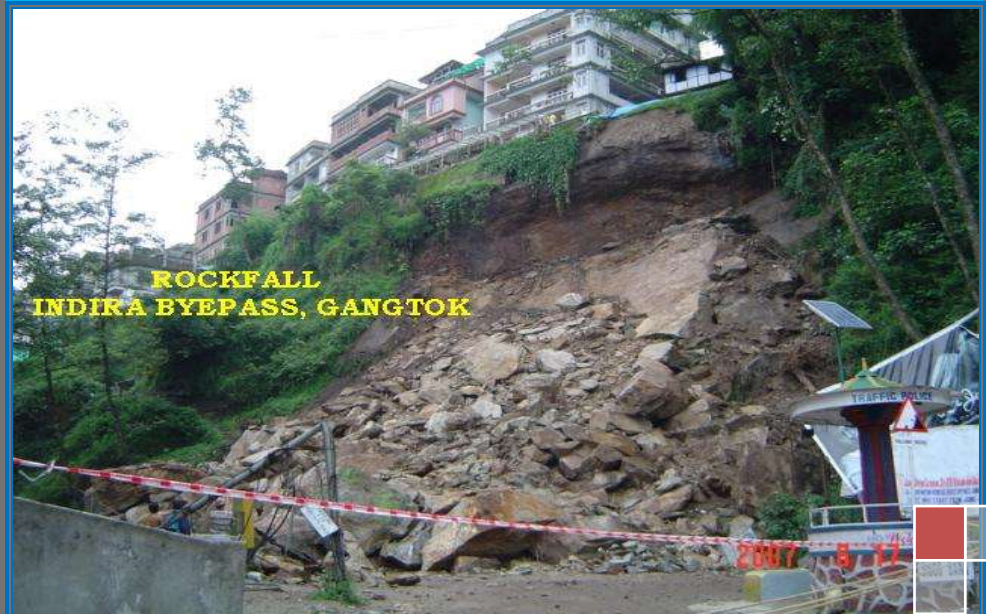


2012

# MULTI-HAZARDS RISK VULNERABILITY ASSESSMENT

GANGTOK, EAST SIKKIM.



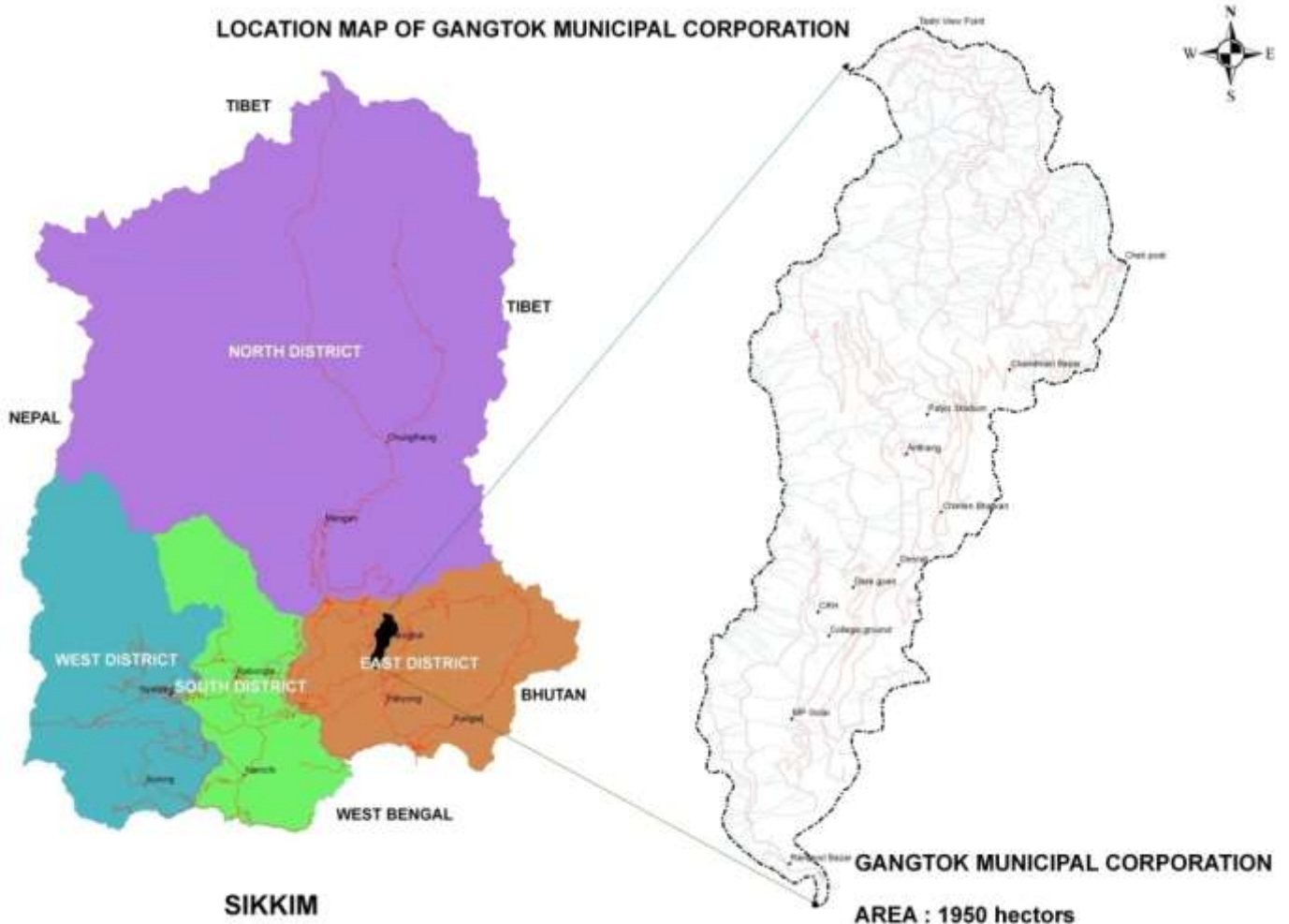
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## INTRODUCTION

The study area comprising of the Municipal Corporation of Gangtok is also the Capital of Sikkim, with an area of about 1950ha. The Gangtok Municipal Corporation divided into fifteen Wards viz. 1. Burtuk 2. Lower Sichey 3. Upper Sichey 4. Chandmari 5. Development Area 6. Diseal Power House 7. Arithang 8. Lower MG Marg 9. Upper MG Marg 10. Tibet Road 11. Deorali 12. Daragoan 13. Tadong, 14. Ranipool and 15.



Syari/Tathangchen. The outer boundary of Gangtok Municipal Corporation along east runs from Tashi View Point-Himalayan Zoological Park, Bulbuley upto 2nd mile Check Post along JN road. Along South it starts from the Dichiling Jhora follows Roro-chu upto Seti pool steel bridge along Ranipool – Pakyong road. Western boundary lies from the confluence point of Rorrochu with Rani Khola runs along the Rani Khola till Takste Jhora near

Penlong. Northern boundary lies from Taktse Jhora to Tashi view point along North Sikkim Highway.

The elevation of the Gangtok Municipal Corporation (GMC) ranges from 880 mts. to 2350 mts. above mean sea level (amsl). Generally maximum of the slope facets are Westerly facing where as few face easterly or southeasterly direction. The average annual rainfall varies from 293 cm to 342.7 cm as recorded from the various weather stations. The establishments along the roadside are more and these areas are thickly populated with high building density. The areas nearing roads are also has medium high building establishment density with little tree cover and the remaining area far from the road side are thickly covered with trees. Number of nalas/jhoras cut across the slope with high discharge of water during monsoon period. Various lineaments in form of shallow or deep seated faults are in existent within different lithological units of Gangtok town. The slopes dip with moderate to high degree with thin, medium thick to thick soil cover over the existing rock units. Lot of surface/sub-surface water activities are present in the area. These contributing forces in tandem make the slopes vulnerable and result in failures as landslides, which creates the hazard.

## **GEOLOGICAL SETTING OF GANGTOK AND SUBURB AREAS**

### **GENERAL GEOLOGY**

The Darjeeling-Sikkim Himalayas have been divided into several belts each of which is separated by major dislocations. Darjeeling-Sikkim Himalayas has been sub-divided into four districts tectonic belts.

1. Sub-Himalaya Belt.
2. Lesser Himalayan Belt.
3. Higher Himalaya Belt.
4. Tethys Himalayan Belt.

The sub-Himalaya or the foot hill belt comprises of Siwaliks group of rocks falling within Darjeeling Himalayas and which does not occur in the State of

Sikkim. Lesser Himalayan belt comprises lower Gondwana sediments, low grade Meta- Sedimentaries of Buxa and Daling group of rocks. The Axial or higher Himalayan belt is characterized by high grade metamorphic rocks viz. high grade gneiss, mica schist, graphite schist, calcareous gneiss, marble, intrusives etc. is separated from lesser Himalayan belt by Main Central Thrust (MCT). Overlying the Axial belts are the rocks Trans-Axial Belt of Tethyan sequence consisting of fossiliferous sedimentary rocks of North Sikkim Tethyan zone.

### **GEOLOGICAL AND GEO-TECTONIC SETTING OF THE AREA**

The west-east or southerly facing slopes of Gangtok and suburb forms part of inner belt with low, medium grade metamorphic rocks and few areas are covered With Schists and Darjeeling Gneisses. The main Gangtok town stand over the intrusive Lingtse Granite Gneiss. The main litho units of area are gneisses, Lingtse granite gneiss, schistose rocks and medium to low grade meta-sedimentaries.

The lower part of Gangtok from Ranipool area till 5th Mile and Tadong comprise of the rocks of low grade meta-sedimentaries consisting of Phyllites, Quartzite, Quartzitic phyllite and Phyllitic quartzite. The rock shows North Easterly dip, striking NW-SE with low to moderate dip amount. These rocks are at places rotated and attain NW dip (at 5th Mile Tadong area). Quartzite and Phyllitic quartzites in some areas form steeper part of slopes and show high relief.

These low grade meta-sedimentaries are overlain by medium to high grade metamorphic rocks represented by Quartz-Mica Schist and Garnetiferous Mica Schist and mica-schist band. The Garnetiferous mica schist band is locally considered as a marker horizon and is exposed north of STCS complex Deorali and can be traced upto Roro-chhu in North east direction and towards Jhakri Falls in north-west direction. This band is overlain by Mica Schist without garnets and which is overlain by Lintse granite gneiss. Quartz mica schist rocks are exposed in and around Gurudwara complex, north of Accountant General Office. Below National Highway from ICAR Complex to Garage Jhora downslope of Indira Bypass

road. Mica schist, Garnetiferous Mica Schist, Quartzitic phyllites are the dominant country rock in this area. The rocks at all places show north easterly dip but down-slope of Gurudwara, rocks show North Westerly dip. Similar rocks are expected at variable depth within the veterinary complex. A fault line present in the area from Deorali to Sokeythang (Marked on the Structural map). These rocks are overlain by Lingtse granite gneiss and the contact between two are suspected to be thrust contact. The contact zone between Mica-Schist band and Lingtse Granite area is shown in the map.

Lingtse Granite Gneiss unit is overlain by Mica Schist followed by high grade metamorphic rocks. As discussed above, mica Schist rocks are expected at variable depth at veterinary complex. The area at Sokethang consists of thick blanket of slope wash material consisting of rock fragments of variable size (derived from Lingtse granite gneiss and mica-Schist of overlying area) followed by sandy & silt cover and fine grained organic soil at the top. Bed rock in this area, similar to rock exposed around 5th Mile Tadong is expected at greater depth.

The Holy Cross School area is subject to instability problems like creep, and subsidence. This is basically because of presence of active fault towards north of school complex. The area below Entel Motors is marked by excessive ground water activity, swampy area and gulley erosion. The seepage of water through fractures, cracks and fissure in slope forming material and rock section is evident in lower part of the area. The Holy Cross-School Complex and the adjoining buildings are facing serious cases of slope instability in form of creep/subsidence due to rock foliations oriented along slope direction, excessive loading, presence of an active fault, vehicular vibrations and so on. Evidence of serious instability around this locality is shown by presence of failure or cracks in buildings, failure of road formations with constant subsidence of the road NH31A.

Similarly there are other such hazard zones effecting the habitation of the capital Town of Gangtok. These are primarily due to effect of one or more types of hazards resulting in loss of human life or property. Sikkim is also

placed in zone iv/v in earthquake vulnerability map of India. This is also an issue of concern and houses need to be constructed in resonance with building bye-laws for construction of earthquake resilient structures. Similarly hazards like Fire, Flashfloods, Hailstorms and etc need to be cared for safe living in Gangtok.

### **Hazard Risk and Vulnerability assessment**

This Hazard Risk and Vulnerability assessment was conducted by SSDMA (Sikkim State Disaster Management Authority) based on the technical data made available by Department of Mines, Minerals and Geology, Government of Sikkim along with other Governmental and Non-governmental central and state government organizations. The GIS mapping was prepared by Disha Services, Gangtok.

#### ***Purpose***

The purpose of Hazard, risk and vulnerability analysis (HRVA) is to help a community and make risk-based choices to address vulnerabilities, mitigate hazards and prepare for response to and recovery from hazard events. *Risk-based* means based on informed choices of alternate unwanted outcomes. In other words, communities make risk reduction choices based on the acceptability of consequences and the frequency of hazards.

### **Hazard Risk and Vulnerability Assessment**

Considering **hazards** alone may lead to a skewed set of priorities for action. It is equally important to consider the **severity** of possible impacts from the hazard as well as the frequency or **likelihood** of a hazard event occurring. The combination of severity and likelihood is termed the **level of risk**. In determining the severity of a hazard event, a community's vulnerability must be examined. **Vulnerability** is defined as people, property, infrastructure, industry and resources, or environments that are particularly exposed to adverse impact from a hazard event. Hazards reflect the frequency of occurrence for a particular hazard event and can range

from rare events occurring every 50 years to more frequent events, which usually have a high number of recorded incidents or anecdotal evidence.

### **Scope**

This HRVA is designed to provide an assessment of the hazards that may present risks to the region of Gangtok Municipal Corporation. The objective of the HRVA is to:

1. Investigate prominent natural and human-caused events.
2. Identify the various hazards affected by that area and hazards likely to occur in Gangtok Municipal Corporation area.
3. Identify any threats that may require a timely and coordinated response to protect lives, property, and to reduce economic losses.
4. Definition of measures to be included in the mitigation plan.
5. Evaluation of the effectiveness of the mitigation and emergency plans and implementation of training activities such as simulation, seminars and workshops.

### **Components for Assessment of Multi Hazards Risk Vulnerability**

#### **Assessment (MHRVA)**

MHRVA are being undertaken where the following hazards are considered for Gangtok Municipal Corporation in East District of Sikkim located in Lower Himalayan land mass in mountainous state of Sikkim as per IS codes and other requisite data from the field, which is required for Multi Hazards Risk Vulnerability Assessment Study.

- a) Earthquake hazards.
- b) Landslide hazards.
- c) Fire hazards.
- d) Flood/ flash floods hazards.
- e) Snow Avalanches hazards.
- f) Drought hazards.
- g) Hailstorm, Thundering and lightening hazards.

h) Riots and stamped.

### ***Vulnerability Assessment***

The intent of this *Hazard Risk and Vulnerability Assessment* is to provide a basis from which local planners, politicians, and responders can create or update the Regional emergency plan, allocate resources for risk mitigation, enhance community preparedness, and prepare budgets for cost-effective, on-going emergency planning. This assessment is based on both primary and secondary sources. Both quantitative and qualitative methods are used to determine hazard ratings for the area of interest.

### **HRVA Risk Rating Interpretation**

#### ***RISK RATING INTERPRETATION***

These risks are ***low***. Implementation of mitigation measures will enhance emergency preparedness but it is of less urgency and highly unlikely to occur in that area than the following hazards.

These risks are ***medium low***. Implementation of mitigation measures will enhance emergency preparedness. Hazards are highly unlikely to occur in that area, but are of more urgency than *low*

These risks are ***medium***. These hazards have intermediate levels of frequency and severity. Hazards classified as moderate are more urgent than medium low hazards and are often common place concerns. Given this, moderate level hazards should be addressed with an appropriate level of urgency.

These risks are ***medium high***. These hazards warrant review and development of mitigation actions to reduce the risk to an acceptable level. But these hazards require immediate examination and mitigation measures to reduce the risk to an acceptable level.

These risks are **very high**. These hazards are both frequent and are of high severity. These hazards require immediate examination and mitigation measures to reduce the risk to an acceptable level.

### **Hazards**

This HRVA is designed to provide an assessment of the hazards that may present risks to the region of Gangtok Municipal Corporation. However, the following hazards are most likely to occur and may result in significant consequences. Each hazard is examined to assess the relative risks to the community and to highlight opportunities for mitigation and coordinated response. In this analysis, extensive background and historical research was compiled and considered in the context of severity and likelihood to assess the hazard risk.

**LANDSLIDE HAZARD RISK  
VULNERABILITY ASSESSMENT OF  
GANGTOK**

### ***Landslide Hazard:***

The term landslide describes a wide variety of processes, including debris avalanches, debris flows, and other rapid mass wasting events which result in the rapid downward and outward movement of soil, rock and vegetation under the force of gravity. Rock falls occur when rocks fall freely from a cliff face. A submarine slide is the movement of materials involving water charged and coarse-grained sediment flowing rapidly on underwater slopes or channels. If the volume of sediment is sufficient, submarine slides can potentially displace enough water to generate destructive surface waves, also known as local marine tsunamis. Landslide events occur when the slope reaches a critical level of instability and may be triggered by rains, flooding, seismic events, and other factors. Slope instability may be variable (i.e. caused by such factors as heavy rain and changes in ground water levels), it may be transient, as in the case of seismic activity or it may be inherent due to the weak composition of the soil or rock structures. New environmental conditions such as those resulting from the removal of vegetation due to construction may also create instability in slopes. Landslides may damage or destroy critical infrastructure such as power and telephone lines, municipal water facilities, waste water facilities, and hazardous materials storage sites.

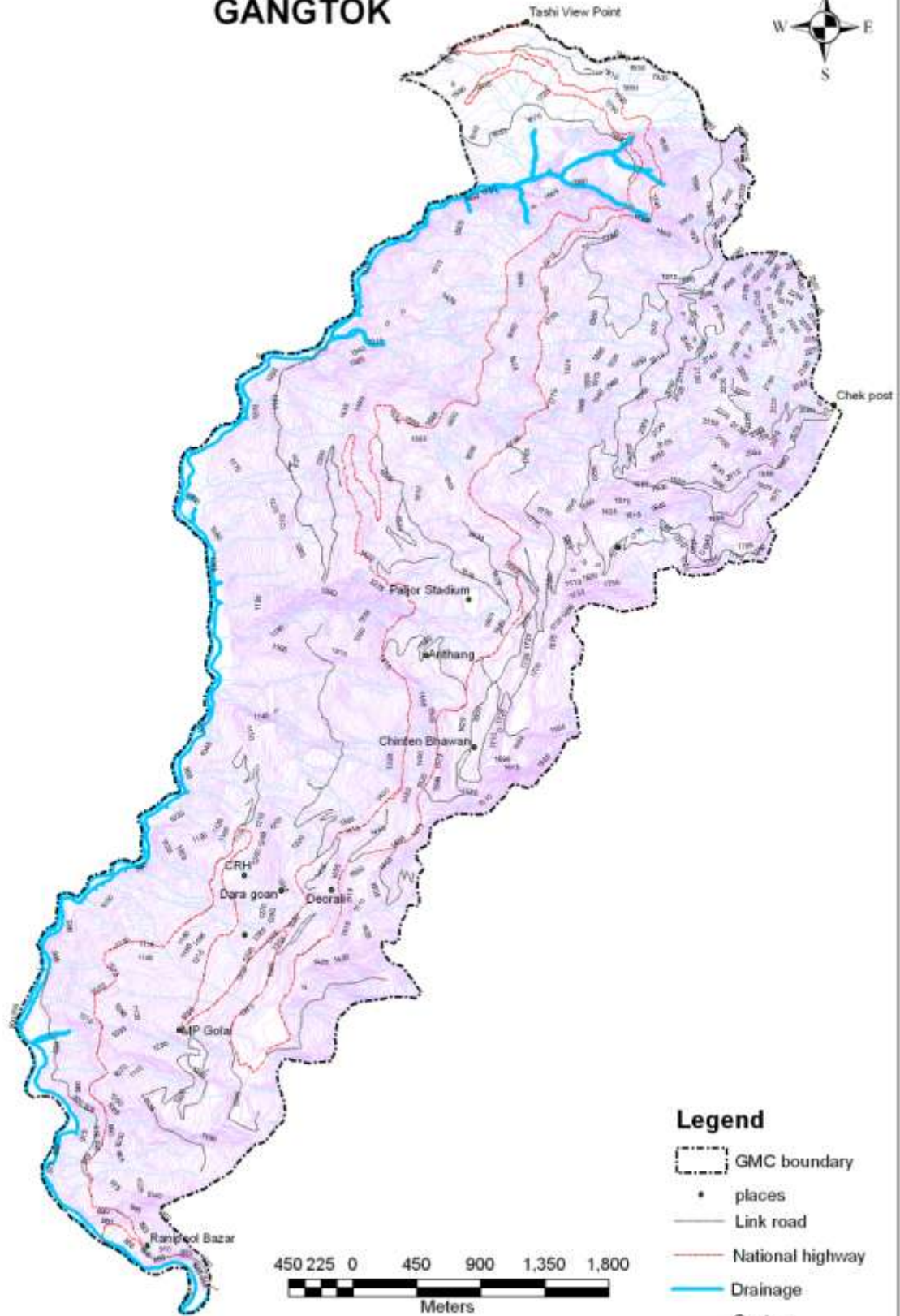
### ***Methodology:***

In the development of Landslide Hazard Risk and Vulnerability Assessment extensive historical research was conducted along with continuous successive field visit with the development and analysis of the following maps:

- Slope Morphometry Map
- Geological/Lithological Map
- Soil Type Map
- Hydrological Map
- Soil Thickness Map
- Landslide Inventory Map

- Relative Relief Map
- Land Use / Land Cover Map
- Rainfall Map

# BASE MAP OF MUNICIPAL CORPORATION GANGTOK

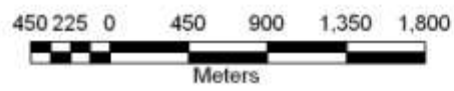


# DRAINAGE MAP OF MUNICIPAL CORPORATION GANGTOK



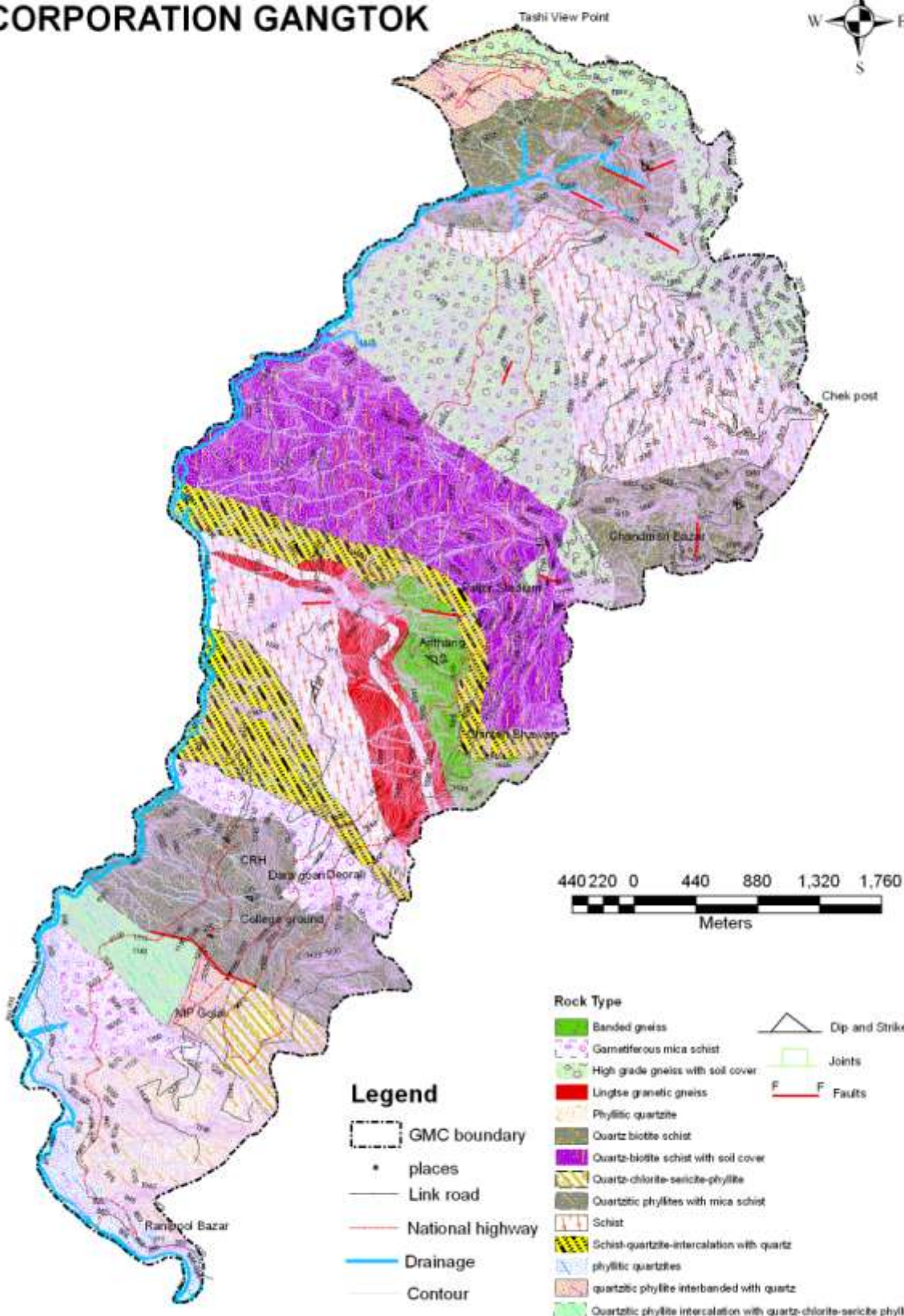
## Legend

-  GMC boundary
-  places
-  Link road
-  National highway
-  Drainage





# GEOLOGICAL/LITHOLOGICAL MAP OF MUNICIPAL CORPORATION GANGTOK



## Legend

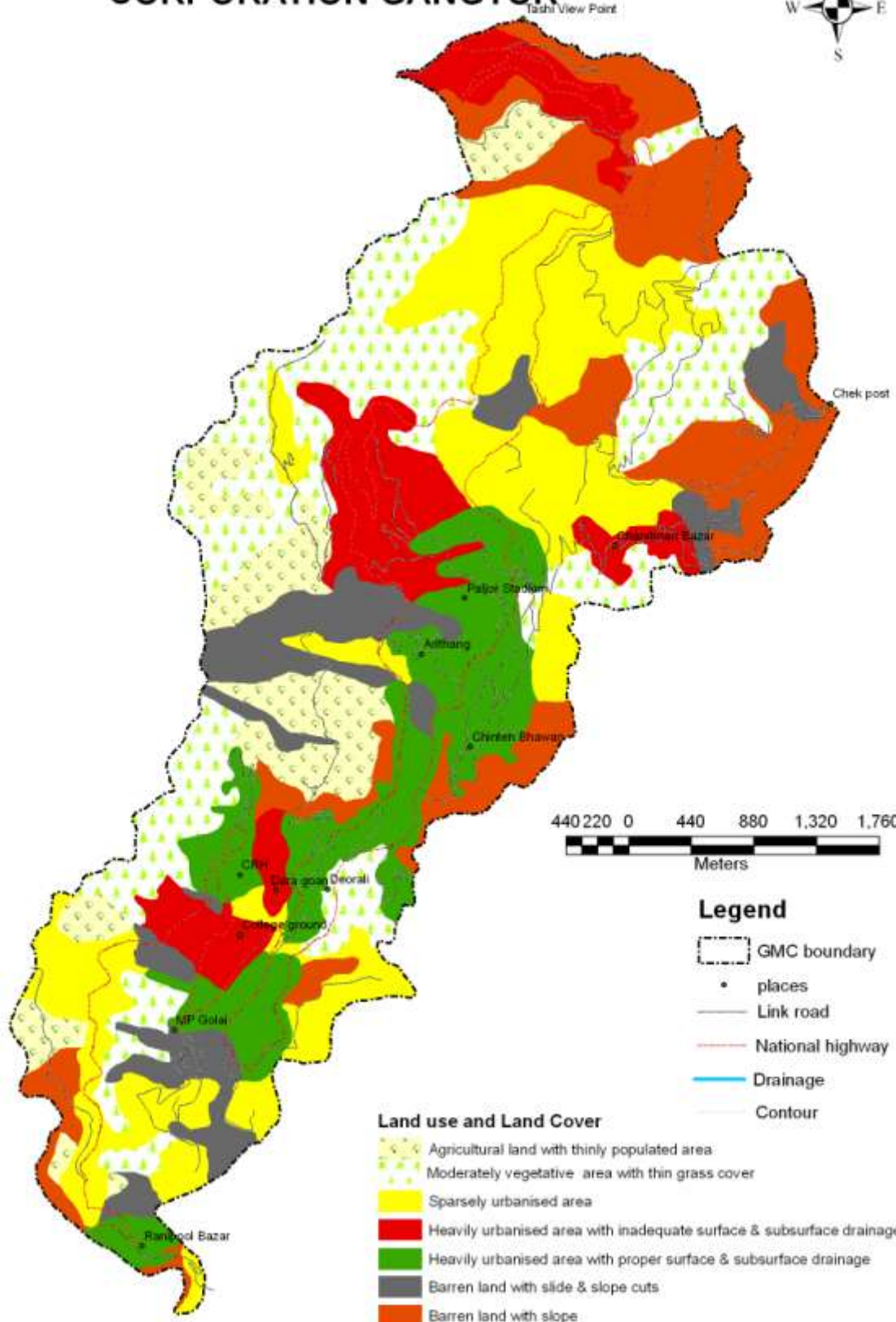
- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

