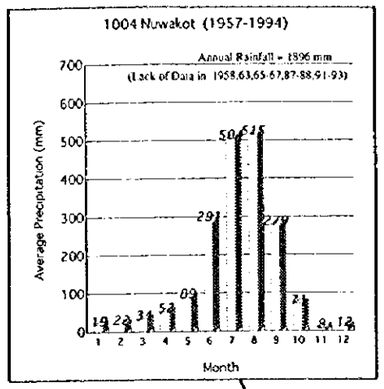

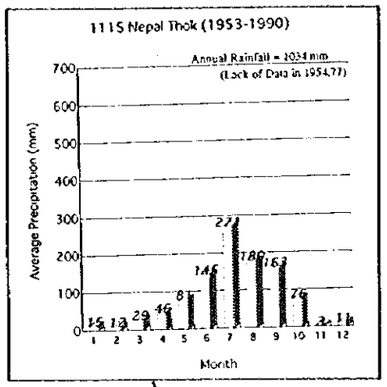

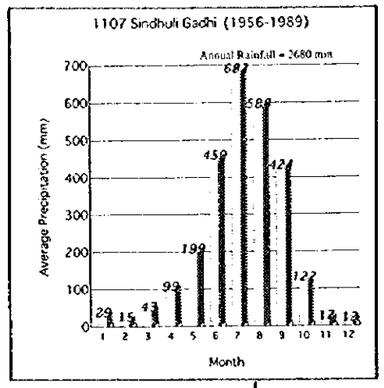

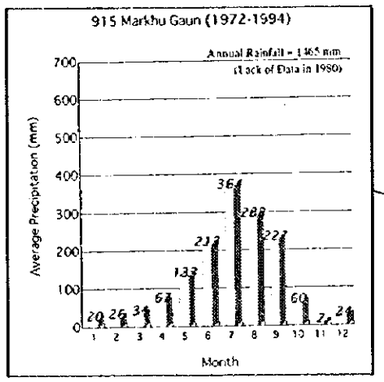

