CHAPTER TWO

INTRODUCTION OF THE STUDY AREA
2.1 PHYSIOGRAPHY AND DRAINAGE:
The Doon Valley can conveniently be divided into two broad physiographic divisions:

A: Montane tract
B: Sub- Montane tract

A: Montane tract:
Montane tract includes two major physiographic divisions -
- NW and NE parts of the valley- the Lesser Himalayan Mussoorie range
- The continuous chain of hills in the SW and SE forming parts of the valley- the Siwalik range

B: Sub-Montane tract:
It is the central synclinal trough i.e. the Doon valley proper; open valley bounded by the Siwalik hill in the south and the outer scarp of the Himalayas in the north. It is apparently a single valley but in reality it belongs to two great river systems, those of the Ganges and the Yamuna. It can be further sub-divided into two divisions as the eastern Doon and the western Doon. In the eastern Doon, the Himalayas rise abruptly from the valley and consequently there is little of the long sloping plateaux that form such a marked characteristic of the western sub division. The surface of the center of the valley is diversified by two isolated hills as Nagsidh, an offshoot of the Siwalik, and Kalanga, an outlier of the lower Himalayas. Both these hills are divided from the parent ranges by rivers, the Nagsidh by the Suswa and the Kalanga hill by the Song. In the western Doon, the lower slope of the Himalayas rises in a gentler gradient.

The Doon Valley has strong and well developed drainage network with majority of rivers flowing seasonally. It can be conveniently divided into two major watersheds those approximately divide the whole valley into two equal halves. In the NW, Asan River with its tributaries forms a watershed. In the SE side, Song River forms another independent watershed. Asan and Song Rivers are parts of bigger watersheds formed by River Yamuna and River Ganges respectively. The major tributaries of Asan and Song Rivers (from west to east) are Sitla Rao, Suarna Rao, Nun Nadi, Tons River and Bindal Rao, Suswa River, Jakhan Rao respectively (Figure 2.1). There is another small watershed in the southeastern part of study area
formed by Motichur River. This is not a part of either Asan or Song river but it drains directly into River Ganges.

2.2 RELIEF AND SLOPE:

According to the shaded relief map prepared from contours, the area is divided into five categories (Figure 2.2). The valley is flanked by high relief in its NE and SW parts. The highest relief is found along the NE part (above 845 meters). In its SW boundary, the relief is between 656–844 meters. The main valley has comparatively higher relief than its adjoining areas towards River Yamuna and Ganga. In the Northern part, relief
rises gradually as compared to the eastern part. In the SE part, towards river Ganga, relief is much flatter than towards river Yamuna. Overall relief varies between 300–2534 meters (figure 2.2). The study area is highly dissected.

Slope refers to the upward or downward inclination of a natural or artificial surface, or a deviation from the perpendicular or horizontal (Clark, 2003). Slope in the region is again divided into seven categories to show maximum variation (Figure 2.3). The Doon valley proper in its central stretch shows slope less than one degree, whereas, in adjoining areas between the Shiwalik and the Lesser Himalayas, slope varies between 2-10 degrees. Highest slope angle is found in the NE part of the study area where maximum area lies between 16-35 degrees. The maximum slope angle (36-60 degrees) is also found in this region. Within the Shiwalik along SW boundary of the study area, slope angle varies between 6-35 degrees. At few stretches, however, slope is between 16-35 degrees. The NE region shows rugged topography and steeper slopes, SW region along the Shiwalik hills have a moderate slope and the Doon valley proper the least gradient.
The Doon valley shows a characteristic feature of a longitudinal strike valley. The structural setting is such that it draws attention to assess relief configuration of the valley. This would help in better understanding of the evolution of the Doon valley. For this purpose, various maps were created in GIS environment with the help of 20 meter contour intervals for the Doon Valley. A surface plot shows a 3D perspective view of what the land surface described by the DEM would look when viewed from different directions. The position of the observer is specified via "compass angle" and "zenith angle". The compass angle is an angle in the x-y plane measured counter-clockwise from due east. The zenith angle is the angle between the zenith direction of "straight up" (away from the center of the earth). Vector is that point from the spot being viewed to the observer. Both angles are specified in units of degrees. For drawing 3D perspective views, the zenith angle is fixed at 20° and compass angle is changed purposefully in order to view it from two opposite directions (Figures 2.4 and 2.5).