## Rock Type

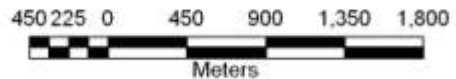
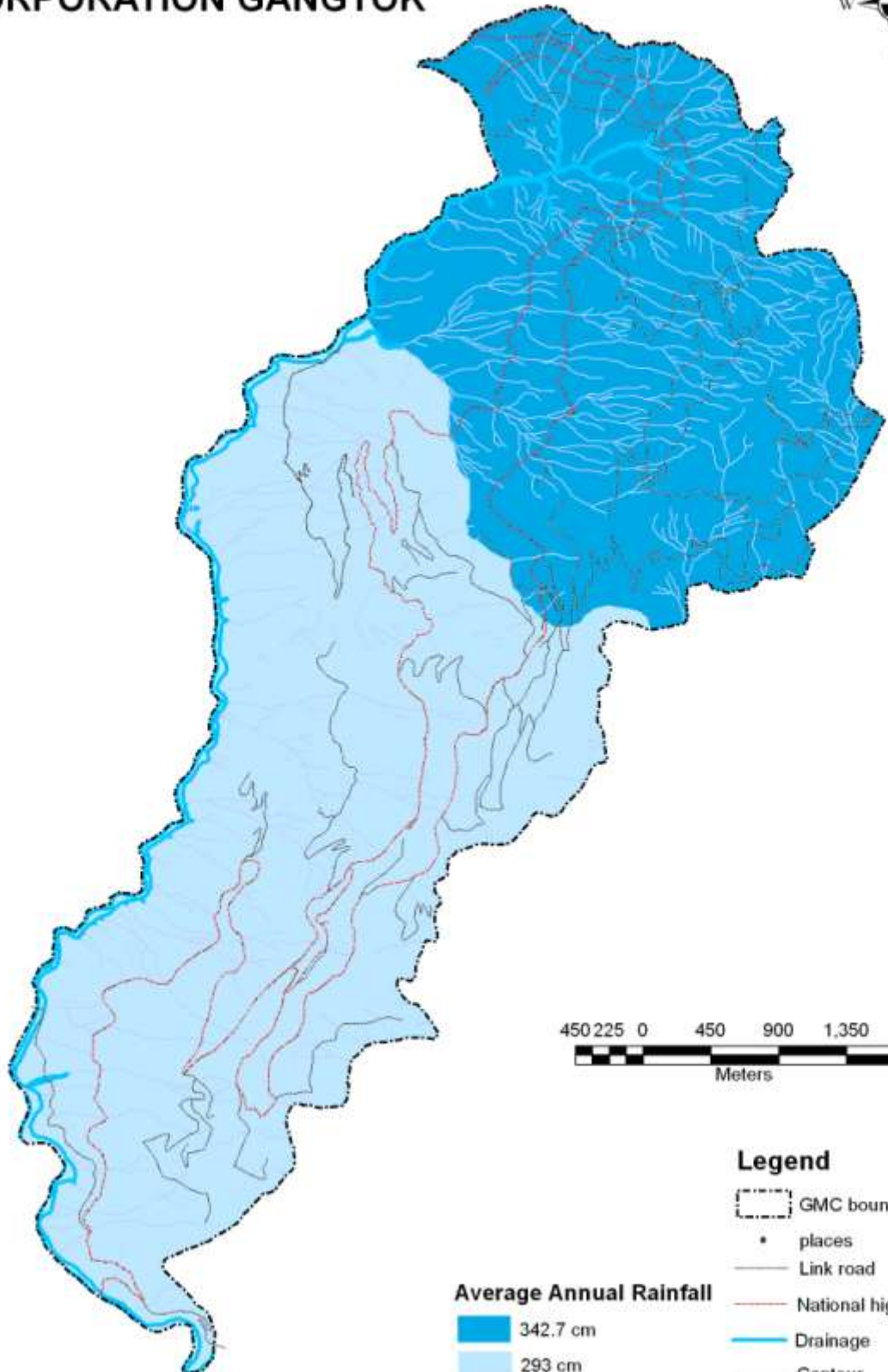
- Banded gneiss
- Garnetiferous mica schist
- High grade gneiss with soil cover
- Lingtse granitic gneiss
- Phyllitic quartzite
- Quartz biotite schist
- Quartz-biotite schist with soil cover
- Quartz-chlorite-sericite-phyllite
- Quartzitic phyllites with mica schist
- Schist
- Schist-quartzite-intercalation with quartz
- phyllitic quartzites
- quartzitic phyllite interbanded with quartz
- Quartzitic phyllite intercalation with quartz-chlorite-sericite phyllite

- Dip and Strike
- Joints
- Faults

# LAND USE LAND COVER MAP OF MUNICIPAL CORPORATION GANGTOK



# AVERAGE ANNUAL RAINFALL MAP OF MUNICIPAL CORPORATION GANGTOK



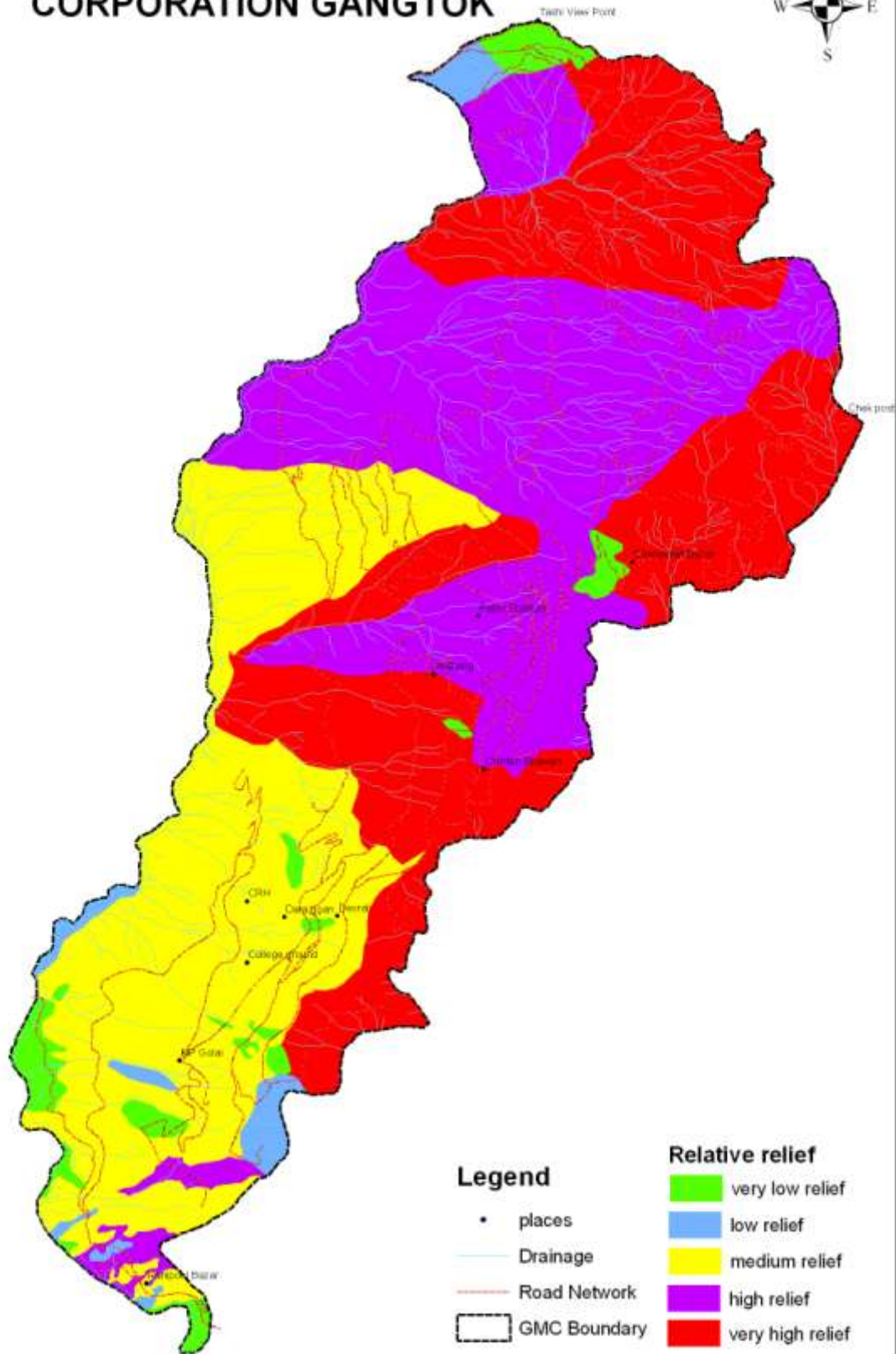
### Average Annual Rainfall

- 342.7 cm
- 293 cm

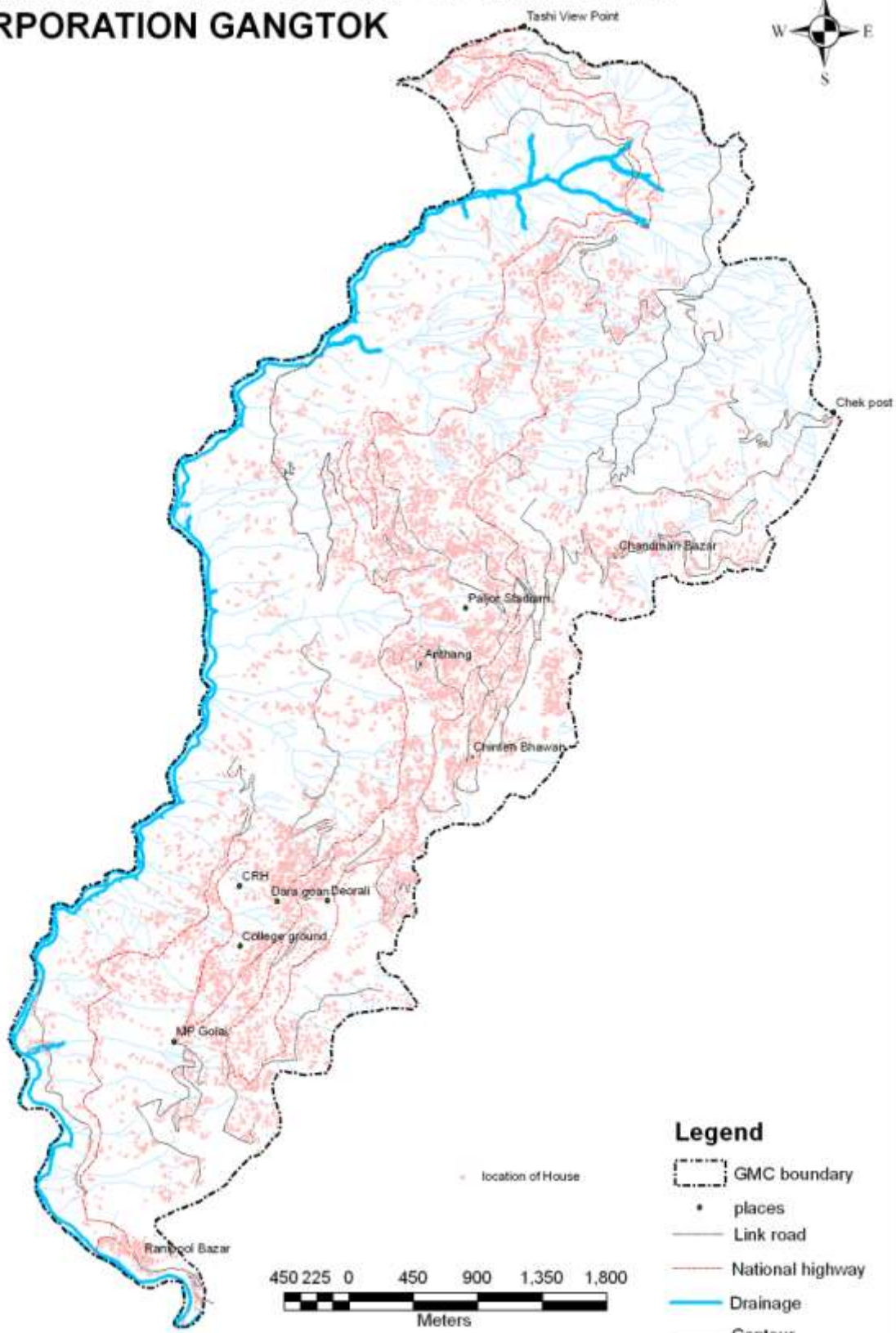
### Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

# RELATIVE RELIEF MAP OF MUNICIPAL CORPORATION GANGTOK



# LOCATION OF HOUSES MAP OF MUNICIPAL CORPORATION GANGTOK

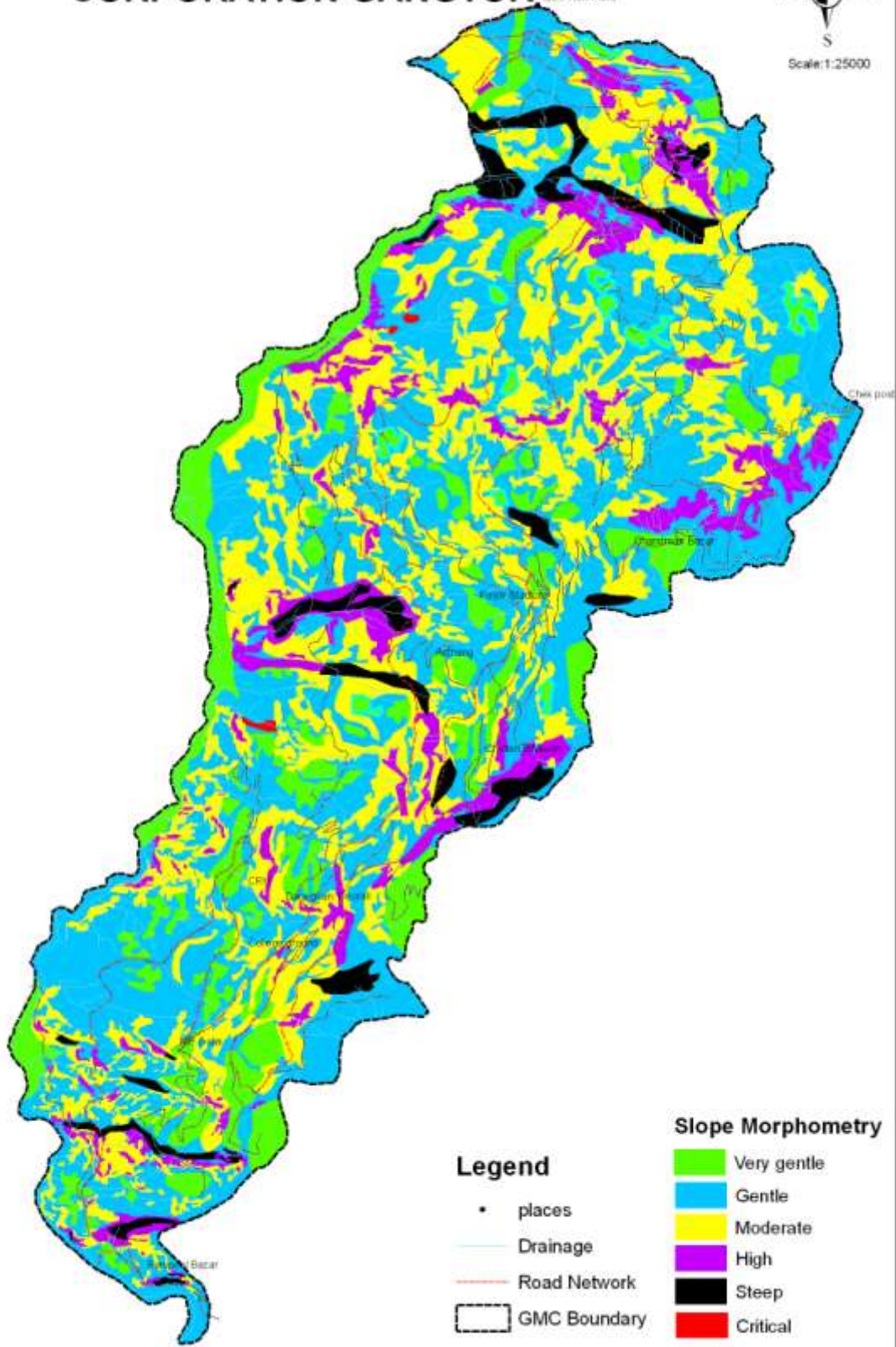


# SLOPE MORPHOMETRY MAP OF MUNICIPAL CORPORATION GANGTOK

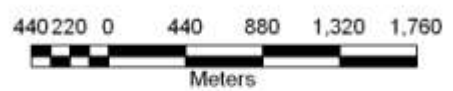
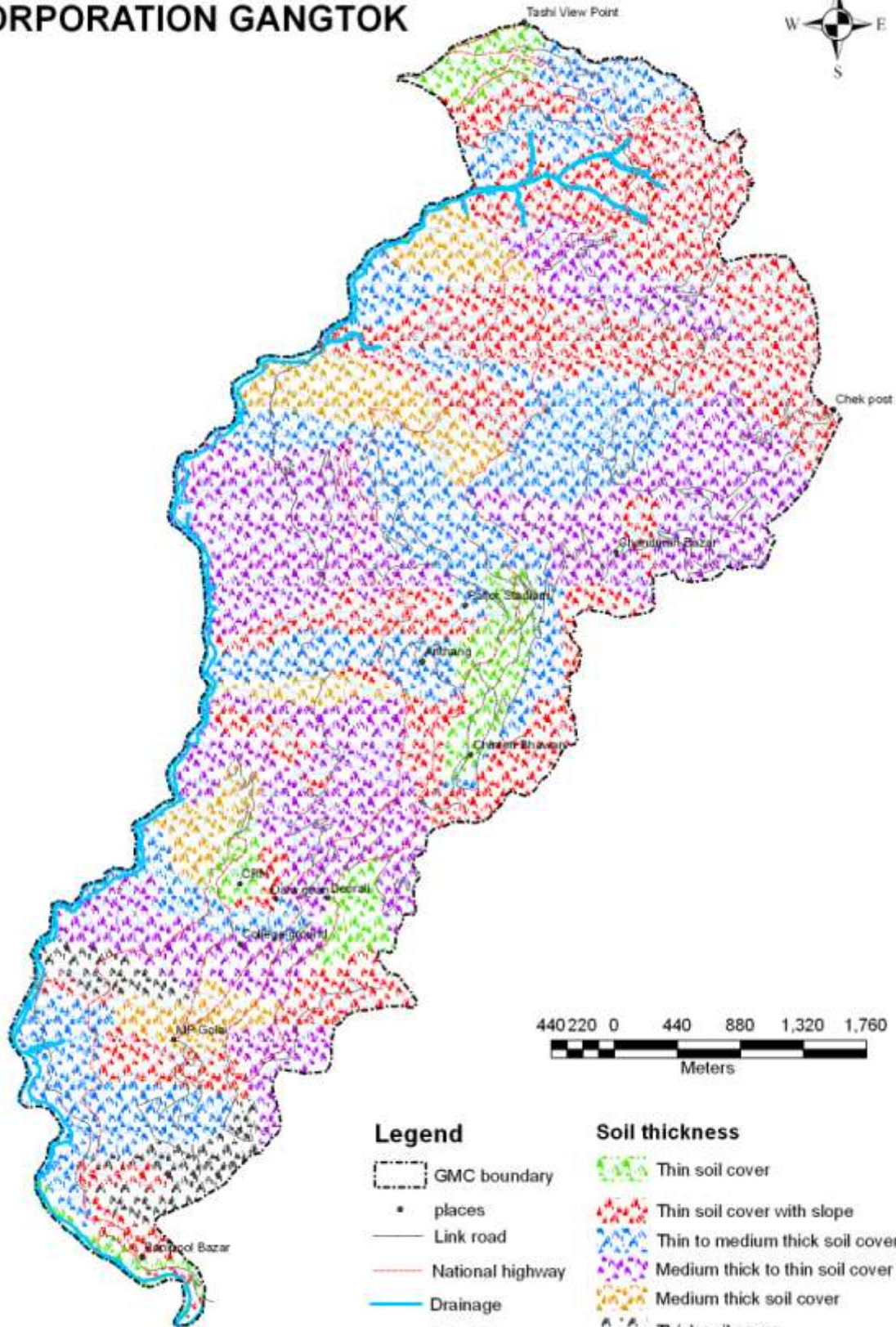
Tashi View Point



Scale: 1:25000



# SOIL THICKNESS MAP OF MUNICIPAL CORPORATION GANGTOK



## Legend

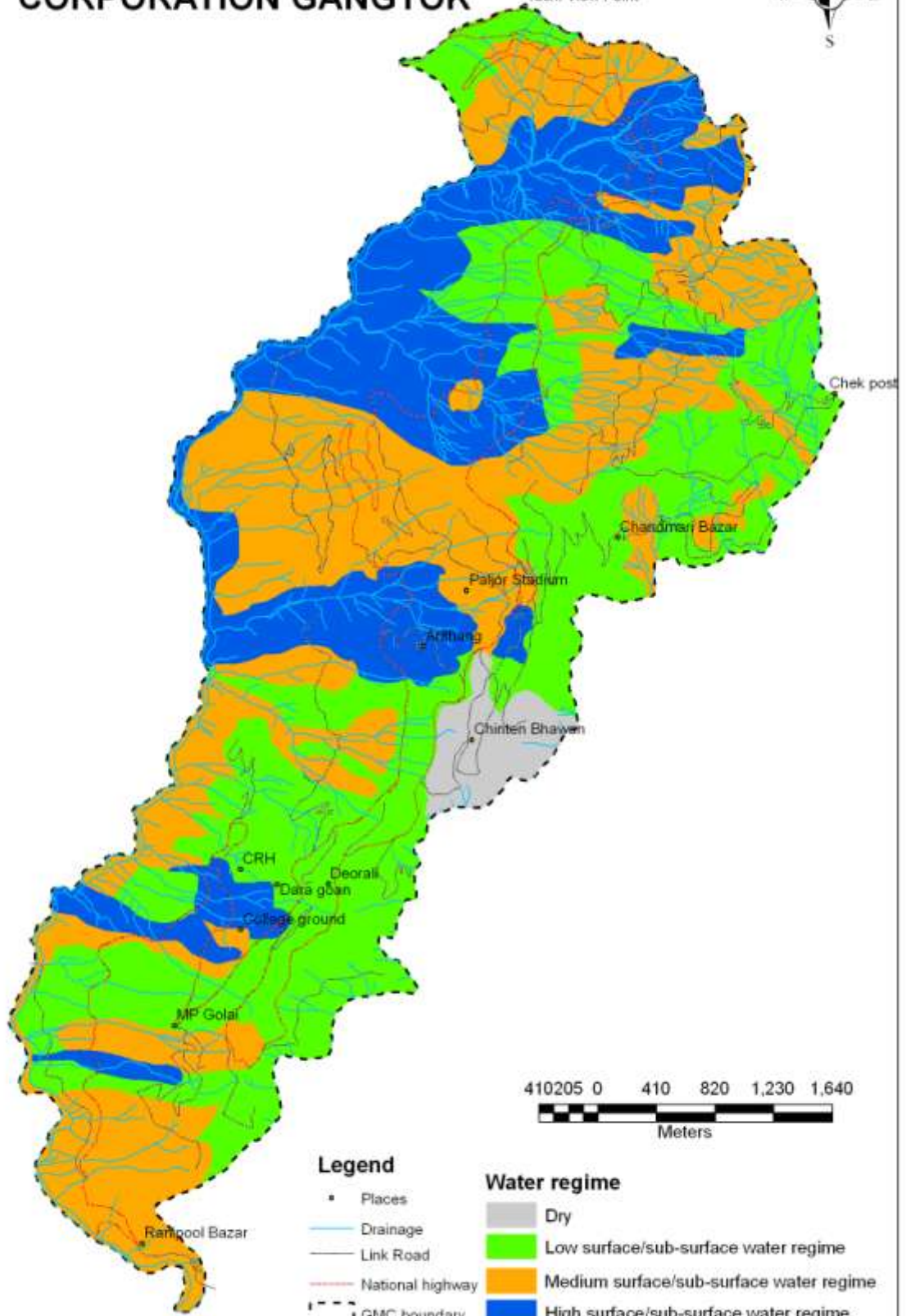
- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

## Soil thickness

- Thin soil cover
- Thin soil cover with slope
- Thin to medium thick soil cover
- Medium thick to thin soil cover
- Medium thick soil cover
- Thick soil cover

# WATER REGIME MAP OF MUNICIPAL CORPORATION GANGTOK

Tashi View Point



## Legend

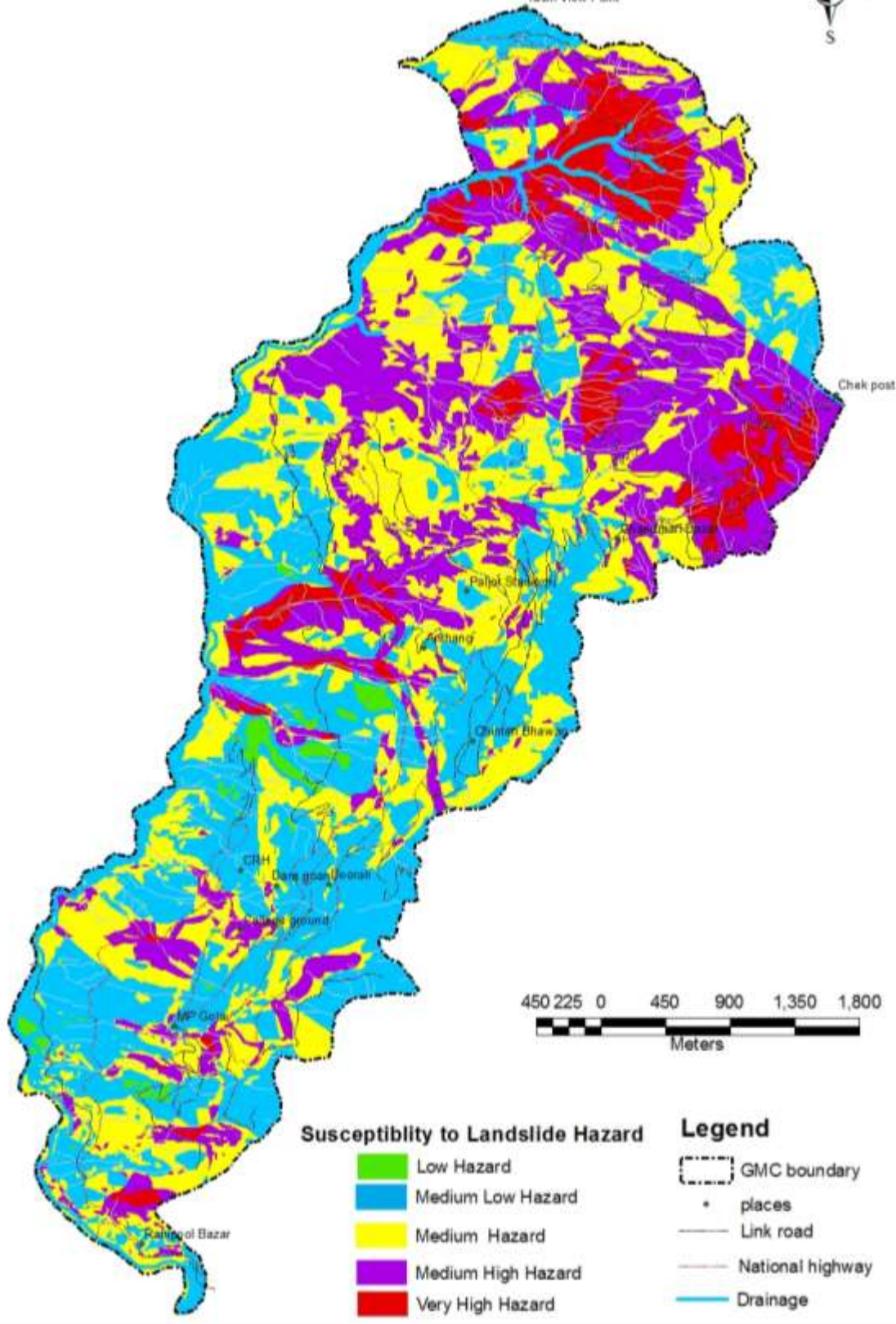
- Places
- Drainage
- Link Road
- National highway
- - - GMC boundary

