Risk Sensitive Land Use Plan of Changunarayan Municipality

चाँगुनारायण नगरपालिकाको लागी जोखिम संवेदनशील भू-उपयोग योजना

December 2018

Prepared for

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This report entitled “Risk Sensitive Land Use Plan of Changunarayan Municipality” is an outcome of the study “Prepare Integrated Risk Sensitive Land Use Plan (RSLUP) and GIS based Evacuation Route Modelling for Changunarayan Municipality” undertaken for Changunarayan Municipality by DanChurchAid (DCA) and implementing partner Friends Service Council Nepal (FSCN) with technical support by GENESIS Consultancy (P) Ltd. The opinions, findings and conclusions expressed herein are those of the consultant/author(s) and do not reflect those of Changunarayan Municipality nor DCA or FSCN.

Data Sources and Credits

GIS datasets and their associated attributes used in the study are developed by GENESIS Consultancy (P) Ltd. for the study. Building footprints, road network and land use data were extracted from Pleiades 0.5m MSS satellite imagery dated 3 January 2018. Geological and geotechnical investigation was undertaken during October-November 2018, community level data were collected from ward level consultative meetings during November 2018 for the study. Sources of other data and maps are cited in the report.

Front Cover

Panoramic view of landscape in Sudal and Tathali area, Changunarayan Municipality photographed from Bojinee, Nagarkot on 13th December 2018. Photo by Anish Joshi

Abbreviations

BAU	Business-as-usual
BBL	Building Bye Law
BC	Building Code
CC	Climate Change
DCA	DanChurchAid
DEM	Digital Elevation Model
DMG	Department of Mines and Geology
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
FAR	Floor Area Ratio
FSCN	Friends Service Council Nepal
GIS	Geographical Information System
Ha	Hectare (1 Ha = 10,000 m^2)
IEC	Information, Education and Communication
INGO	International Non-Governmental Organization
km	kilometre (1km = 1,000 m)
LDRM	Local Disaster Risk Management
MBT	Main Boundary Thrust
MMI	Modified Mercalli Intensity
NSC	National Seismological Center
NSDRM	National Strategy for Disaster Risk Management
PDNA	Post Disaster Needs Assessment
PGA	Peak Ground Acceleration
pph	Population Per Hectare
R-A-P-D	Ropani-Aana-Paisa-Dam
RSLUP	Risk Sensitive Land Use Plan
HOS	Humanitarian Open Space

Contents

List of Tables

List of Figures

Annexes

1. BACKGROUND

1.1. Introduction

This assignment entitled "Risk Sensitive Land Use Plan of Changunarayan Municipality", was implemented through "PRAYAS- Promoting new Resilience Approaches in Younger and Smaller Municipalities" Project, in partnership between development partner DanChurchAid (DCA) with supporting NGO Friends Service Council Nepal (FSCN) and private sector urban planning consulting firm GENESIS. This unique partnership brings in international network of development partners through DCA, local network in the municipality and knowledge base through FSCN; and technical expertise in RSLUP through GENESIS.

This assignment aims to contribute by developing municipal Risk Sensitive Land Use Plan (RSLUP) and emergency evacuation route plan for improved disaster risk governance at the municipality level. This assignment will directly contribute to the Local Disaster and Climate Resilience Plan (LDCRP) and Municipal Emergency Preparedness and Response Plan (MEPRP) prepared for Changunaryan Municipality.

1.2. Rationale and Objectives of the Assignment

Bhaktapur district was one of the worst affected districts by the 25th April 2015 earthquake (M_w= 7.8) and its aftershock, notable the 12th May 2015 aftershock (M_w=6.9) epicentered in Sindhupalchowk district. Changunarayan Municipality, suffered greater damages with .

Development of RSLUP and building-bye laws will enable the municipality to sustainably and safely plan its growth as well as build resilience against disaster and climate change impacts. This will promote safe construction practices ensuring safe land tenure and overall development of the municipality through regulated land management and infrastructure development.

With this rationale, the overall objective of the assignment is to strengthen Changunarayan Municipality by developing Risk Sensitive Land Use Plan (RSLUP) and its implementation framework. The assignment also envisages to undertake comprehensive analysis of available potential humanitarian open space and evacuation route for emergency evacuation planning.

The objective of the assignment is to prepare "Integrated Risk Sensitive Land Use Plan (RSLUP) and GIS based Evacuation Route Modelling for Changunarayan Municipality". The specific objectives of the assignment are listed below

a. Develop municipal base line information along with current land use and future growth projection
b. Identify multi hazard risks and vulnerabilities in the municipality
c. Identification of potential open spaces
d. Preparation of ward level emergency evacuation route
e. Prepare risk sensitive land use plan and implementation framework for the municipality

1.3. Risk Sensitive Land Use Planning – Concept and Context

Risk Sensitive Land Use Planning (RSLUP) identifies the safest areas in order to prioritize immediate investments in urban development and infrastructure projects (Jha, Miner, and Stanton-Geddes 2013). In general, the process of mainstreaming disaster risk management parameters in land use planning is termed as Risk-sensitive Land Use Planning (World Bank and EMI 2014). Risk-sensitive Land Use Planning

a. Identifies and mitigate the disaster risks embedded in the current land use and development practices through building bye-laws and regulatory ordinances for use of land in hazard prone areas;
b. Reduces losses by facilitating faster responses by providing open spaces, well planned evacuation road networks for rescue operations;
c. Promotes controlled urban growth without generating new risks through rebuilding and upgrading infrastructure – "building back better" using hazard resistant construction

1.4. Risk Sensitive Land Use Planning – Framework

Risk sensitive adds two new considerations in the conventional land use planning approaches (World Bank and EMI 2014):

- Disaster Risk Reduction (DRR) goals and objectives are formulated and integrated in the conventional land use planning approaches based on the information related to hazard, vulnerability, risk and capacity parameters together with the disaster/emergency management requirements.

Figure 1 Framework and process of RSLUP [Adapted from (Bendimerad 2012)]

- Integration and mainstreaming in formal government activities by undertaking measures to ensure understanding, acceptance, ownership and support for the plan through improving competency and knowledge about the risk-sensitive land use planning among the policy makers, planners, development professionals and through raising awareness and fostering support of all the stakeholders.

These additional considerations require scientific and evidence based assessment of hazards, vulnerability and risk along with coping and adaptive capacities of the communities including the governance system; review of information, aspirations, perceptions of the targeted communities and stakeholders; assessment of the legislative framework and institutional capacities of the government and implementing authority and supporting agencies; assessment of non-government organizations and private sectors to support implementation of the tools and business models of the plan for successful and sustainable implementation

1.5. Risk Sensitive Land Use Plan Approach

RSLUP development evolves from generation of relevant baseline information; multi-hazard, vulnerability and capacity assessment; adaptation of best practices, participatory planning and mainstreaming into development activities.

- Development of information and knowledge base needed for evidence-based decision support in planning
- Participation of stakeholders and concerned in collaborative decision making
- Development of RSLUP and its implementing tools and bye-laws
- Development of stakeholder's engagement plan and information, education, communication action plan for implementation of municipal RSLUP

This approach for Risk Sensitive Land Use Planning is relatively new in the context of DRR and urban planning in Nepal. *Per se,* integration of DRR parameters into urban planning to "Make cities and human settlements inclusive, safe, resilient and sustainable (SDG 11)" is a noble concept where Land Use Planning, DRR context and Urban Development are integrated for addressing SDG challenges (economic, social, environmental goals).

1.6. Risk Sensitive Land Use Planning in Changu Narayan Municipality

RSLUP in Changunarayan Municipality is being prepared following the aforementioned framework and development process. Further, with the involvement of Kathmandu Valley Development Authority (KVDA) in developing a "New Town" in the municipal and surrounding region, strong collaboration and sharing of information with the KVDA is done to compliment and support both the initiatives.

The development process of RSLUP in Changunarayan has engaged elected leadership and representatives from the onset of the undertaking, starting with a sensitization workshop at the municipal office. Several consultation meetings and participatory planning works have been organized at the municipal office and ward offices with very strong participation of the leadership and ward representatives in defining the vision, mission and goals as well as in the planning processes. The use of spatial information on hazards and vulnerability and integration of spatial planning with participatory planning using spatial analysis approaches is a paradigm shift from the conventional urban planning process in Nepalese context.

RSLUP provides a guidance to other plans and policy instruments by recommending "safe place" for investments in infrastructure, economic activities, conservation and protection and urban development. RSLUP also provides base for DRR/DRM plans by recommending safer use of land for various DRR/DRM related activities.

At the municipal level, RSLUP recommendations are translated into legal documents such as Building Bye-Laws and other municipal ordinances for implementation. Integrated Development Plan (IUDP) which incorporates infrastructure, economic, social development and environment protection should be prepared on the foundation of RSLUP recommendations on safe and sustainable use of land resources. The activities and programs recommended by the RSLUP should be mainstreamed into the annual municipal activities and budgetary plans. Therefore, RSLUP must not be considered as an independent or a separate plan for urban development, rather it is a foundation plan for any other development related policies and plans.

Evidently, Changunarayan RSLUP will direct the future urban spatial form and growth vision of the municipal region. The Changunarayan RSLUP can be considered as a model plan for replicating to New Town development in the Kathmandu Valley and elsewhere in the country.

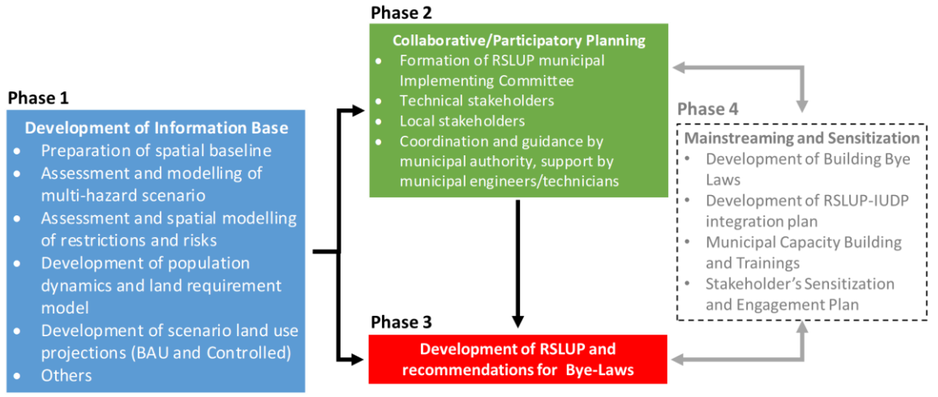


Figure 2 RSLUP development process

1.7. Risk Sensitive Land Use Plan – Way Forward

RSLUP is an initiation of broader planning scenario and envisioning of the future urban form to provide the basic right of any citizen i.e. safer place to live and prosper. RSLUP's recommendations and guidelines are implemented through a legal document "building bye-law" by the municipal authority. The building bye-law must be implementable, acceptable and inclusive to translate the future safer growth vision of the municipal region. RSLUP's recommendations and guidelines are implemented through various mechanisms and tools related to urban development, land management, financial incentivizing such as land readjustment (land pooling), transfer of development rights, infill development, building pooling etc. The most appropriate mechanism with legal basis needs to be piloted with stakeholders/citizen's participation, financial investments and upscaled considering future sustainability. At the same time, institutional capacity building of the municipal authority is required to implement the RSLUP and its implementing tools efficiently and effectively.

2. MUNICIPALITY DEVELOPMENT PROFILE

2.1. Built Resources

2.1.1. Existing Infrastructure and Services

Road Network

Changunarayan Municipality has altogether 455.86 km of road out of which 48.63 km is blacktopped, 86.92 km is earthen, 47.59 km is gravelled and remaining portion either earthen or paved with other materials such as RCC slab, stone, brick etc. District road only covers 6.51% (29.67 km) of total road length which has been paved or gravelled. The major Strategic Road Network (SRN) connecting main parts of the municipality are Sallaghari-Duwakot-Changunarayan road section, Bhaktapur-Kamalbinayak-Nagarkot road section and Bhaktapur-Kharipati-Nagarkot road section that has been categorized as Strategic road (SRN) and it covers 7.05% of total length with 32.16 km. Main Collector road covers 51.31 km and Main Tole road covers 34.95 km which accounts 11.25% and 7.67% respectively. The municipality has 67.87 km of Other Collector road and 239.91 km of Other Tole Road categories.