![Figure 2.4: Surface Plot at compass angle 45°](image)
The surface plot at compass angle of 45° shows that topography varies from high – low – very high and vice versa, if viewed at compass angle of 225°. It is intercepted by some high elevations in the middle by Nagsidh towards the Shiwalik and Kalanga hills towards the Lesser Himalayas. A breakup in the topography is seen in form of Motichur hills towards River Ganga. The lowest areas are towards River Yamuna and Ganga (Figures 2.4 and 2.5).

Aspect refers to the direction to which slope faces. The aspect can make very significant influence on local climate as well as intensity of geomorphological processes (Figure 2.6). Significance of aspect varies according to hemispheric location on the surface of earth, and by the global as well as local winds. In the northern hemisphere, the south facing slopes receives more sunlight. Aspect is an important terrain parameter for land utilization assessment. Aspect together with the slope makes significant influence on growth of vegetation, human settlement, geomorphic processes and land-use pattern. As for the climate and global position (i.e. northern hemisphere) of India is concerned, generally the south, southwest and southeast facing slopes are best suited for settlement and agricultural activities whereas others are utilized for grasslands, plantation, orchards etc.
Generally, the Shiwalik hills upto the river beds of Asan and Song in the study area have north to NE aspect. In the rest of the study area, SE and south aspect is more dominant, covering almost one third of the study area. SW aspect is also found in the significant area (Figure 2.6).

2.3 GEOLOGY:

Geology is considered to be very important since it regulates genesis, formation and type of soil occurrence, distribution and flow of groundwater and determines presence of minerals. Geology deals with different rock types that constitute the earth's crust, their origin, composition, chronology and tectonic settings. The geological surveys are based on field observations made along a traverse line at regular intervals on a topographic base.
The Doon valley is bounded to the north by the Main Boundary Thrust (MBT) that separates the Precambrian rocks of the Krol belt of the Lesser Himalaya from the Cenozoic sediments of the outer Himalaya (Thakur, 1992). To the south, sudden topographic rise of the Shiwalik ranges is demarcated by the Himalayan Frontal Thrust (HFT) that brings the Shiwalik group of rocks against the recent alluvial sediment. The Himalayan frontal thrust, locally called the Mohand thrust, dips towards NE, and in seismic section is interpreted as extending below the Doon valley (Thakur, 1995). The Lesser Himalayan region shows complex geology in comparison to the Doon valley and the Siwalik zone. According to the geological map modified from NATMO, the study area has various types of geological formations (Figure 2.7). These are Tal, Krol, Baliani, Nagthat bearing, Mandhali (Sor and Kedhar), Chandpur formations and upper Siwalik, lower Siwalik and Doon gravels. Mandhali formation is named after village Mandhali (30° 51' N, 77° 59'E) in northern Chakrata area (not within study area). This formation of greyish-green and black carbonaceous pyretic phyllites and plastically folded blue-banded limestones and the variety of lentiforms. Thus, the clasts of quartzite, limestone, dolomites and slates are embedded in the matrix of black limestone and
carbonaceous slate (the Sor and Thal are the name of similar formations in Pithoragarh district in eastern Kumaon), (Valdiya, 1980).

The Chandpur formation was named by Auden (1934) after the peak (30° 42' N, 77° 40' E) lies in the southeastern Himachal Pradesh. These are the olive green and grey phyllite inter-bedded and finely inter-banded with meta-siltstone and very fine-grained wackes, with local meta-volcanics. These also represent low-grade metamorphics (Valdiya, 1980).

The Nagthat formations are the assemblage of purple-fawn, white and green quartzarenite (orthoquartzites) that are locally pebbly or conglomeratic, and inter-bedded with greenish and purple slates that succeed the Chandpur. The equivalent of the Nagthat of the Krol belt in the inner sedimentary zone is known as Berinag formation (Valdiya, 1962).

The Blaini formation embodying conglomerate with siltstone, grey-wacke and slates of grey, olive green, and black colour and impersistent lenticular beds of purple and red limestone, associated with purple slate and sandstone rests upon the Nagthat quartzite in the Krol belt (Valdiya, 1980).

The Krol formations are the sequence of limestone, grey and greenish-grey and purple slate, siltstone in the upper part, massive dolomite, which follows the Blaini without perceptible break, was named by Medlicott (1864) as the Krol series after the Krol mountain (30°32'N, 77°51'E) near Solan in Himachal Pradesh (Valdiya, 1980).