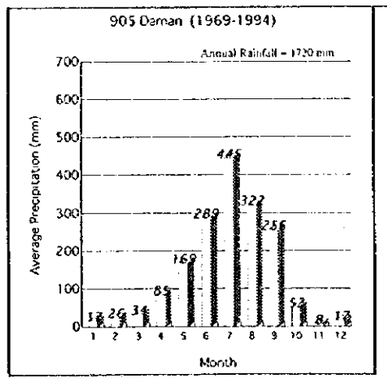

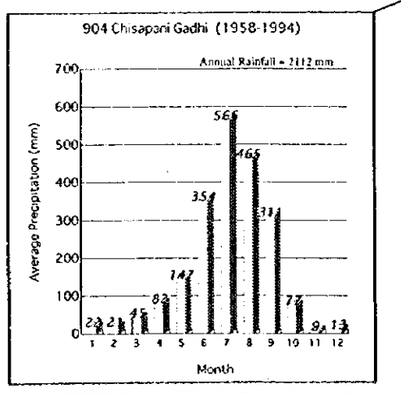

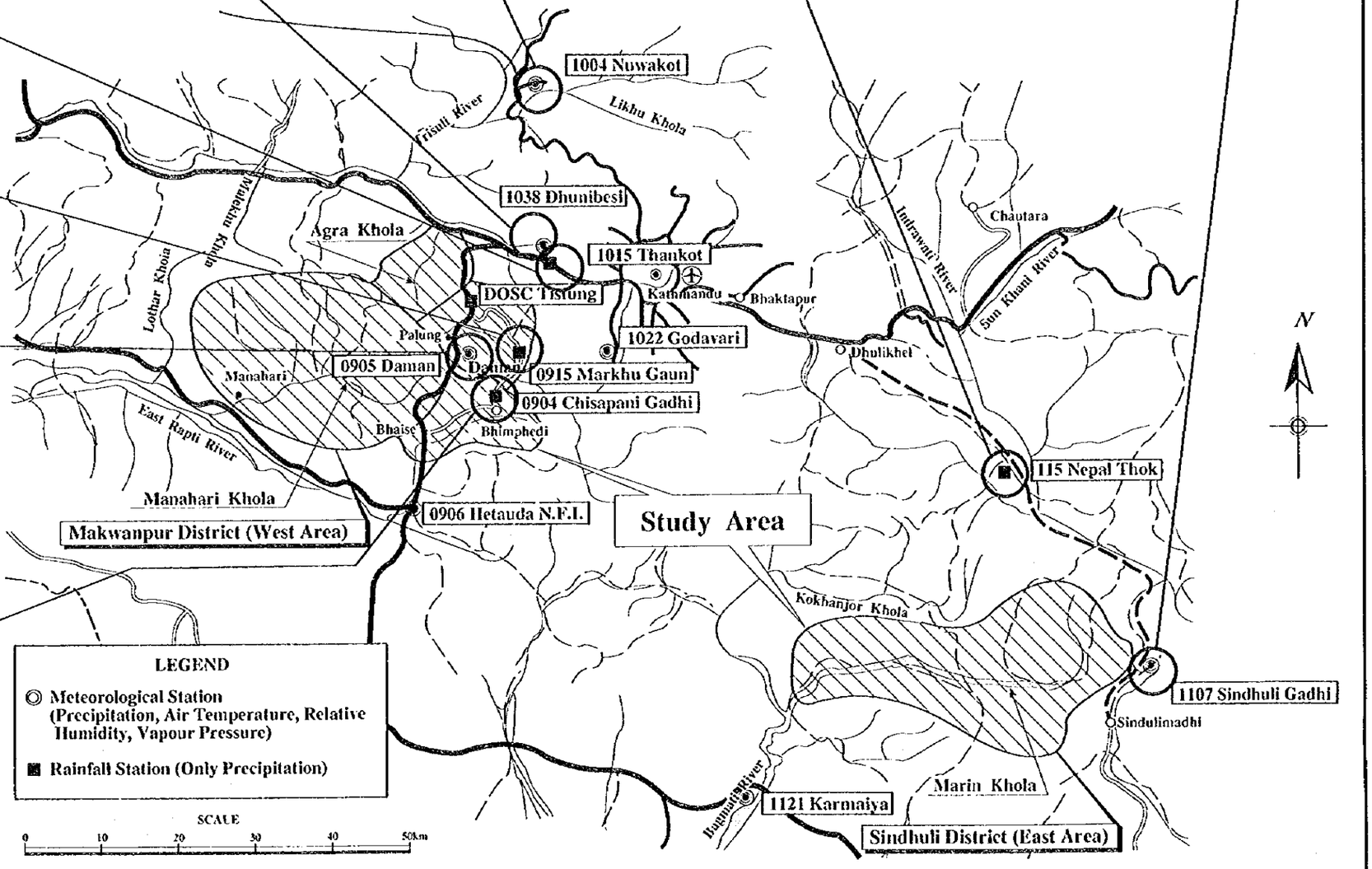