Table 1 Road network in Changunarayan Municipality

Wards	District Road	Main Collector	Other Collector	Main Tole Road	Other Tole Road	Grand Total
1	1.06	6.38	3.23	0.45	24.61	35.73
2	2.91	4.60	8.21	2.20	44.02	61.94
3	1.53	5.18	10.40	2.29	11.28	30.69
4	5.81	9.22	7.78	2.97	25.90	51.68
5	9.35	6.57	16.90	6.37	35.87	75.06
6	12.17	7.93	3.40	1.92	12.84	38.26
7	3.06	3.69	7.84	4.12	14.47	33.18
8	14.07	4.58	1.03	7.54	30.32	57.54
9	11.85	3.15	9.08	7.10	40.61	71.79
Total	61.82	**51.31**	**67.87**	**34.95**	**239.91**	**455.86**

Source: Extracted from Pleaides satellite imagery of January 2018 and MTMP of Changunarayan Municipality

Solid Waste Management

The municipality is coordinating with "Nepal Swakchya Batabaran Srijana Kendra" in Kirtipur to manage its HH solid waste. According to Total Sanitation Strategic Plan 2018 prepared by Changunarayan Municipality, around 15% of the total HH living in municipality have membership for their solid waste collection while 85% HH have no membership. The HH without membership either disposed the waste by burning or illegally dump in common area like-riverbank, public land and vacant land. Table 2 presents the ward wise distribution of household with or without membership for the solid waste management. Similarly, around 60.74% of household in the municipality have the practice of solid waste segregation while 39.26% have no practice of segregation.

Table 2 Access to Membership of HH for Solid Waste Management

Ward	1	2	3	4	5	6	7	8	9	Total	%
Household having Membership	533	687	134	107	81	19	43	56	74	1734	14.91
Household remaining to get Membership	705	571	1035	1175	1348	885	1183	1635	1653	10190	87.64
Total Household	1238	1258	1169	1285	1429	904	1226	1691	1427	11627	100
%	10.65	10.82	10.05	11.05	12.29	7.78	10.54	14.54	12.27	100	

Source: Changunarayan Municipality Survey, 2074

Table 3 Segregation of solid waste

Ward	1	2	3	4	5	6	7	8	9	Total	%
Yes	840	917	740	741	792	577	732	1079	648	7066	60.74
No	396	319	419	544	687	326	488	611	778	4568	39.26
Total	1236	1236	1159	1285	1479	903	1220	1690	1426	11634	100
%	10.62	10.62	9.96	11.05	12.71	7.76	10.49	14.53	12.26	100	

Source: Changunarayan Municipality Survey, 2074

Source of Drinking Water

The primary source of water for households in the Municipality is public water source (42.06%) and private water source (36.89%). Other source of drinking water in the Municipality is Well and Stone Spout water. Most of the commercial water companies are distributing drinking water in major core areas around Bhaktapur district by deep bores.

Table 4 Drinking water sources

Sources	1	2	3	4	5	6	7	8	9	Total	%
Private Water	592	588	526	273	285	334	689	824	188	4299	36.89
Public water	328	353	260	510	1118	501	449	783	604	4906	42.09
Spring / Stone Spout	29	76	44	361	42	47	17	32	35	683	5.86
Well	270	220	286	125	28	21	26	44	435	1455	12.48
Other source	17	20	43	16	6	0	39	7	164	312	2.68
Total	1236	1257	1159	1285	1479	903	1220	1690	1426	11655	100
%	10.60	10.79	9.94	11.03	12.69	7.75	10.47	14.50	12.24	100	

Source: Changunarayan Municipality Survey, 2074

Sewerage and Night Soil Disposal

Around 86.6% of total households have their toilet connected to septic tank, 9.7% have Pit Latrine, 1.1% have connected the toilet into streams, 0.5% have connected the septic tank into Bio-gas plant and remaining 2.12% have other type of disposal method.

Table 5 Present status of sewerage and night soil disposal

Ward	1	2	3	4	5	6	7	8	9	Total	%
Drainage	9	1	2	17	55	26	7	7	3	127	1.08
Pit latrine	29	44	53	160	210	116	200	78	251	1141	9.71
Septic tank connected to Biogas	0	1	6	3	8	1	13	22	3	57	0.49
Septic tank	1199	1209	1097	1039	1174	775	982	1556	1139	10170	86.59
Other	1	4	9	74	42	3	40	38	39	250	2.13
Total	1238	1259	1167	1293	1489	921	1242	1701	1435	11745	100
%	10.54	10.72	9.94	11.01	12.68	7.84	10.57	14.48	12.22	100	

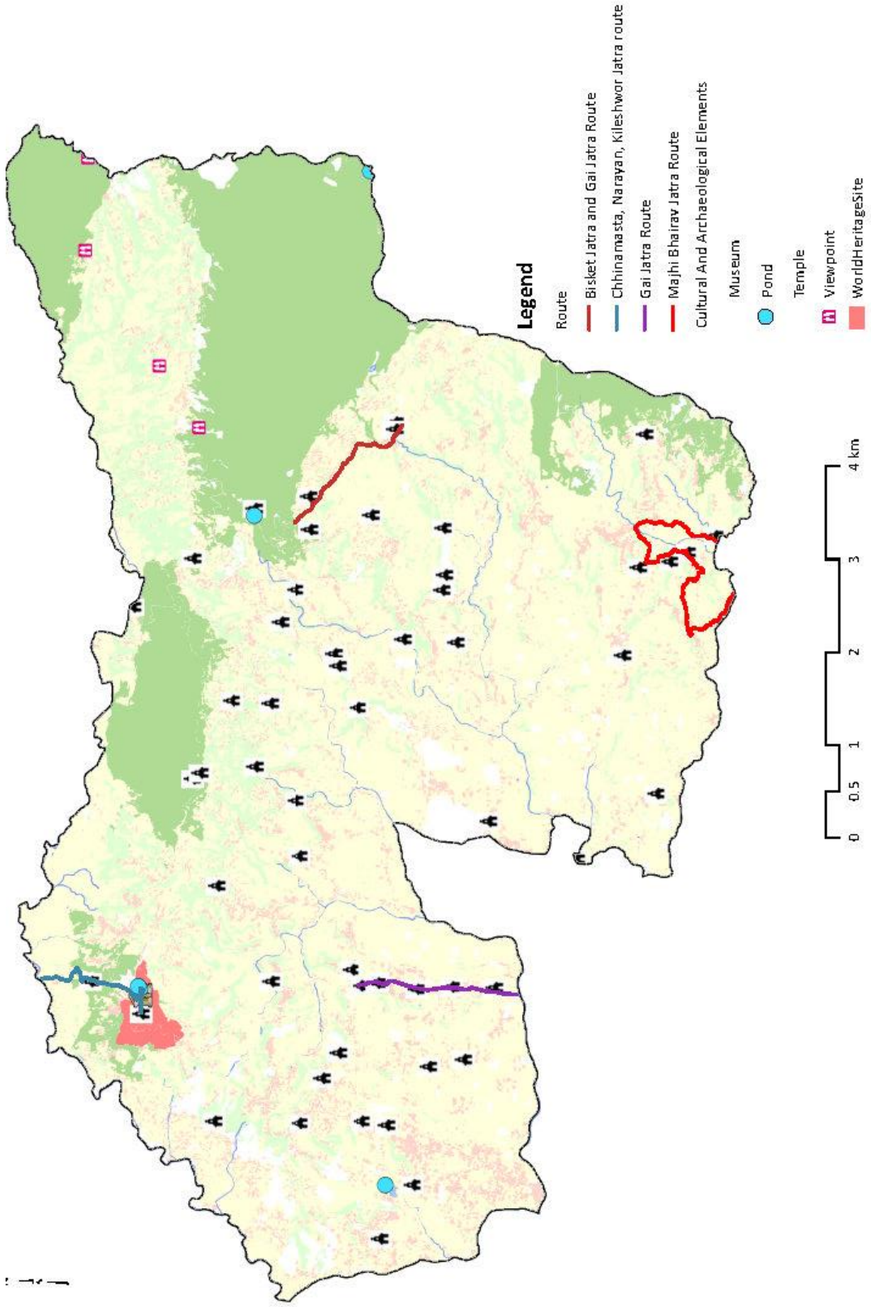
Source: Changunarayan Municipality Survey, 2074

2.1.2. *Cultural and Archaeological Heritage*

The Municipality comprised of one of the oldest temple in Kathmandu valley which is dated back to around 5th Century. The temple has great significance due to its architectural style, composition and ambience around the complex. It is one of the seven structures cited by UNESCO as World Heritage Sites in Valley. Apart from this Temple it has Mahamanjushree Temple in ward 8, Jyotirlingeshwor temple in ward 3, Mahadev Pokhari in ward 6 and Yatu Mahadev Temple in ward ward 7 that appeared as popular pilgrimage sites in Kathamndu valley. Every year a huge number of devotees around valley visit these holy sites to offer homage. The municipality is full of shrines, rest house, stone spout and religious ponds covering approx. 1.5 hectare of the total area.

Beside tangible heritage the municipality is also rich in intangible heritage. According to the local representatives, there exist four Jatra routes in the municipality where the chariot of deity is carried throughout the local settlements during festival. The traditional settlements of different ethnic groups have their own traditions and religion and celebrate festivals with their intrinsic style. Some of the festivals observed in the municipality are Dahsain, Tihar, Gai Jatra, Maghe Sankranti, Janai Purnima, Rishi Panchami and Shivaratri

Figure 2 Culturally and religiously significant places in Changu Municipality a) Changunarayan Temple, b) Phaidhoka Ganesh Temple, c) Manjushree Temple, d) Brahmayani Temple and e) Mahadev Pokhari



2.1.3. *Market Centre*

There are numerous local market centers in the municipality where major economic activities like business, banking, services and exchange of goods takes place. People from nearby settlement visit these markets for various commercial purposes. Local farmers transport their agricultural products to these market which is either locally consumed or exported to other nearby markets of neighboring Municipalities such as Kamalbinayak, Chyamasing, Sallaghari, Byasi and Sukuldhoka of Bhaktapur Municipality, Nagadesh, Bode, Gankhu, Thimi of Madhyapur Thimi Municipality, Sankhu of Sankharapur Municipality, Kalimati, Koteshwor, Naxal of Kathmandu Metropolitan city and Sanga, Nala, Banepa Bazaar of Banepa Municipality.

Table 6 Local Market Centers in Municipality

Wards	Market Center
1	Buspark area, Changu School Area, Mahankal Area, Saraswoti Temple Area, NEC College Area and Health post area
2	Duwakot chowk, KMC chowk, Phiadhoka area
3	Neupane chowk, Gelal gaun chowk, Thapa Gaun
4	Changu area and Pauwa
5	Kharipati-Nagarkot road section
6	Kharipati, Telcot and Nagarkot
7	Nayabasti, Bansbari, Kharipati, Bageshwori Health post area, Muhanpokhari-Bageshwori- Sudal road corridor
8	Jitpur, Sudal, Saraswotisthan, Chareli, Kalamasi and Ratopati area
9	Phaidhoka, Tathali

Source: Ward Consultation Meetings

Figure 3 Nagarkot Bazaar area (Left) and Changu Bazaar Area (Right)

2.1.4. *Land Market*

In Nepal, the parcel rate is generally fixed by the land revenue office based on the type of roads i.e. metalled, gravel or earthen and the location of such roads. The valuation is basically used for the taxation during land transfer. The government rates though do not reflect the market value, provide a fair approximation on the trend of increase of land value. In the past one year, the land value has increased as high as 2 to 3 times within the municipal region . Such high increment has been observed mainly in Duwakot and Jhaukhel VDCs (currently wards 1, 2 and 3 of Changunarayan Municipality).

The land prices of other wards have also high value. The most expensive land, as valued by the government, is the parcels adjoining to Bhaktapur-Kathmandu old route which is about Rs. 10.5 lakh per Anna. Similarly, most of the land parcels in land pooling area and plotting area are also equally expensive with land prices 15-25 lakhs per Aana.

2.2. Natural Resources

2.2.1. *Forests*

Around 20.5 percent (1287.01 ha) of the total area is covered by forest. Forest area is prevalent in northern parts of the municipality, in wards 4, 5, 6 and 7. Khari, Thulo phalant, Dudhilo, Musure katus, Chilaune, Uttis, Kattus, Kaffal, Salla are the major species present in the area. The forest is well preserved in and around Changunarayan temple, Nagarkot and Bageshwori. The forest in Nagarkot and Bageshwori is the major source of water to many settlements. There are numerous community forests in the area. As per data provided by FECOFUN, there are around 20 community forests in the area.

2.2.2. *Water Bodies*

Around 0.37 percent of the total area is water bodies. The major rivers flowing in the municipality are Manohara, Hanumante and Khasangkhusung River. The areas near to the rivers are prone to flash flood in case of sudden incessant rainfall. In 2016 and 2018, the flash flood in Manohara and Hanumante River temporarily displaced many people of Bhaktapur.

Apart from rivers and streams, there are small ponds in the area. Most of the ponds are of culturally significance, while some are used for commercial fisheries.