## Water regime

- Dry
- Low surface/sub-surface water regime
- Medium surface/sub-surface water regime
- High surface/sub-surface water regime

# SUSCEPTIBILITY TO LANDSLIDE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK

Tashi View Point



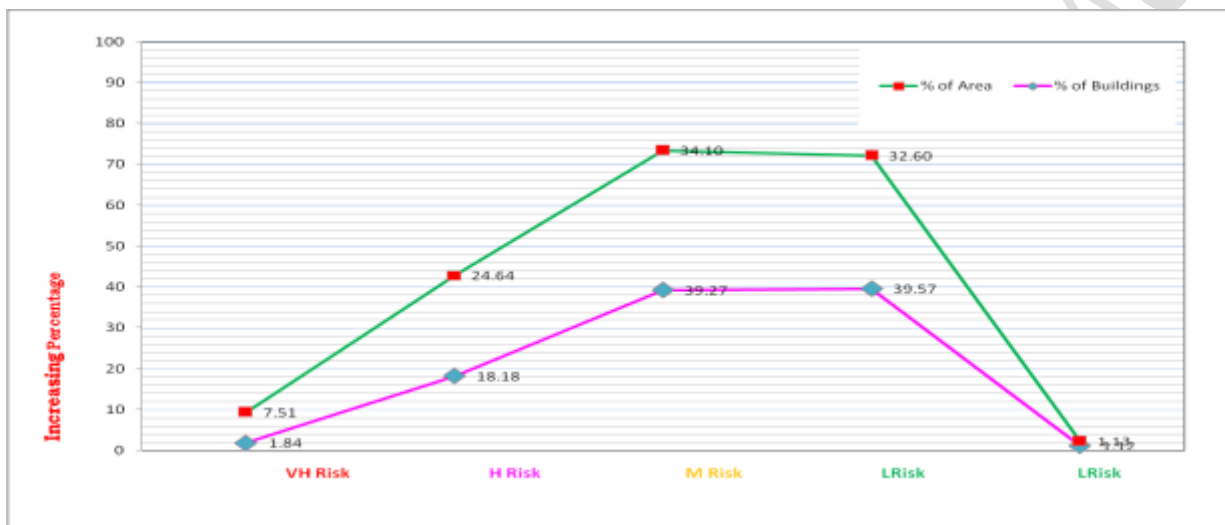
## Susceptibility to Landslide Hazard

- Low Hazard
- Medium Low Hazard
- Medium Hazard
- Medium High Hazard
- Very High Hazard

## Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage

Landslide Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazar	7.51	1.84	Very High
Medium High Hazards	24.64	18.18	High
Medium Hazards	34.10	39.27	Medium
Medium Low Hazards	32.60	39.57	Low
Low Hazards	1.13	1.12	Low



## Conclusion:

After extensive study and research of various maps and data it was possible to develop Landslide Hazard Risk and Vulnerability Map for the Gangtok Municipal corporation. The study leads to the following conclusions:

- The area's most likely to be affected by landslide were areas in and around 6<sup>th</sup> mile near holy cross school, along PS jhora and area around Burtuk.
- 7.51% of the area fell in very high risk zone with 1.84% of the total settlement to be affected
- 24.64% of the area fell in very medium high risk zone with 18.18% of the total settlement to be affected
- 34.10% of the area fell in very medium risk zone with 39.17% of the total settlement to be affected
- 32.60% of the area fell in very medium low zone with 39.57% of the total settlement to be affected.
- 1.13% of the area fell in very low risk zone with 1.12% of the total settlement to be affected

***EARTHQUAKE HAZARDS RISK  
VULNERABILITY ASSESSMENT OF  
GANGTOK***

## ***Earthquake***

Earthquakes may cause a number of phenomena, including ground motion, surface faulting, ground failure, and liquefaction. An earthquake's magnitude reflects an earthquake's strength. Damage to buildings generally begins to occur at magnitude six, while an earthquake above magnitude seven may be a major disaster if it occurs near a populated area. - Sikkim placed in Zone IV/V of the earthquake zonation map of India is subject to high magnitude earthquake tremors. Most of the loss of life in past earthquakes has occurred due to the collapse of buildings, constructed in traditional materials like stone, brick, adobe and wood, which were not particularly engineered to be earthquake resistant. In view of the continued use of such buildings in most countries of the world, it is essential to introduce earthquake resistance features in their construction.

## **SOCIO-ECONOMIC CONSIDERATIONS IN SEISMIC SAFETY OF BUILDINGS**

From the results of studies on the performance of buildings during past earthquakes, it appears that (i) certain building types should entirely be ruled out in seismic zones having probable seismic intensity of VIII or more on Modified Mercalli or the MSK Intensity Scales. This would include earthen houses, random rubble masonry as well as brickwork in clay mud mortar, and the like; (ii) Rich mortars involving cement and lime should be used in fired brick and coursed stone masonry; and (iii) substantial steel reinforcement should be introduced in the walls in both directions of the building. But there are a number of socio-economic constraints such as the following which do not permit the adoption of high level of safety in the buildings for the masses:

- (i) lack of concern about seismic safety due to infrequent occurrence of earthquakes;
- (ii) lack of awareness that buildings could be made earthquake resistant at small additional cost only, hence lack of motivation;

(iii) lack of financial resources for additional inputs for meeting earthquake resistance requirements in building construction;

(iv) other normal priorities on financial inputs in the daily life of the people;

(v) scarcity of cement, steel as well as timber in the developing countries in general; and

(vi) lack of skill in a seismic design and construction techniques and unorganized nature of the building sector.

***Methodology:***

In the development of Earthquake Hazard Risk and Vulnerability Assessment extensive historical research was conducted along with continuous successive field visit with geo-technical assessment of the area.

- Earthquake Inventory Map
- Soil Type Map
- Soil Liquefaction Map
- PGA Map
- Lineament Density Map
- Geological Map
- Structural map
- Slope Morphometry

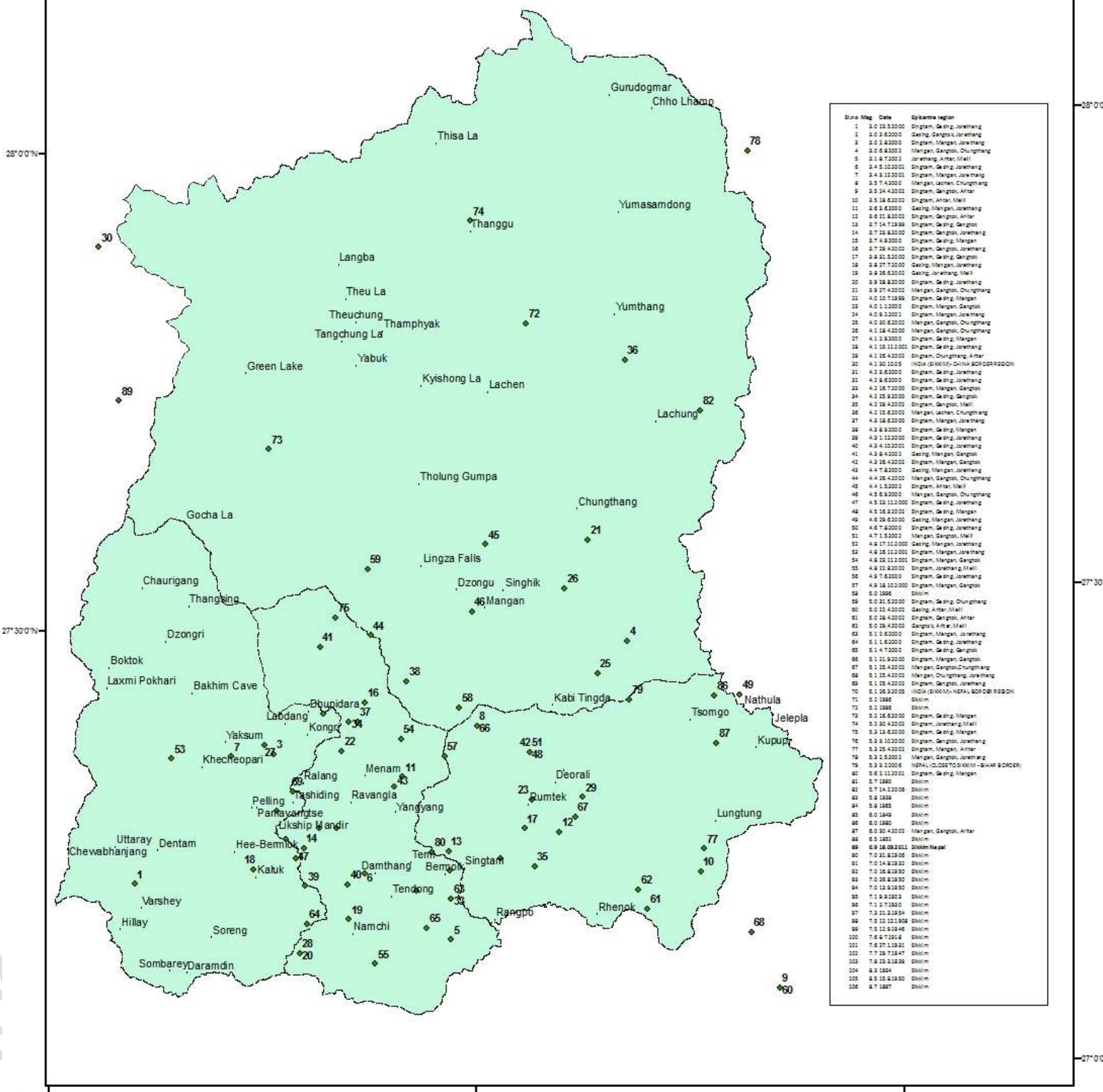
88°30'0"E

89°0'0"E

# LOCATION OF EPI-CENTRES OF EARTHQUAKE OCCURRENCE

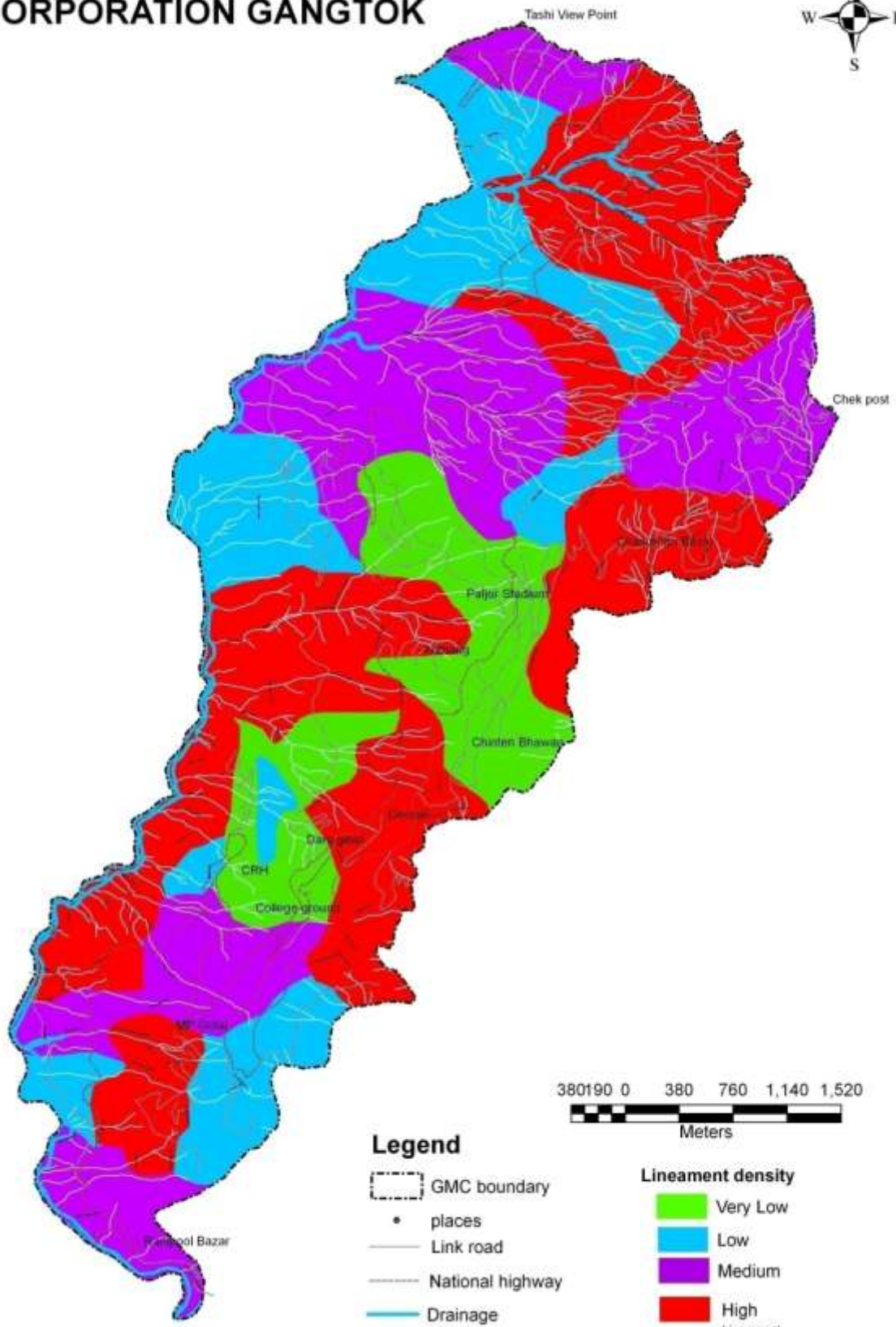


## IN SIKKIM AND SURROUNDING REGION

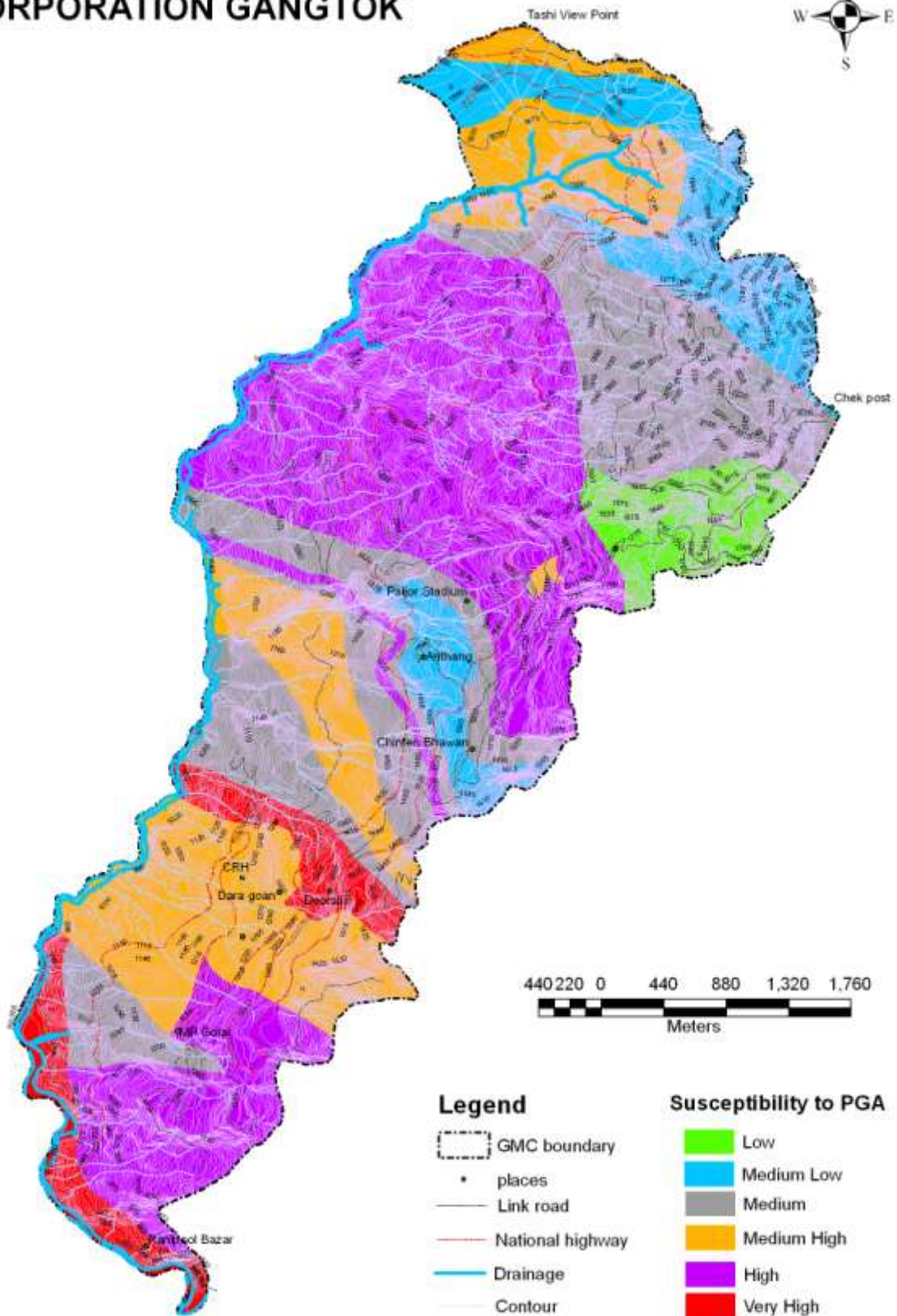


Sikkim Mag.	Date	Epicentre region
1	2.0.23.2000	Singam, Gesh, Jorethang
2	2.0.6.2000	Gesh, Gangtok, Jorethang
3	2.0.8.2000	Singam, Mangen, Jorethang
4	2.0.8.2000	Mangen, Gangtok, Chungthang
5	2.1.6.2000	Jorethang, Arun, Mall
6	2.4.5.10.2001	Singam, Gesh, Jorethang
7	2.4.4.12.2001	Singam, Mangen, Jorethang
8	2.5.7.12.2001	Mangen, Lachen, Chungthang
9	2.5.24.4.2001	Singam, Gangtok, Arun
10	2.5.18.6.2001	Singam, Arun, Mall
11	2.5.3.6.2001	Gesh, Mangen, Jorethang
12	2.5.15.8.2001	Singam, Gangtok, Arun
13	2.7.14.7.19.99	Singam, Gesh, Gangtok
14	2.7.22.8.20.00	Singam, Gangtok, Jorethang
15	2.7.4.9.20.00	Singam, Gesh, Mangen
16	2.7.25.4.20.01	Singam, Gangtok, Jorethang
17	2.8.21.5.20.00	Singam, Gesh, Gangtok
18	2.8.27.7.20.00	Gesh, Mangen, Jorethang
19	2.8.26.6.20.01	Gesh, Jorethang, Mall
20	2.8.18.8.20.00	Singam, Gesh, Jorethang
21	2.8.27.4.20.01	Mangen, Gangtok, Chungthang
22	4.0.10.7.19.99	Singam, Gesh, Mangen
23	4.0.1.1.20.00	Singam, Mangen, Gangtok
24	4.0.8.2.20.01	Singam, Mangen, Jorethang
25	4.0.20.6.20.01	Mangen, Gangtok, Chungthang
26	4.1.18.4.20.00	Mangen, Gangtok, Chungthang
27	4.1.2.9.20.00	Singam, Gesh, Mangen
28	4.1.15.11.20.01	Singam, Gesh, Jorethang
29	4.1.28.4.20.01	Singam, Chungthang, Arun
30	4.1.30.10.01	INDIA (SIKKIM)-CHINA BORDER REGION
31	4.2.8.6.20.00	Singam, Gesh, Jorethang
32	4.2.8.6.20.00	Singam, Gesh, Jorethang
33	4.2.16.7.20.00	Singam, Mangen, Gangtok
34	4.2.25.9.20.00	Singam, Gesh, Gangtok
35	4.2.28.4.20.01	Singam, Gangtok, Mall
36	4.2.15.6.20.01	Mangen, Lachen, Chungthang
37	4.2.18.6.20.00	Singam, Mangen, Jorethang
38	4.2.8.9.20.00	Singam, Gesh, Mangen
39	4.2.1.12.20.00	Singam, Gesh, Jorethang
40	4.2.8.10.20.01	Singam, Gesh, Jorethang
41	4.2.8.4.20.01	Gesh, Mangen, Gangtok
42	4.2.28.4.20.01	Singam, Mangen, Gangtok
43	4.4.7.2.20.01	Gesh, Mangen, Jorethang
44	4.4.26.4.20.01	Mangen, Gangtok, Chungthang
45	4.4.1.5.20.01	Singam, Arun, Mall
46	4.5.9.9.20.00	Mangen, Gangtok, Chungthang
47	4.5.12.11.20.00	Singam, Gesh, Jorethang
48	4.5.16.2.20.01	Singam, Gesh, Mangen
49	4.6.5.10.6.20.00	Gesh, Mangen, Jorethang
50	4.6.7.8.20.00	Singam, Gesh, Jorethang
51	4.7.1.5.20.01	Mangen, Gangtok, Mall
52	4.8.17.11.20.00	Gesh, Mangen, Jorethang
53	4.8.16.11.20.01	Singam, Mangen, Jorethang
54	4.8.21.11.20.01	Singam, Mangen, Jorethang
55	4.8.22.2.20.01	Singam, Jorethang, Mall
56	4.9.7.8.20.00	Singam, Gesh, Jorethang
57	4.9.12.12.20.00	Singam, Mangen, Gangtok
58	5.0.1.9.95	SIKKIM
59	5.0.21.5.20.00	Singam, Gesh, Chungthang
60	5.0.21.4.20.01	Gesh, Arun, Mall
61	5.0.18.4.20.01	Singam, Gangtok, Arun
62	5.0.28.4.20.01	Gangtok, Arun, Mall
63	5.1.1.6.20.00	Singam, Mangen, Jorethang
64	5.1.1.6.20.00	Singam, Gesh, Jorethang
65	5.1.4.7.20.00	Singam, Gesh, Gangtok
66	5.1.21.9.20.00	Singam, Mangen, Gangtok
67	5.1.25.4.20.01	Mangen, Gangtok, Chungthang
68	5.1.25.4.20.01	Mangen, Chungthang, Jorethang
69	5.1.25.4.20.01	Singam, Gangtok, Jorethang
70	5.1.26.3.20.01	INDIA (SIKKIM)-NEPAL, border region
71	5.2.1.9.95	SIKKIM
72	5.2.1.9.95	SIKKIM
73	5.2.16.6.20.00	Singam, Gesh, Mangen
74	5.2.20.4.20.01	Singam, Jorethang, Mall
75	5.2.16.6.20.00	Singam, Gesh, Mangen
76	5.2.8.10.20.00	Singam, Gangtok, Jorethang
77	5.2.25.4.20.01	Singam, Mangen, Arun
78	5.2.1.3.20.01	Mangen, Gangtok, Jorethang
79	5.2.3.1.20.06	NEPAL (C.D.D.P. TO SIKKIM)-SIKKIM border region
80	5.6.11.20.01	Singam, Gesh, Mangen
81	5.7.1.9.95	SIKKIM
82	5.7.18.2.20.06	SIKKIM
83	5.8.1.9.95	SIKKIM
84	5.8.1.9.95	SIKKIM
85	5.8.1.9.95	SIKKIM
86	5.8.1.9.95	SIKKIM
87	6.0.20.4.20.01	Mangen, Gangtok, Arun
88	6.5.1.9.95	SIKKIM
89	6.9.18.09.20.01	Sikkim Nepal
90	7.0.21.8.19.95	SIKKIM
91	7.0.14.8.19.95	SIKKIM
92	7.0.15.8.19.95	SIKKIM
93	7.0.25.8.19.95	SIKKIM
94	7.0.12.8.19.95	SIKKIM
95	7.1.9.9.19.95	SIKKIM
96	7.1.1.7.19.95	SIKKIM
97	7.2.21.2.19.94	SIKKIM
98	7.5.11.11.19.94	SIKKIM
99	7.5.12.2.19.94	SIKKIM
100	7.6.7.19.94	SIKKIM
101	7.6.27.1.19.91	SIKKIM
102	7.7.29.7.19.94	SIKKIM
103	7.8.23.2.19.94	SIKKIM
104	8.2.1.9.94	SIKKIM
105	8.5.15.8.19.95	SIKKIM
106	8.7.1.9.97	SIKKIM