The Tal formation first studied at the Bibasini – Tal confluence, ESE of Rishikesh comprises various opinions. 1) Black carbonaceous often pyretic mudstone inter-bedded in basal part by phosphatic chert and limestone in the Mussoorie hills and by conglomeratic mudstone and greywacke (pebbly mudstone). 2) A variety of sand stone of whitish pale yellow, deep brown and black colour quartzite of variable grain-size and characterized by deep limonite staining or presence, or feldspar as a component, inter-bedded with subordinate purple as well as black slates. Significantly, the Tal happens to be the only Lesser Himalayan formation (except Bansi and Subathu), which has yielded reliably datable fossils, bryozoans and brachiopods. The Tal has now assumed a prominent position in the stratigraphic scheme of the outer Lesser Himalaya, (Valdiya, 1980).

The Doon gravels are post Siwalik sediments. These gravels are mainly composed of quartzite and quarzitic sandstone, which appear to have been derived
from the lesser Himalayan formation to the north or reworked from the boulder conglomerate of the Siwalik. Secondary carbonate precipitates are widely distributed within the fan gravels and at many places they form lime-indurated breccias.

The lower Siwalik is exposed in northern part of the Doon valley. It consists of brown, grey, indurated, fine to coarse-grained sandstones, inter-bedded with brown and grey mudstones. The sandstone bodies occur in ribbon and or sheet geometry with low angle cross-stratification and with horizontal laminations. The mudstone shows pedogenic modification, mottling and bioturbation (Thakur, 1995).

The Upper Shiwalik is well exposed in the alluvial plain and southern border of the Doon valley, and to the north of the lower Siwalik exposure. The upper Shiwalik is composed of thickly bedded conglomerate in sandy matrix and inter-bedded sandstone and minor mudstone having total thickness of 2000 meters. Overall, clast size of conglomerate shows an upward coarsening trend. In the lower part conglomerate are well stratified, imbricated and show fining upward whereas in upper part these are massive.

2.4 SOILS:

The area mainly consists of thick units of soils, boulders, pebbles inter-bedded with clay bands known as the Doon gravels. Sub-montaine soils of the region are derived from sand stones and shales and some of them transported and alluvial in nature. It consists of mostly dark-grey soils, varying from loam to sandy-loam, singin structure and generally rich in organic matter. The soil of the valley consists of 23 percent clay, 38 percent silt and 40 percent sand (NIH, 1997). The soil resources of the Doon valley are being affected by high level of human activities and there is a strong need to recognize the importance of watershed management as the base for development of the valley for a balanced growth in future (Sharma, et al 1995). The microclimatic conditions of the valley, with soil accumulated over centuries through the rivers, place this area to the high porosity landscape. Soil constitutes a major element in the natural environment, linking climate and vegetation and having profound effect on human activity through its relative fertility. According to the USDA soil taxonomy, the soil resources of the Doon valley can broadly be classified into three categories, i.e. ultisol, entisol and
mollisol. The ultisol or the brown hill soil is found in the northwestern part of the study area i.e. the lesser Himalayan zone. It is deeply weathered leached acidic soil. The entisol or the *bhabar* soil covers the major portion of the Doon valley. The southernmost portion of the study area is covered with the mollisol or the tarai soil. This soil commonly occurs in the foothills and lower portions of the gentle slopes. The main characteristics of these soils are their fine loamy to coarse loamy texture, with thick organic rich surface layer.

2.5 CLIMATE:

The Doon valley enjoys salubrious climate almost throughout year (NIH, 1997). The broad climatic pattern can be regarded as a permanent feature, although the land use/land cover can modify the microclimate to some extent. Similarly, of all the resource factors, climate has the most direct significance on the general characteristic and broad pattern of biological activity. The climate of this region is similar to those in the plains. Locally, the temperature varies with elevations. In general, climate is temperate and the year may be divided into four season’s viz. cold, hot, monsoon and post-monsoon season. The spatial distributions of climatic parameters are mapped with the help of climatic data obtained from 21 IMD weather stations in and around study area (Appendix I,II). Only Dehra Dun and Mussoorie IMD weather station lies within this study area.
AVERAGE MINIMUM TEMPERATURE: DOON VALLEY

AVERAGE MAXIMUM TEMPERATURE: DOON VALLEY

AVERAGE ANNUAL TEMPERATURE: DOON VALLEY
2.5.1 TEMPERATURE:

The study area enjoys comfortable temperature conditions throughout the year. Average minimum and maximum temperature varies between 10.4°C to 28.0°C. Average annual temperature varies between 14.3°C to 21.7°C (Figure 2.8). The spatial variation of temperature data shows decrease in temperature from south to north. Apart from this, the temperature in Doon valley also varies locally and is highly guided by elevations, land cover etc. Temperature along Siwalik Hills is lower than the Doon depression but higher compared to the lesser Himalayan zone. Built up areas also correspond with the heat island in the valley.