2.2.3. *Agriculture Land*

Around 47.44 percent (2984.64 ha) of the total area is agriculture land. Rice is the major crop grown in the area. Vegetables such as potato, tomato, cauliflower, radish etc. are also grown in the area. People have also started using tunnel farming for growing different off-season vegetables.

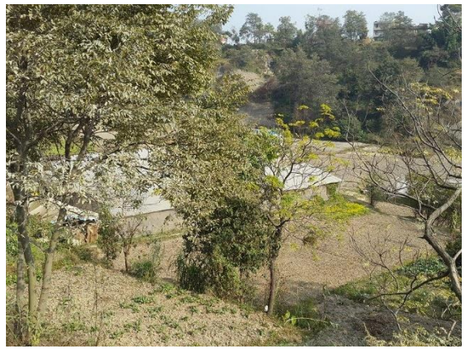


Figure 4 Agriculture and commercial tunnel farming in Changunarayan Municipality

2.3. Demographics

2.3.1. *Population Pattern*

Population and Household

According to the municipal profile, the present population of the Changunarayan Municipality is 54551 with 27342 male inhabitants, 27137 female inhabitants and 72 other inhabitants. It has altogether 11878 households distributing across nine wards as shown in the table below. The average household size of the municipality is 4.5 and average sex ratio is 95.31 based on CBS 2011

Table 7 Ward wise distribution of Population and Household

Ward	Male	Female	Other	Population 2018	Household 2018
1	3095	2995	11	6101	1244
2	3069	2937	14	6020	1229
3	2890	2807	5	5702	1211
4	2976	3048	0	6024	1286
5	3160	3229	9	6398	1464
6	1984	2040	0	4024	904
7	2871	2841	11	5723	1126
8	4189	4104	2	8295	1687
9	3108	3136	20	6264	1727
Total	**27342**	**27137**	**72**	**54551**	**11878**

Source: Changunarayan Municipality Survey, 2074

Population Composition

The municipality has diverse pattern of ethnicity and caste such as Brahman (20%), Chhetri (15%), Dalit (11%), Janajati (33%) and others (21%). Others includes various ethnic groups that comprises small proportions of the population such as, Gharti-Bhujel, Ghale, Damai, Badi, Majhi, Rai, Thakur, etc.

Differently Abled Population

About 1.5% of the total population of municipality have been reported to have some kind of disability. Below table shows the types of disability in the municipality with highest proportion of people with physical problem followed by mental and speech problem.

Table 8 Status of differently able population

Disability	Male	Female	Total	%
Physical disable	208	175	383	43.67
Visual defect	31	49	80	9.12
Hearing defect	46	36	82	9.35
Deaf and Blind	16	10	26	2.96
Dumb	60	48	108	12.31
Mental disable	94	43	137	15.62
Other disability	40	21	61	6.96
Total	495	382	877	100

Source: Changunarayan Municipality Survey, 2074

2.3.2. Income Source and income

Changunarayan Municipality is in the stage of Structural transformation due to increase in service sector and decrease in agricultural sectors. Non-agricultural sectors such as Tourism, Mining and Quarrying and Service sectors including retail trade, hotels and restaurants, real state and business services is gradually replacing agricultural sectors in most part of the municipality. While the rural parts of the municipality still prevail agriculture as primary source of income. According to the Municipality profile, the maximum monthly household income of the municipality is Rs. 10 lakh and maximum expense is Rs. 8 lakh while the minimum monthly income is found to be Rs. 200 and minimum expense as Rs. 500.

Table 9 Minimum and Maximum HH income

Level	Monthly Income (NRs)	Monthly Expense (NRs)
Minimum	200	500
Maximum	10,00,000	8,00,000

Source: Friends Service Council Nepal, Nagar Profile 2074

3. Municipality Hazard Profile

3.1. Geology of Changunarayan Municipality Region

Changunarayan Municipality consists of Kathmandu Valley sediments as well as bedrocks of different origin which are described as follows.

3.1.1. Kalimati Formation

It is predominantly made up of black clay or silt beds with some thin beds of fine to very fine sand and diatomite. The sediments were accumulated in the center of the lake, mainly from suspension and they represent the prodelta deposits interrupted by infrequent turbidity flows from an adjacent delta.

3.1.2. Gokarna Formation

It is a fluvio-lacustrine deposit that occupies the north part of the valley. It contains dark brown colored, laminated arkosic sand, silty clay and peat. There also occur some diatomite-bearing black silt and clay beds. It frequently contains fossil wood.

3.1.3. Kulekhani Formation

It consists of fine grained quartzites and schists in various proportions. It exhibits dark green-grey lustrous colors, which become subdued in more quartzitic bands. The beds are generally tens of centimetres thick but there are also varieties of thin beds as well as laminated sequences of schist and quartzites.

3.1.4. Markhu Formation

It is composed mainly of three rock types: schists, quartzites and carbonates, occurring in various proportions. About 50% of the total rock volume is represented by marble. The marble band range in thickness from a few centimetres to tens of meters. They are medium to coarse crystalline; some of them are pure marbles, displaying white and pink colors, whereas others contain much quartz and mica, including biotite.

3.1.5. Tistung Formation

It mainly comprises of slates, phyllites ad metasandstones. There is distinct decrease in metamorphic grade from bottom to top. The lower portion of the Tistung Formation consists of dark grey phyllites and fine biotite schists, but while moving stratigraphically upwards, biotite gradually disappears and sericite and chlorite remain as the constituent metamorphic minerals. Similarly, the dark green-grey colors, so characteristic of the schists and quartzites composing the underlying formations, give way in places to conspicuous pink, buff and purple tints.

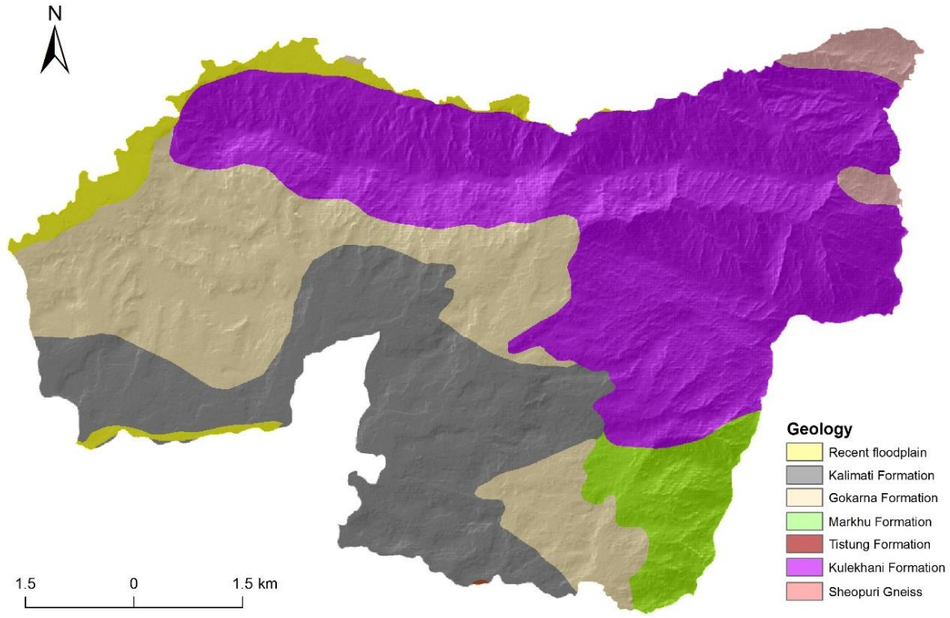


Figure 5 Geological Map of the Changunarayan Municipality

3.2. Seismotectonic of Nepal

The entire Himalayan range is dynamic zone of active deformation due to continuous moving of the Indian plate beneath the Eurasian plate. The collision of those two plates has started about 50 Ma (million years) ago and produced a giant mountain range with thickened crust and lateral tectonic setting (Molnar and Tapponnier 1975). Powell and Conaghan (1973) proposed an evolutionary model presenting two phases of orogeny in the formation of Himalaya (Powell and Conaghan 1973). At first, an active subduction zone presented along the present-day Indus-Tsangpo suture zone in Mesozoic - early Tertiary time. That phase ended in Eocene by collapsing the suture zone after collision of two plates occurred. The second phase is characterized by the formation of the intracontinental thrusts from Miocene to the present in the Indian plate where the Indian plate is underthursting the Eurasian plate since middle Tertiary to the present. At present, the Indian plate is converging to the Eurasian plate at the rate of 5 mm/yr (Patriat and Achache 1984). GPS measurements show that a part of this convergence (about 2 mm/yr) is still being absorbed by a horizontal shear and crustal shortening in the Himalaya (Bilham et al. 1997, Jouanne et al. 2004). The crustal shortening processes are still active in the Himalayan range that are exhibited by large earthquakes (Mw>8.0), e.g., the Nepal-Bihar Earthquake (1934), the Kangara Earthquake (1905), or the Pakistan Earthquake (2005). Apart from the convergence of Indian plate, the shortening of the Himalayan crust is being occurred due to

southward propagation of the thrusts. To the north of the Himalaya, entire Tibetan Plateau comprises extensional tectonics characterized by movement along E–W trending strike-slip faults and N–S trending normal faults associated with several grabens.

3.3. Seismicity

During the past few decades, the entire Himalayan range has been recognized as an active seismic zone that is supported by historical and recent earthquakes (e.g., Pakistan earthquake, 2005; Sikkim earthquake, 2011). The overall characterization of Himalayan range is solely based on the measured magnitudes of the earthquakes experienced in this belt. Historical catalogue of earthquake shows that most of the seismic events are located on the front part of the Higher Himalaya trending east to west. Likewise other region, the Nepal Himalaya is characterized by a very intense microseismic activity to keep it seismically active. In Nepal, a narrow belt of seismicity follows approximately the topographic front of the Higher Himalaya as a main feature of microseismicity in Nepal Himalaya, which was recognized in Central Nepal from the analysis of the 1985-1995 earthquake data recorded around the Kathmandu (Pandey et al. 1995).

In case of Siwalik, there are very few earthquakes recorded throughout the Himalaya. The Udayapur earthquake in 1988 (Magnitude 6.5) is the most noticeable earthquake observed in this range that occurred in the depth of 50 km beneath the Siwalik. It has no equivalent earthquake along the entire arc.

3.3.1. Earthquake Catalogue of Nepal

The instrumental records of the seismic events in Nepal show a non-uniform distribution of seismicity throughout the Nepal Himalaya although a general trend can be recognized. The trend consists of a narrow belt of predominantly medium sized earthquakes beneath the Lesser Himalaya, which extends from east to west just south to the Higher Himalayan front. All the available fault-planes indicate that the cause of seismic origin is solely thrusting. The focal depths for the Himalayan earthquake vary from 10 – 20 km.

Historical records show that Nepal has experienced numbers of large earthquakes in the past centuries. The most devastating earthquakes had been recorded in 1255, 1408, 1681, 1803, 1810, 1833, 1866, and 1934 (Chitrakar and Pandey 1986, Pandey et al. 2002, Pandey and Molnar 1988). Due to lack of seismic instruments, the magnitude and intensity of each previous earthquake are unknown. ***Error! Reference source not found.*** summarizes the major historical earthquake events recorded within Nepal.

The 1934 Nepal-Bihar earthquake (Mw = 8.3) is thought to be a repetition of 1833 Rasuwa-Sindhupalchok earthquake, which had a magnitude of 7.8 (Bilham 1995). National Seismological Center (NSC) has been continuously monitoring the earthquake events since 1978; however the seismic data are available only after 1994. There are several small to medium earthquakes by magnitudes that have been occurred making epicenter near to Kathmandu Valley that have caused relatively less to no damage in the valley.