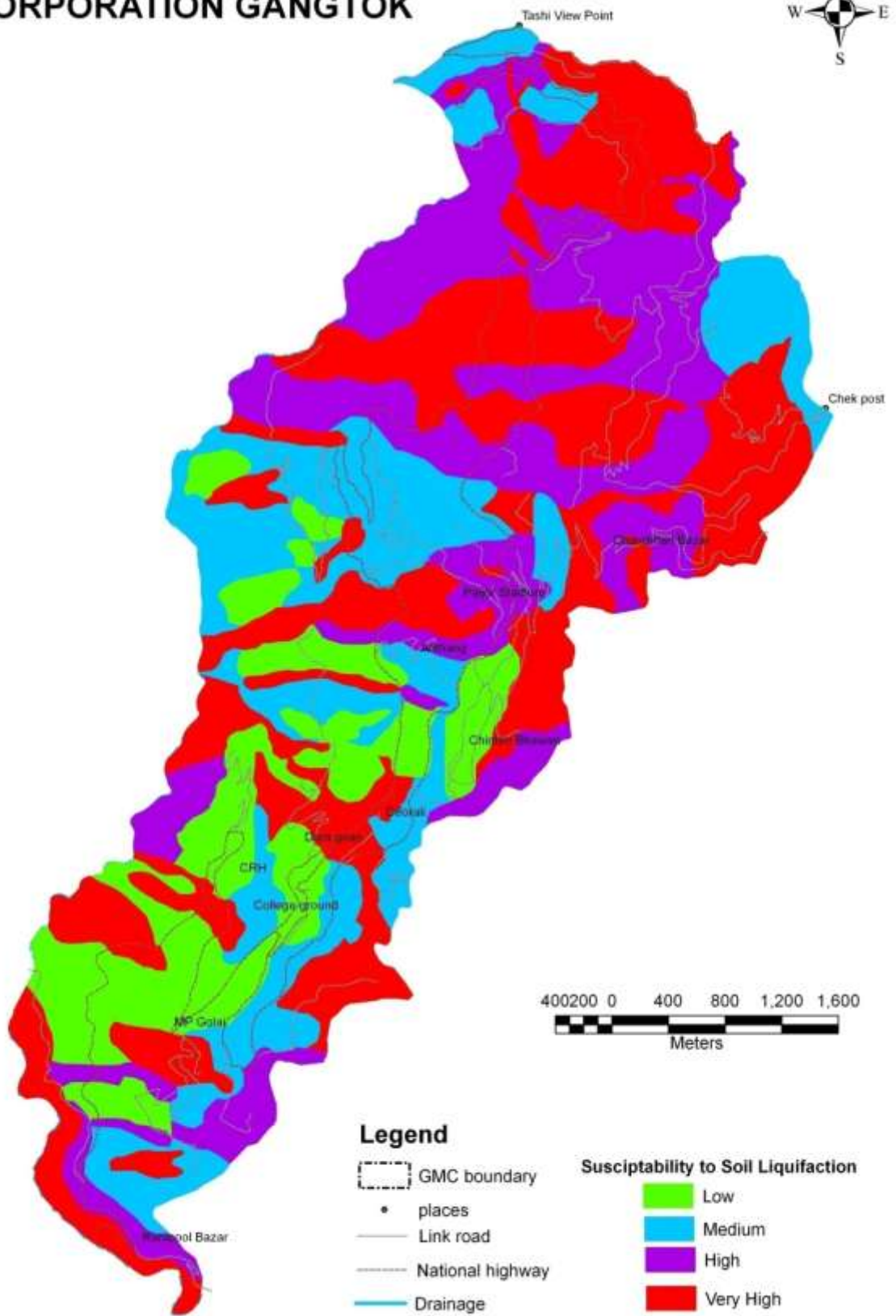
# LINEAMENT DENSITY MAP OF MUNICIPAL CORPORATION GANGTOK



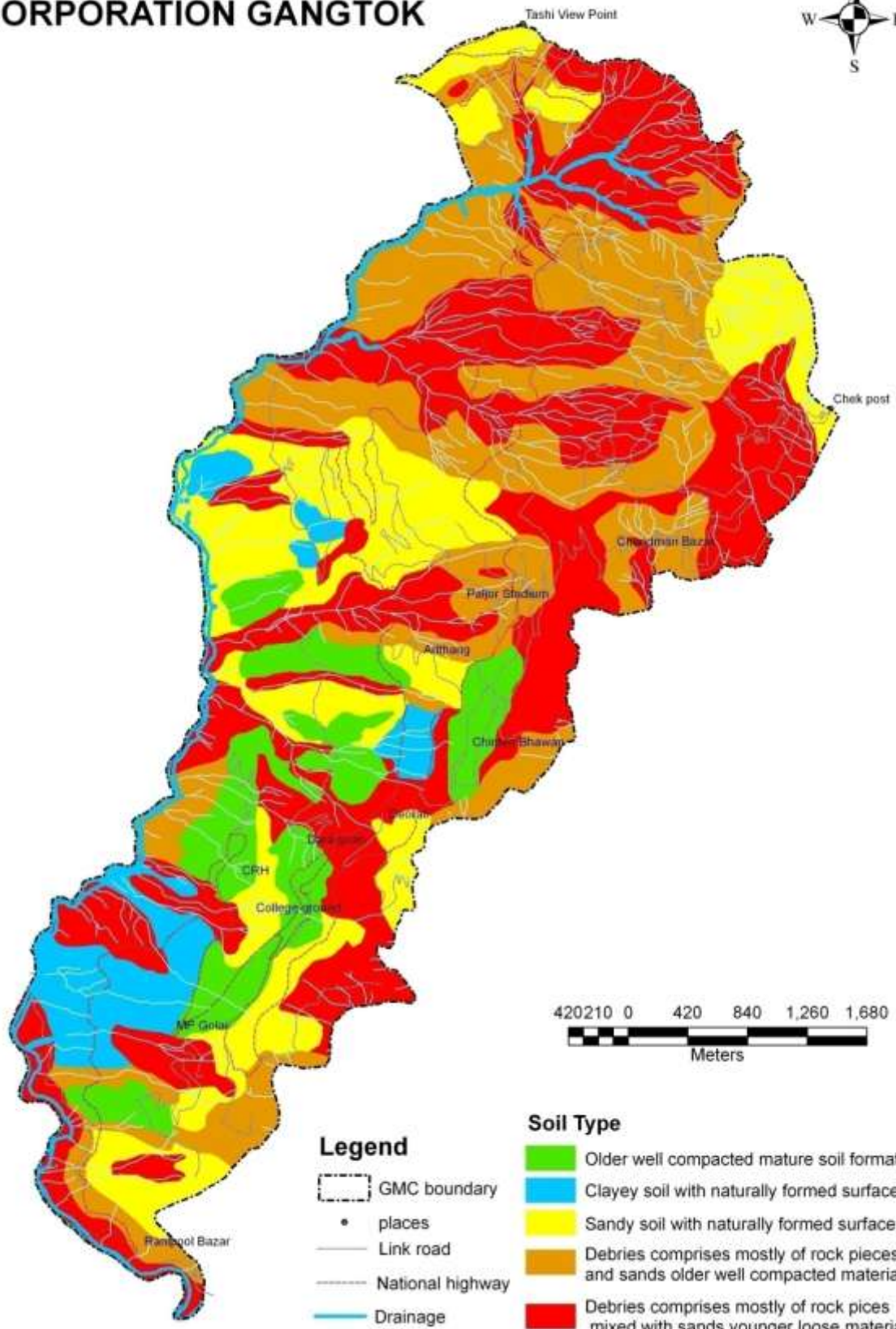
# SUSCEPTIBILITY TO PGA MAP OF MUNICIPAL CORPORATION GANGTOK



# SOIL LIQUIFACTION MAP OF MUNICIPAL CORPORATION GANGTOK



# SOIL TYPE MAP OF MUNICIPAL CORPORATION GANGTOK



420 210 0 420 840 1,260 1,680  
Meters

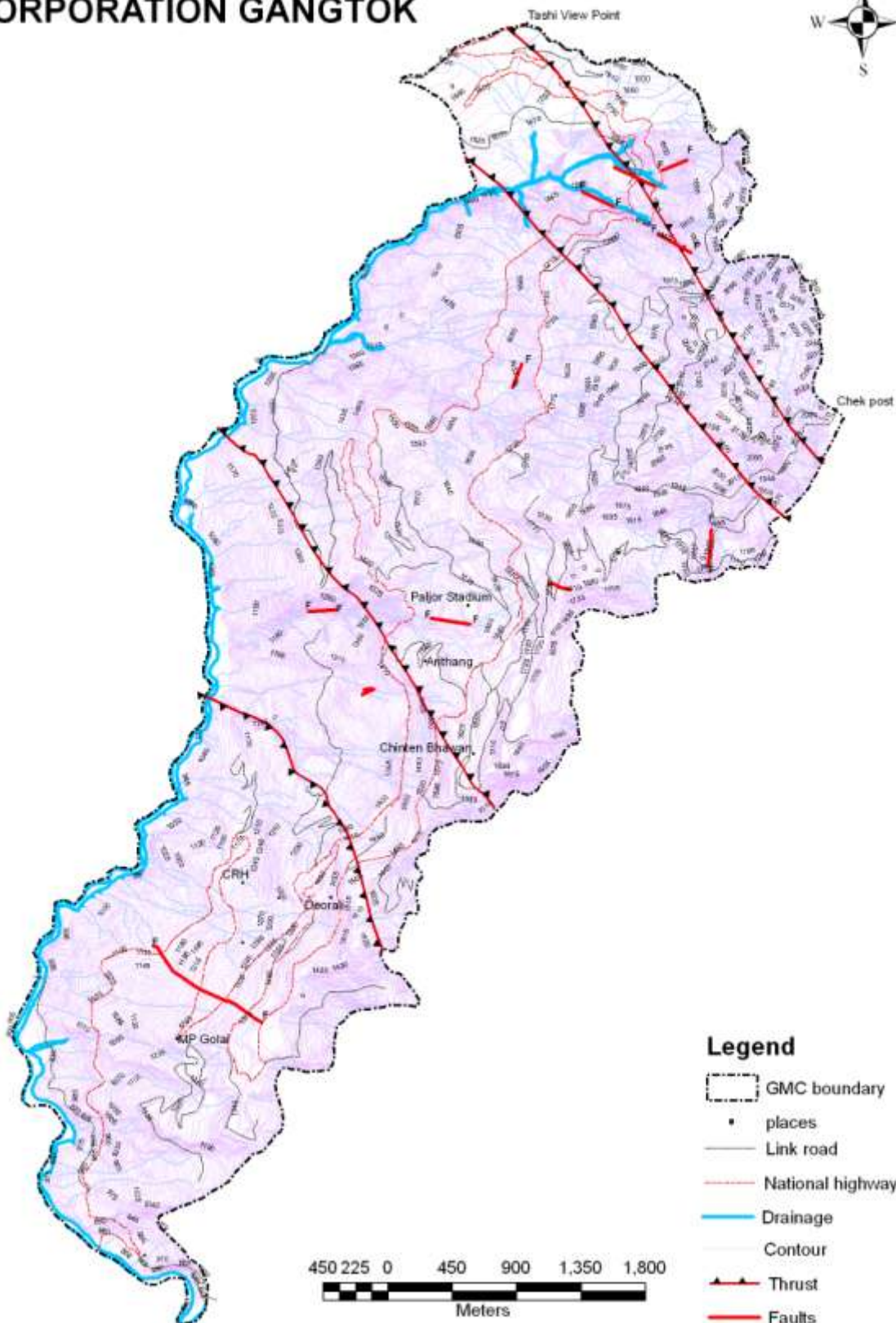
## Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage

## Soil Type

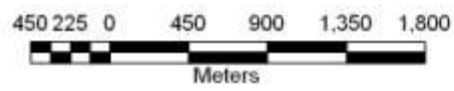
- Older well compacted mature soil formation
- Clayey soil with naturally formed surface
- Sandy soil with naturally formed surface
- Debris comprises mostly of rock pieces and sands older well compacted materials
- Debris comprises mostly of rock pieces mixed with sands younger loose materials

# STRUTURAL GEOLOGICAL MAP OF MUNICIPAL CORPORATION GANGTOK

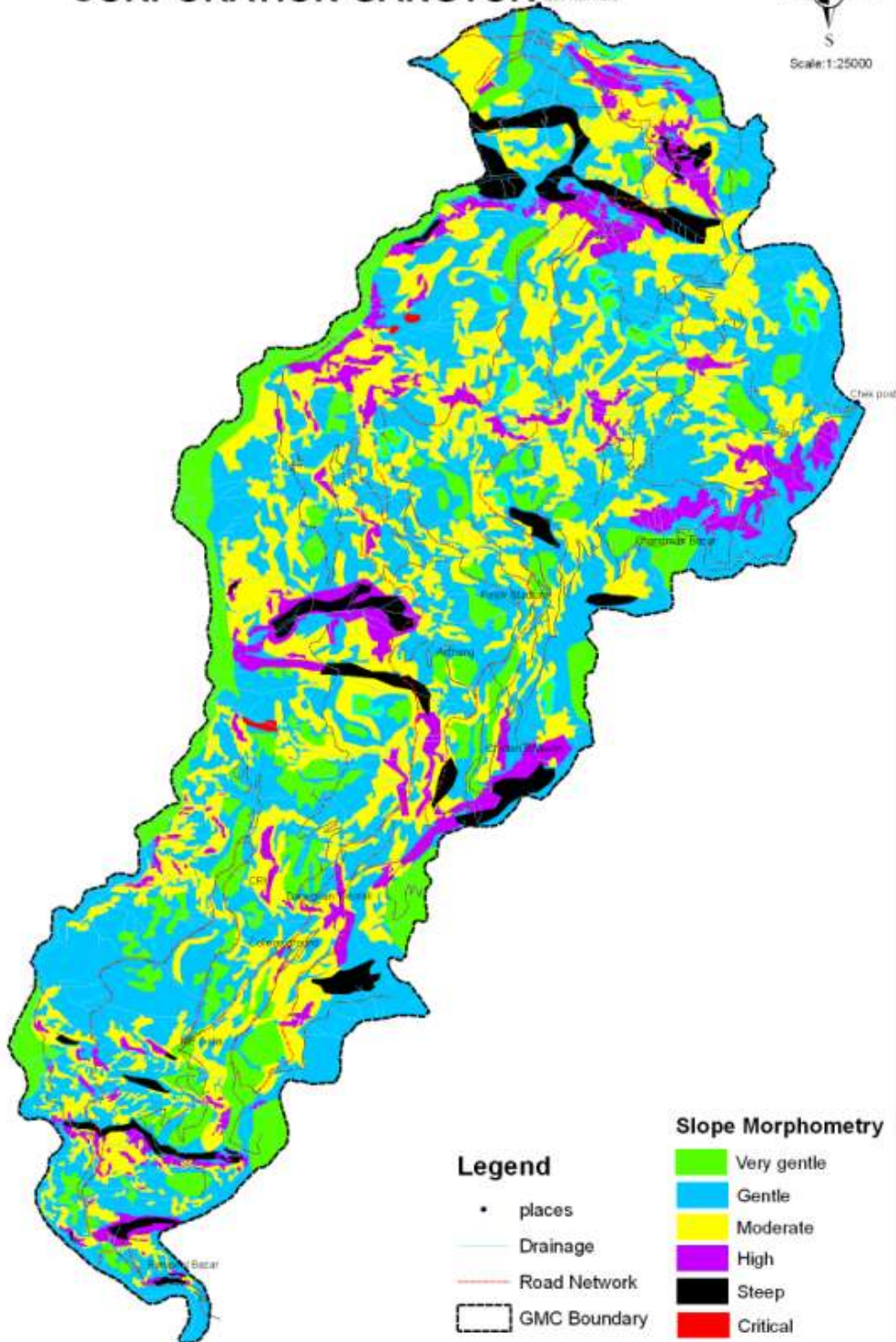


## Legend

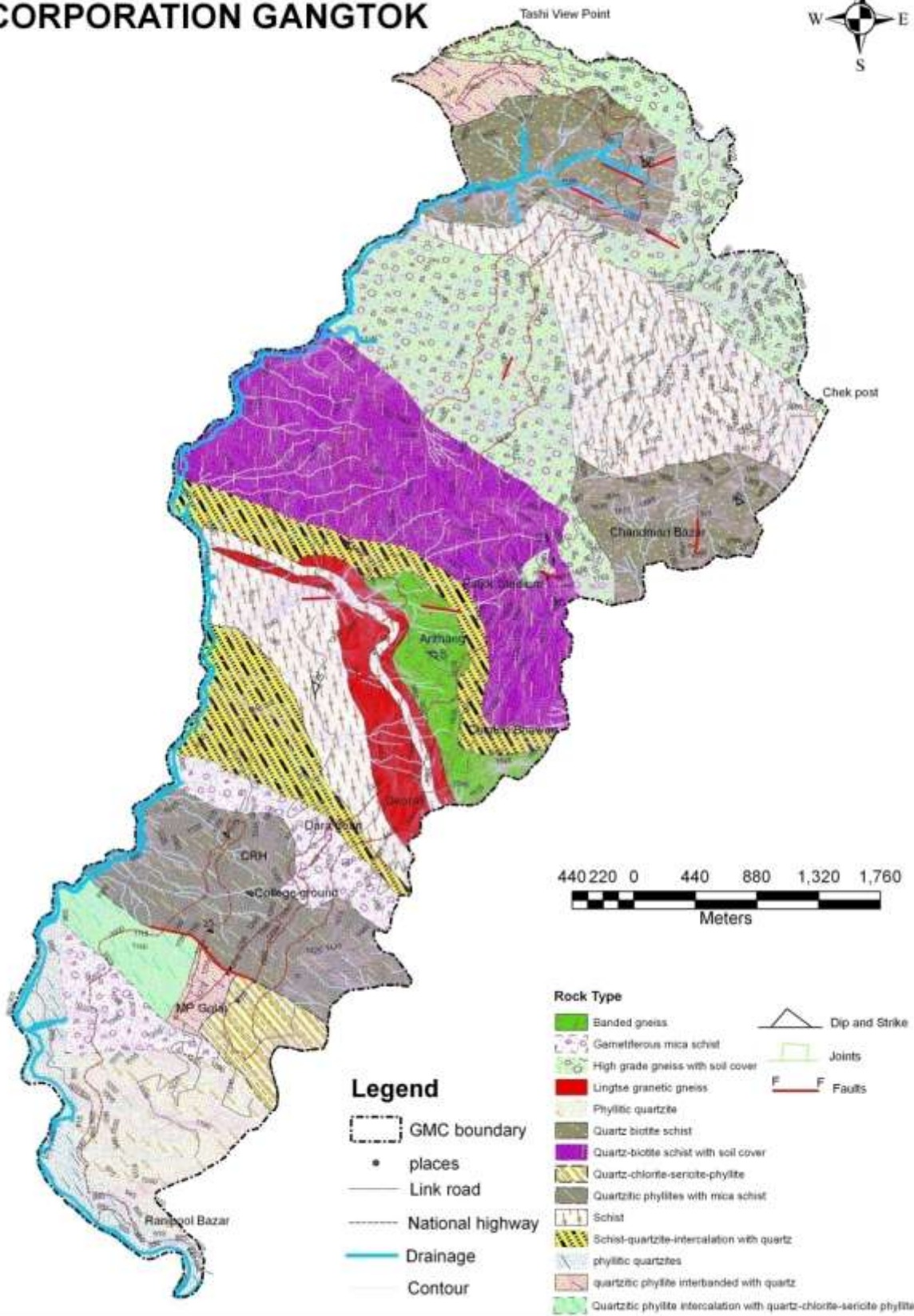
- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour
- Thrust
- Faults



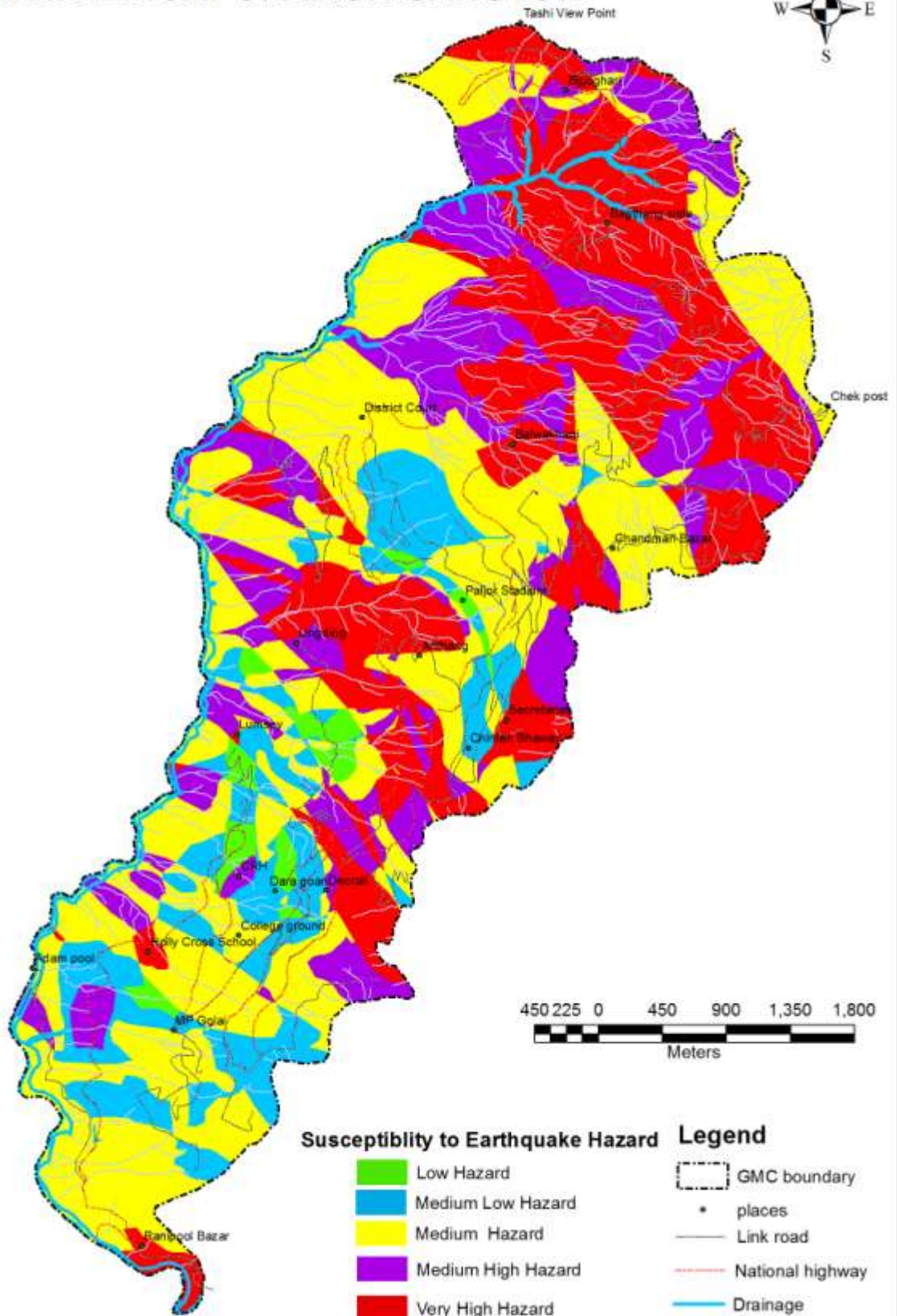
# SLOPE MORPHOMETRY MAP OF MUNICIPAL CORPORATION GANGTOK



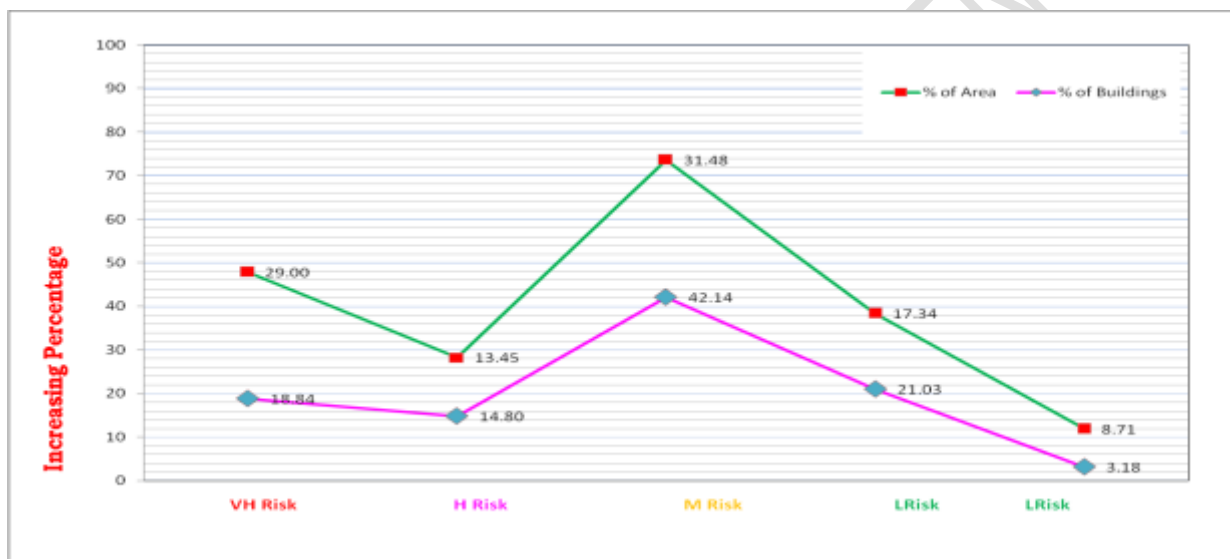
# GEOLOGICAL/LITHOLOGICAL MAP OF MUNICIPAL CORPORATION GANGTOK



# SUSCEPTIBILITY TO EARTHQUAKE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



Earthquake Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazard	29.00	18.84	Very High
Medium High Hazards	13.45	14.80	High
Medium Hazards	31.48	42.14	Medium
Medium Low Hazards	17.34	21.03	Low
Low Hazards	8.71	3.18	Low



### Conclusion:

After extensive study and research of various maps and data, develop Earthquake Hazard Risk and Vulnerability Map for the Gangtok Municipal Corporation. The study leads us to the following conclusions:

- The area's most likely to be affected by Earthquake were areas in and around below Arithang, below Paljor stadium and area around Amdo golai, burtuk etc.
- 29% of the area fell in very high risk zone with 18.84% of the total settlement to be affected
- 13.45% of the area fell in very medium high risk zone with 14.80% of the total settlement to be affected
- 31.48% of the area fell in very medium risk zone with 42.14% of the total settlement to be affected
- 17.34% of the area fell in very medium low zone with 21.03% of the total settlement to be affected

- 8.71% of the area fell in very low risk zone with 3.18% of the total settlement to be affected

ANKIM STATE DISASTER MANAGEMENT AUTHORITY

## ***FIRE ( FOREST/HUMAN INDUCED )***

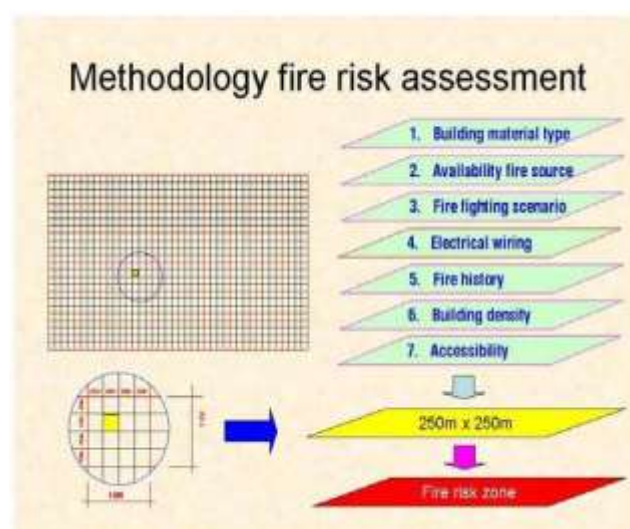
The most common hazard in forests is forests fire. Forests fires are as old as the forests themselves. They pose a threat not only to the forest wealth but also to the entire regime to fauna and flora seriously disturbing the biodiversity and the ecology and environment of a region. During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twinges, which could burst into flames ignited by the slightest spark. The Himalayan forests have been burning regularly during the last few summers, with colossal loss of vegetation cover of that region.

## **FIRE HAZARD RISK VULNERABILITY ASSESSMENT**

The fire risk zone mapping was decided to be carried out in few stages. The first is to define the map units that can delineate the component of attributes to potential fire hazard. The research studies taken place in similar environment elsewhere and local knowledge helped the project to examine the factors attributing to fire hazard in the context of Vientiane. In considering the suitability of a particular area for residential or other forms of development in the urban surroundings of the Vientiane city, the potential fire hazard ratings have been assessed in relation to the following criteria or factors; The mapping has been done using a 1:10,000 base map (land use and infrastructure map) of GMC is prepared. The map has been divided into grid of 250m x250m.

