AREA OF STUDY
Chhota Shigri glacier is a valley glacier that lies in the Chandra Bhaga river basin on the northern ridge of the Pir Panjal range in the Lahaul-Spiti valley of Himachal Pradesh, in the Western Himalaya (Fig.3.1). It is included in the Upper basin of the Chandra River, contributing to the Chenab River, one of the tributaries of the Indus river basin. This glacier is oriented roughly north – south in its ablation area, and has variety of orientation in the accumulation area. From its snout to the accumulation zone near the Sara Umga Pass (4900m), it extends up to a length of 9 km and the width varies from 3 to 1.5 km. Table 3.1 gives the geographical and topographical characteristics of Chhota Shigri Glacier.

Table 3.1: Geographical and topographical characteristics of Chhota Shigri glacier

<table>
<thead>
<tr>
<th>GENERAL FEATURES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Country, state</td>
<td>India, Himachal Pradesh</td>
</tr>
<tr>
<td>Mountain range</td>
<td>Western Himalaya, Pir Panjal range</td>
</tr>
<tr>
<td>District</td>
<td>Lahaul and Spiti</td>
</tr>
<tr>
<td>Drainage system</td>
<td>Chandra River-Indus River (Chenab branch)</td>
</tr>
<tr>
<td>Climate</td>
<td>Monsoon-arid transition zone</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GLACIER CHARACTERISTICS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>32.19-32.288 N</td>
</tr>
<tr>
<td>Longitude</td>
<td>77.49-77.558 E</td>
</tr>
<tr>
<td>Maximum elevation</td>
<td>6263 ma.s.l.</td>
</tr>
<tr>
<td>Snout position</td>
<td>4050 ma.s.l.</td>
</tr>
<tr>
<td>Basin area</td>
<td>34.7km² (47% glacierized) at 3900ma.s.l. on the proglacial stream</td>
</tr>
<tr>
<td>Total glacierized area</td>
<td>16.3km²</td>
</tr>
<tr>
<td>Chhota Shigri Glacier area</td>
<td>15.7km²</td>
</tr>
<tr>
<td>Glacier length</td>
<td>9 km</td>
</tr>
<tr>
<td>Mean orientation</td>
<td>North</td>
</tr>
<tr>
<td>Mean annual temperature at ELA₀</td>
<td>Between -5.5 and -6.58 °C</td>
</tr>
</tbody>
</table>

(Wagnon et al., 2007)
Fig. 3.1: Location map of the Chhota Shigri glacier
3.1 Climate

The climate of the area is mainly characterised by the cold winter extending from October to April. The earlier records of climate are not available; the nearest weather station at Kelong records a maximum temperature of not exceeding 24°C. During the period 1987-1989, the temporary meteorological observatories were set up at the latitudes of 4050 and 4600 m (Dobhal et al., 1995). The recorded variations between the maximum and the minimum temperature at equilibrium line (4600m) were found to be 10.5°C to -5.2°C, whereas near the snout a maximum temperature of 16°C and a minimum of 4°C have been recorded (Dobhal et al., 1995).

It has two distinct climatic regimes (Bookhagen and Burbank, 2006); most of the precipitation occurs in summer (July – September) due to the Asian monsoon, but there is also a significant amount in winter (January – April) due to mid westerlies, this is typical of the monsoon – arid transition zone where both the summer Asian monsoon and the winter mid – latitude westerlies influence the climate regime. The Chandra river valley, where the glacier is situated, is drier than the southern slopes of the Pir Panjal rage. This is the leeward effect of the main ridge mostly oriented west – east, thus preventing part of the monsoon flux from reaching the valley (Bookhagen and Burbank, 2006).

3.2 Drainage

The Chhota Shigri glacier drains into the Chandra River. The total drainage area of the glacier basin at 3900 m a.s.l. on the proglacial stream is 34.7 km² (45% glacierized), (Wagnon et al., 2007). Four tributaries and several small suspended glaciers belong to this drainage basin. The total glacierized area is 16.3 km² while Chhota Shigri Glacier comprises of 15.7 km² (including tributaries), (Wagnon et al 2007). Several supra glacial water streams are formed in the ablation zone. It is also observed that most of them terminate into moulins, crevasses or ponds. At the snout, where the melt-water comes out along with the sediment load, depends upon the discharge of these sub glacial water system.