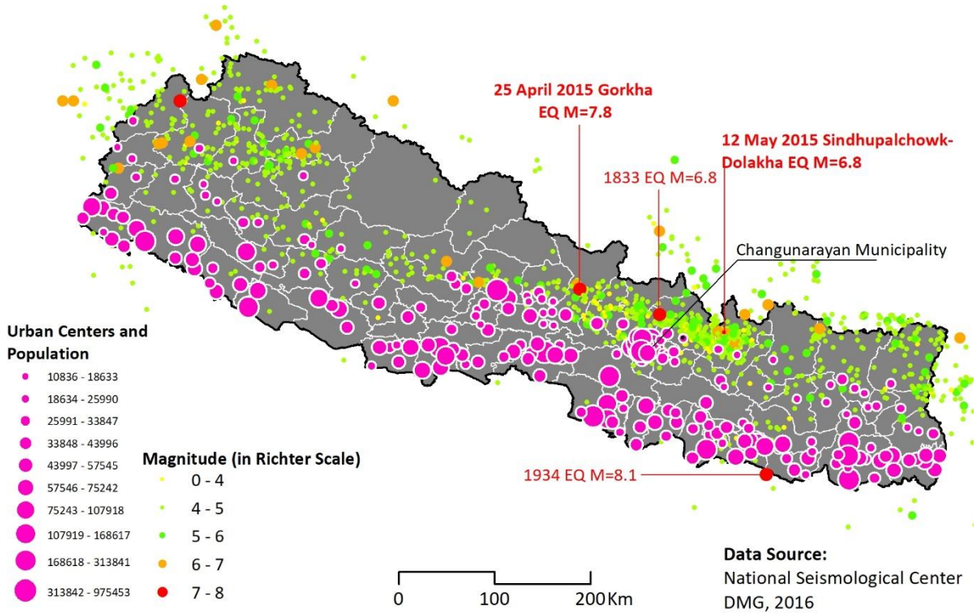


Figure 6 Earthquake catalogue of Nepal (1996-2018 and historic earthquakes)

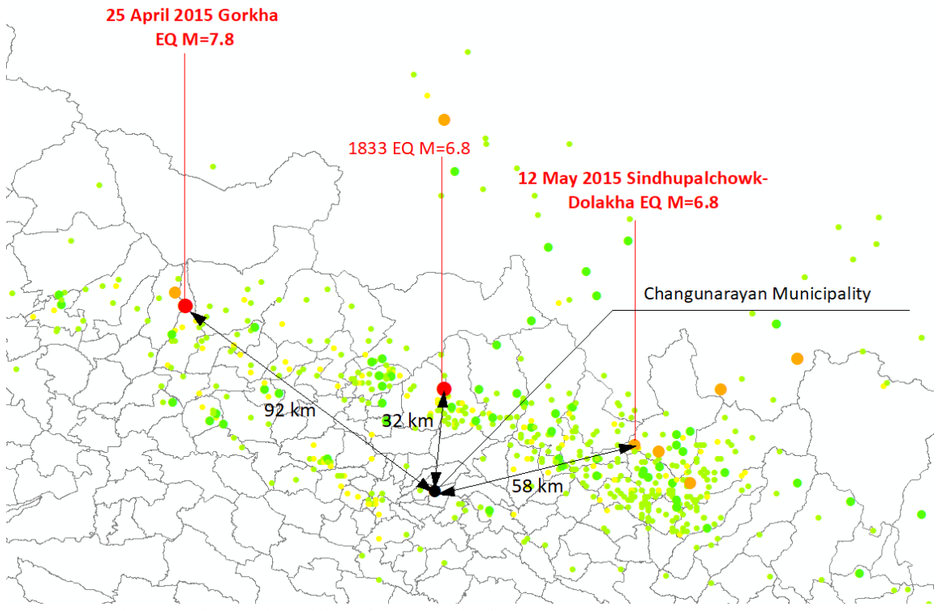


Figure 7 Historic and recent earthquakes in central region

3.4. Seismic Hazard Assessment and Mapping

Seismic hazard is usually expressed in terms of probabilities of occurrences of certain earthquake induced ground shaking in a given spatial as well as temporal frame (Giardini et al. 1999). Earthquake hazard is commonly described in terms of the level of ground shaking that has a 10% chance of being exceeded in 50 years corresponding to a return period of 475 years (Sinadinovski et al. 2005).

Seismic hazard can be accessed through different models such as earthquake source models, occurrence models, ground motion models, and seismic hazard calculation approaches (Balassanian 2002). The ground motion models are generally attenuation relationship that expresses the ground motion as a function of magnitude and distance from the epicenter of an earthquake. The ground motion attenuation relationship has been determined through two different approaches: empirical and theoretical. The empirical approach is based on previously recorded ground motion, while the theoretical approach is based on seismological models to generate synthetic ground motions that account for source, site and path effects (Balassanian 2002).

In the present study, the theoretical approach has been adopted. In this study, the ground motion at a particular place is generated based on the regional seismicity model, an attenuation model, and a site response model. The ground motion is represented by the *Peak Ground Acceleration* (PGA), which defines the maximum acceleration experienced by the soil during the scenario earthquake. Seismic intensity in modified Mercalli scale (MMI) is computed from the obtained PGA values at corresponding site to show the earthquake hazard for a particular scenario earthquake.

3.4.1. Probabilistic Seismic Hazard Analysis

The Probabilistic seismic hazard analysis (PSHA) accounts for the uncertainties in the size, location, rate of recurrence of earthquakes, and in the variation of ground motion characteristics with earthquake size and location to be explicitly considered in the evaluation of seismic hazards. PSHA provides a framework in which these uncertainties can be identified, quantified and combined in a rational manner to provide a more complete picture of the seismic hazard. Kramer (2003) describes PSHA as a following four step process :

1. Identification and Characterization of earthquake sources.
2. Determination of Seismicity or recurrence relationship each of the potential seismic sources.
3. Ground motion attenuation relationships.
4. Computation of seismic hazard curve between acceleration and probability of exceedance of ground shaking in a given time finite period to produce seismic hazard and related uncertainties at appropriate scale.

3.4.2. Potential Earthquake Sources

The essential ingredients of seismic hazard analysis are the description and location of all the seismic sources likely to affect the region under consideration and an estimate of the likely future recurrence of earthquakes of various magnitudes for each of the sources. The region, in which there is likelihood of occurrence of an earthquake of the magnitudes considered in earthquake engineering, is termed as the seismic source.

Keeping the view of seismo-tectonics model and earthquake variation along the Nepal Himalaya, two types of source models are used for the present study.

Characteristics Source Model

The characteristic-earthquake model is based on the observation that during repeated rupture episodes occurring on the same fault (or fault system), some characteristics, like fault geometry, source mechanism, and seismic moment, remain approximately constant over a large timescale; these parameters depend on the direction and intensity of the regional stress field. We have considered four sources, for this type of model, around 200 km from the proposed site for the evaluation of seismic hazard (**Error! Reference source not found.**). Two sources as a detachment earthquakes which nucleate at ramp-flat transition and propagate the rupture all the way to surface exposure of MFT. First one as the same source as the 1934 Bihar-Nepal earthquake in Eastern Nepal and second one with prevailing seismic gap of the western Nepal which has not been ruptured since 1505 megha-events. Other two sources are in Central Nepal; one in the source area of 2015 Gorkha earthquake and other in the south of the Gorkha earthquake. The seismic characteristic of each source are given in Table 10 Seismic characteristics of source used for characteristics model.

Table 10 Seismic characteristics of source used for characteristics model.

Source	Western	Central-North	Central-South	Eastern
Max. Characteristics Earthquake	8.5	7.8	7.8	8.2
Min. Characteristics Earthquake	7.5	7	7	7.5
Medium value of Return Period (Yrs)	700	200	200	700
Time elapsed Since last earthquake (Yrs)	500	3	150	85

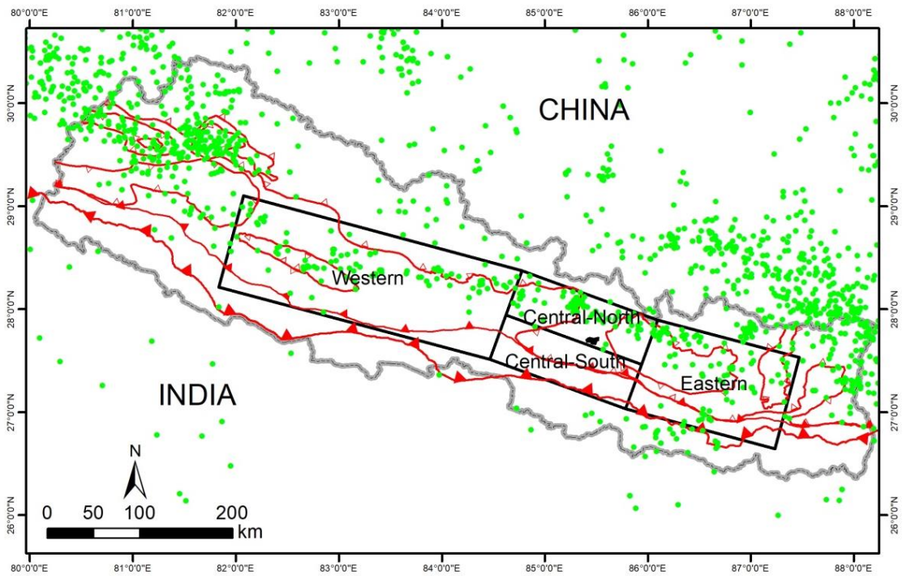


Figure 8 Planar characteristics source models (black hollow rectangles) used in the study

In Figure 8**Error! Reference source not found.**, green circles are the seismicity (> 4 magnitude) published by Department of Mines and Geology, Nepal after removing the aftershocks of 2015 Gorkha Earthquake. Red lines indicated the main thrust system of Himalaya; MCT, MBT and HFT from north to south respectively. Black polygon in the central Nepal are the site of the study.

Gutenberg-Richter Source Model

For this type of source model, we have considered one sources around 200 km from the proposed site for the evaluation of seismic hazard (**Error! Reference source not found.**).

By analysing these available seismicity datasets and following parameters are assigned to the seismic source:

Table 11 Seismic parameters for Earthquake Source of Gutenberg-Richter model

Source zone	Central Nepal
Threshold mag (Mo)	5
No. Earthquake(M ≥ Mo) per year λ	0.4
b-value	1.0
Max mag (Mu)	8.5
Uncertainty of Mu	±0.3

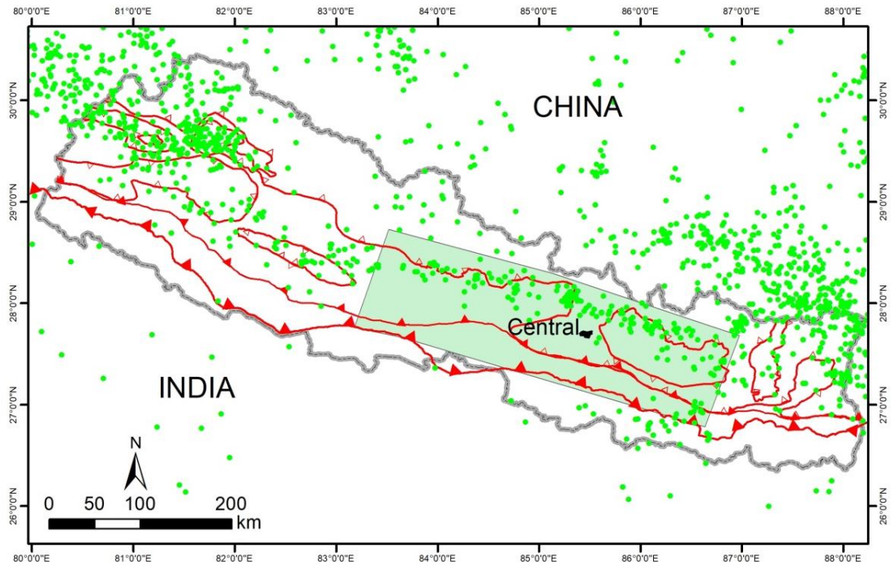


Figure 9 Planar source (blue filled rectangle) used in Gutenberg-Richter source model used in this study

3.4.3. Attenuation Relationship

The estimation of seismic hazard at a site of interest largely depends upon the attenuation relationship used. An attenuation laws in the form of PGA relating with the earthquake magnitude and source-to-site distance with other seismological parameters are popularly used. These laws, in general, are derived from strong ground motion records for a particular region. Himalayan regions including Nepal although have a long history of earthquakes; however, there is no adequate data available. As a result, attenuation law specific to this region have yet to be established. Identification and selection of the existing attenuation laws, which best suit the region is the only alternative to evaluate the seismic hazard. Most of the recent research/projects use the Next Generation Attenuation relationships which provide predictive relationships for the orientation-independent average horizontal component of ground motions.

One of the major criteria in the selection of suitable attenuation law of Nepal from among the existing empirical relationships may be the set of parameters similar to that of Nepal Himalaya. The Ground Motion Prediction Equations (GMPE) used for this analysis were developed for Pacific Earthquake Engineering Research center (PEER) Next Generation Attenuation (NGA) project. A hybrid model based on the four GMPEs from NGA-West2 program for shallow crustal earthquakes is used. Comparison of four attenuation models by Abrahamson et, al., 2014; Boore et. al., 2014; and Chiou and Youngs, 2014 which are used, is given as in

GEMP	Abrahamson et, al., 2014	Boore et. al., 2014	Campbell and Bozorgnia, 2014	Chiou and Youngs, 2014
Magnitude Range	3-8.5	3-8.5	3-8.5	3-8.0
Distance Range	0-300 km	0-300 km	0-300 km	0-300 km
Distance Type	Rrup	Rjb	Rrup	Rrup
Spectral Period Range	0-10 sec	0-10 sec	0-10 sec	0-10 sec
Residual Distribution	Log Normal	Log Normal	Log Normal	Log Normal

In general, the median ground motions by all GMPEs are similar, within a factor of about 1.5–2.0 for 5 < M < 7 and distances between 10–100 km. Differences increase for large-magnitude (M > 8) earthquakes at large distances (R > 100-200 km) and for close distances (R < 10 km). A similar increase is observed for hanging-wall sites. All GMPEs aleatory variability models are a function of magnitude with higher overall standard deviations values for the smaller magnitudes when compared to the large-magnitude events.