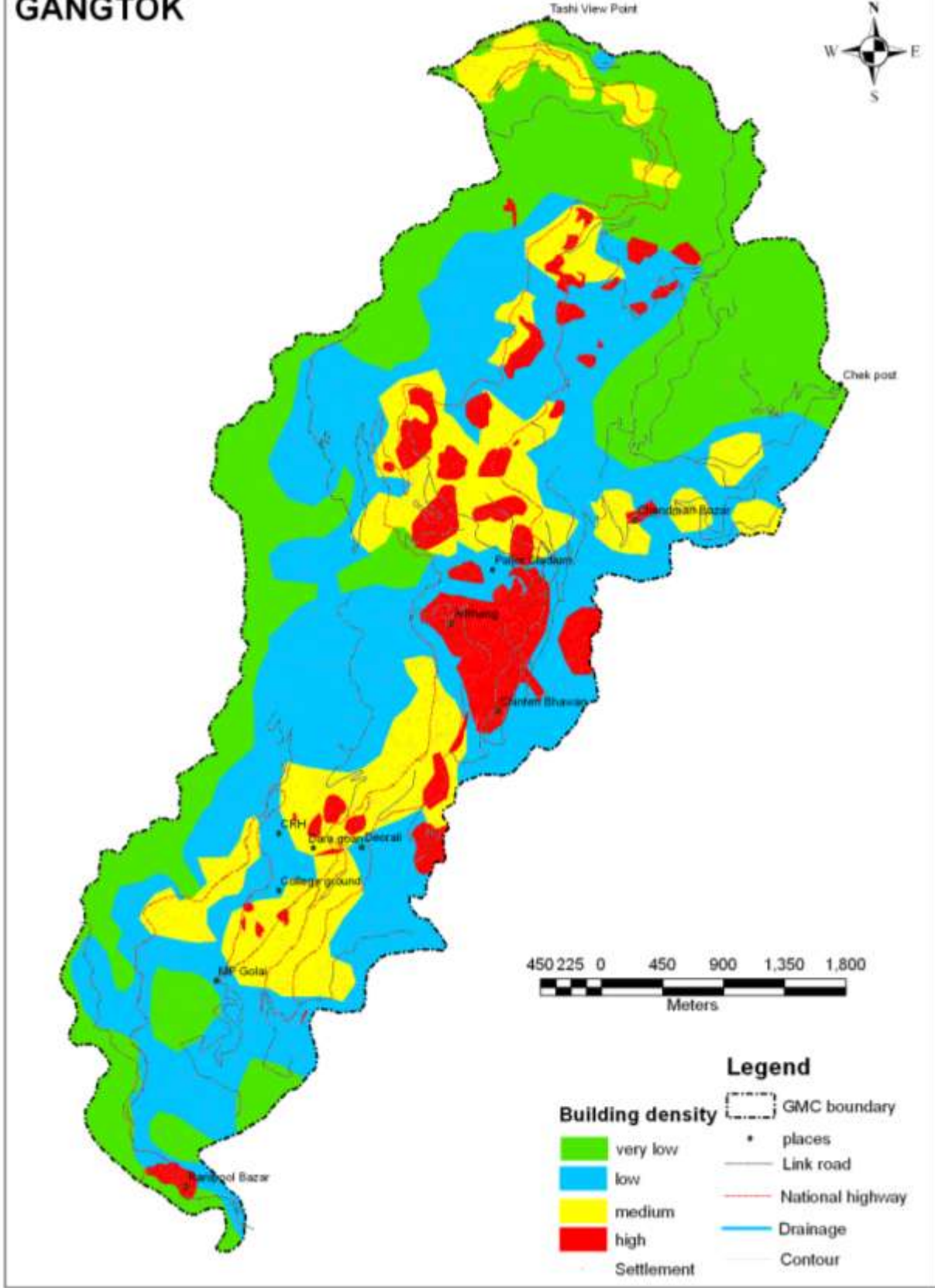
**Table: Criteria for assessment of fire risk ratings**

## **URBAN FIRE HAZARD RISK VULNERABILITY ASSESSMENT OF GANGTOK**

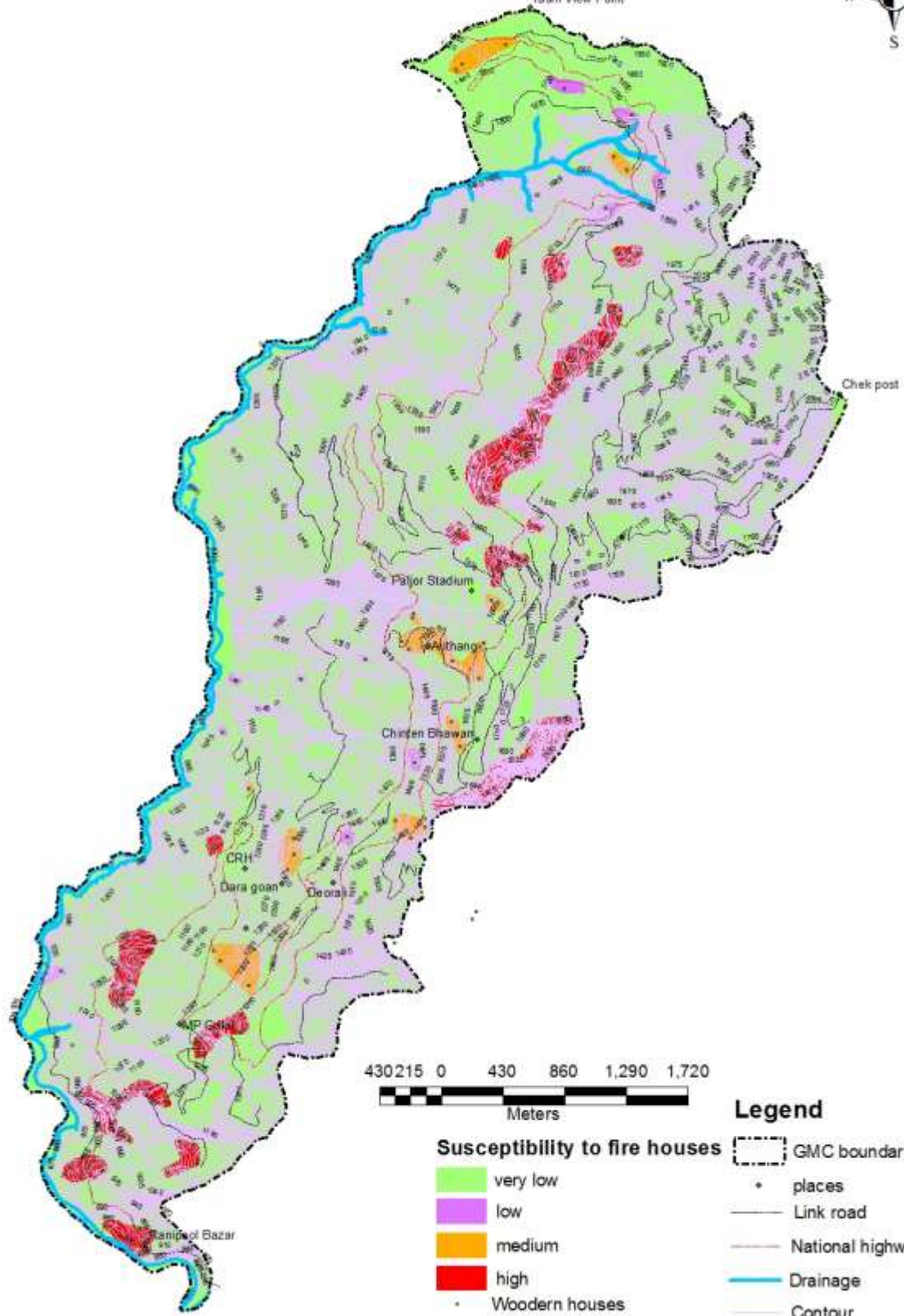


- 1 Building material type
- 2 Availability of fire sources
- 3 Fire fighting scenario
- 4 Electrical wiring
- 5 Fire history
- 6 Building Density
- 7 Accessibility

# BUILDING DENSITY MAP OF MUNICIPAL CORPORATION GANGTOK



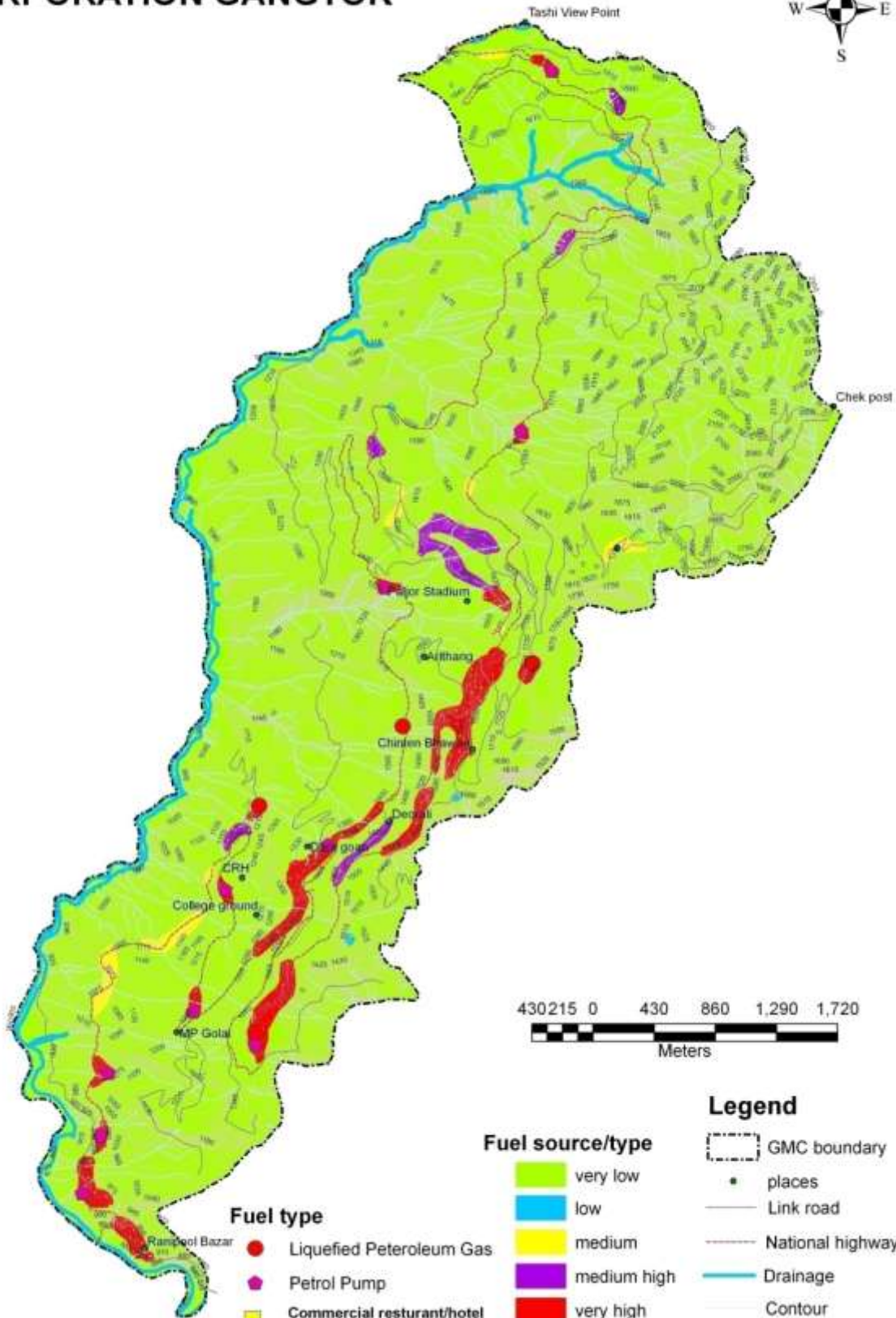
# SUSCEPTIBILITY TO FIRE PRONE HOUSES MAP OF MUNICIPAL CORPORATION GANGTOK



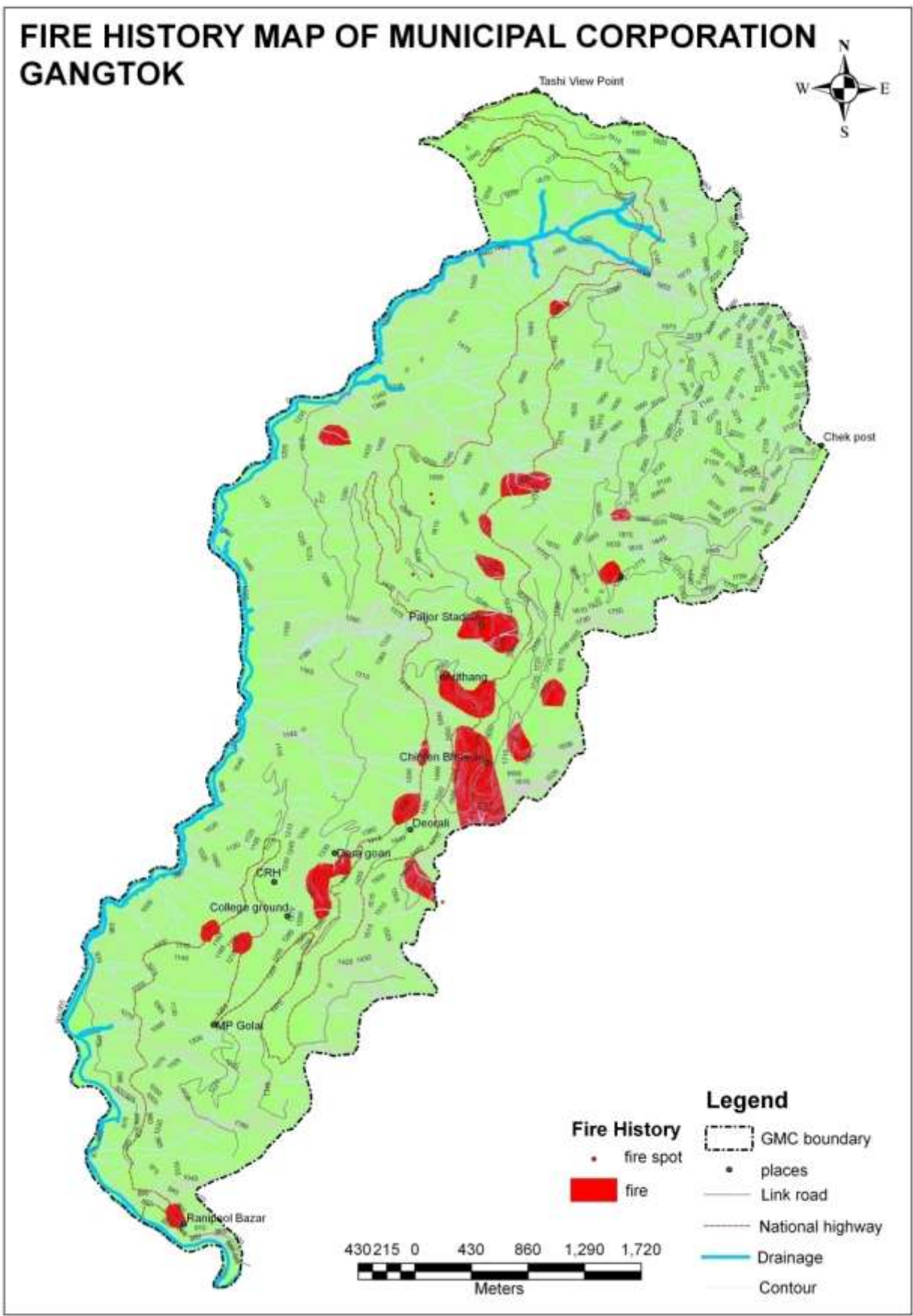
AKIM C

SRIT

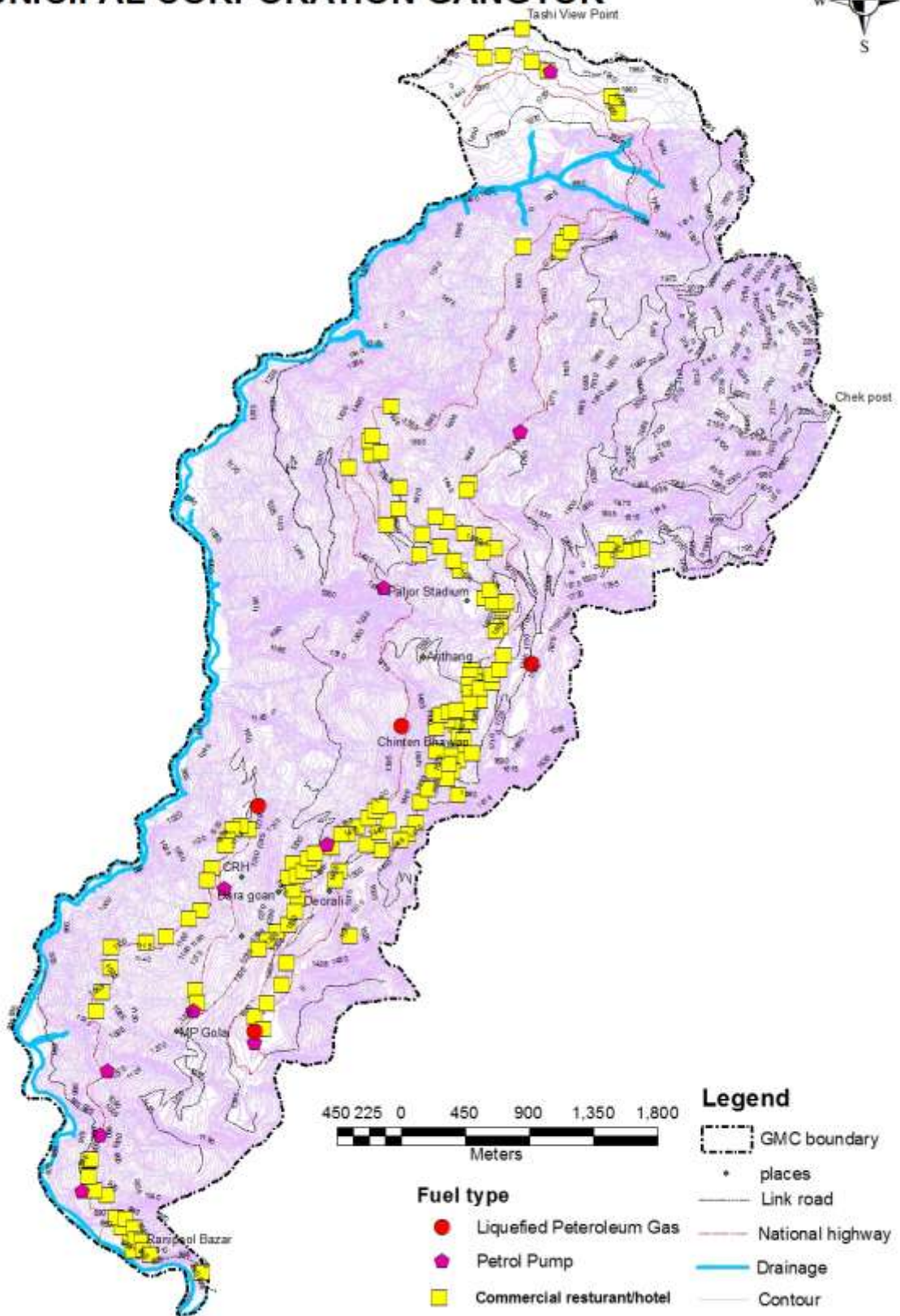
# FUEL TYPE/SOURCE ZONE MAP OF MUNICIPAL CORPORATION GANGTOK



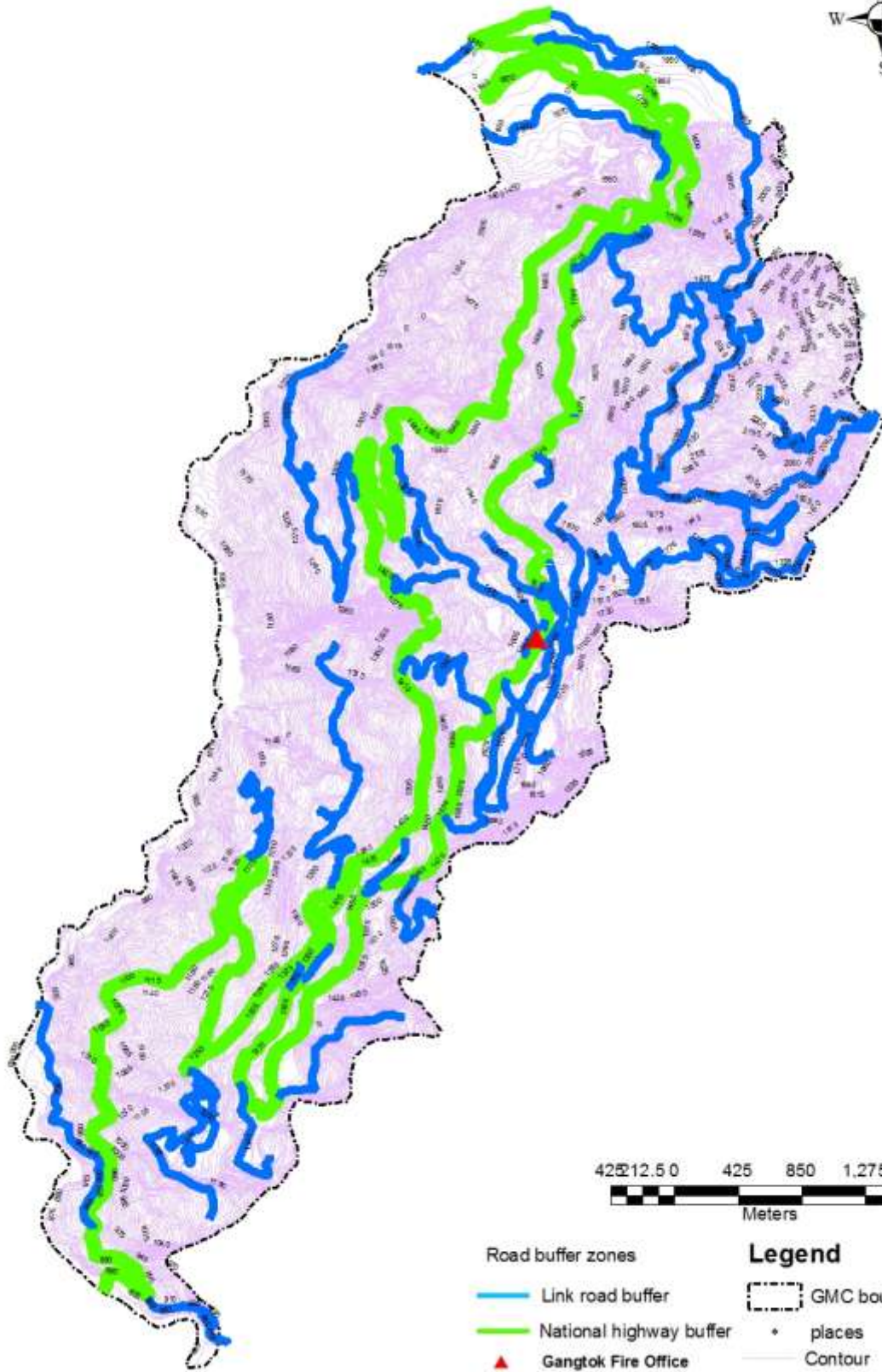
# FIRE HISTORY MAP OF MUNICIPAL CORPORATION GANGTOK



# LOCATION OF HIGH FUEL STORAGE AREA MAP OF MUNICIPAL CORPORATION GANGTOK



# ROAD NETWORK BUFFER ZONE MAP OF MUNICIPAL CORPORATION GANGTOK



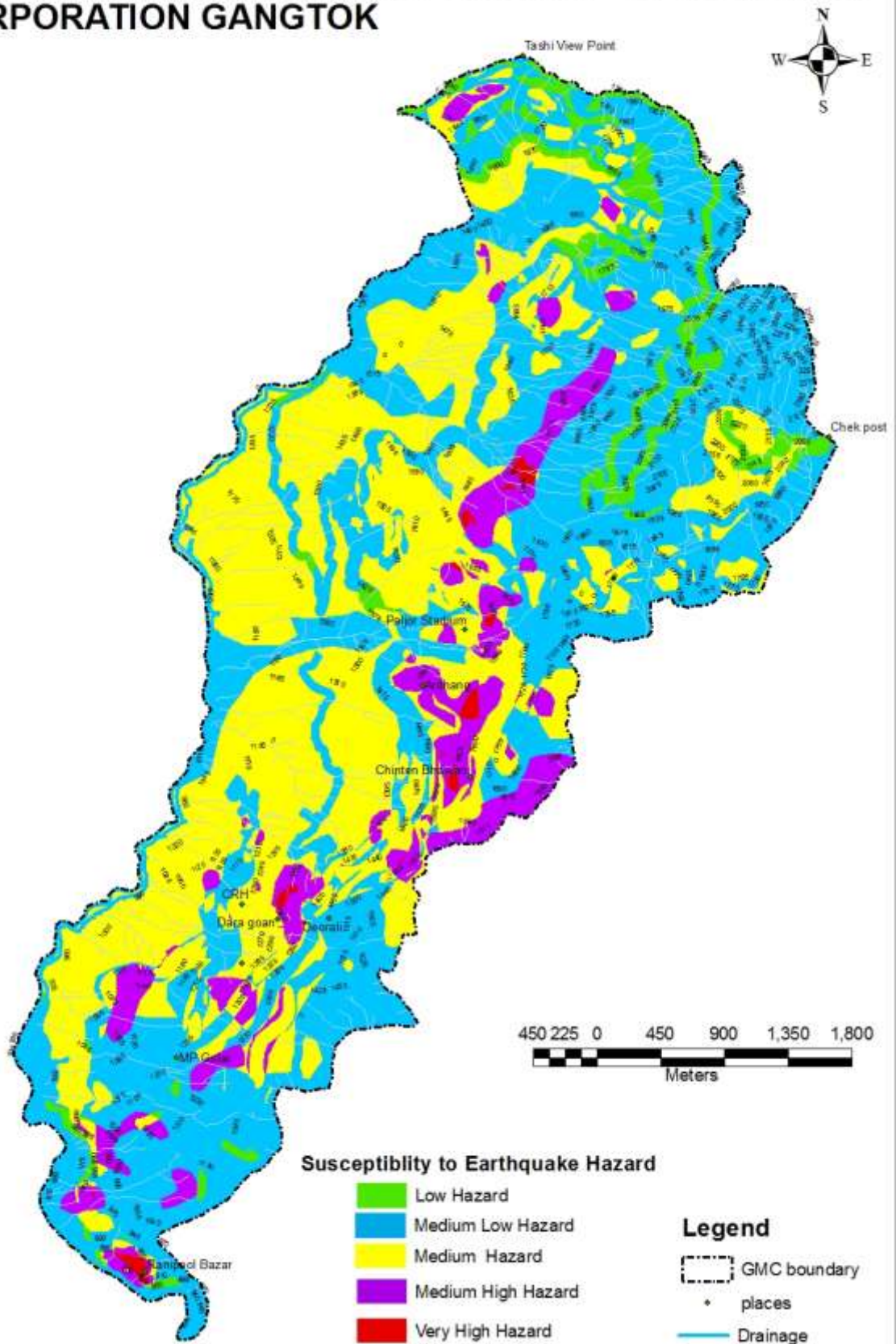
Road buffer zones

- Link road buffer
- National highway buffer
- Gangtok Fire Office

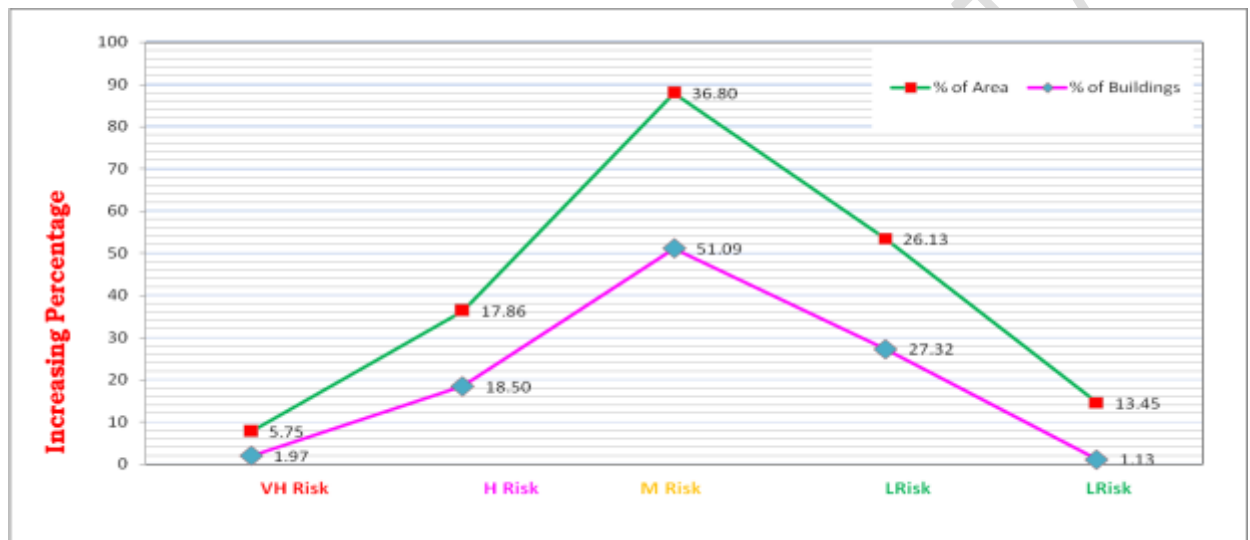
## Legend

- GMC boundary
- places
- Contour

# SUSCEPTIBILITY TO FIRE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



Fire Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazar	5.75	1.97	Very High
Medium High Hazards	17.86	18.50	High
Medium Hazards	36.80	51.09	Medium
Medium Low Hazards	26.13	27.32	Low
Low Hazards	13.45	1.13	Low



### Conclusion:

After extensive study and research of various maps and data, develop Fire Hazard Risk and Vulnerability Map for the GMC. The study leads us to the following conclusions:

- 5.75% of the area fell in very high risk zone with 1.97% of the total settlement to be affected
- 17.86% of the area fell in very medium high risk zone with 18.50% of the total settlement to be affected
- 36.80% of the area fell in very medium risk zone with 51.09% of the total settlement to be affected
- 26.13% of the area fell in very medium low zone with 27.32% of the total settlement to be affected
- 3.13.45% of the area fell in very low risk zone with 1.13% of the total settlement to be affected