The average discharge of this glacier during the summer season has been calculated as 1.12 m³/s, 1.72 m³/s and 0.88 m³/s in 2003, 2004 and 2005 respectively (Sharma, 2007). Average suspended sediment yield for Chhota Shigri glacier area in a day was
estimated as 4 tons/ km$^2$ in 2003 and 2005 while it was 9.5 tons/ km$^2$ in 2004 (Sharma, 2007).

3.3 Glacier Profile

The longitudinal profile of the Chhota Shigri glacier is shown in Fig. 3.2. The glacier is a valley glacier with 80° slope of the valley measured; the bed rock topography has been plotted on the basis of ice thickness (Dobhal et al., 1995).

**Accumulation zone**

The accumulation zone of the Chhota Shigri glacier starts above the ELA which is at 5100 m. The accumulation zone covers an area of 5.03 km$^2$. The length is about 1.2 km and the maximum width is about 1.50 m in the eastern flank of the glacier. The tributaries of the accumulation zones are oriented differently in the different part of the glacier, at the eastern flank it is oriented SE between coordinates 32.20, 77.52 – 32.20, 77.51; NE between 32.22, 77.54 – 32.21, 77.53 and 32.22 – 77.52; EW between 32.22, 77.54 – 32.22 – 77.52 respectively. On the other hand, it is about 1 km long and has a maximum width of 1.4 km on the western flank. The tributaries of the western flank is oriented EW between coordinates 32.23, 77.48 – 32.22, 77.49 and 32.24, 77.48 respectively.

*Fig. 3.2: Longitudinal profile of the Chhota Shigri glacier.*
Ablation Zone

Ablation zone of the Chhota Shigri glacier is about 10.66 Km². The lower part of the ablation zone is fully covered by debris layer varying from small pebbles to boulders. At this zone several features such as glacier table, glacier tills, moulins, crevasses etc are found. During the ablation season the lower half of the ablation zone experiences supra glacial flows in form of supra glacial channels due to superficial melting of glacial snow and ice. These channels disappear into deep crevasses and moulins before reaching to the snout thus forming the englacial drainage system.

Snout

The present snout of the glacier is at the height of 4200m. The first record of snout position available for the glacier front is from the Survey of India toposheet No.53H/11 (1962-1963 edn) on 1:50,000 scales. The results of the study, carried out by Dobhal et al., in 1995, show that the total retreat of Chhota Shigri glacier from year 1962-1963 to 1984 was about 165m, with an average retreat of 7.6 m/yr. During 1984-1986 the glacier retreat varied with average rate of 2.6 m/yr. For the years 1986-1989, the snout position measured by EDM survey from the stable reference point indicates a glacier retreat of about 7.5 m/yr (Dobhal et al., 1995). The total retreating of glacier snout since 1962-1963 to 1989 (26 yrs) was about 195m with an average rate of 7.5m/yr. Now the retreat rate is about 10 – 15 m/yr.

Equilibrium line

The equilibrium line is an imaginary line where the amount of ablation is equal to the amount of accumulation; here the mass balance is zero. During the end of the ablation season it is also a representative of the snow line. This snow line show variation from year to year; during the studied period from 2003 – 2007 the equilibrium line altitude (ELA) varied from 4855 in 2005 to 5185 in 2006. From the previous studies done (Dobhal et al., 1995) in 1987, 1988 and 1989 ELA was found to be at 4650m (1987), 4750m (1988) and 4840m (1989) respectively.

3.4 Morphological Features

The process of mechanical weathering is prominent in and around the Chhota Shigri glacier, due to extreme temperature fluctuation, leading to the formation of various
morphological features. The geomorphological map of the Chhota Shigri glacier on the scale of 1:10,000 is shown in Fig. 3.3 (Dobhal et. al. 2005). The weathered materials are carried downstream due to melt water or mass flux which leads to the formation of many depositional features such as moraines, till deposits etc.

**Moraines**

During the course of retreat, the glacier leaves behind the material, which it carries as a load, in form of well defined depositional structures, moraines. Moraines can be terminal, lateral and medial depending upon its orientation.