2.5.2 RAINFALL:

Rainfall is a major weather parameter and a precious natural resource. It is received in measurable and sometimes predictable amount. In the Doon valley, generally rainfall increases as one proceeds from the south–west towards the north–east, the region around Rajpur gets the maximum rainfall, while the areas around Ambari and to the east gets the least rainfall in the area. About 87 percent of the rainfall is received during the months from June to September, generally July and August being the rainiest (Gazetteer of Dehra Dun). The area has monsoonal climate. The heavy concentration of rainfall in the monsoon month causes many of the rivers in the area to carry water only in that season (Nossin, 1971).

Broadly, the region is divided into three rainfall classes. The highest annual average rainfall occurs in the central part of the study area. It is between 2055-2315 mm (Figure 2.9).
Rainfall gradually decreases towards lower elevations along the valley. The reason for this pattern may be due to orographic factors. The rain bearing clouds coming through passes along the rivers Yamuna and Ganga converge at middle part of the valley and gains height. This results into precipitation. A day is declared rainy day when it receives at least 3 mm of rainfall. Number of rainy days in the study area varies between 79-109. The highest number of rainy days i.e. 99-109, is witnessed in the same region of highest rainfall. Lowest numbers of rainy days are found towards southern end of the study area (Figure 2.10).

2.5.3 HUMIDITY:

The relative humidity is high during the SW monsoon season, generally exceeding 70 percent on an average. The mornings are comparatively more humid than afternoons. It is less during the rest of the year, the driest part of the year being the summer season with relative humidity in the afternoons becoming less than 45 percent. Annual average relative humidity decreases from south to north in the study area. Humidity is between 69.4-71 percent from Ganga valley up to middle of study area is highest. Lowest annual average relative humidity is found in the northern part around Mussorie and at small portion in the eastern side of the study area (Figure 2.11). The reason for such a
pattern may be due to the movement of monsoonal winds into the valley. It gets favorable entry through southern part adjoining the Ganga valley.

2.5.4 Cloudiness:

The skies are generally heavily clouded or overcasted during the SW monsoon season, and short spells of rains are associated with the western disturbances. Hills are often seen enveloped in clouds. During rest of the year, it is usually lightly clouded or clear.

2.5.5 Wind:

Wind system in the region shows variable directions in different season but is generally light. In the Doon, winds in the post monsoon and in the mornings in the rest of the year are variable in direction, though northerly to north-easterly winds are sometimes experienced during post-monsoon and winter mornings. In the afternoons winds are mostly from direction between south-west and north-west throughout the year, except in October and November. In the hilly regions, from May to September, wind blow from direction between south-west and south-east. In the post- monsoon and cold season these winds continue to be most common, but on many days in the morning northerly and north- easterly winds also blow. In March and April, morning winds are northerly to north-easterly and afternoon winds are south-easterly to south-westerly.

Table: 2.1, Month Wise Mean Wind Speed for Dehra Dun and Mussoorie in Kilometer per Hour (data from 1931-1961)

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>MEAN WIND SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DEHRA DUN</td>
</tr>
<tr>
<td>JANUARY</td>
<td>2.6</td>
</tr>
<tr>
<td>FEBRUARY</td>
<td>3.1</td>
</tr>
<tr>
<td>MARCH</td>
<td>3.6</td>
</tr>
<tr>
<td>APRIL</td>
<td>4.2</td>
</tr>
<tr>
<td>MAY</td>
<td>4.1</td>
</tr>
<tr>
<td>JUNE</td>
<td>3.6</td>
</tr>
<tr>
<td>JULY</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Wind rose above shows that wind speed of Mussoorie (6.7 km/h) has more than double wind speed that to Dehra Dun (3.2 km/h). This may be due to the rising winds along the slopes of Mussoorie hills and its windward location of the town. Month-wise analysis show that Dehra Dun experiences maximum wind speed in the months of April and May i.e. 4.2 km/h and 4.1 km/h respectively, and least wind speed in the month of August i.e. 2.5 km/h. After June, wind speed shows decline in its speed again in October and November speed increases to just remains below the annual average. The wind speed at Mussoorie also shows somewhat similar trend but speed is approximately double the wind speed recorded value at
Figure: 2.13
Dehra Dun, (Figure: 2.12).