***RIOTS/STAMPS HAZARD RISK  
VULNERABILITY ASSESSMENT OF  
GANGTOK***

## **RIOTS**

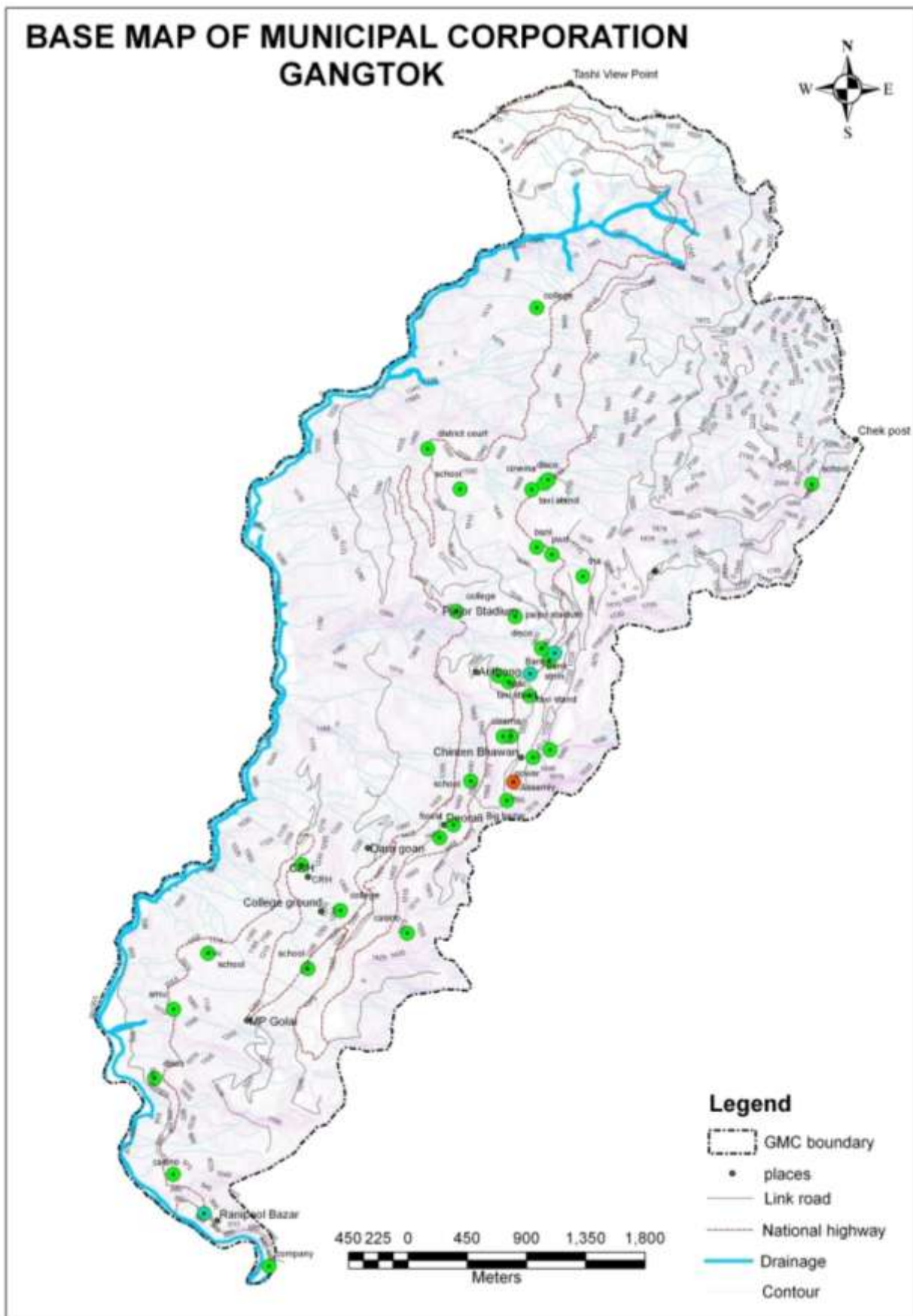
A **riot** is a form of civil disorder characterized often by disorganized groups lashing out in a sudden and intense rash of violence against authority, property or people. While individuals may attempt to lead or control a riot, riots are typically chaotic and exhibit herd behavior, and usually generated by civil unrest. Riots often occur in reaction to a perceived grievance or out of dissent. Historically, riots have occurred due to poor working or living conditions, government, oppression, taxation or conscription, conflicts between Ethnic groups, food supply or religions (see race riot, sectarian violence and pogrom), the outcome of a sporting event or frustration with legal channels through which to air grievances. Riots typically involve vandalism and the destruction of private and public property. The specific property to be targeted varies depending on the cause of the riot and the inclinations of those involved. Targets can include shops, cars, restaurants, state-owned institutions, and religious buildings.

### ***Methodology:***

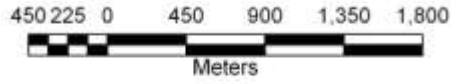
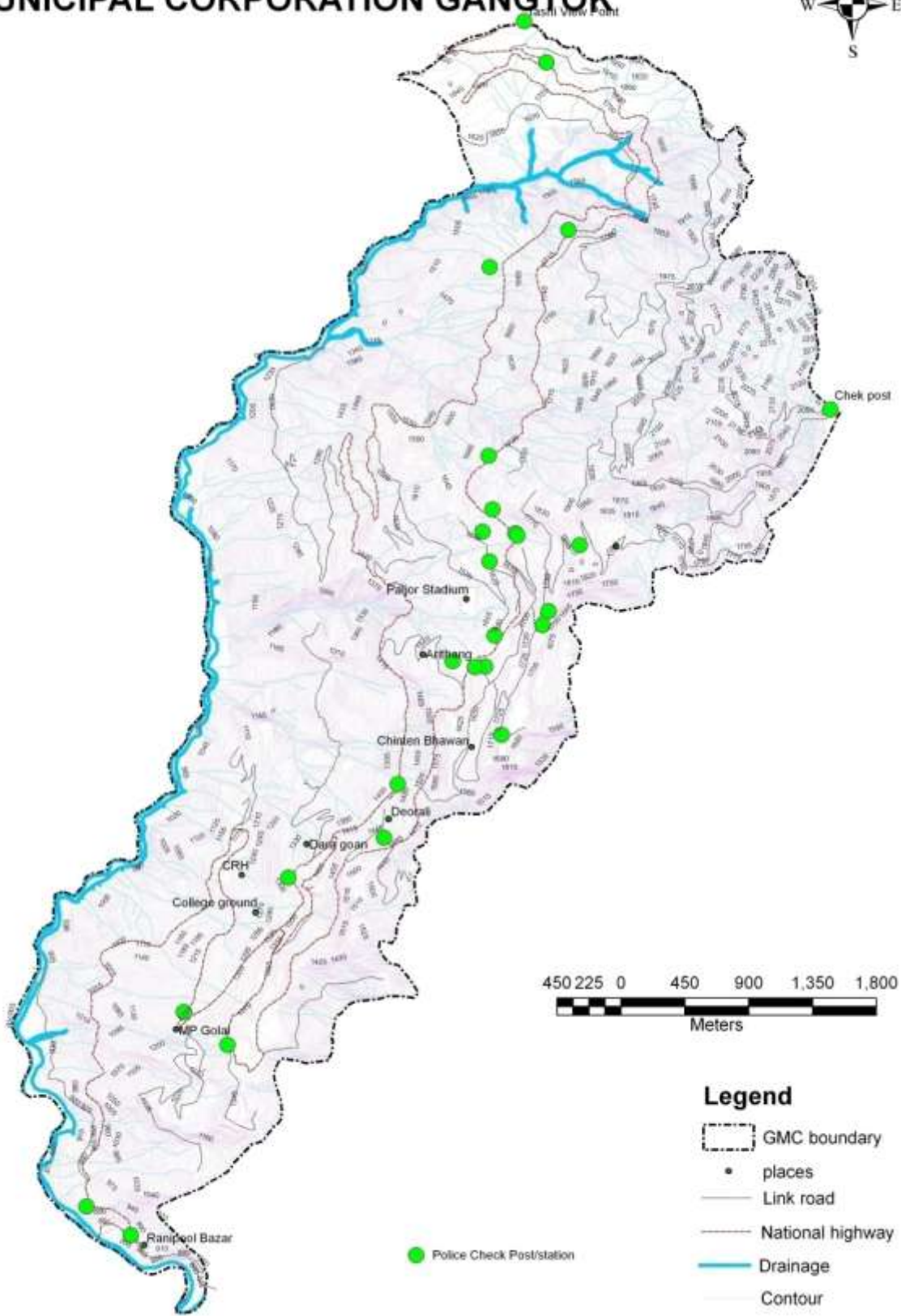
In the development of Riots/Stamped Hazard Risk and Vulnerability Assessment extensive historical research was conducted along with continuous successive field visit with the development and analysis of the following maps:

- Household Density Map
- Location of police check post
- Police patrolling zone
- Sensitive area buffer zone

# BASE MAP OF MUNICIPAL CORPORATION GANGTOK



# LOCATION OF POLICE CHECK POST MAP OF MUNICIPAL CORPORATION GANGTOK

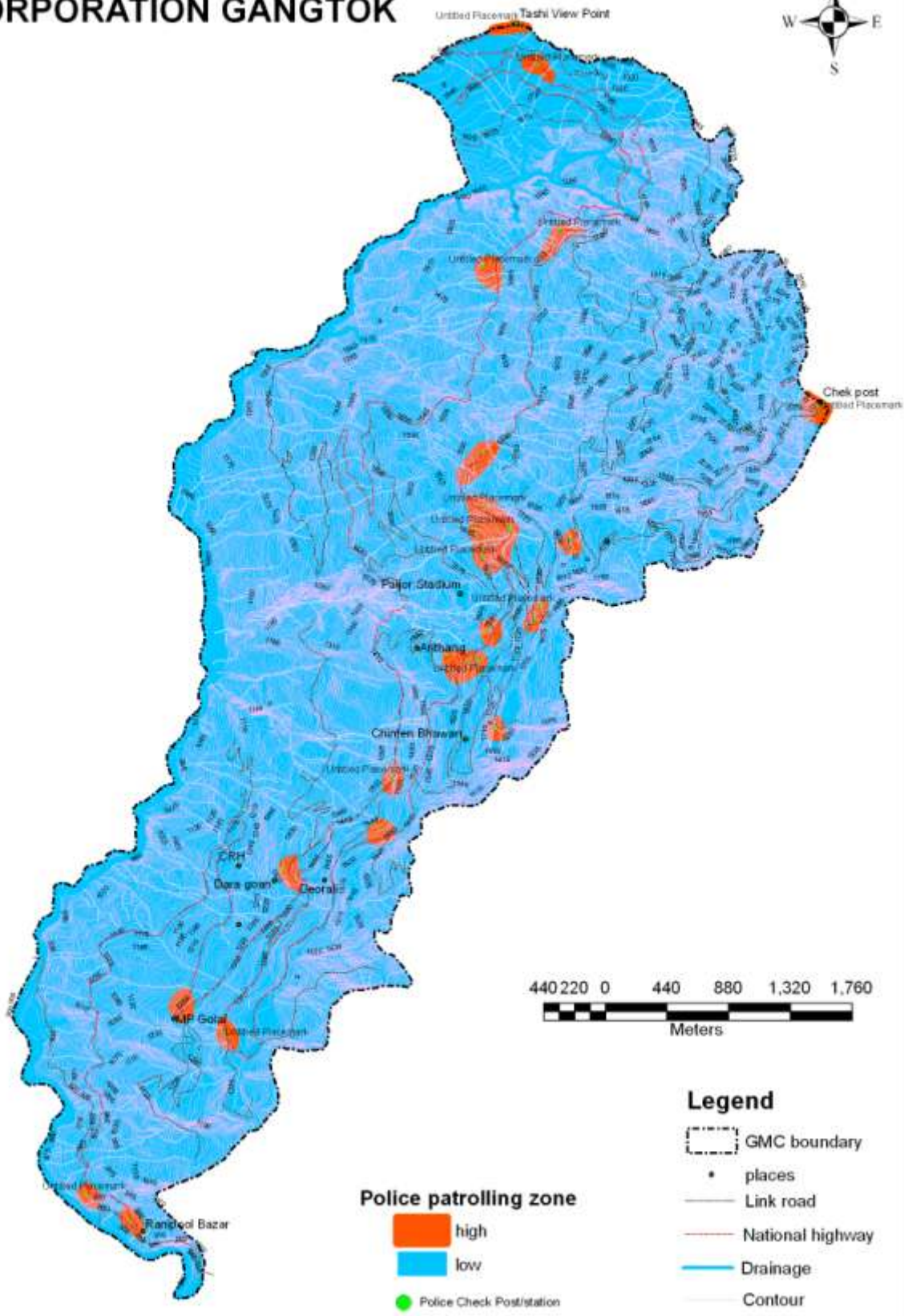


### Legend

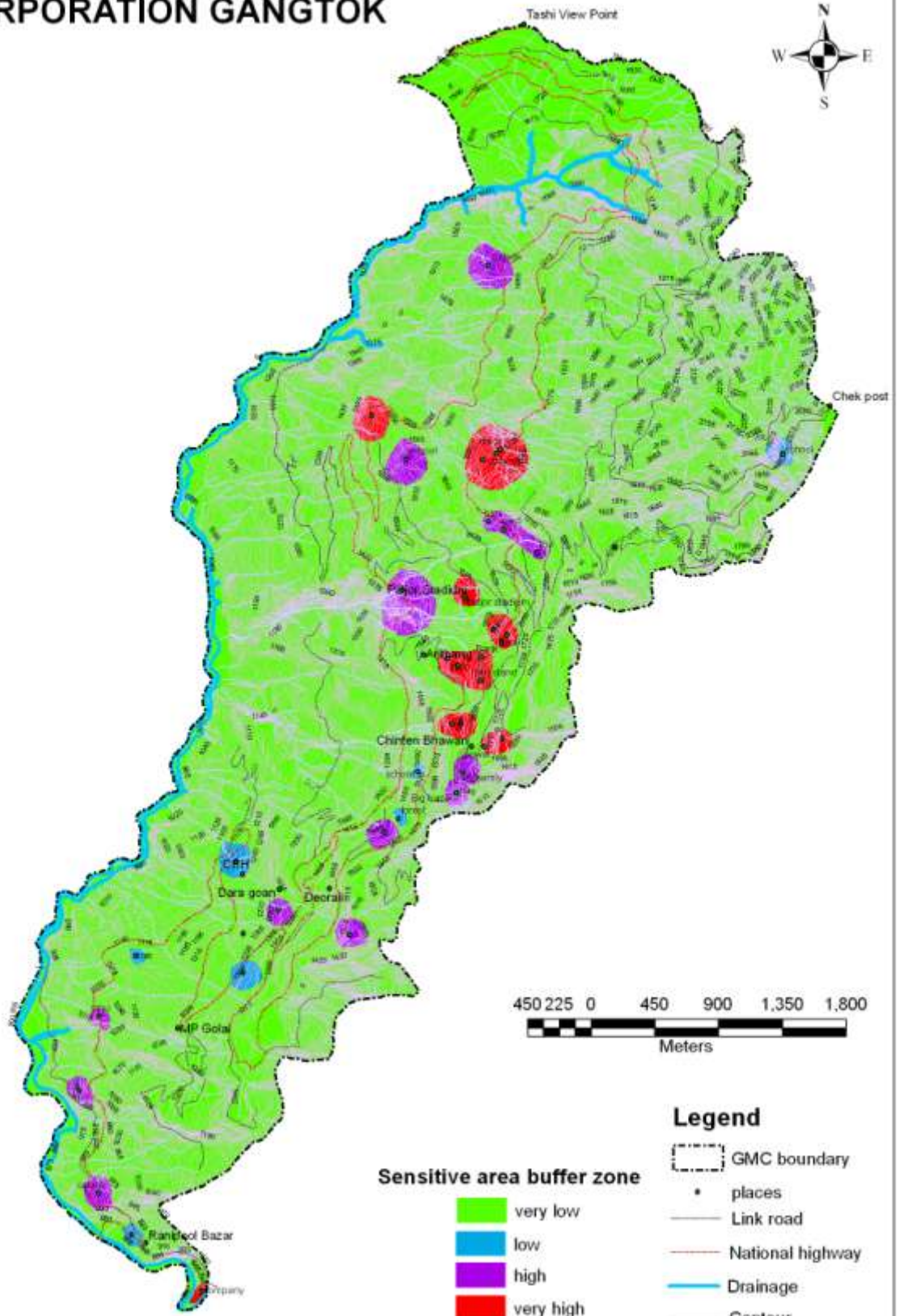
- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

Police Check Post/station

# POLICE PATROLLING ZONE MAP OF MUNICIPAL CORPORATION GANGTOK



# SENSITIVE AREA BUFFERZONE MAP OF MUNICIPAL CORPORATION GANGTOK



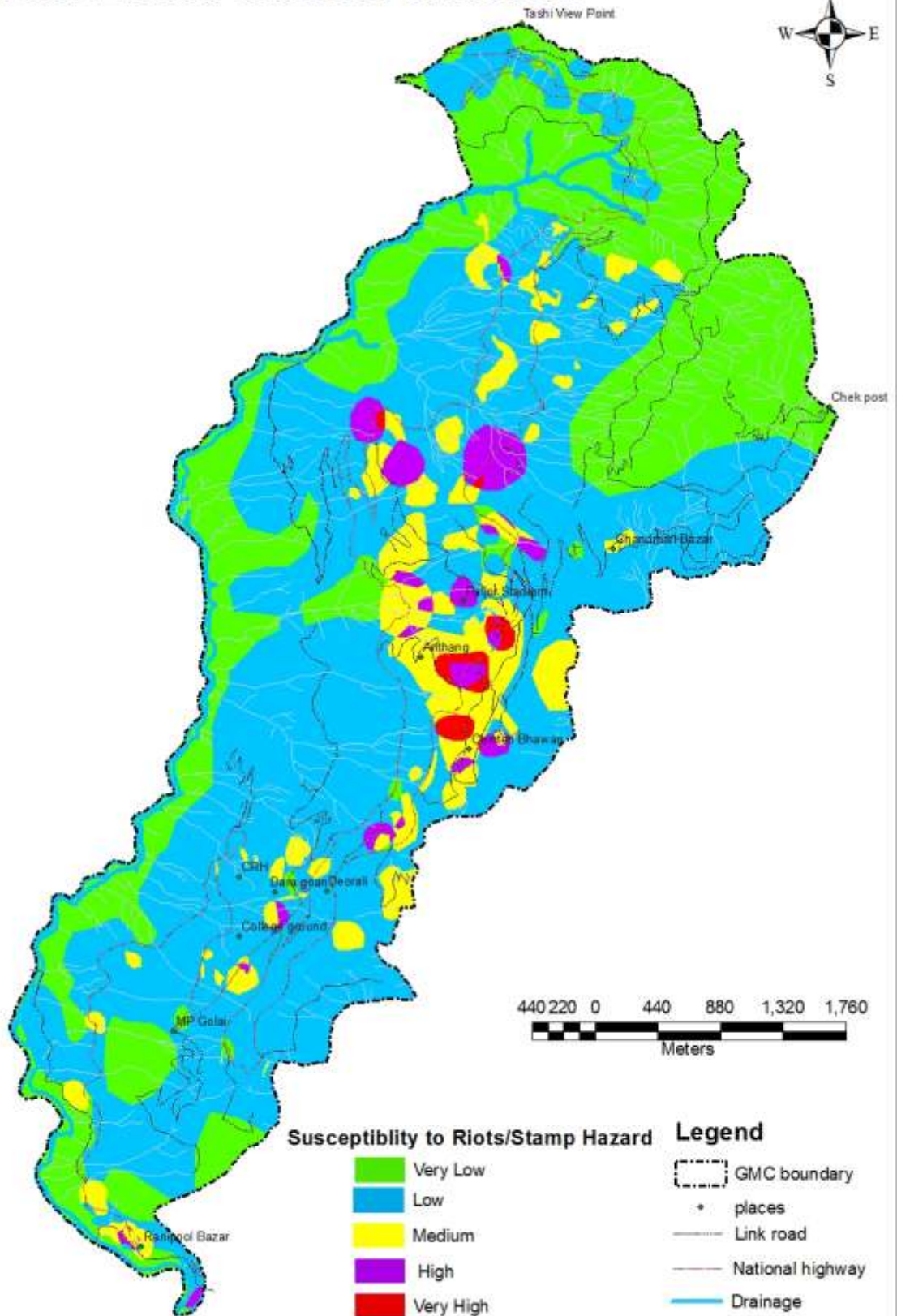
## Sensitive area buffer zone

- very low
- low
- high
- very high

## Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

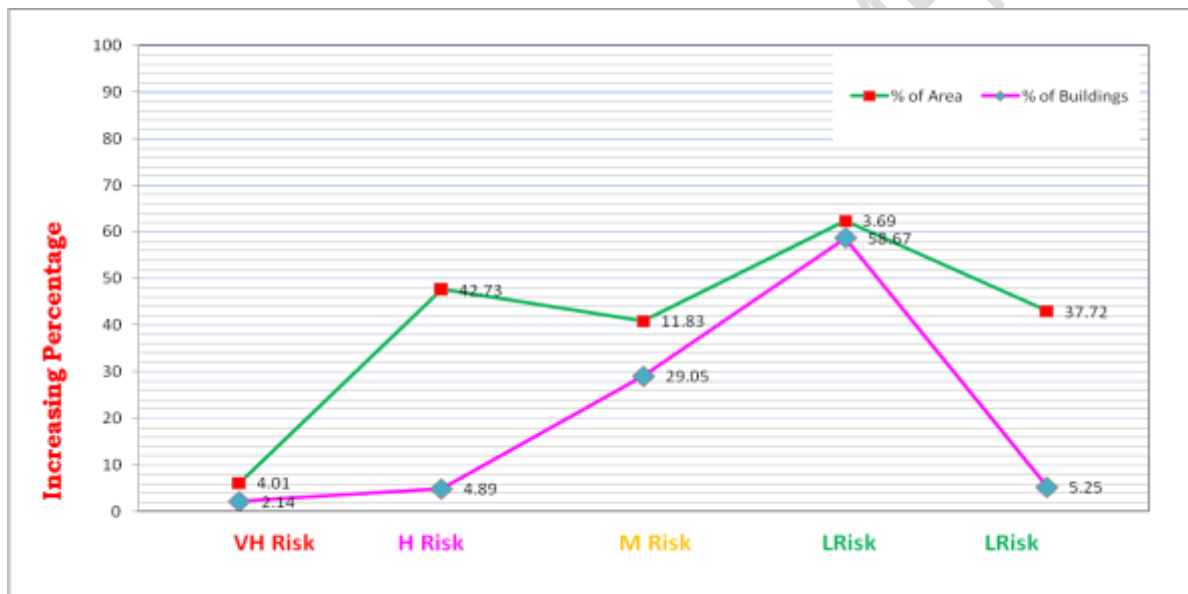
# SUSCEPTIBILITY TO RIOTS/STAMP HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



AKIM C

SRIT

Riots/Stamped Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazar	4.01	2.14	Very High
Medium High Hazards	42.73	4.89	High
Medium Hazards	11.83	29.05	Medium
Medium Low Hazards	3.69	58.67	Low
Low Hazards	37.72	5.25	Low



#### Conclusion:

After extensive study and research of various maps and data, develop Riot Hazard Risk and Vulnerability Map for the GMC. The study leads us to the following conclusions:

- 4.01% of the area fell in very high risk zone with 2.14% of the total settlement to be affected
- 42.73% of the area fell in high risk zone with 4.89% of the total settlement to be affected
- 11.83% of the area fell in medium risk zone with 29.05% of the total settlement to be affected
- 3.69% of the area fell in very low risk zone with 58.67% of the total settlement to be affected
- 37.72% of the area fell in very low risk zone with 5.25% of the total settlement to be affected

**FLASHFLOOD HAZARD RISK  
VULNERABILITY ASSESSMENT OF  
GANGTOK**

## ***Flash Flood***

Flash floods are dangerously fast moving floods caused by a large amount of heavy rain in a localized area. This torrential downpour may transform a normally calm area into a powerful river of death in only a few short minutes. Many people are caught unprepared for the power and speed of a flash flood, which results in dangerous situations. Flash floods are slightly different from normal floods. Normal floods involve water rising and overflowing from its normal path. However, flash floods appear quickly and move swiftly across land with little warning. Flash floods occur for a variety of reasons including concentrated rainfall during a slow moving thunderstorm, hurricanes, and tropical storms. The most devastating flash floods are from dam and levee failures. When either structure breaks, an enormous amount of water is suddenly unleashed, destroying everything in its path. The water in a flash flood moves at such a high velocity that it can move boulders, uproot trees, demolish buildings, and destroy bridges. The walls of water in such a flood can be anywhere from ten to twenty feet tall and usually carry a substantial amount of debris.