The GMPEs provide estimates of spectral accelerations in the period range of 0 to 10 seconds, representing the randomly oriented average horizontal component of ground motions. All models provide ground motion estimates as a function of average shear wave velocity of top 30 meters of the site which is used as 1100 m/s to compute the bed rock motion. The weighting of all four GMPEs to find the hybrid model is given in Logic Tree section.

Use of Logic Tree

In probabilistic seismic hazard analyses, it is common to use logic trees for handling the epistemic uncertainty associated with the seismogenic sources and the ground-motion prediction models. A logic tree consists of a series of branches that describe the alternative models and/or parameter values. At each branch, there is a set of branch tips that represent the alternative credible models or parameter. The weights on the branch tips represent the judgment about the relative credibility of the alternative models. The branch tip weights typically sum to unity at each branch point.

Logic trees are used to allow multiple models to be considered with weights that reflected the degree of belief of the scientific community in the alternative models. In this way, all proposed models that were credible could be considered without having to select a single best model. In this analysis, a logic tree is constructed based on the previously described seismic source model and ground motion prediction equations as shown in Figure 10. For the two different sources models, equal weights are given as sufficient data / research are not available for defining suitable models for typical Himalayan large to great earthquake. To build the hybrid ground motion model from the selected four GMPEs, equal weightage is given for all four models.

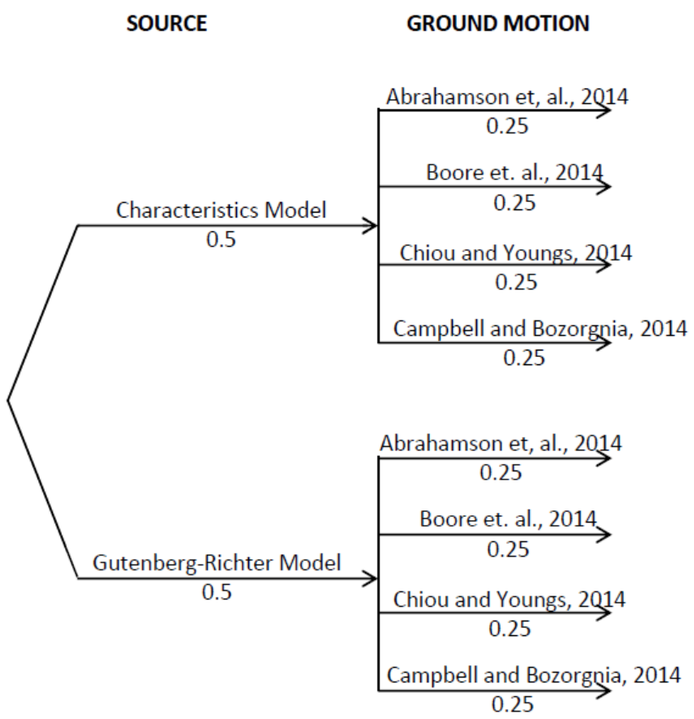


Figure 10 A logic tree model for the seismic source and GMPEs with their relative weights

3.4.4. Ground Model

The ground model is prepared on the basis of borehole logs distributed in the Kathmandu Valley around the Changunarayan Municipality. There are 14 boreholes of depth up to 20m used to prepare layers and sub-layers beneath the surface. The lithological and geotechnical properties of soil materials are used to calculate the response of the scenario earthquakes.

The borehole logs give information on thickness of soil layers, groundwater level, and geotechnical properties of soil such as the standard penetration test (SPT)-N values and soil densities. The N-values were further used to compute the site amplification. Shear wave velocities (V_S) were computed for each borehole location site. An empirical relationship between N-value and shear wave velocity is adopted from Pokhrel (2006), which was based on field and lab experiments.

$$V_s = 117\, N^{0.234}$$

where, N is SPT value and V_s is shear wave velocity

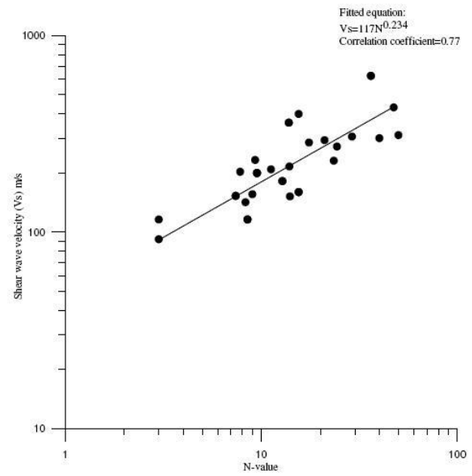


Figure 11 Relationship between N-value and Vs

3.4.5. Acceleration in Ground Surface

The ground motion is computed as a function of magnitude and distance of an earthquake from the particular place, and properties of earth materials at that place, which is expressed as an attenuation relation. In the present study, peak ground acceleration (PGA) values were calculated at each borehole location for each different scenario earthquakes, where SPT and/or shear wave velocity (V_s) values are available.

3.4.6. Peak Ground Acceleration (PGA)

The peak ground acceleration (PGA) at a given location is the maximum acceleration experienced by the soil materials at ground surface during an earthquake. For each earthquake scenario with the known moment magnitude and epicenter distance, the maximum ground acceleration was determined at particular location by using the relation of (Boore, Joyner, and Fumai 1997)

$$\ln Y = b_1 + b_2\,(M_w - 6) + b_3\,(M_w - 6)^2 + b_5\,\ln r + b_v\left(\ln\frac{V_s}{V_A}\right)$$

where, $r = \sqrt{(r_{jb})^2 + h^2}$

and

$$b1 = \begin{cases} b_{1SS}\ for\ strike-slip\ earthquakes\ (b1 = -0.313); \\ b_{1RS}\ for\ reverse-slip\ earthquakes\ (b1 = -0.117); \\ b_{1ALL}\ if\ mechanism\ is\ not\ sprecified\ (b1 = -0.242). \end{cases}$$

In this equation, *Y* is the ground motion parameter (i.e., peak horizontal acceleration, *PGA*) in *g* unit;

M_w is the moment magnitude,

r_{jb} is horizontal distance from the station to the epicentre (in *Km*),

V_s is the shear wave velocity (in *m/sec*), and b_2, b_3, b_5, b_V, *h, and* V_A are the coefficients.

The values of coefficients in the above equation are to estimate PGA for the random horizontal component at 5 percent damping.

In the present study, $b_1=b_{1ALL}$ (=-0.242) was taken since the mechanism of earthquake scenario is not specified. Similarly, b_2=0.527, b_3=0.0, b_5=-0.778, b_V=-0.371, h=5.57, and V_A=1396 are used in the present analysis following (Boore, Joyner, and Fumai 1997).

3.4.7. *Field Survey*

Multichannel Analysis of Surface Waves (MASW) was performed in one location for field verification of the prepared data (Annex C). The multichannel analysis of surface waves (MASW) method is one of the seismic survey methods evaluating the elastic condition (stiffness) of the ground for geotechnical engineering purposes. MASW first measures seismic surface waves generated from various types of seismic sources—such as sledge hammer—analyzes the propagation velocities of those surface waves, and then finally deduces shear-wave velocity (Vs) variations below the surveyed area that is most responsible for the analyzed propagation velocity pattern of surface waves. Shear-wave velocity (Vs) is one of the elastic constants and closely related to Young's modulus. Under most circumstances, Vs is a direct indicator of the ground strength (stiffness) and therefore commonly used to derive load-bearing capacity. After a relatively simple procedure, final Vs information is provided in 1-D, 2-D, and 3-D formats.

Figure 13 Seismic field survey (MASW) performed behind the Kathmandu Medical College, Duwakot, Ward 2, Changunarayan Municipality

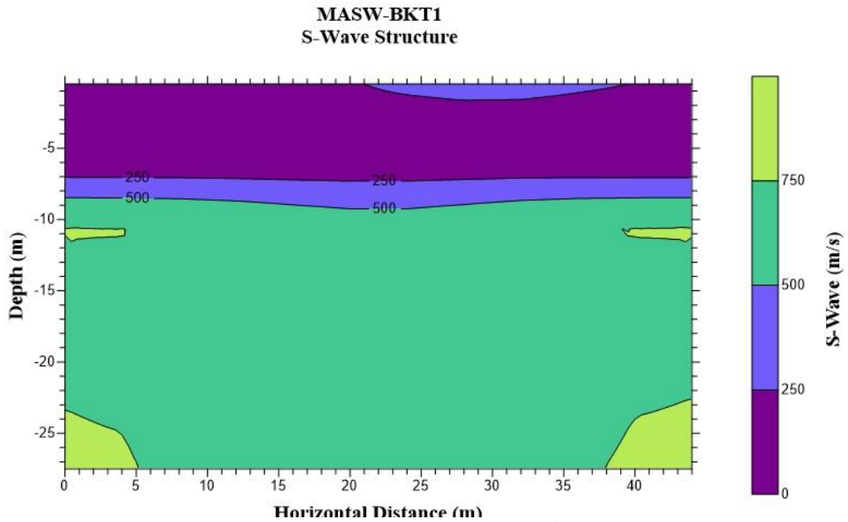


Figure 12 Result of the Seismic Field Survey (MASW) performed behind the Kathmandu Medical College, Duwakot, Ward 2, Changunarayan Municipality

3.4.8. *Distribution of PGA in Changunarayan Municipality*

The peak ground acceleration (PGA) value for smaller extent of area such as a municipality level doesn't generally vary much as this has a regional impact with big extent. PGA maps with probability of 22% and 10% of exceedance in 50 years corresponding to recurrence interval of 200 and 475 years were prepared using the bedrock PGA and ground model Figure 15 and Figure 16). The PGA value is high towards the central and southern part in places such as Chhaling, Kharipati while the PGA values are lower in the eastern and western parts such as Bode, Nagarkot. The PGA values ranges from 282.43 to 297.9 gal for 200 years return period while the PGA value ranges from 492.35 to 538.6 gal for 475 years return period

3.4.9. *Distribution of Intensity in Changunarayan Municipality*

The seismic intensity distribution for the probable intensity of the scenario earthquakes in terms of Modified Mercalli Intensity (MMI) scale is computed at each grid cell from the PGA distribution map using PGA-MMI relationship (Trifunac and Brady 1975):

$$\log_{10}(PGA) = 0.3\,MMI - 0.014$$

where, PGA is the peak ground acceleration, and MMI is the modified Mercalli intensity.

The Modified Mercalli Intensity (MMI) value for smaller extent of area such as a municipality level doesn't generally vary much as this has a regional impact with big extent. MMI maps with probability of 22% and 10% of exceedance in 50 years corresponding to recurrence interval of 200 and 475 years were prepared using the PGA map (Figure 14 and Figure 17). The MMI value is high towards the central and southern part in places such as Chhaling, Kharipati while the MMI values are lower in the eastern and western parts such as Bode, Nagarkot. The MMI values ranges from 8.1 to 8.2 (MMI Class VIII) for 200 years return period while the MMI value ranges from 8.9 to 9.0 (MMI Class IX) for 475 years return period.