According to the IMD classification for number of days of average annual wind speed, the Doon valley does not experience wind speed 62kms/h or more. Numbers of days for 20 – 61 kms/h are very less in this study area. In this wind speed for highest number of days remains between 0.4 – 0.5 km/hr along the valley of river Yamuna and Ganga. The maximum average annual numbers of days are found in the wind speed of 1 – 19 kms/h and 0kms/h. In the wind speed range of 1 – 19 kms/hr, the number of days varies between 141.8 – 200 days in a year. Whereas the highest number of class is found in the region around Mussoorie and it decreases southwards. The most of the days in a year comes under the wind speed of 0kms/h. The number of days with 0 kms/h wind speed in region around Mussoorie comes under class of 165 – 184.4 days in a year. The number of days in this wind speed generally increases southwards. (Figure: 2.13)

2.5.6 SPECIAL WEATHER PHENOMENA:

Special weather phenomenon mainly refers to thunderstorms, hail and fog etc. During the cold season, passing western disturbances affect the weather over the region, causing occasional thunderstorms, some of which are accompanied with hail. Thunderstorms occur during summer and monsoon season as well. Fog occurs occasionally during the cold season.

Table: 2.2 Frequency of Special Weather Phenomenon for Dehra Dun and Mussoorie (1931-1961)

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>THUNDER</th>
<th>HAIL</th>
<th>DUSTSTORM</th>
<th>SQUALL</th>
<th>FOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>M</td>
<td>D</td>
<td>M</td>
<td>D</td>
</tr>
<tr>
<td>JANUARY</td>
<td>3.0</td>
<td>1.6</td>
<td>0.2</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>FEBRUARY</td>
<td>2.0</td>
<td>1.6</td>
<td>0.1</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>MARCH</td>
<td>5.0</td>
<td>4.0</td>
<td>0.3</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>APRIL</td>
<td>4.0</td>
<td>5.0</td>
<td>0.2</td>
<td>1.2</td>
<td>0.0</td>
</tr>
<tr>
<td>MAY</td>
<td>8.0</td>
<td>8.0</td>
<td>0.2</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>JUNE</td>
<td>10.0</td>
<td>9.0</td>
<td>0.5</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>JULY</td>
<td>12.0</td>
<td>9.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

31
### 2.5.6.1 Thunderstorms:

The maximum numbers of days with thunderstorms are confined to the months of June, July, August and September at Dehra Dun and Mussoorie. But number of days with thunder at Dehra Dun is more compared to Mussoorie. Dehra Dun and Clement town comes under the area of highest number of average annual thunder days i.e. 57.0 to 66.5 (Figure 2.14). This may probably be due to its lower location or valley floor location. Minimum days with thunderstorm occur in the month of November due to subsiding wind that causes calm weather (Figure 2.15). Spatial variations in the thunder days show that highest numbers of thunder days are found in the central part of the valley and it decreases towards the edge of the study area.

<table>
<thead>
<tr>
<th></th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
<th>DECEMBER</th>
<th>ANNUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>12.0</td>
<td>10.0</td>
<td>3.0</td>
<td>0.5</td>
<td>0.7</td>
<td>70.0</td>
</tr>
<tr>
<td>M</td>
<td>9.0</td>
<td>9.0</td>
<td>2.0</td>
<td>0.5</td>
<td>1.4</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.7</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>1.6</td>
<td>67.0</td>
</tr>
</tbody>
</table>

*Source: IMD, 1931-1961.*

*D - Dehra Dun
*M - Mussoorie*
2.5.6.2 Hail:

Annually, Mussoorie has more than five times the number of days with hails than Dehra Dun. At Mussoorie, maximum number of days with hail is confined to the months of January, February, March and April. This may be due to cold weather season and high altitude (Figure 2.17).