### ***Methodology:***

In the development of Flashflood Hazard Risk and Vulnerability Assessment extensive historical research was conducted along with continuous successive field visit with the development and analysis of the following maps:

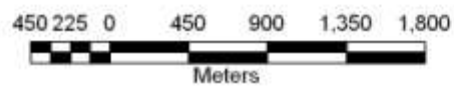
- Drainage Map
- Slope Analysis Map
- Rainfall map

# DRAINAGE MAP OF MUNICIPAL CORPORATION GANGTOK

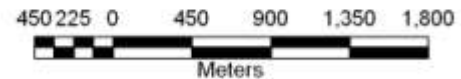
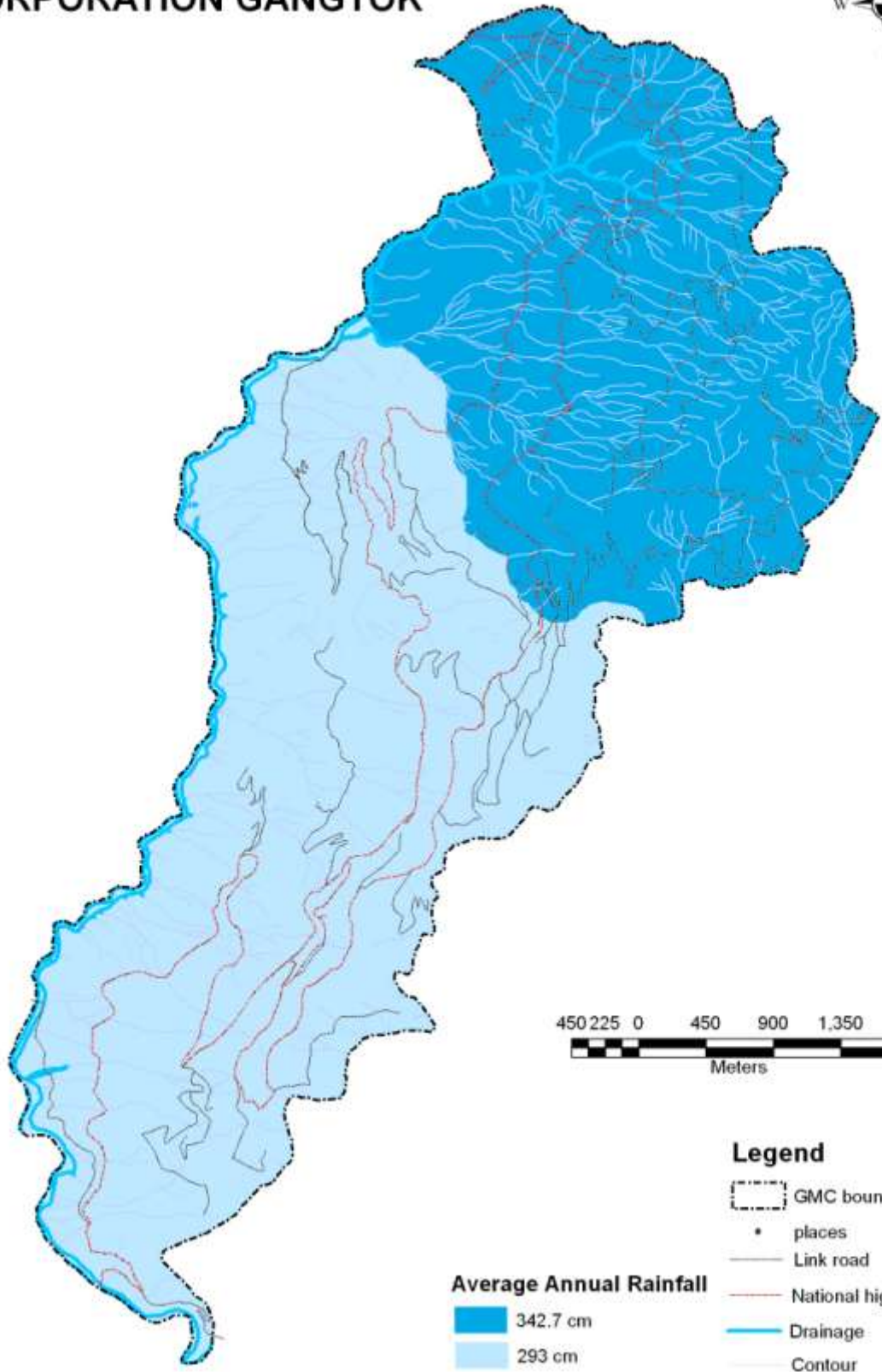


## Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage



# AVERAGE ANNUAL RAINFALL MAP OF MUNICIPAL CORPORATION GANGTOK



### Average Annual Rainfall

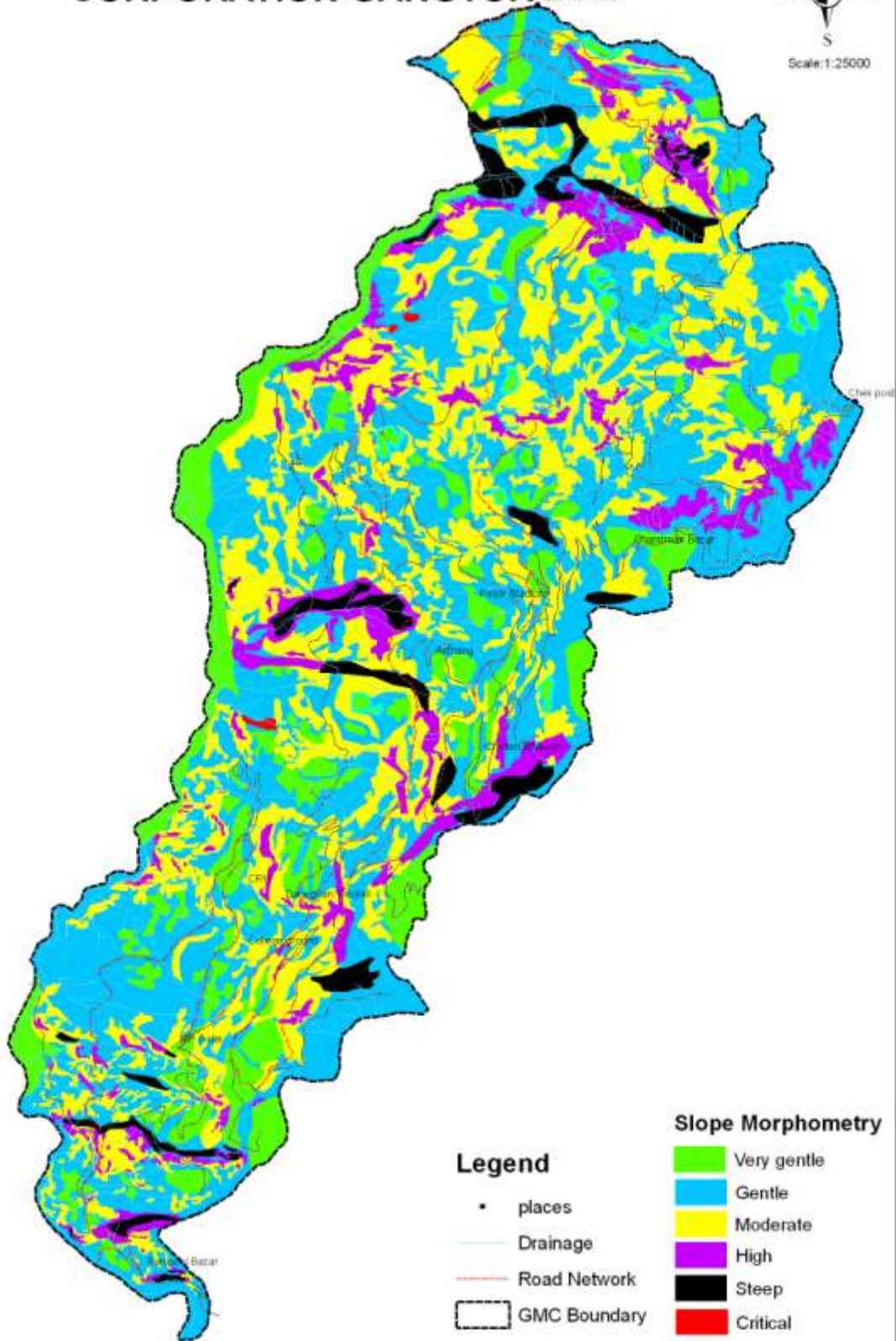


### Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage
- Contour

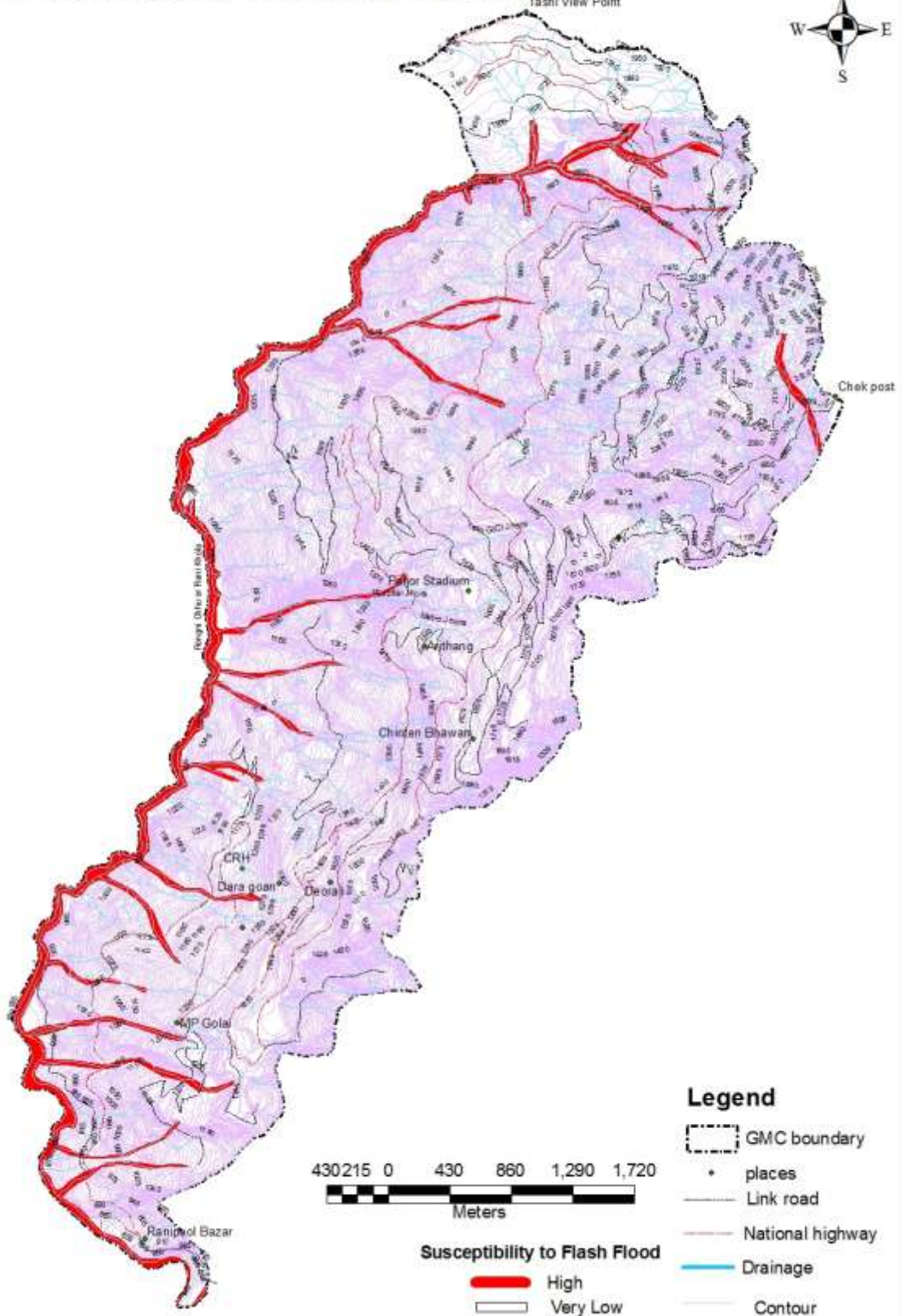
# SLOPE MORPHOMETRY MAP OF MUNICIPAL CORPORATION GANGTOK

Tashi View Point

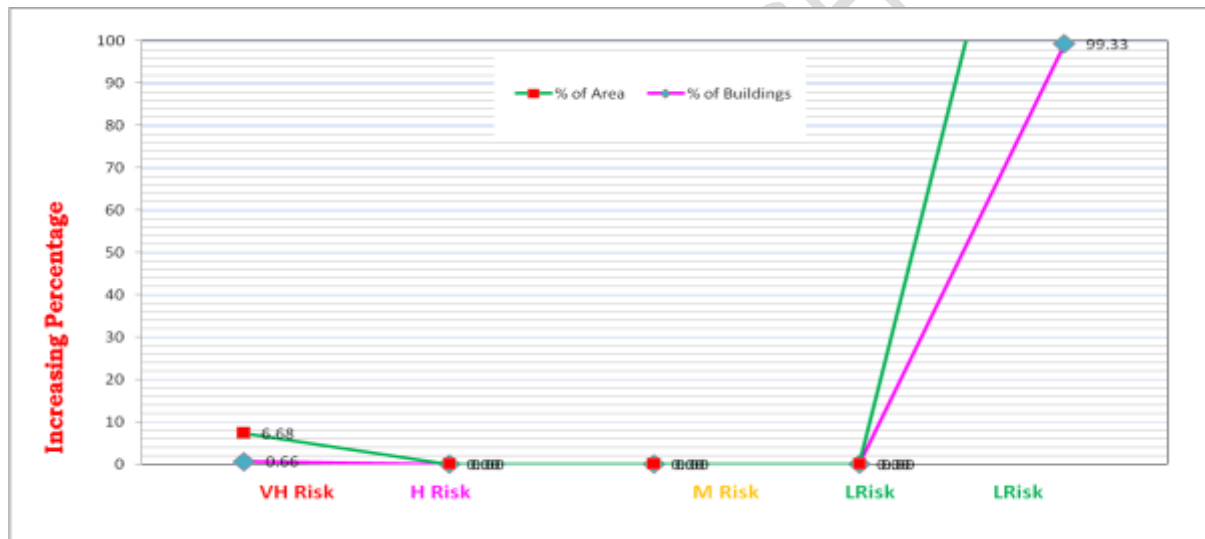


# SUSCEPTIBILITY TO FLASH FLOOD HAZARDS MAP OF MUNICIPAL CORPORATION GANGTOK

Tashi View Point



Flash flood Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazar	6.68	0.66	Very High
Medium High Hazards	0.00	0.00	High
Medium Hazards	0.00	0.00	Medium
Medium Low Hazards	0.00	0.00	Low
Low Hazards	93.32	99.33	Low



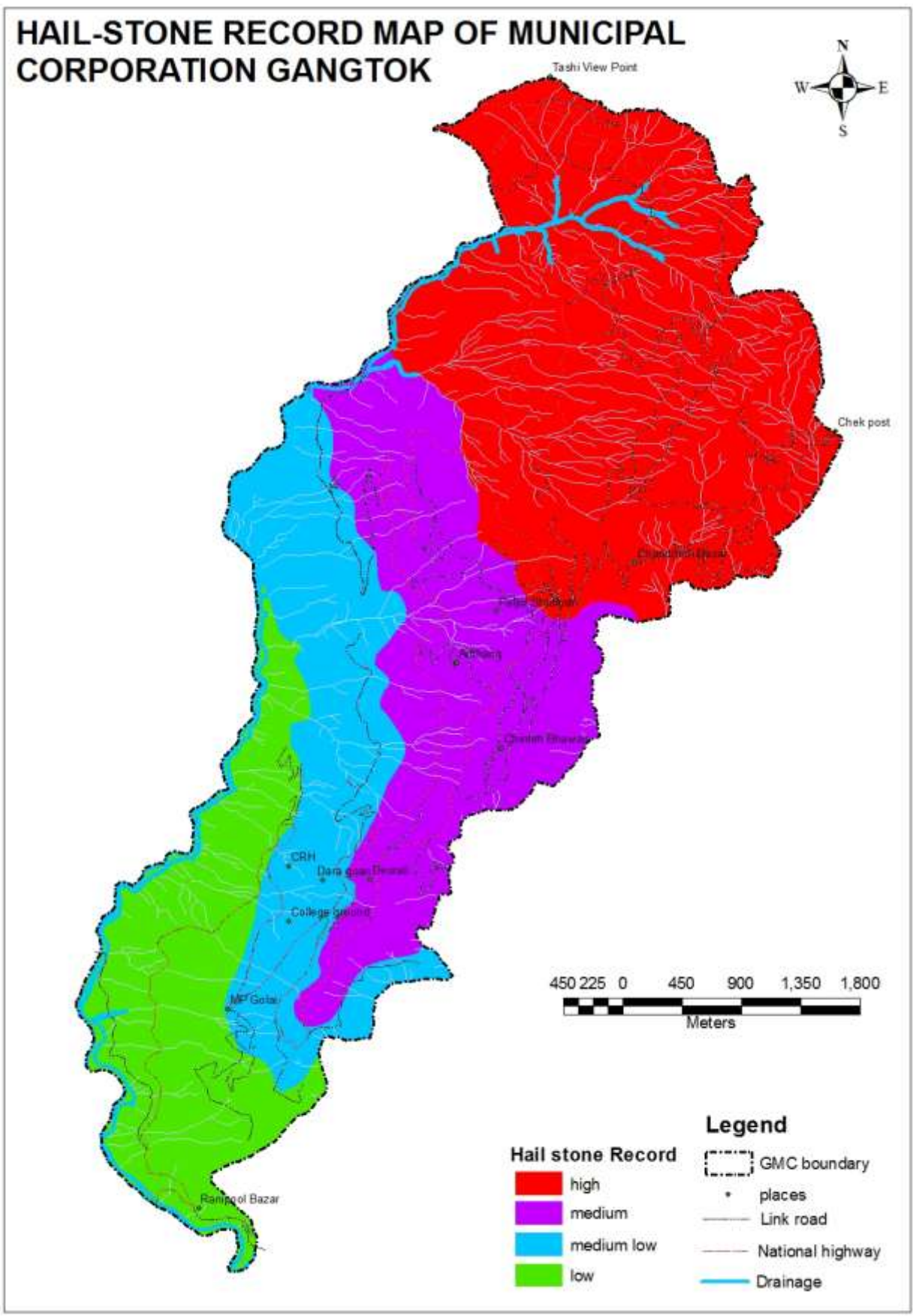
### Conclusion:

After extensive study and research of various maps and data, develop Flashflood Hazard Risk and Vulnerability Map for the GMC. The study leads us to the following conclusions:

- 6.68% of the area fell in very high risk zone with .66% of the total settlement to be affected
- 93.32% of the area fell in very low risk zone with 99.93% of the total settlement to be affected

**HAIL-STONE HAZARD RISK VULNERABILITY  
ASSESSMENT OF GANGTOK**

# HAIL-STONE RECORD MAP OF MUNICIPAL CORPORATION GANGTOK



***MULTI-HAZARDS RISK VULNERABILITY  
ASSESSMENT OF GANGTOK MUNICIPAL  
CORPORATION***

**Multi-hazards:**

Taking into account the different Hazards that may affect the region of Gangtok Municipal Corporation, developed a multi hazard map and a Risk Matrix Chart to assess the impact of each hazard in the respective GPU.

Risk Matrix Chart							
5	Frequency / Likelihood	EVERY YEAR				FIRE	LAND SLIDE
4		2-10 YRS		DROUGHT T*			
3		11-20 YRS				RIOTS	EARTHQUAKE
2		21-30 YRS				FLASHFLOOD	
1		31-50 YRS	HILLSTORMS, SNOW AND AVALANCHES				
Score Of likelihood		Score of Impact	1 TO 7	8 TO 14	15 TO 21	22-28	29-35
Severity/ magnitude of damage							

RELATIVELY INCREASING RISK

LOW	MEDIUM LOW	MEDIUM	HIGH	VERY HIGH

## **Methodology**

In this analysis extensive background check was done with extensive historical research, as well as observational data. Different kinds of maps were created so as to assess the risk and vulnerability of the region. This information was then considered in the context of the seven impact criteria, which are outlined in Table 1 below. The impact criteria were individually ranked on an ascending scale from one to five, one being the least severe and five being the most severe. The sum of these scores was taken to create an overall consequence score, the score was then contrasted against a likelihood rating of one to six, one being the least likely and six being most likely. Details regarding the measure of likelihood are seen in Table 2. The aggregate score of each hazard, combined with the hazard impact consequence and likelihood provide the basis for a risk ranking of **low**, **medium low**, **medium**, **medium high** and **very high**.

<b>Categories of Impact</b>	<b>Score</b>	
Fatality	1 TO 5	
Injury	1 TO 5	
Critical Facilities (Hospitals, Fire/Police Services etc.)	1 TO 5	
Lifelines (Water, Gas, Power, etc.)	1 TO 5	
Property Damage	1 TO 5	
Environmental Impact	1 TO 5	
Economic and Social Impact	1 TO 5	

<b>Table 2 - Measure of Likelihood</b>		
<b>Measure of Likelihood</b>	<b>Return Period (yrs)</b>	<b>Score</b>
Frequent or Very Likely Every	EVERY YEAR	5
Moderate or Likely Every	2-10 YRS	4
Occasional, Slight Chance Every	11-20 YRS	3
Unlikely, Improbable Every	21-30 YRS	2
Highly Unlikely, Rare Event Every	31-50 YRS	1

**Table 3 – HRVA Risk Rating Interpretation**

***RISK RATING INTERPRETATION***

These risks are **low**. Implementation of mitigation measures will enhance emergency preparedness, but it is of less urgency and highly unlikely to occur in that area than the following hazards.

These risks are **medium low**. Implementation of mitigation measures will enhance emergency preparedness, Hazards is highly unlikely to occur in that area, but is of more urgency than *low*

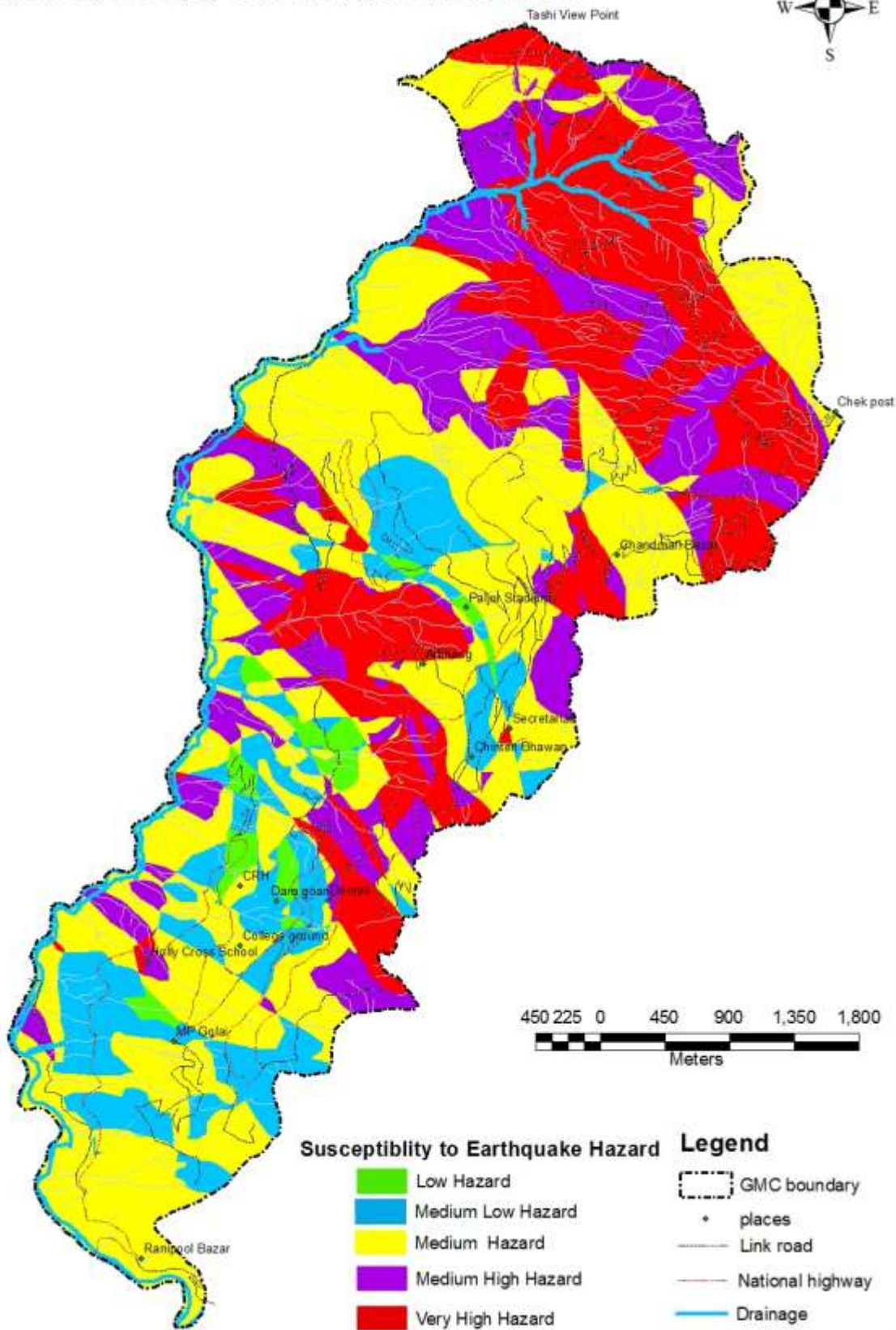
These risks are **medium**. These hazards have intermediate levels of frequency and severity. Hazards classified as moderate are more urgent than medium low hazards and are often common place concerns. Given this, moderate level hazards should be addressed with an appropriate level of urgency.

These risks are **medium high**. These hazards warrant review and development of mitigation actions to reduce the risk to an acceptable level. But these hazards require immediate examination and mitigation measures to reduce the risk to an acceptable level.

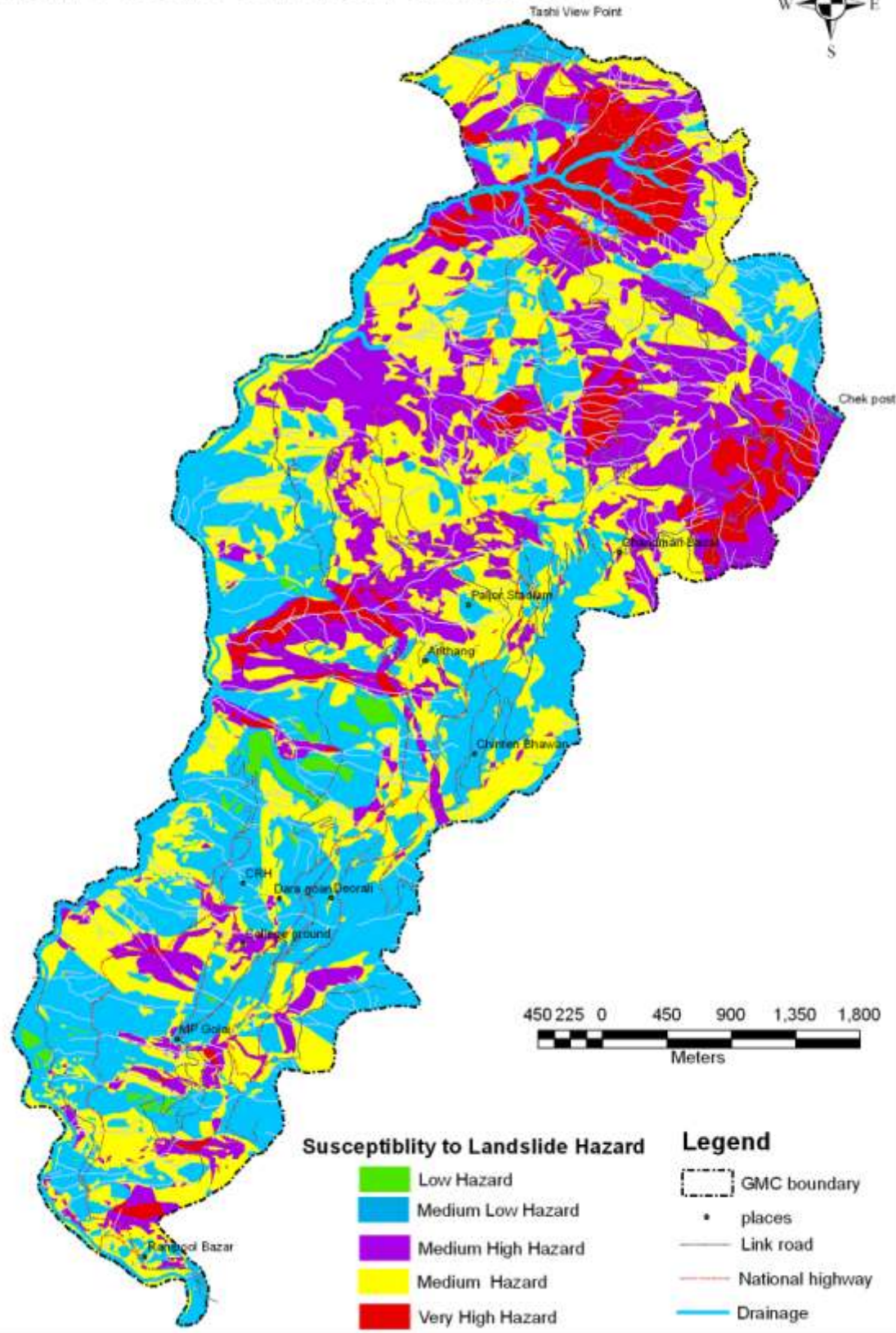
These risks are **very high**. These hazards are both frequent and are of high severity. These hazards require immediate examination and mitigation measures to reduce the risk to an acceptable level.