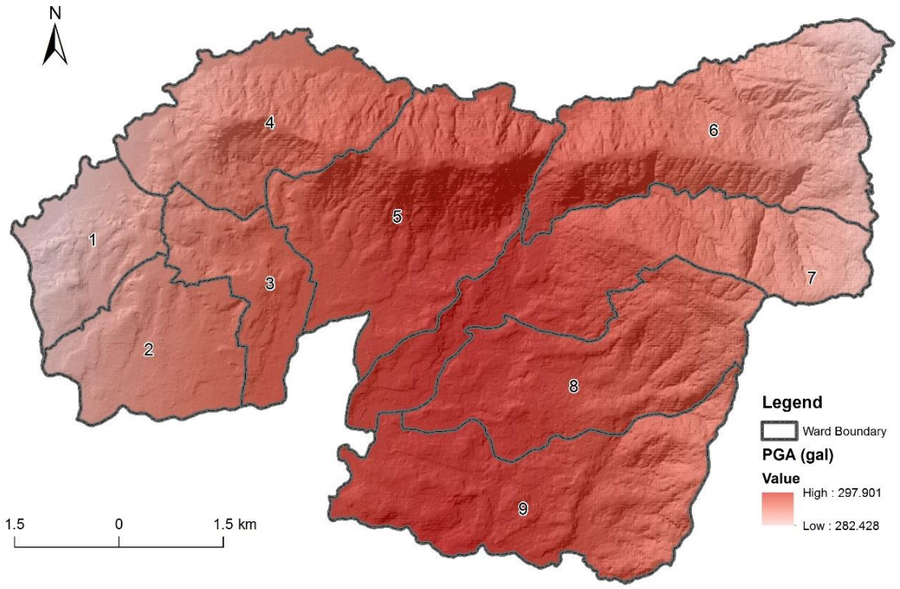


Figure 15 PGA map of the Changunarayan Municipality for 200 years return period

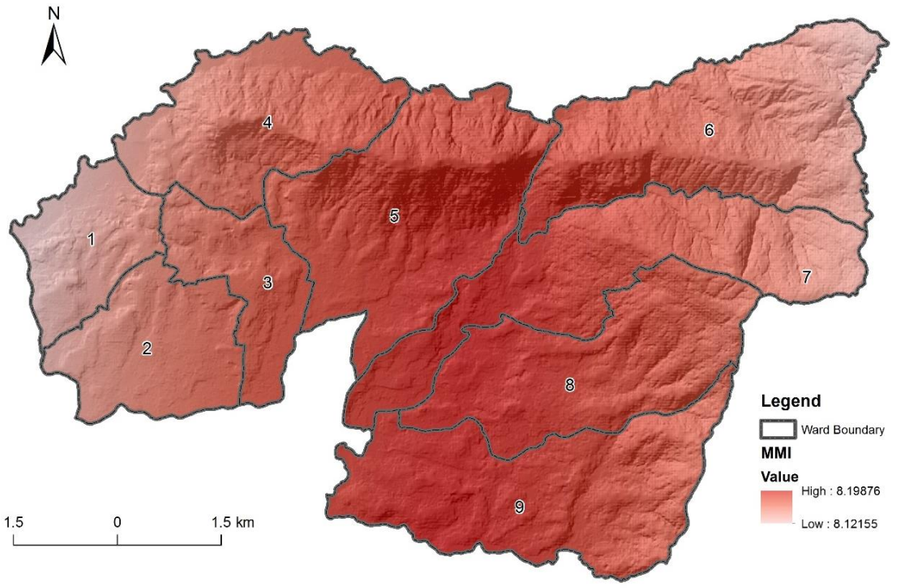


Figure 14 Seismic intensity map of Changunarayan Municipality for 200 years return period

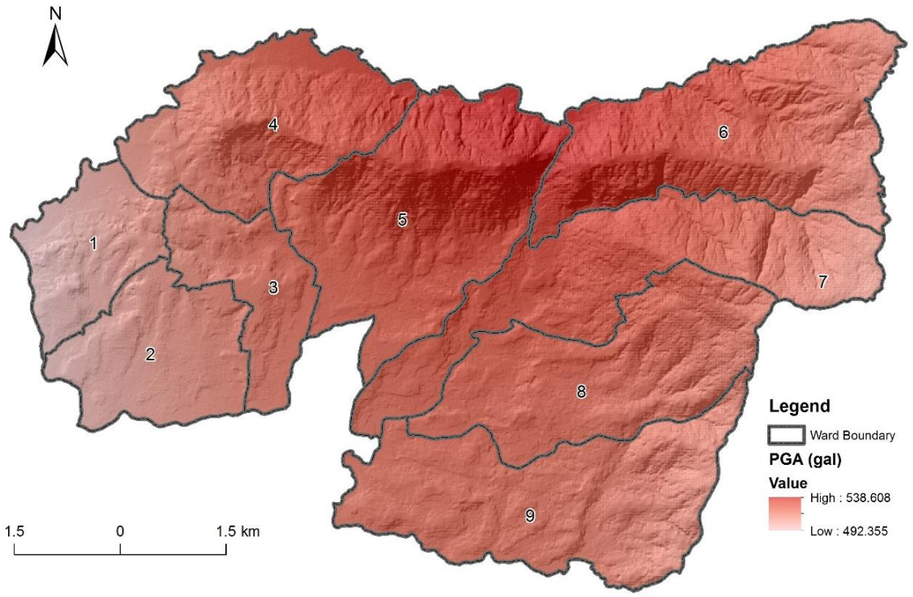


Figure 16 PGA map of the Changunarayan Municipality for 475 years return period

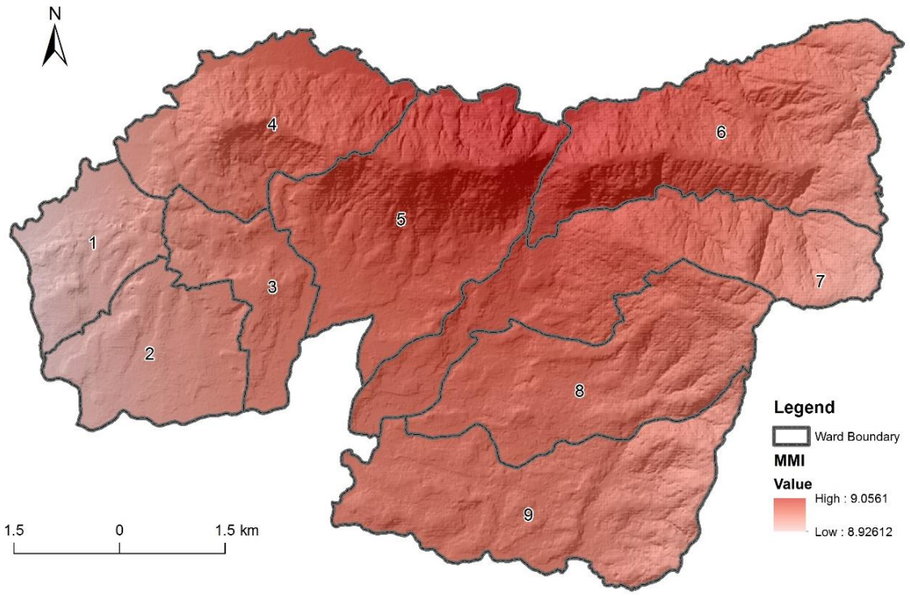


Figure 17 Seismic intensity map of Changunarayan Municipality for 475 years return period

3.5. Liquefaction Susceptibility Assessment and Mapping

Liquefaction is always associated with an earthquake if the earthquake is occurred in non-consolidated sediments dominant with sand and silt. The term 'Liquefaction' was originally used by Mogami and Kubo in 1953. The generation of excess pore pressure under undrained loading condition is principal criteria for all liquefaction. When cohesionless soils are saturated with water and rapid loading occurs under undrained condition, the pore pressure increase and the effective stress decreases to result the liquefaction. Liquefaction is caused by earthquake shaking in the loose sediments. Since, the Kathmandu Valley is filled up with unconsolidated to semi-consolidated sediments, liquefaction hazard assessment is very crucial. A liquefaction susceptibility map demonstrates the spatial distribution of different liquefaction potential zones. The liquefaction potentiality depends basically on the engineering properties of soil, water table, and strength of ground motion during an earthquake.

3.5.1. Factors Affecting Liquefaction Susceptibility

Liquefaction susceptibility is a function of the geotechnical properties of soil and topographic position of the unit. There are several factors that affect the liquefaction susceptibility, such as sedimentation process, age of deposit, water table depth, engineering properties of sediment grains, depth of burial, density state, proximity to a free face and ground slope (Youd and Perkins 1978). In the present study, a liquefaction susceptibility map is prepared for the Kathmandu valley based on the following processes and parameters:

- Sediment grain size, inter-granular relationship, and type of origin (manually filled-up or naturally deposited),
- Elevation of groundwater table,
- Age of sedimentary deposits and the depositional environment,
- Historical records about liquefaction occurred in the area,
- Surface and subsurface geological condition, thickness of individual soil layers,
- Spatial distribution of Standard Penetration Test (SPT) N-values obtained from the boreholes in the area, and
- The estimated 'Ground motion threshold' required to initiate liquefaction.

3.5.2. Liquefaction Hazard Analysis

Various methods are in practices for the liquefaction hazard analysis under two approaches: qualitative and quantitative. The analysis of liquefaction susceptibility following qualitative approaches was performed by (Iwasaki et al. 1982), and (Youd and Perkins 1978), while the analysis of liquefaction susceptibility based on quantitative approach can be found in the works of several researchers such as (Iwasaki, Tokida, and Arakawa 1984, Seed 1979, Seed and Idriss 1971) and others. In the present study, a quantitative approach presented by (Iwasaki, Tokida, and Arakawa 1984) has been used to analyse the liquefaction susceptibility. Based on this method, the liquefaction potential can be estimated simply by using the fundamental properties of soils, viz. N-value, unit weight, mean particle diameter (D_{50}), and maximum acceleration at the ground surface (PGA). Pit soil samples from 4 different locations were taken and tested in lab for validating the prepared data and results. (Annex 1)

The liquefaction potential for an individual layer stands by comparing the resistance against liquefaction of this layer (R) with the driving dynamic force that could cause liquefaction (L). With these values, factor of safety with respect to liquefaction (F_L) is determined using the relation at an arbitrary depth (Iwasaki, Tokida, and Arakawa 1984)

$$F_L = \frac{R}{L}$$

where, F_L for specific soil at certain location is less than 1.0, it can be said that the soil liquefies during an earthquake.

In the above relation, L is the earthquake-induced dynamic load in soil element, which can be simply estimated by (Iwasaki, Tokida, and Arakawa 1984).

$$L = \frac{\tau_{\max}}{\sigma_v'} = \frac{\alpha_{s\max}}{g} * \frac{\sigma_v}{\sigma_v'} * r_d$$

where, τ_{max} is the maximum shear stress (in kgf/cm), α_{smax} is the PGA at the ground surface (in gals), g is the acceleration of the gravity (= 980 gals), σ_v is the total overburden pressure (in kgf/cm^2), σ_v' is effective stress (in kgf/cm^2) and r_d is the reduction factor expressed as

$$r_d = 1 - 0.015z$$

where, z is depth in meters from the ground surface.

Similarly, *in-situ* resistance of the soil element to dynamic load in terms of R is (Iwasaki, Tokida, and Arakawa 1984)

$$R = 0.882\sqrt{\frac{N}{\sigma_v' + 0.7}} + 0.225\log_{10}\frac{0.35}{D_{50}}$$

for $0.04\text{mm} \leq D_{50} \leq 0.6\text{mm}$, and

$$R = 0.882\sqrt{\frac{N}{\sigma_v' + 0.7}} - 0.05$$

for $0.6 \leq D_{50} \leq 1.5\text{mm}$.

where, N is the number of blows, σ_v' is effective stress (in kgf/cm^2) and D_{50} is the mean particle diameter (in mm).

The liquefaction potential in terms of potential index (P_L) is defined as (Iwasaki, Tokida, and Arakawa 1984)

$$P_L = \int_0^{20} F(z)\, W(z) dz$$

where, z is the depth in meters; $W(z)$ is a depth-weighting factor, $W(z) = 10 - 0.5z$,

$F(z) = 1 - F_L(z)$ for $F_L(z) \leq 1$ and $F(z) = 0$ for $F_L(z) > 1$

This equation considers just the profile in the top 20m; P_L values calculated from this equation ranges from 0 to 100. In this study the soil layer above water table were considered as non-liquefiable layer. The cumulative liquefaction potential for a location at the surface (P_L) is classified according to Table 12.

Table 12 Classification of liquefaction susceptibility

Value	Susceptibility class	Remarks
PL = 0	No / Very Low Liquefaction	Liquefaction susceptibility is very low or not at all.
0< PL <5	Low	Liquefaction susceptibility is low. Detailed investigations on soil necessary for important structures.
5<PL<15	High	Liquefaction susceptibility is high. Detailed soil investigation necessary.
15<PL	Very High	Liquefaction susceptibility is high. Detailed soil investigation mandatory

The liquefaction hazard map and the ward wise distribution of the liquefaction hazard for 200 years return period shows that most of the part of the Changunarayan Municipality will have no to low liquefaction hazard. High liquefaction hazard are present at the northern, eastern and southern edges of the Changunarayan Municipality. Wards 1,2 and 9 have the high liquefaction hazard for the 200 years return period.