While at Dehra Dun, maximum number of days with hail is during the month of June. This may be due to uprising convectional current resulting out of intense heating. Spatial variations in the number of days show that it increases from south to north. Mussoorie and its adjoining hills have maximum number of hail days. Maximum average annual numbers of hail days vary in 3.5-4.3 days (Figure 2.16).
2.5.6.3 Dust Storm:

Dust storms are less frequent both at Mussoorie and Dehra Dun, occurring only in the months of May and June (Figure 2.19). The few dust storms come in summer season which is the driest period in the year. Average annual number of days of dust storm in the study area decreases from south to north. The study area is divided into three classes. The highest class category i.e. between 1.5-1.9 covers almost half of the study area. The lowest number of days with dust storm is around Mussoorie (Figure 2.19).
2.5.6.4 Squalls:

Dehra Dun experiences maximum numbers of squalls in the months of March and April, while Mussoorie has maximum number of days with squalls in March, April and May. These all months are pre-monsoon months. Mussoorie also experiences squalls in the month of September (Figure 2.20). These are post-monsoon squalls. Annually, Mussoorie has more number of days with squalls than Dehra Dun.

Figure: 2.19

Figure 2.20
2.5.6.5 Fog:

Dehra Dun has maximum number of days with fog in the month of July and August. While Mussoorie has maximum number of days is in the months of July, August and September. This may be due to the presence of clouds in the rainy season. Annually maximum numbers of days with fog at Mussoorie are much higher than Dehra Dun. This may be due to its higher altitude and windward location than Dehra Dun. Mussoorie has fog every month; while most of the months at Dehra Dun are fog free (Figure 2.22). Average annual number of fog days show increase from south to north. The highest numbers of days are found in northern hilly regions around Mussoorie i.e. 28.4-42.1. Maximum portion of the study area comes under the class 0.6 – 14.4 (Figure 2.21).
2.6 GEOHYDROLOGY:

Geohydrological studies of intermontane Doon valley have revealed three distinct zones namely; Lesser Himalayan zone, characterized by springs and seepages; synclinal central zone forming main aquifer of the Doon valley and characterized by the occurrence of tube wells and dug wells; Shiwalik zone, characterized by wide occurrence of springs (Bartarya, 1995).

![Figure 2.23](image)

In terms of ground water potential, the Lesser Himalayan zone falls in the category of outer less productive aquifer (yield 15 – 25 liters/sec) and an unproductive aquifer (Figure 2.23). This zone is located in the steeply sloping northeasterly flank of the valley. It is composed of rocks of the lesser Himalayan formation such as quartzite, schist, phyllite, hard sand stone, lime stone and dolomite of Chandpur, Nagthat, Blaini, Krol and Tal formation having secondary porosity and permeability characterized by springs and seepages the zones of lineament, fault and main boundary thrust shows pockets of high secondary porosity. The ground water/sub surface water in this zone occurs largely as disconnected local bodies in favorably perched aquifers under both confined and unconfined conditions and also in the zones of jointing, fracturing and faulting.
Cavities and solution channels oriented along WNW–ESE and NW–SE trending joints characterize the limestone and dolomite of the krol formation. Selective solutions along these fractures and joints have created network of underground water courses leading to almost complete lack of 1st and 2nd order perennial streams over surface. The sand-gravel deposits of fluvial and colluvial origin in the lesser Himalayan zone lying in the lower reaches of the streams or near the confluence of the two streams in the form of fans and terraces are highly porous and permeable and therefore, hold sufficient quantity of water.

The Siwalik zone also corresponds with the outer less productive aquifer (yield 12-25 litres/sec) and unproductive aquifer zone. Though, the conglomerate unit of the Upper Siwalik is highly porous and permeable but because of steep slopes, due to fan forming piedmont zone along the southern fringe of the valley and moderate to steep dips of the beds, the water quickly drains as runoff.

The main productive aquifer (yield 25–50 litres/sec) corresponds with the synclinal central zone. The groundwater is present in the multi-tier aquifers under unconfined and confined conditions. The zone is classified under piedmont zone occupied by Doon gravels, having primary porosity and permeability. The course sand and gravels underlain by clay beds are the main water bearing strata. It is characterized by high infiltration rate. A number of dug wells and tube wells are confined in this zone.

