3. HYDROMETEROLOGY

3.1 Introduction

Hydrometeorology is a branch of meteorology and hydrology that studies the transfer of water and energy between the land surface and the lower atmosphere. Detailed hydrological investigation of catchments of the river system traversing NCR and its adjoining States are of paramount importance for proper assessment of water resource potential and extent of flood and drainage problems.

3.2 Hydro-meteorological Aspect

In the NCR about 79% of the rainfall is contributed by summer monsoon and remaining 21% by other seasonal rains. The area receives total annual rainfall of 614mm/hr. Depressions/cyclonic storms and low pressure systems that form in the Bay of Bengal and Arabian Sea during monsoon/post monsoon season travel generally in their final phase over NCR area, Punjab, Haryana, Rajasthan, West UP, Uttaranchal and Himachal Pradesh and yield very heavy rainfall over these areas resulting in flood in Yamuna and Ganga basin.

3.3 Rain Gauge Stations

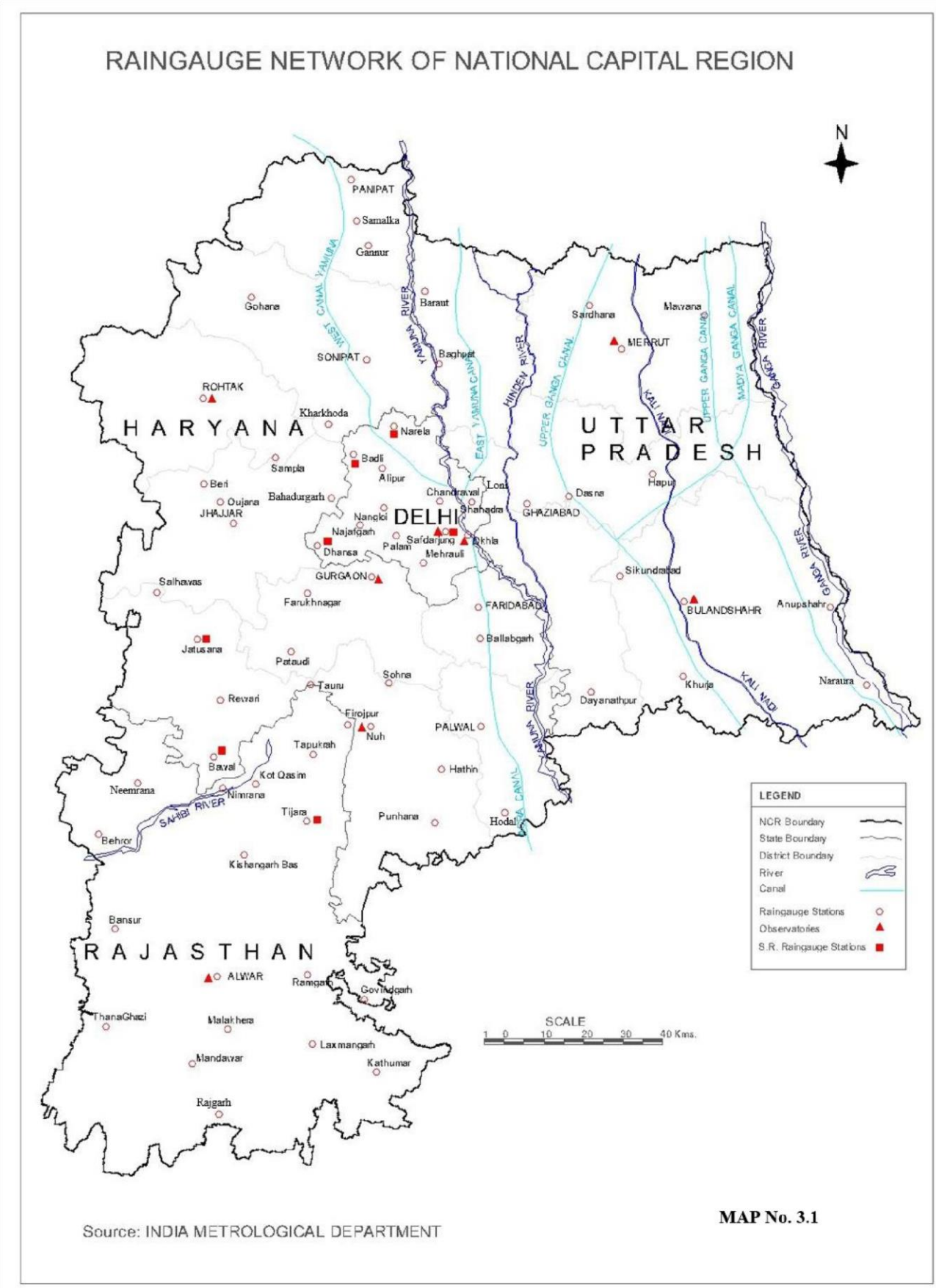
World Meteorological Organization (WMO) has recommended density of Rain Gauge Station in plain area as 600 to 900 km^2 per station. NCR has an area of 34,144 km^2 and there are 56 Rain Gauge stations (Map 3.1: Rain Gauge Network in National Capital Region). The density of Rain Gauge stations works out to be 610 $km.^2$ in NCR and meets the WMO standard. The sub-region wise Rain Gauge station distribution is given in Table 3.1.