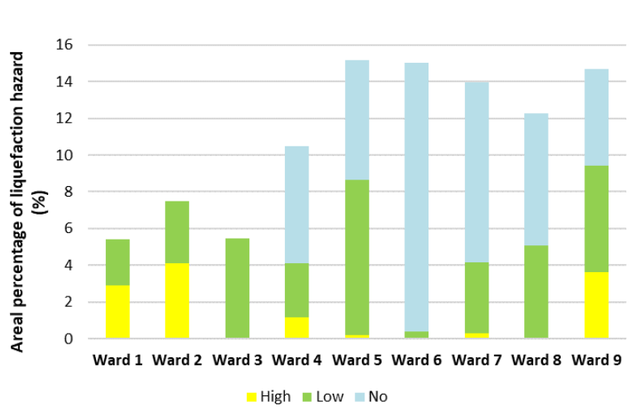


Figure 19 Ward wise distribution of liquefaction hazard for 200 years

The liquefaction hazard map and the ward wise distribution of the liquefaction hazard for 475 years return period shows that most of the part of the Changunarayan Municipality will have no liquefaction hazard. Very high liquefaction hazard is present at the northern, eastern and southern edges of the Changunarayan Municipality. Wards 1, 2, 4 and 9 have the very high liquefaction hazard for the 475 years return period.

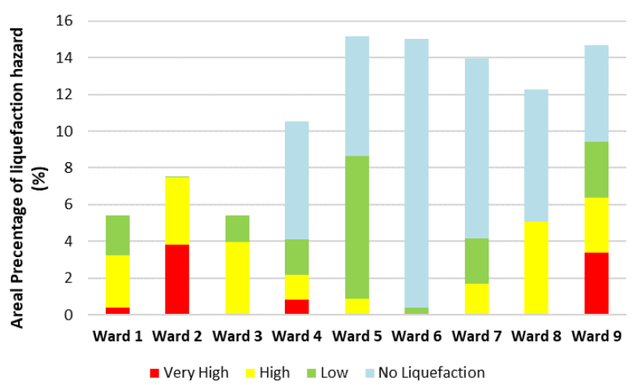


Figure 19 Ward wise distribution of liquefaction hazard for 475 years return period

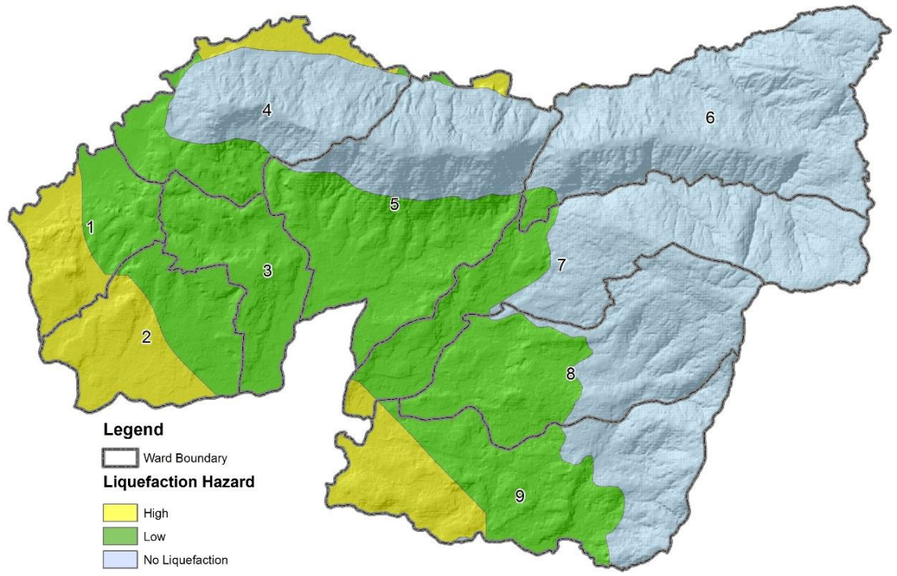


Figure 21 Liquefaction Hazard Map of Changunarayan Municipality for 200 years return period

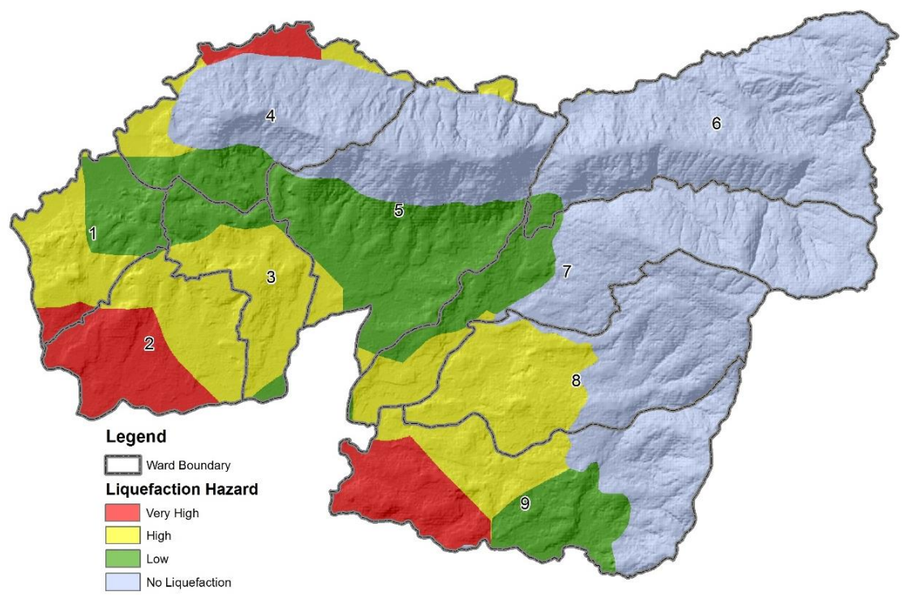


Figure 20 Liquefaction hazard map of the Changunarayan Municipality for 475years return period

3.6. Landslide and Erosion Hazard Assessment and Mapping

Landslide and erosion hazard usually involves preparing a landslide and erosion inventory together with an assessment of the areas with a potential to experience landslide or erosion in the future with assessment of the frequency (annual probability) of the occurrence of landslides or erosion. Landslide and erosion hazard maps are prepared on the basis of the intrinsic factors such as bedrock geology, geomorphology, soil depth, soil type, slope gradient, slope aspect, slope curvature, elevation, land use pattern, drainage pattern and so on along with extrinsic factors such as rainfall, earthquakes and volcanoes (Cevik and Topal 2003; Dahal et al. 2008). Varnes (1984) emphasized on the consideration of different factors while preparing hazard maps.

3.6.1. Weight of Evidence (WOE) Method

Bivariate statistical analysis method such as WOE is one of the methods used to conduct hazard mapping (Sumaryono et. al, 2015).

This method utilizes historical data events to gain patterns geofactor or parameters that controlling and influence of the landslide/ erosion occurrence and GIS-based statistical methods have become very popular in landslide hazard assessment (van Westen et al. 2006), because of effective data management, simultaneous use, graphic and attribute crossing of these digital layers, and providing accurate output data and superior image quality. Advantages of this method are the accuracy that can be accounted and can be done quickly. Geo-factor Maps is some layer parameters containing the input parameters for a statistical approach. Each statistic methods are obtained from the relationship between geofactor of landslide/erosion and distribution of landslide/erosion. Bivariate statistical analysis using weight of evidence that a method based on the Bayes theorem is constructed but not for spatial analysis for diagnosis in the medical field since the '80s but found the application that can be used in earth science is the exploration of natural resources and also can be used in vulnerability assessment of ground movement (van Westen et al, 2003). Calculation of each particular predictive variable a positive weight (W^+), when the event occurs and a negative weight (W^-), when the event does not occur. The weights are measures of correlation between evidence (predictive variable) and event, facts that make them easy to interpret in relation to empirical observation.

$$W_i^+ = log \frac{P(\frac{B_i}{S})}{P(\frac{B_i}{S^c})}$$

$$W_i^- = log \frac{P(\frac{B_i^c}{S})}{P(\frac{B_i^c}{S^c})}$$

where,

B_i= presence of a potential landslide conditioning factor,

B_i^c= absence of a potential landslide conditioning factor,

S = presence of landslide,

S^c= absence of landslide.

The weights can be used to produce a contrast value (C) for the particular hazard variable.

$C = W^+ - W^-$

The obtained difference between weights (*C*) provides a measure of the strength of the correlation between the analyzed variable and landslides.

3.6.2. Factor Maps for Analysis

Ten different factors maps selected on the basis of previous literature for similar research and biasness analysis, along with the landslide and erosion distribution map were prepared in GIS environments for the hazard map preparation. Digital Elevation Model (DEM) of 10m×10m extracted from Pleaides stereo imagery was used for the analysis.

Slope of a feature is defined as its inclination relative to a horizontal plane or its steepness. Slope plays a key role in the stability of the mass at certain height because it will be more prone to falling or sliding as the slope angle increases. It is an important factor because slopes become less stable as the slope angle increases generally. The slope value was classified into 4 categories which are <15˚. 15˚- 30˚, 30˚- 45˚, and >45˚.

Geology defines the type of the exposure present within the given area. The physical, chemical and engineering properties of the rock types also play a major role in landslide initiation and triggering. Each rock type of the study area has its own characteristics. The geological map was prepared on the basis of field work and the geological maps of petroleum exploration produced by DMG were taken as reference maps. The geology of the Changunarayan municipality was mainly divided into different geological formations representing the recent flood plains, valley sediments and bedrock.

Elevation is the vertical height taken from a constant reference level (mean sea level in this case). It is a very important factor because it is directly related to the volume as well as the distance through which a mass moves down slope. Generally, higher the elevation more is the velocity and the volume of mass moving downwards. The class interval of 100 m was taken for this study.

DEM derivatives such as plan and profile curvature also define surface conditions which might trigger landslides and erosion.

Streams are one of the major hydrological agents of erosion, transportation and deposition of the sediments. They are one of the important triggering factors for the erosion and landslides especially through toe cutting, sheet erosion and gully erosion. Running water slowly erodes the surface and banks in normal condition which increases abruptly during flood events. In such cases, they cause huge loss of landmass and properties. So, distance of the exposure from the river is taken as one of the factors. The distances have been classified as <10 m, 10-25 m, 25-50 m and >50 m.

Aspect is the direction at which the slope is facing. It is also an important factor because it controls the physical and chemical weathering condition of the exposure. The slopes facing the sun are generally dry while that not facing the sun are moist. The aspect is divided into nine classes which are flat, north, northeast, east, southeast, south, southwest, west and northwest.

Geological structures also play a vital role in triggering erosion and landslides. So, distance from faults were taken with interval of within 200m, 200-500m, 500-1000m and greater than 1000m.

Rainfall is one of the most important triggering factors for erosion and landslide. The soft sediments of the Kathmandu Valley as well as surrounding bedrocks are eroded, deformed, transported and deposited due to action of rain and runoff. In this study, the daily precipitation data of 35 years (1974-2009) provided by the Department of Hydrology and Meteorology (DHM) was used and analyzed to get the frequency of precipitation of greater than 100mm per day for 8 meteorological stations in the study area.