Figure 1.3.1 Monthly Rainfall Pattern in the Study Area

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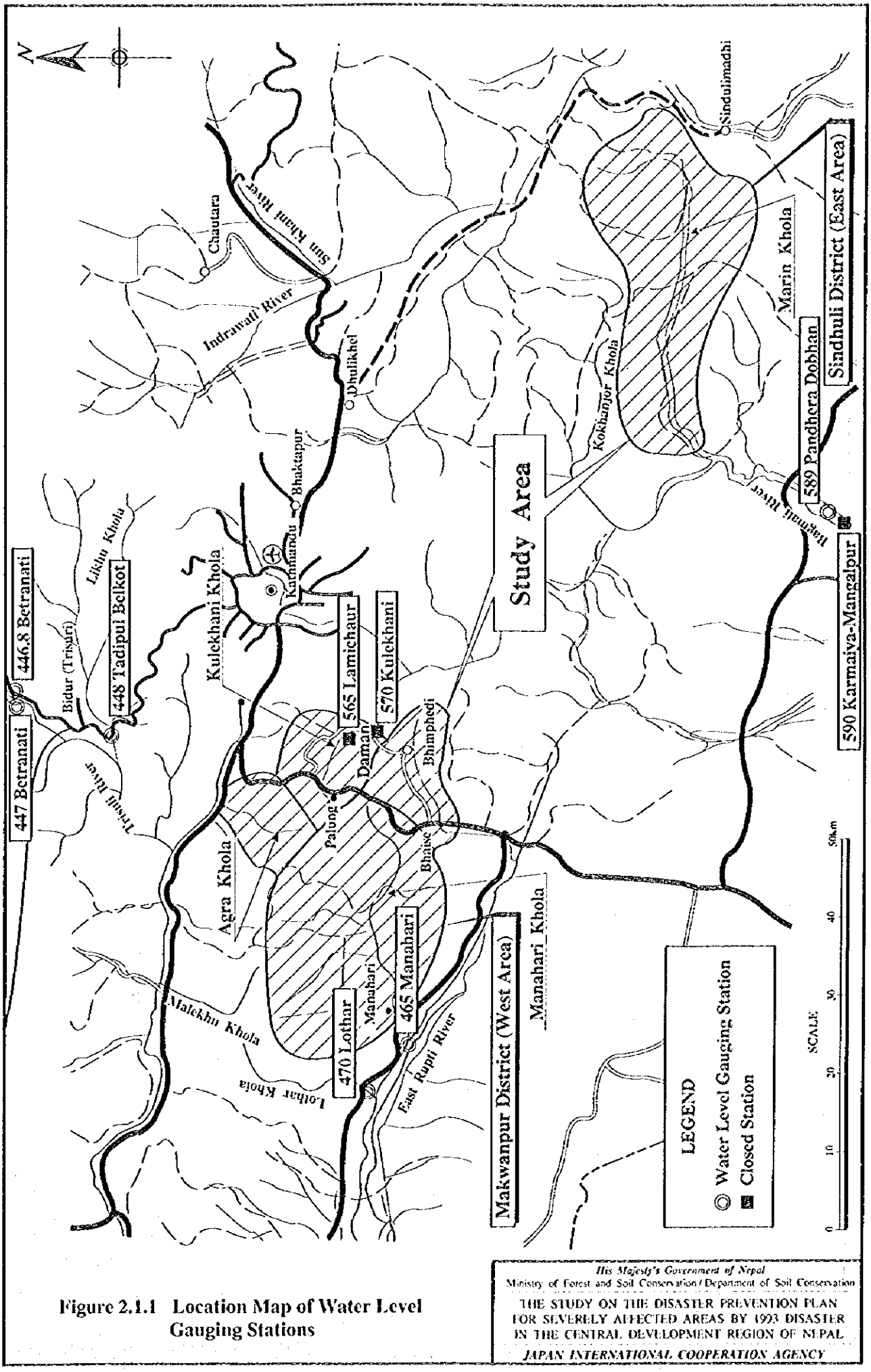