Table 3.1Rain Gauge Stations in NCR

Sub-Region	Area (km^2)	No. of Rain Gauges Stations
Haryana	13,413	25
NCT-Delhi	1,483	12
Rajasthan	7,829	8
U.P.	10,853	11
NCR	**34,144**	**56**

Source, India Metrological Department, Govt. of India

Map 3.1 Rain Gauge Network of National Capital Region



3.4 Important Features of Climate of NCR

The geographical location of NCR about 2,000 km away from Bay of Bengal coast and U.P. hills in the northeast and semi-arid region of Rajasthan in the southwest determines the climatic conditions of NCR area. The total area of National Capital Region extends over 34,144 km^2. It is about 217 km wide and 234 km long plain area. Yamuna River flows north to south in the central region NCR part and Ganga River flows along the eastern boundary of NCR. A long rocky ridge of insignificant height of the Aravali Systems range extends roughly from north-east direction to south- west direction.

3.4.1 Important Weather Systems

Following important weather systems give significant rainfall in different parts of NCR and adjoining States:

3.4.2 Western Disturbances

Western disturbances are shallow but extensive low-pressure systems and travel across the northern India from west to east. On an average, six western disturbances pass through the Northern region of the country each month during winter season but all are not active.

It begin to get active from middle of December, remain there for a day or two over Punjab and sometimes intensify. These disturbances have higher frequency in January and February over Haryana, Punjab, Himachal Pradesh & Western U.P. Hills and results in rainfall in plains and snowfall in higher reaches of hilly regions. During this season, Delhi, Punjab and Haryana get normally 5 to 6 cm rainfall. Occasionally, these western disturbances also bring rain to the central parts of the country. It is of great economic importance over most of the areas. The crop of wheat in the northern and central areas of country depends upon this winter rainfall. The period from December to February is generally very unpleasant due to biting cold wind when a series of severe cold waves are associated with western disturbances affect the region.

3.4.3 Thunderstorms/ Dust storms

The weather during the period March to June is of gusty afternoon winds and convective phenomena like dust-devils, dust-storms, thunderstorms and hail prevails. Western disturbances continue to travel across the region eastwards, the cold fronts in their rear being generally associated with dust-storms or dry thunderstorms. Moderate to strong westerly dry land winds prevail especially in March and April. Thunderstorms and dust-storms increase in frequency with the progress of the season in West Uttar Pradesh and in the Kumaon Hills. Where less moisture is available, the convection generates violent squalls and dust-storms.

These violent squalls and dust-storms are called “Andhis” charged with dust, the atmosphere becomes hazy. Occasionally in May and June, after extensive dust-storms in the west, the air over East and North Punjab and in Uttar Pradesh becomes charged with fine dust which reduces visibility considerably; this dust-haze often extends to heights over 3 km.

Rainfall is rare in the plains in April and May. In June, it occurs intermittently in West Rajasthan and East & North Punjab, especially near the hills. This is the season of dust storms and thunderstorms; earlier in the season there is little rain; but the associated rainfall increases as the season advances.

3.4.4 Southwest Monsoon

The agriculture of the greater part of India depends upon the rainfall of the southwest monsoon that accounts for nearly 90% of the rainfall of the whole year, except in the southern parts of the country. Towards the end of May, south-east trade winds in the Indian Ocean advances rapidly northwards across the equator into the Arabian Sea and the South Bay of Bengal and in course of about a fortnight, the monsoon enters the Indian area in two main currents, the Arabian Sea and Bay of Bengal currents. The former gives heavy rain to the coastal districts south of Bombay and on the hills of Western Ghats. After crossing the Ghats, the monsoon winds branch into two streams. The southern stream blows across the peninsula and the northern part crosses Kathiawar coast, gives rain mostly in the coastal districts and then near Aravali hills and Punjab & Kumaon hills but very little rain in the plains of Rajasthan. The Bay of Bengal currents also split into two branches. One advance up the Burma Coast, and the other, which crosses the West Bengal coast, is directed westwards up the Ganga plain by the deflecting action of the mountains to the east and north of West Bengal.