The main productive aquifer is found in the synclinal zone along river Asan and Song, and also along river Ganges and river Yamuna. The water table contour, that is the depth of water table below ground surface, shows variations from 340 feet to 600 feet. Water table contour map shows that it is shallowest towards river Ganges in Song catchment area and deepest close to the water divide of Asan and Song River, north of Dehra Dun. In general, water table occurs at shallow depth towards the distal parts of the fans, which is towards the Asan and Song River and at higher level towards the proximal parts of the fan.

Although, the groundwater flow pattern is locally modified by fractures, faults, colluvial and fluvial deposits. But, in general the ground water flow in the lesser Himalayan region is roughly south, south-east and south-west direction, where in Siwalik region groundwater roughly flows in north and north-eastern direction. The flow system is also locally modified by fractures, faults, colluvial and fluvial deposits which have created local flow systems (NIH, 1997). Moreover, the
ground water contour suggests that eastern and western parts of the valley flows towards the river Ganges and river Yamuna respectively, through the river terraces and fans in the form of sub-surface runoff in the lower reaches of Song and Asan.

2.7 NATURAL VEGETATION:

Natural vegetation in the region includes a vast range of species which varies from tropical to alpine species owing to the variation in altitude and aspects. The Doon valley is best known for excellent Sal (Shorea robusta). Forest in the northeastern slopes of Siwalik shows high density. The other dominant species that are found here are, Chir Pine (Pinus roxburghii) and Oak (Quercus incana). The dominant species of shrubs are Dhaula (Woodfordia latifolia) and Siaru (Debregeasia hypoleuca) and dominant herb species are Kala Bansa (Colebrookia oppositifolia) and Lantana camara.

2.8 GENERAL LANDUSE/ LANDCOVER:

The general land use in the Doon valley can be broadly correlated with the types of landforms as summarized below:

<table>
<thead>
<tr>
<th>LANDFORMS</th>
<th>LANDUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>High mountains</td>
<td>Barren with scattered bushes and forest</td>
</tr>
<tr>
<td>Medium high</td>
<td>Barren with grass and bushes, occasional forest</td>
</tr>
<tr>
<td>Upper reaches of piedmont</td>
<td>Forest comprising grass and shrubs and cultivation</td>
</tr>
<tr>
<td>Lower reaches of piedmont</td>
<td>Usually cultivated</td>
</tr>
<tr>
<td>Northern Siwalik</td>
<td>Forest</td>
</tr>
<tr>
<td>Southern Siwalik</td>
<td>Forest with occasional cultivation</td>
</tr>
<tr>
<td>Terraces</td>
<td>Usually cultivated</td>
</tr>
<tr>
<td>Uplifted terraces</td>
<td>Forest with occasional cultivation</td>
</tr>
</tbody>
</table>

*Source: Gazetteer of Dehra Dun*

Sal is the most dominant species found in this region and covers the maximum area among all the tree vegetation. The mixed forest species include Chir Pine, Oak, Dhaula, Sisaru and Kala Bansa etc. Agriculture is mainly confined in the main valley in the west and east. Terraces are cultivated, and these patches can be traced in the mountainous region. Orchards are mainly confined around settlements and easy modes of transport lines. That is the reason orchards cover more area in the
eastern half of the valley. Plantation orchards mainly include tea gardens, litchy garden, mango and other tree plantations. Settlements are in clusters and scattered throughout the valley. Main clusters are shown in western, central and eastern part of the valley. Water and sand is shown along the river channels and in few scattered patches.

2.9 OTHERS:

Other related information is compiled from various unpublished sources and published literature. It is compiled in order to overview human activities in the study area. The region is served by roads and rails. Dehra Dun and Rishikesh are the two railway terminals of the northern railway. The length of railway line in Dehra Dun district is 64.50 kms. The entire area is served by a total length of 2383 kms of roads. Of the total road length, the State Public Works Department manages 1528 kms of which State Highway accounts for 144 kms. Main district roads have a total length of 265 kms, whereas other district and village roads comprise 1119 kms respectively. Besides, 501 kms of roads are managed by the local governmental bodies and about 354 kms are being managed by other state departments.