Figure 2.1.1 Location Map of Water Level Gauging Stations

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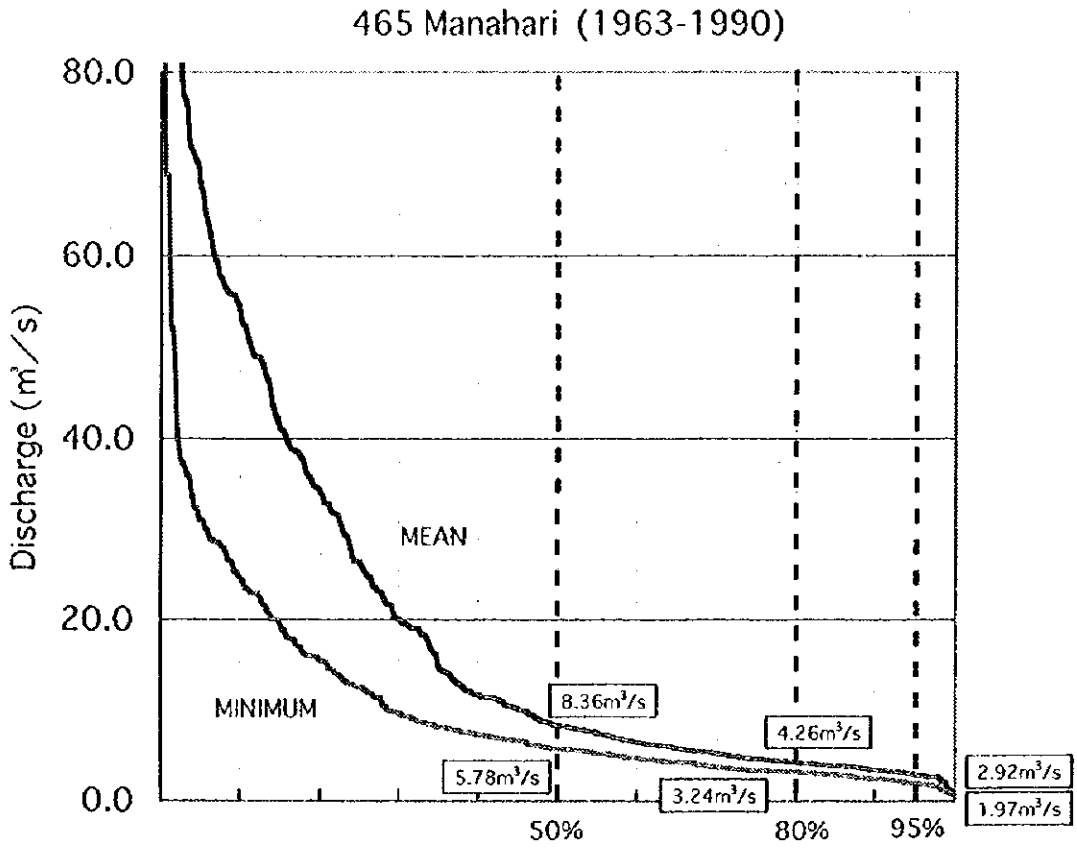