The trough of the low pressure exists throughout the monsoon season between the westerly winds of the Arabian Sea and easterly winds of the deflected Bay of Bengal current. The eastern end of the trough usually extends into the Head Bay of Bengal just before the formation of the depression there. As the depression moves westward from the Head Bay of Bengal, rainfall extends to Bengal, Orissa, Bihar and Madhya Pradesh. By this time, the Arabian Sea current is also strengthened and the rainfall is carried by the depression to Rajasthan and Gujarat before it merges in the seasonal low pressure over Northwest India. Sometimes the depression curves are round and eventually break up in the sub-mountain regions of Punjab and hill districts.

In the absence of these depressions, the distribution of rainfall in the season is strongly influenced by the orography and the position of the monsoon trough. During September occurs the gradual weakening of the monsoon and its withdrawal from northwest India. The depressions form in more southerly latitudes and after advancing initially westwards into land area, take a more north westerly or northerly course towards Himalayas where they break up. These cause occasional spells of heavy rain occurs in Punjab, Kumaon Hills and their adjoining areas/plains. The monsoon withdraws from Northwest India by the third week of September and from Western Uttar Pradesh by the end of September.

3.4.5 Cyclonic Storms/Depressions

During October and November, cyclonic storms form in the Bay of Bengal and carry heavy rainfall along their track and later in the season, they mostly strike the Coromondel coast and produce very heavy rainfall in southeast India.

After the withdrawal of the monsoon, clear bright weather prevails during the season. Occasionally, western disturbances cause clouding in Kashmir, Punjab and Himalayas. A few days of thunder may be experienced in East and North Punjab and near the Aravali Hills. A series of cold waves associated with western disturbances affect the States of Rajasthan, Haryana, Punjab and Uttar Pradesh. Under the influence of western disturbances rainfall occurs over the region.

3.5 Rainfall

In India rainfall is measured at 0830 IST every day. Description terms for the spatial distribution and intensity of rainfall given in Table 3.2.

Table 3.2 Description Terms of Rainfall

I. **Spatial Distribution of Rainfall**

Distribution	**No. of Places**	**Description**
Isolated	One or two places	<25% of stations gets rainfall
Scattered	At a few places	(26-50)% of stations get rainfall
Fairly Widespread	At many places	(51-75)% of stations get rainfall
Widespread	At most places	(76-100)% of stations get rainfall
Dry	-	No station reported rainfall

II. **Intensity of Rainfall**

Descriptive Term used	**Rainfall amount in mm (24 hours)**
No Rain	0.0
Very Light Rain	0.1-2.4
Light Rain	2.5-7.5
Moderate Rain	7.6-35.5
Rather Heavy	35.6-64.4
Heavy Rain	64.5-124.4
Very Heavy Rain	124.5-244.4
Extremely Heavy Rain	>244.5
Exceptionally Heavy Rain	When the amount is a value near about the highest recorded rainfall at or near the station for the month of season. However, this term will be used only when the actual rainfall amount exceeds 120 mm.

Source, India Metrological Department, Govt. of India

The District-wise average rainfall data for the 50 years (1951-2000) for NCR shows that Meerut district received maximum average rainfall (1918.0 mm) followed by Ghaziabad (766.3 mm), Bulandshahr (779.90mm) and NCT-Delhi (747.1 mm). While Jhajjar district received the lowest rainfall (489.0 mm) followed by Rewari (492.2 mm), Gurgaon (544.40 mm) and Palwal followed by Mewat (572.0 mm). Average rainfall for 50 years is given in Table 3.3.

Table 3.3 District-wise average Rainfall Data of NCR (normal -1951-2000)

District/Sub-Region	Normal Rainfall (mm)
NCT-Delhi	747.1
Haryana	
Jhajjar	489.0
Rewari	492.2
Faridabad	697.6
Gurgaon	544.0
Mewat	572.0
Palwal	508.1
Panipat	624.1
Rohtak	618.0
Sonipat	644.2
Uttar Pradesh	
Meerut	918.0
Ghaziabad	766.3
Bulandshahr	779.0
Baghpat	646.7
Gautambudh Nagar	669.3
Rajasthan	
Alwar	630.9

Source, India Metrological Department, Govt. of India

The mean annual rainfall for 45 years (1930-1970) is 754 mm with the maximum of 1230 mm in 1964 and the minimum of 321.8 mm in 1938. The rainfall was also quite high in 1975 when it was 1197 mm. Of the total rainfall, 90% occurs during the months of July and September by Southwest monsoon and the rest during the winter. The rainfall is generally erratic and is not too frequent, but several times precipitation is very heavy and floods occurred in 1924, 1947, 1956, 1976, 1977, 1978 and 2010 in NCR.