2.9.1 AGRICULTURE AND IRRIGATION

Agriculture in the Doon Valley is carried on the same way as in the plains, but in the hilly areas it requires hard labour and skill. The facilities for irrigation from canals and rivers are abundant but there is great deficiency of manure. Cultivation in the hill tract of the study area is of two descriptions, regular and intermittent. The hilly region, however, contains very little level ground and terraced cultivation is, therefore, the rule. Intermittent cultivation is practised in small patches along sloppy sides made cleared of shrubs and grass usually by fires. These patches are cultivated for a year or so and then left fallow in order to recuperate the soil nutrients and also it enables the coarse grasses to grow. There are two harvests including that of Kharif crop sown in June or little earlier in the hills reaped in September and October, and of the Rabi crop sown in October-November and reaped in March in the plains and in April and May in the hilly terrains of the region. Paddy is one of the most important Kharif food crops in the region. Many kinds of rice are sown in the area comprising both varieties of superior and
inferior. This region is world famous for the superior quality of its Basmati rice. Other important Kharif crops are maize, mandus, jhangora, sonk, urd, kulath, tur (arhar) and sugar cane. Wheat is the principal crop of Rabi season and is grown in almost all parts of the region. Barley and mustard are other two important Rabi crops.

The important fruits grown in the region are mango, guava, peach, grape, strawberry, pear, lemon and litchi. Dehra Dun is famous for Litchi fruit. Among vegetables, potato is the most important commercial crop. Potato cultivation in the Mussoorie hills is an age-old cropping pattern that largely caters to the agro-based industries in the region. Besides, it also exports a considerable share of the potato production to other regions of the state.

2.9.2 ANIMAL HUSBANDRY

Livestock plays an important role in rural economy. Cows and buffaloes are the main sources of milk, while male cattle are used for ploughing the fields. Sheep and goats are reared for meat and wool. Wool is of immense importance in the region used for making home-spun woollen clothes and blankets. The production of milk per milch animal is very low. Efforts are being taken for the improvement of breed of the cattle. There is ample scope for poultry development in the district.

2.9.3 INDUSTRIES

Tourist Industry possesses tremendous possibilities of development. On the one hand, there are beautiful hill resorts like "Queen of Hills-Mussoorie", Chakrata there are places like Sahasra Dhara, famous for its sulphur springs, religious and ancient places like Rishikesh and Lakhmandal, Dak Pathar-ideal picnic spot and Kalsi-place of historical importance of Ashoka's edict.

Many institutions of national importance like the Forest Research Institute; Oil and Natural Gas Corporation; Indian Military Academy; Indian Institute of Petroleum and Survey of India etc. are located in Dehra Dun which make it a place of national importance attracting tourists in large numbers.

A variety of items are produced in small scale units of industries like dairy, canning and preservation, bakery, chocolate, khandasari, teal, malt, textiles, card board boxes, printing, timber goods, steel furniture, liquor, ayurvedic medicines, resin and turpentine, tubes, leather products, musical instruments,
optical lenses, miniature bulbs, medical instruments, agricultural implements, utensils and hospital equipments, sewing machines, metal goods and Plaster of Paris etc.

In the rural areas, a number of cottage and village industries like woollen industry, handloom, power loom, durries, tailoring, oil, gur, rice, apiary, baskets, cots and mats, walking sticks, pottery, brick kilns, black smithy and leather flourish. Under the sericulture scheme, the government controlled silk farm has been established at Prem Nagar in the district. This farm distributes healthy mulberry trees to the silk worm rearers which fetches good amount from the production of cocoons.

2.9.4 TRADE, COMMERCE AND EXPORT

The important commodities manufactured are woollen wears, bulbs, carpets, soap, walking sticks, plaster of paris, gur and medicines. There are also the important commodities which are largely exported. The important items imported are food grains, glass, cotton cloth, coal, potato, ginger and sugar.

2.9.5 EDUCATION

The ratio of 5.11 Primary Schools per 10,000 population is obtained in urban areas of the region ranging between maximum of 15.93 in the Mussoorie and minimum of 0.65 in the Clement town Cantt. The ratio of Middle Schools works out to be 2.42 per 10,000 in urban populated area. The maximum ratio of 6.09 Middle Schools is observed in the Majra and minimum of 0.65 in the Clement town Cantt. For every 10,000 persons with urban population, there are 1.45 schools of Matriculation Standard. With 5.24 schools of Matriculation Standard, Landour Cantt presents the highest proportion per 10,000 of population. The ratio of intermediate colleges works out to be 0.94 colleges in urban areas of the region. Maximum ratio of 5.24 colleges is observed in the Landour Cantt. Thus, Landour Cantt shows the highest ratio per 10,000 of population of schools in case of Matriculation Standard and Intermediate Colleges.