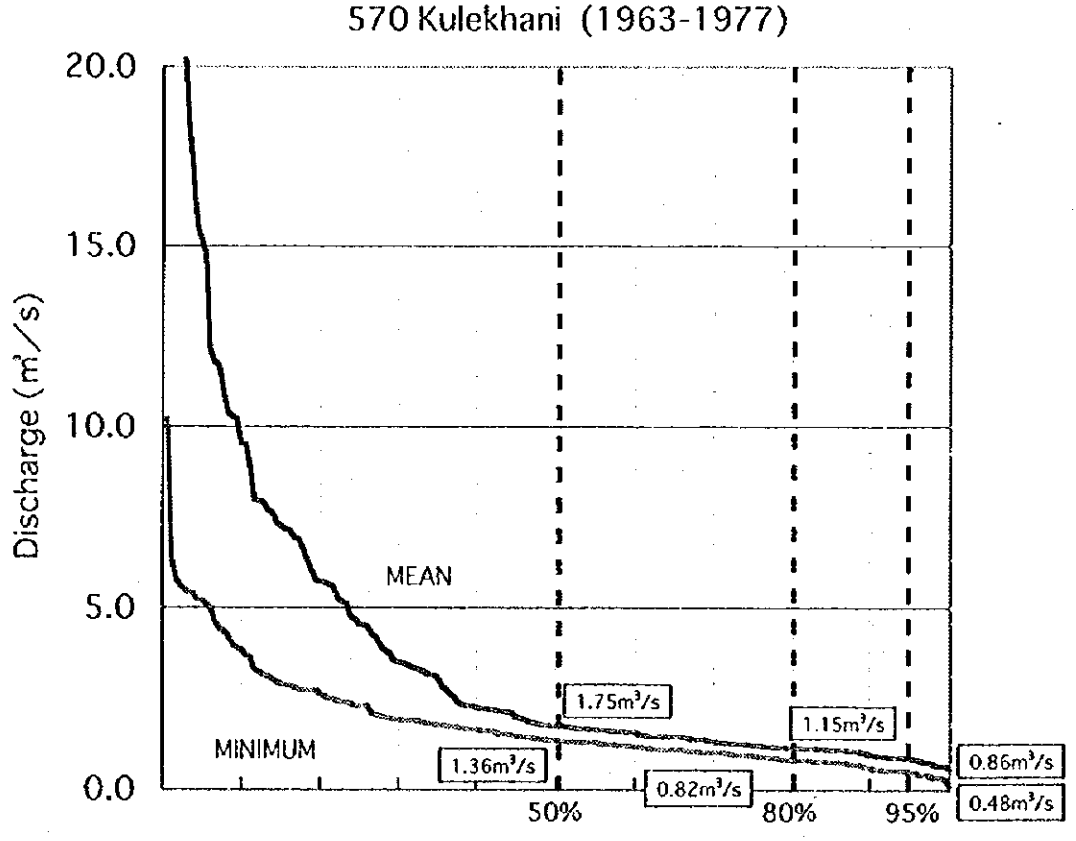

Figure 2.2.1 Duration Curve in Water Level Gauging Station

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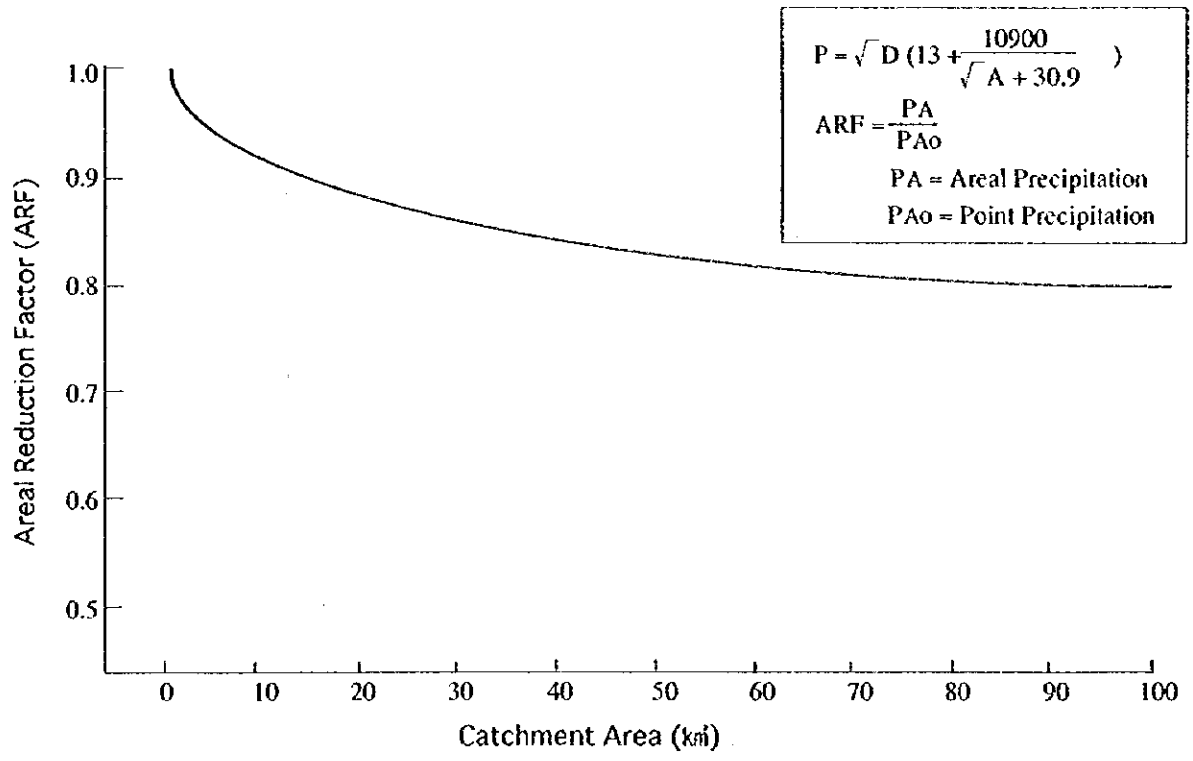