*a) Terminal Moraine*

In the Chhota Shigri glacier valley, four stages of glaciation can be inferred by the morainic deposits near the Chandra river (Shruti, 2003). The first terminal morainic loop lies 150 m south of the Chandra river, eroded by the Chhota Shigri stream, second one lies about 100 m south of the previous one, third one lies 2 km south of the second morainic deposit and the fourth loop lies about 100m south of the third loop and is about 50 m from the snout.

*b) Lateral Moraine*

Lateral moraines are well developed on the eastern as well as on the western margins of the glacier, they start right from the upper part of the ablation zone and run several meters below the snout. Eastern lateral moraines are steep and the slope is oriented in NW direction where as western lateral moraines are gentle and slopes towards west to east.

*c) Medial Moraine*

Medial moraine is one of the distinguished feature of the Chhota Shigri glacier, running from the upper part of the ablation zone at an altitude of 4831 m to the lower middle part of the ablation zone at an altitude of 4525 m. It stretches along the main flow line of the glacier. It separates the glacier into two parts the eastern flank and the western flank.
Crevasse Patterns

Crevasses are prominent surface features on the glaciers and are developed by the fragmentation of ice. They form open fractures in response to the stress field at the surface. In Chhota Shigri glacier, these features are mainly developed in and around the equilibrium line and lower ablation zone (Dobhal, 1995). Most of the open crevasses are in the lower middle part of the ablation zone and just below the equilibrium line which are partially covered by snow. The length of the crevasses varies from 10 -20 m to 200 meters. These crevasses are generally oriented in NW and NE direction. Transverse crevasses dominate the glacier whereas longitudinal crevasse are generally found in the lower part and at the sides of the glacier.
Fig. 3.3: Geomorphological map of the Chhota Shigri glacier.
3.5 Geology
Chhota Shigri glacier lies within the central Crystallines of the Pir Panjal range of the Himachal Himalaya. This crystalline axis is comprised mostly of meso- to ketazonal metamorphites, migmatites and gneisses (Fig.3.4). At few places, granitic rocks of different composition and younger age indicate rejuvenation. But 3 km upstream of Chhota Dara, in the upper Chandra valley, older Palaeozoic granitic rocks are exposed. The Haimanta formation overlies these with a tectonic break, where black slates, phyllites and fine-grained biotite-schists are exposed. The slates and phyllites show a well developed thrust tectonic contact, which form the crest of the northern ridge. Box type folds with decollement are quite prominent in the Haimanta formation. The Haimantas, which rest directly on basement rocks, are highly metamorphosed metasediments and show intense folding and shearing. The brown biotite, with a fine-grained texture, shows intense heating effect, which indicates periodic reheating of the granitic rocks below. The various types of granitic and gneissic rocks present in the basement also indicate this. Schistose gneiss and augen gneiss have developed in the granite without any distinct margins (Kumar, 1979, 1996). Chhota Shigri glacier rests on the granitic basement rocks. On both sides the ridge tops are at an altitude of 6300m and the bottom of the Chandra Valley lies at 3300 m. The overall relief is 3000m.

3.6 Vegetation
The Lahaul and Spiti valley is considered to be a cold desert. The area around the Chhota Shigri glacier does not possess any permanent vegetation because most of the time it is covered by fresh snow, moraines and tills. However, during the ablation season in summer, snow melts and few patches of grass and wild flowering plants (wild strawberry) can be traced along the lower ridge.
Fig. 3.4: Geological map of the area around Chhota Shigri Glacier

(Source: Kumar, et. al. 1986)
Plate 3.1: Lower part of the ablation zone showing supra-glacial streams.

Plate 3.2: Formation of glacial lake on the western flank of the glacier.
Plate 3.3: One of the features in the ablation zone of the glacier

Plate 3.4: Glacier table on the middle part of the ablation zone
Plate 3.5: The accumulation zone of the Chhota Shigri Glacier (Western Flank)

Plate 3.6: Lateral Crevasse in the middle part of the ablation zone
Plate 3.7: Snout of the glacier, covered by moraines

Plate 3.8: Medial moraine of the Chhota Shigri glacier, which differentiate the glacier, into eastern and western flank.