ARKANSAS STATE DISASTER MANAGEMENT AUTHORITY

# SUSCEPTIBILITY TO EARTHQUAKE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



# SUSCEPTIBILITY TO LANDSLIDE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



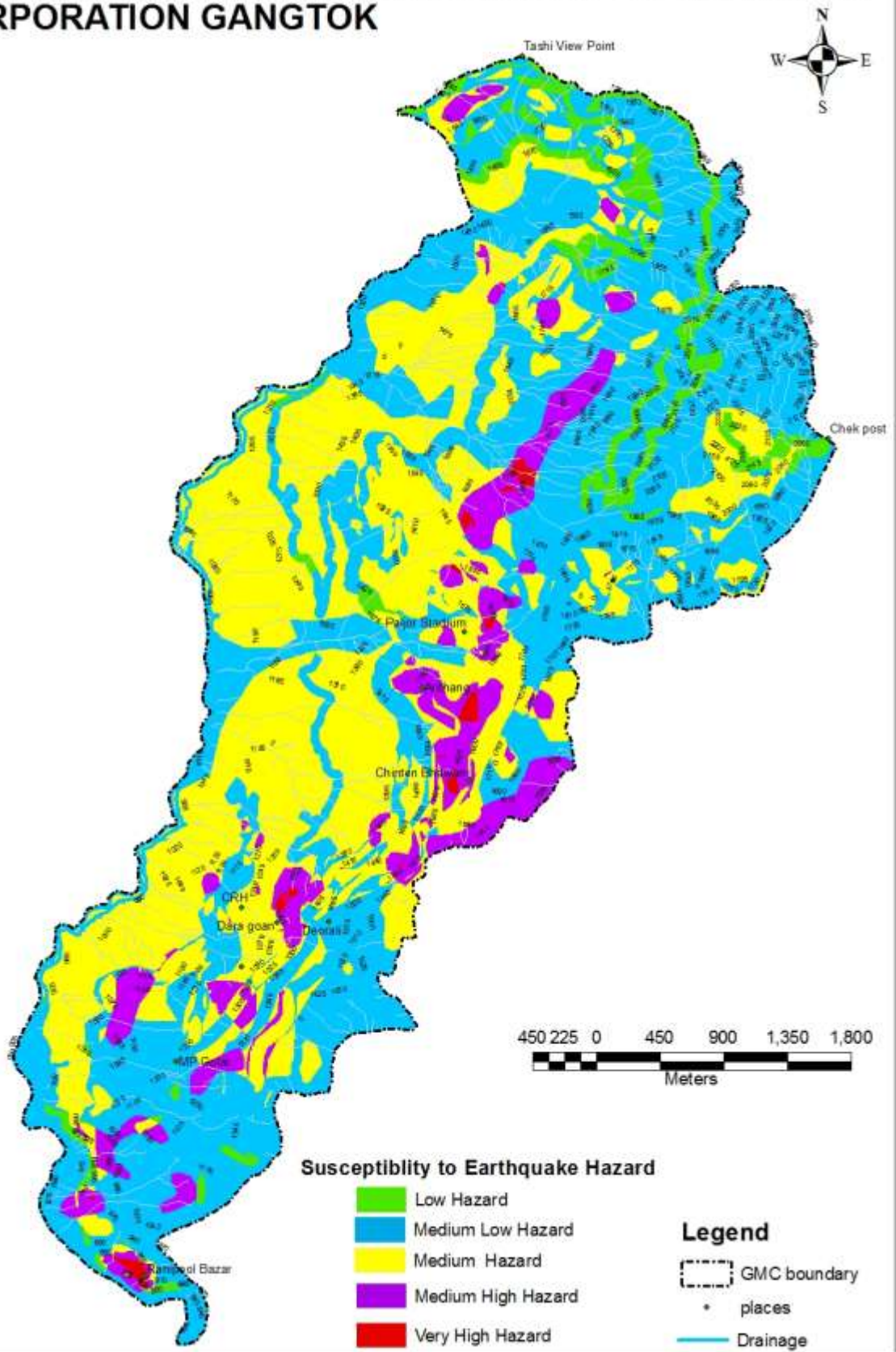
## Susceptibility to Landslide Hazard

- Low Hazard
- Medium Low Hazard
- Medium High Hazard
- Medium Hazard
- Very High Hazard

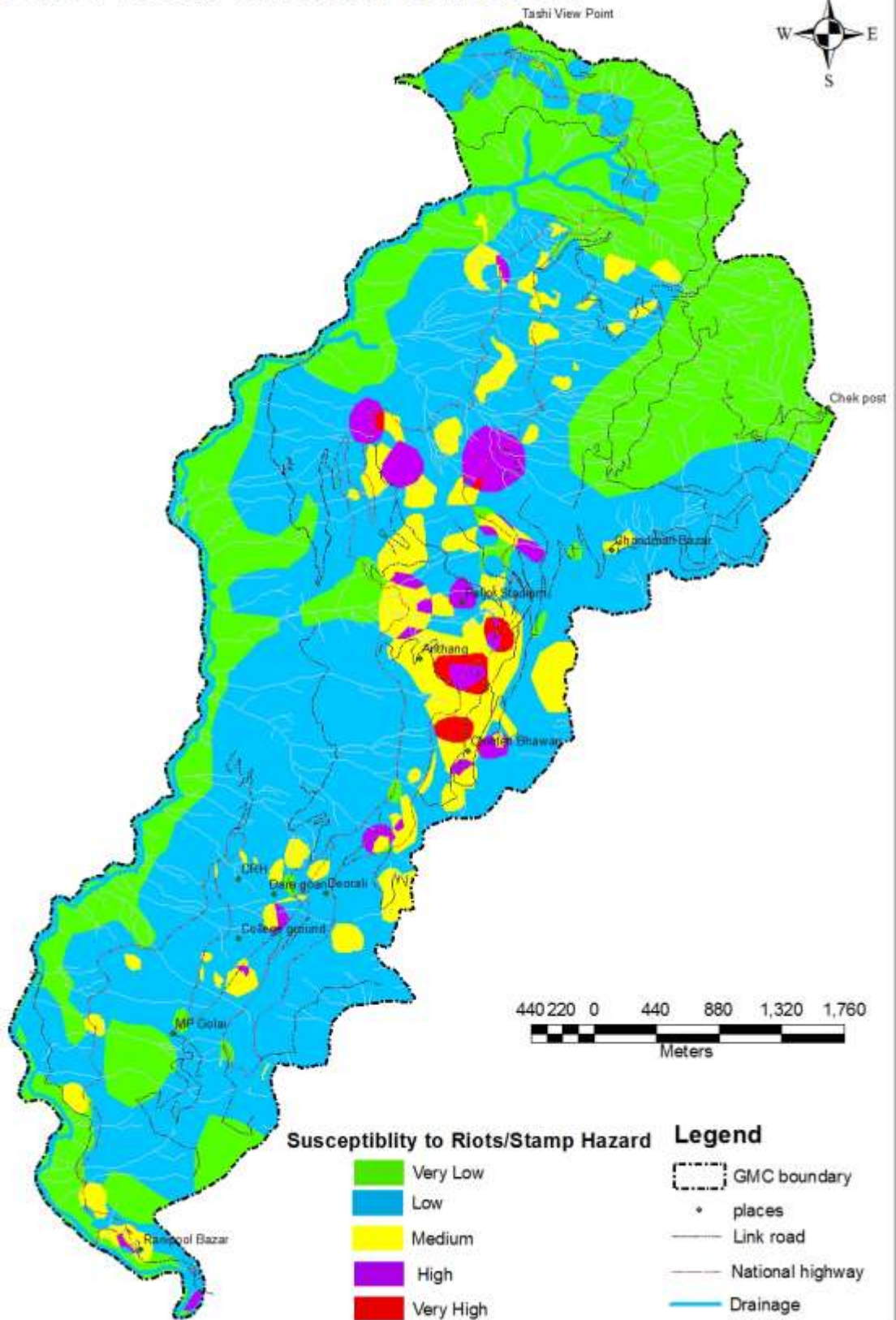
## Legend

- GMC boundary
- places
- Link road
- National highway
- Drainage

# SUSCEPTIBILITY TO FIRE HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



# SUSCEPTIBILITY TO RIOTS/STAMP HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK

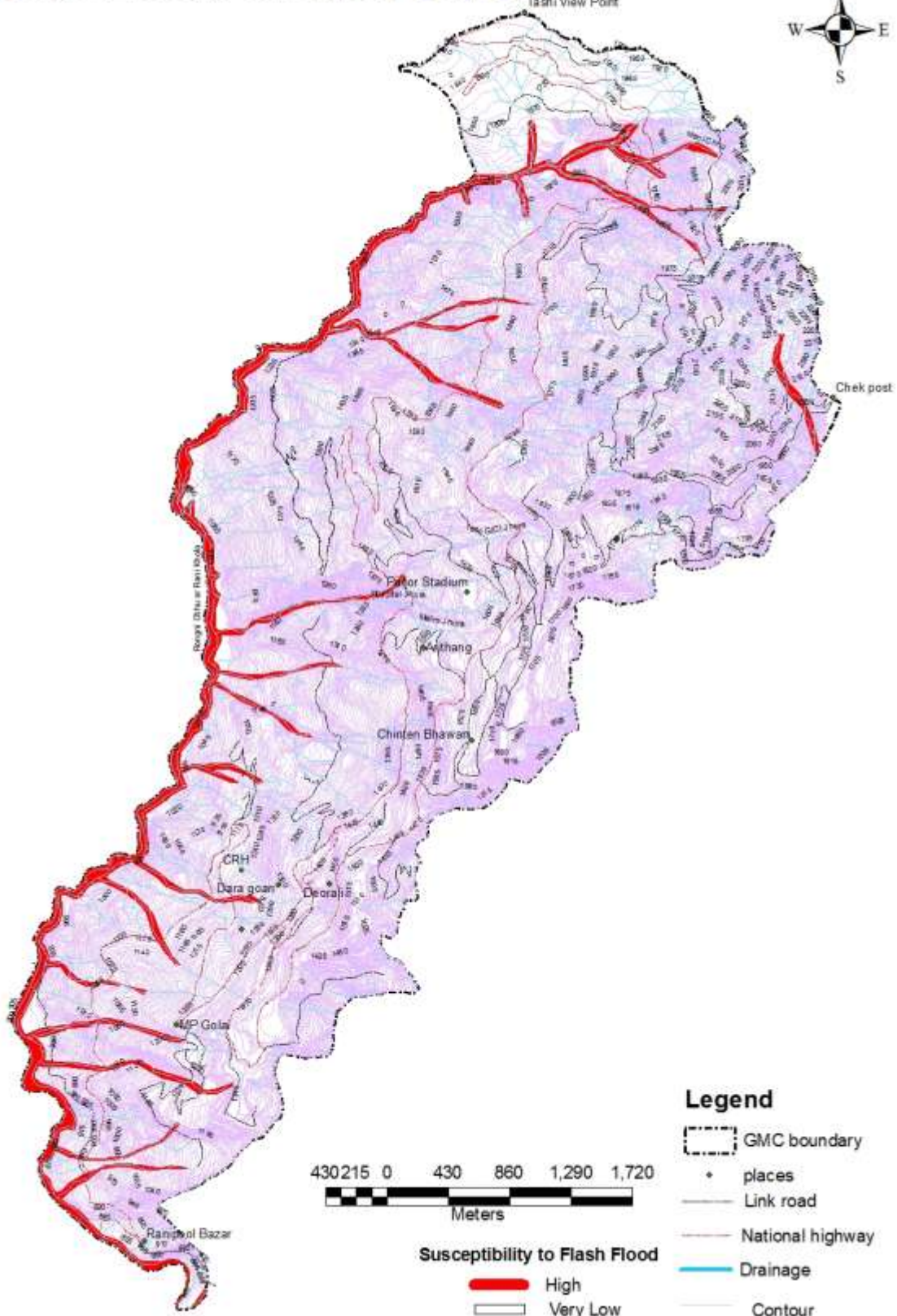


AKIM C

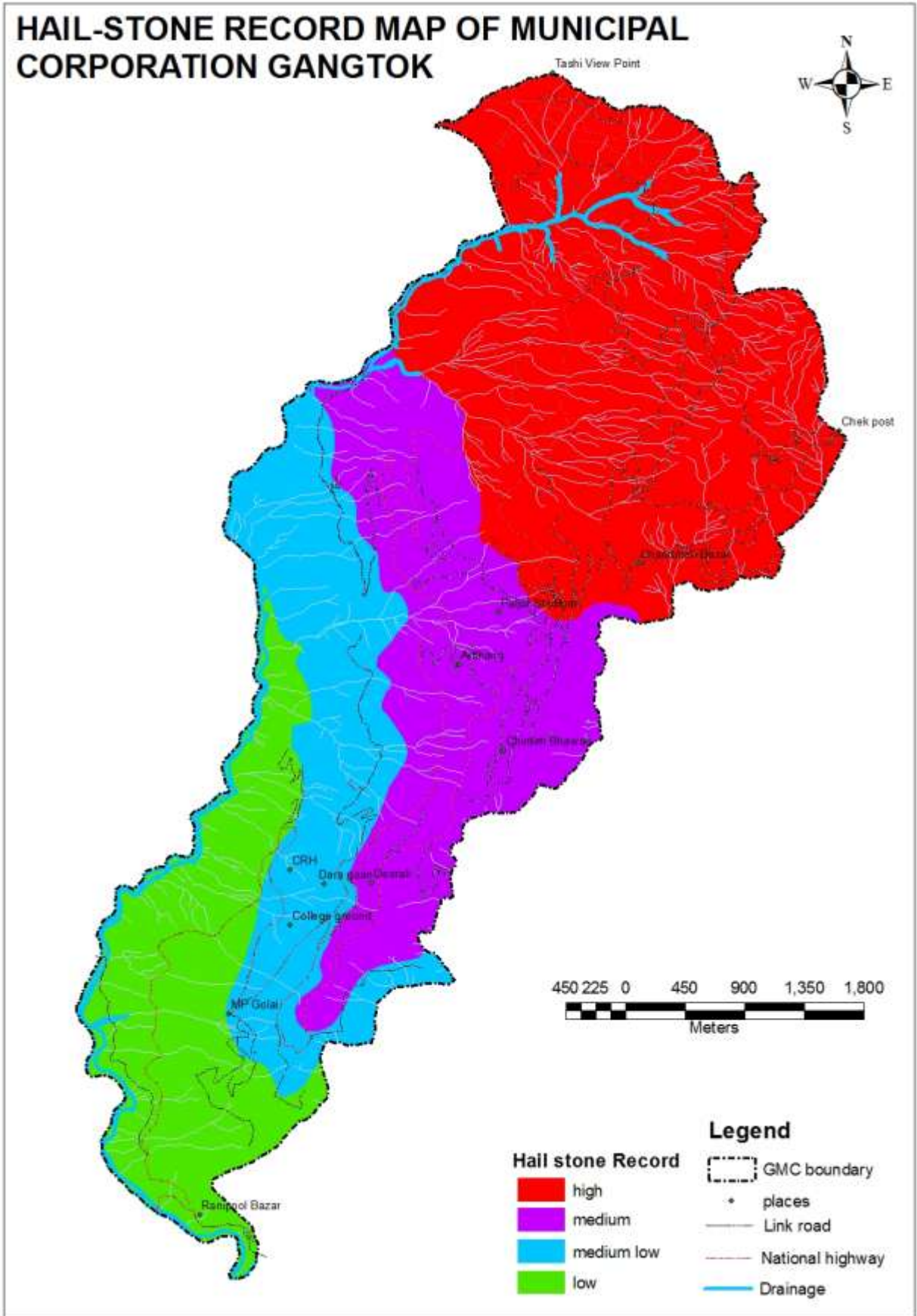
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# SUSCEPTIBILITY TO FLASH FLOOD HAZARDS MAP OF MUNICIPAL CORPORATION GANGTOK

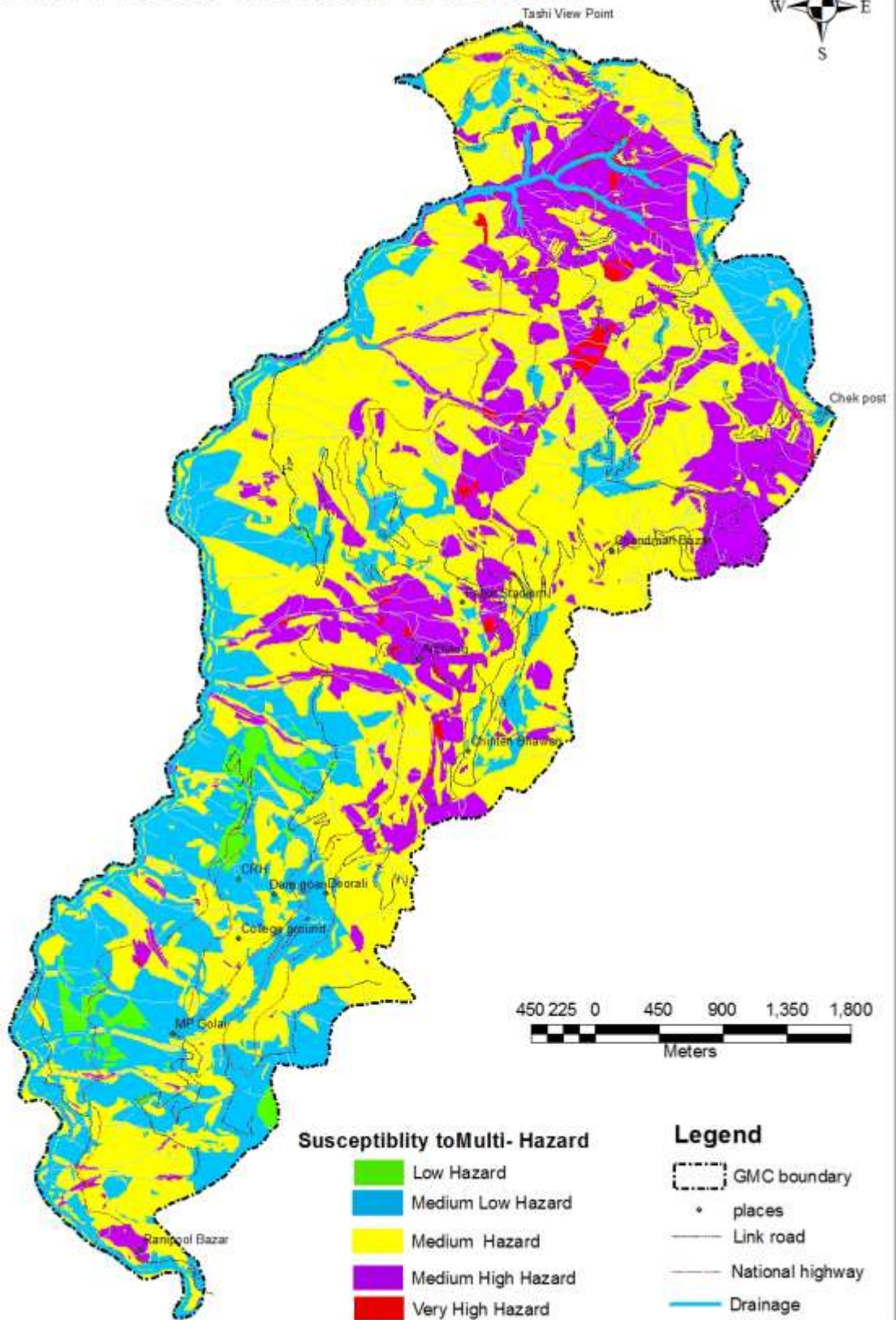
Tashi View Point



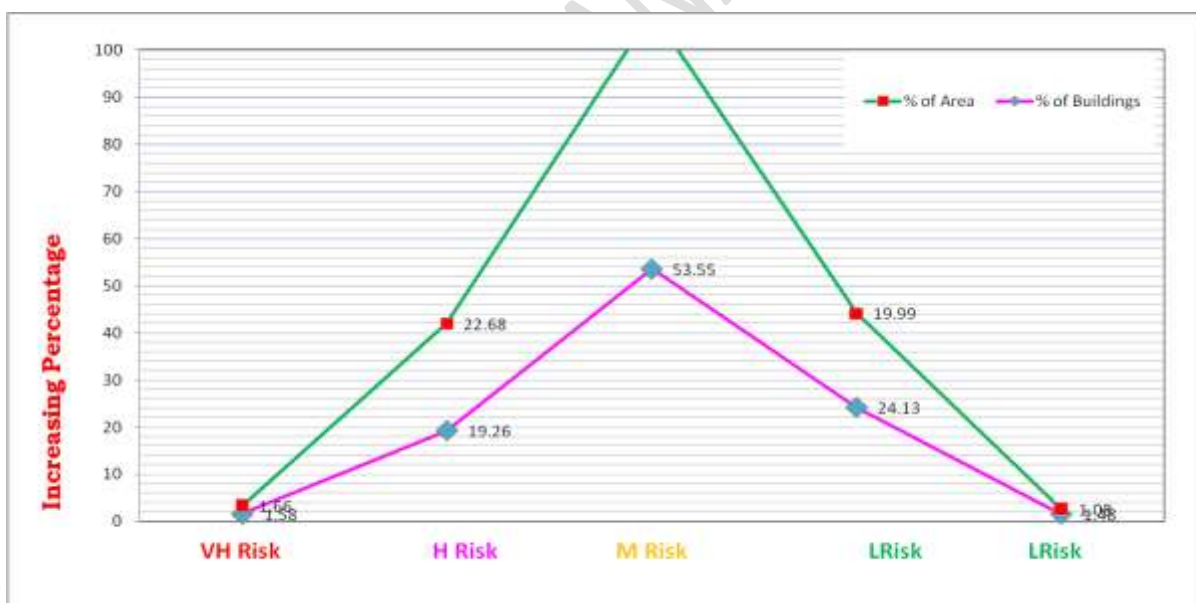
# HAIL-STONE RECORD MAP OF MUNICIPAL CORPORATION GANGTOK



# SUSCEPTIBILITY TO MULTI - HAZARD MAP OF MUNICIPAL CORPORATION GANGTOK



Multi- Hazards			
Hazards Category	% of Area	% of Buildings	Risk type
Very High Hazar	1.66	1.58	Very High
Medium High Hazards	22.68	19.26	High
Medium Hazards	54.57	53.55	Medium
Medium Low Hazards	19.99	24.13	Low
Low Hazards	1.08	1.48	Low



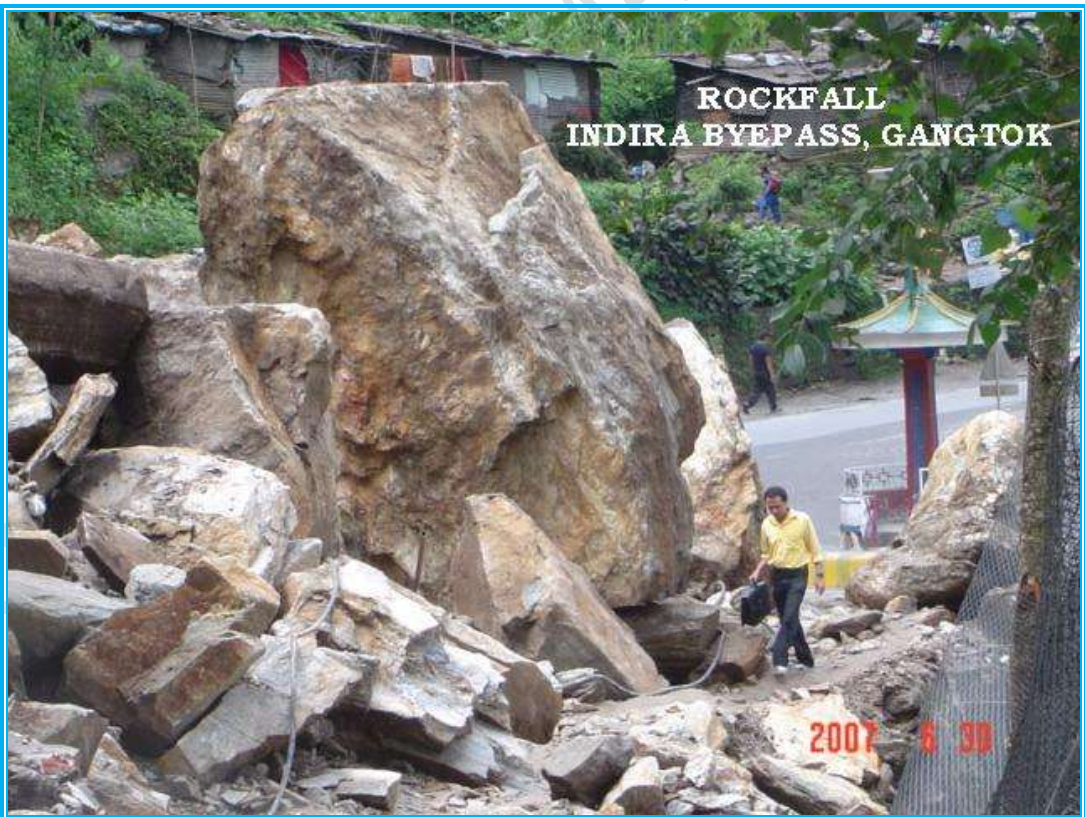
## **Conclusion and Recommendation**

Multi-Hazard Risk Vulnerability Assessment (MHRVA) Gangtok town have been layout in 1:25,000 scale (as base map of the area is prepared as 1:15,000 scale) in GIS platform. Various hazard components affecting the risk of the town were taken into consideration. For a particular hazard, various sub-components liable to increase the risk for the particular hazard were taken into consideration. This way the stake holders could understand the risk type creating the hazards which ultimately contribute to the vulnerability of the area and try to carryout mitigation programmes which can decrease the risk for the hazards types. Varieties of awareness campaign can be carryout, right from educating the masses upto hazard resilient construction of civil structures. For a developing town like Gangtok the MHRVA needs to be carried out in small scale i.e in micro level with scale of at least 1:5000 or in 1:2000.

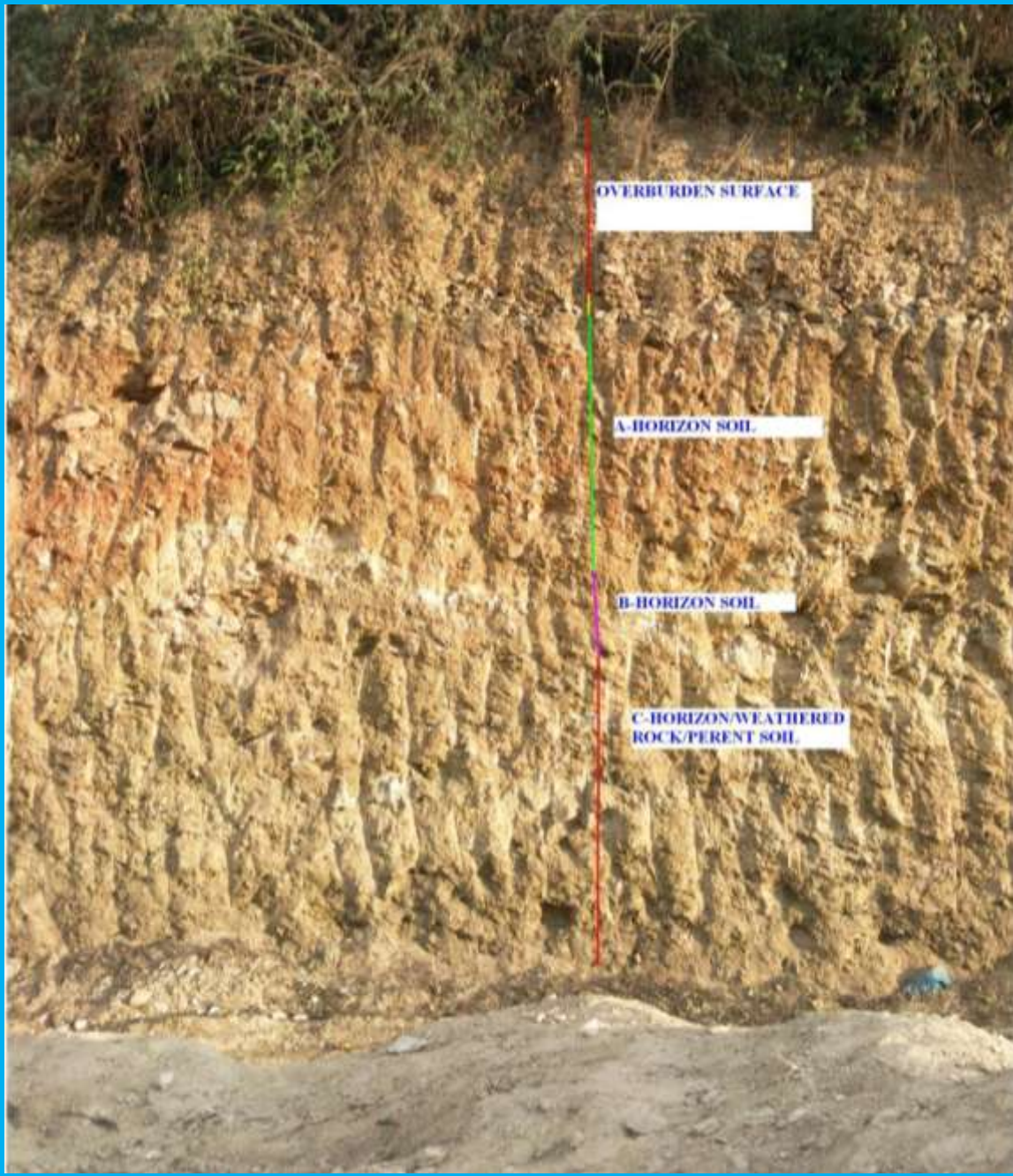
Moreover, even with the present scale lot of understanding of the hazard types and vulnerability of the town can be understood. A proper approach is therefore necessary for taking up mitigation programme with the understand as made by the preparation of this Multi-Hazard Risk Vulnerability Assessment (MHRVA) of Gangtok.



**ROCKFALL  
INDIRA BYEPASS, GANGTOK**



**ROCKFALL  
INDIRA BYEPASS, GANGTOK**



**Soil Profile at Gangtok (Picture & Classified by K K Luitel)**



**Slide at Gangtok during House Construction**



**Fig: Bagthang slide Gangtok, far view**



**Fig: Bagthang slide Gangtok, close view**



**Fig: Building collapse at Lumsey, Gangtok, close view.**



**Fig: Building collapse at Gangtok due to September 18<sup>th</sup> Earthquake**



**Bending of column rod at Secretariat, Gangtok**



**Building collapse at Balwakhani, Gangtok**

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