Figure 3.3.1 Areal Reduction Factor By DDA Analysis

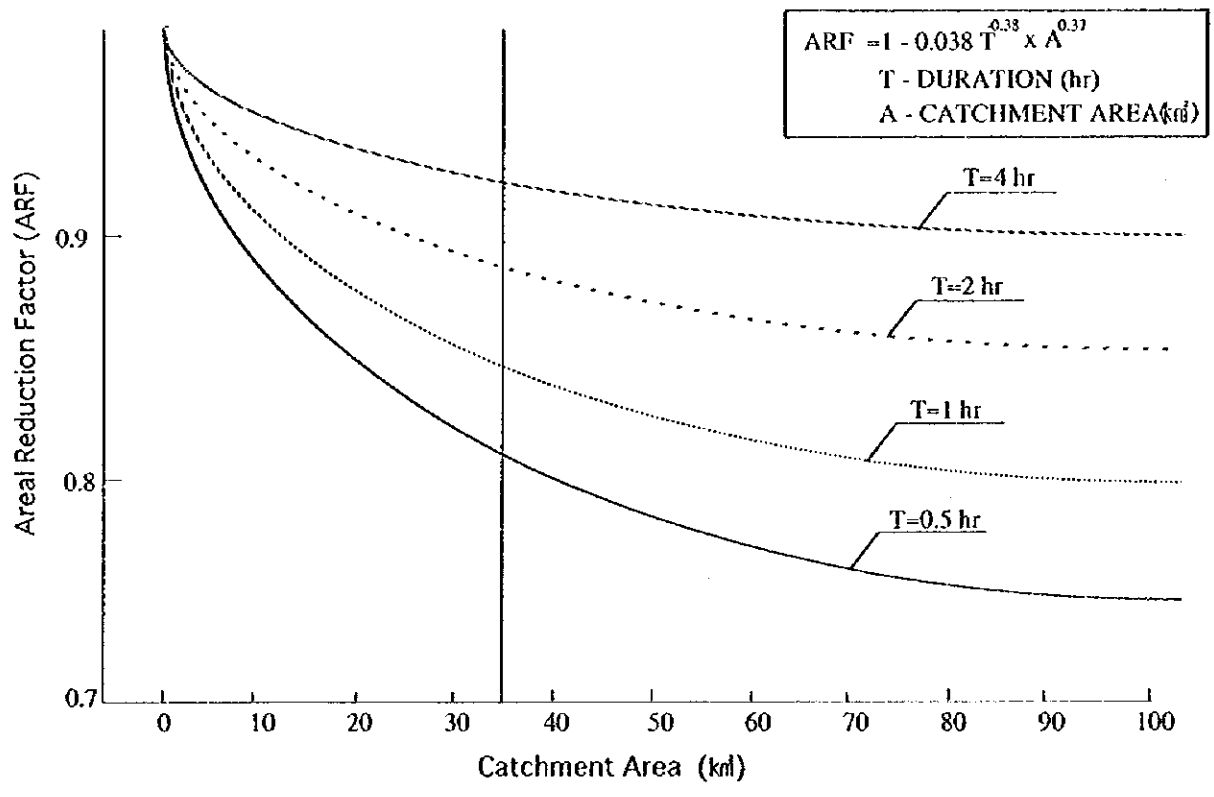

Figure 3.3.2 Areal Reduction Factor

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