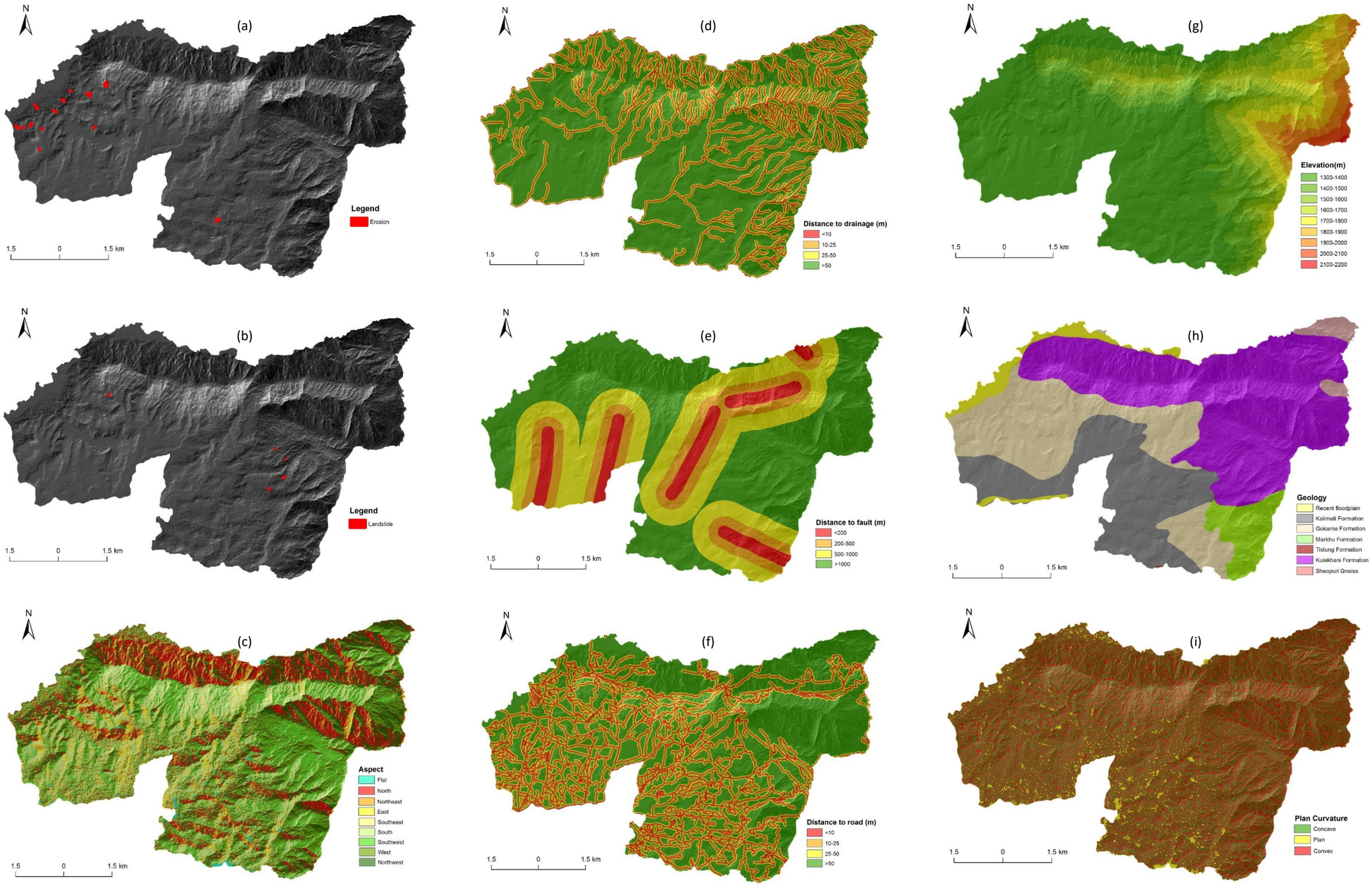


Figure 22 (a) Erosion inventory (b) Landslide inventory (c) Aspect (d) Distance to drainage (e) Distance to fault (Source: extracted from Geological Map of Department of Mines and Geology) (f) Distance to road (g) Elevation gradient (h) Geological map (Source: Geological map of Department of Mines and Geology) (I) Plan curvature

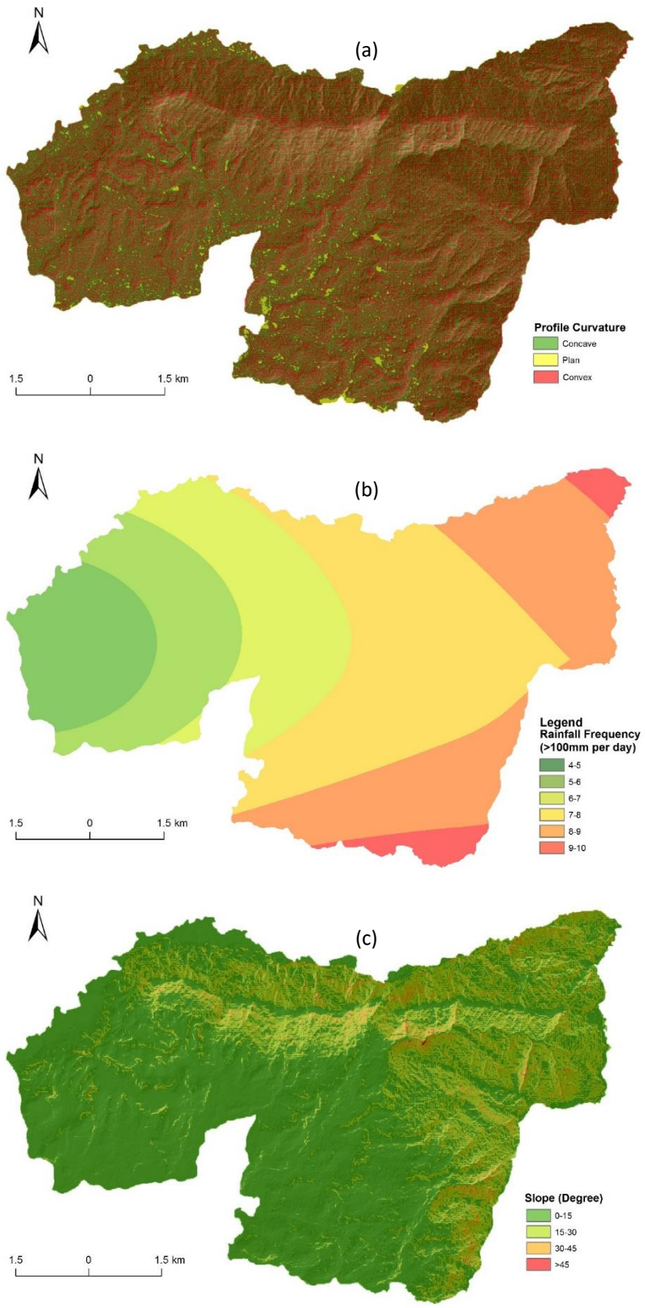


Figure 23 (a) Profile curvature (b) rainfall frequency (>1000mm per day) based on past 35 years data (Source: DHM) (c) Slope Map (Source: Pleaides Image, GENESIS)

3.6.3. Erosion and Landslide Susceptibility

Erosion hazard map and the distribution graph shows that high erosion hazard is prevalent in the western part of the municipality including wards 1,2, 3 and 4. Erosion susceptibility is higher in parts of wards 5 and 9. Soft sediments, haphazard sand quarry and development works such as road and building construction are triggering the erosion as well as slides in these areas.

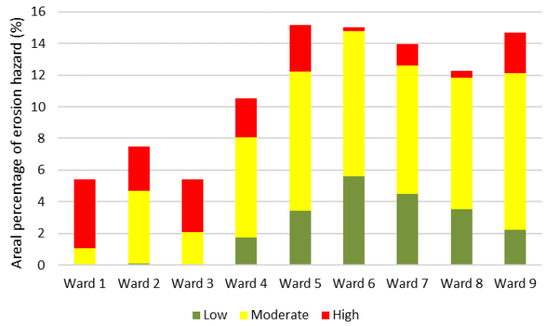


Figure 24 Erosion hazard distribution within different wards of the Changunarayan Municipality

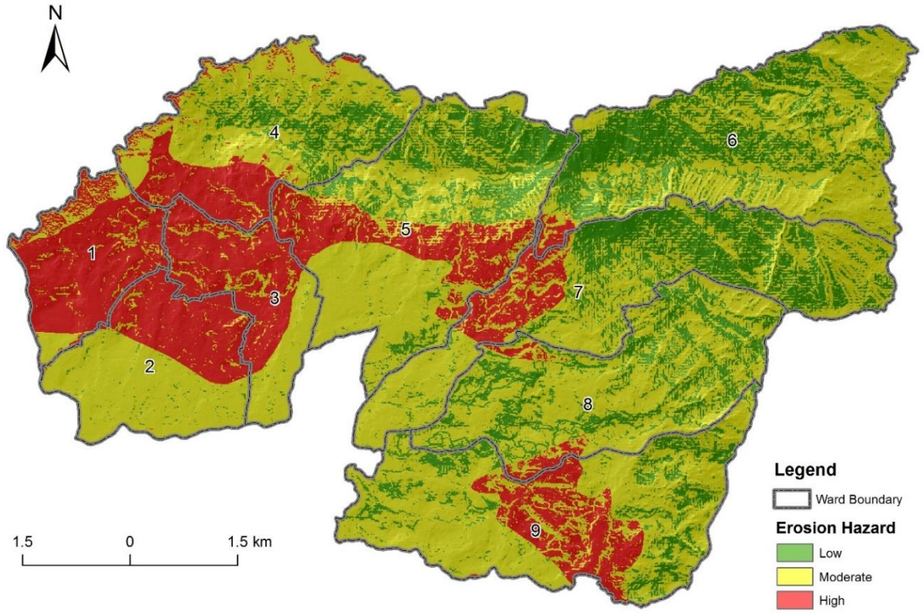


Figure 25 Erosion hazard map of the Changunarayan Municipality

Similarly, landslide hazard map and distribution chart shows that high landslide hazard is mostly present in the eastern part of the Changunarayan Municipality especially in wards 7 and 8. The hills on the northern part are also highly hazardous to landslides. Signs of creeping can be observed at various places especially near the Changunarayan Temple area.

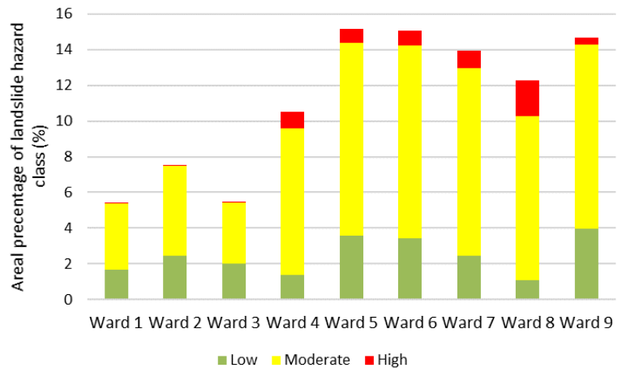


Figure 26 Landslide hazard distribution within different wards of the Changunarayan Municipality

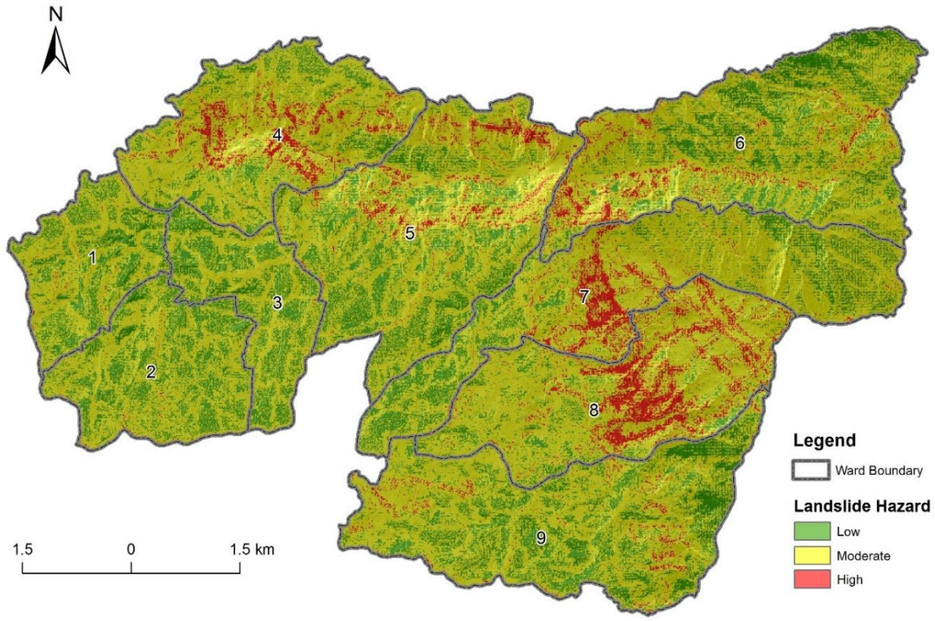


Figure 27 Landslide Hazard map of the Changunarayan Municipality

Recommendation based on geo-technical investigation and geo-hazard assessment study are:

- Sand quarry should be monitored regularly and avoided near the residential area. There have been news of land subsidence due to haphazard extraction of sand in Duwakot area.
- Haphazard excavation of slopes for residential purposes and road construction should be prohibited.
- Drainage management should be done for easy outlet for the running water which may be rain or used ground water.
- Bioengineering should be done on the barren surfaces to hold the fragile topsoil.
- The natural gullies and streams should not be disturbed while constructing roads and buildings. The road from Muhanpokhari to Nagarkot has similar situation where the overflowing materials during monsoon covers the road.

4. Urban Growth Trend and Projection

4.1. Urban Growth Trend

Changunarayan Municipality witnessed an increase of 140.39 ha in built-up area from 508.38 ha in 2012 ha to 648.77 ha in 2018. Around 136.31 ha of agriculture and 8 ha of sand mining area were converted to built-up during the course. Tree clusters (from urban and rural area) were also converted to built-up area.

During the period (2012-2018), the rate of urbanization was low. The built up area did not increase significantly, and had an annual growth rate (AGR) of 0. 37 %[1]. The built up area increased from 508.38 ha in 2012 ha to 648.77 ha in 2018. The highest growth was concentrated in Ward 1 and 2. In ward 1, the built up area increased from 40.24 ha to 62.49 ha, while in ward 2, the built up area increased from 65.27 to 92.90 ha. Ward 6 had the lowest increase in built up area, from 47.06 ha to 54.24 ha. The details of the built up area change in each ward from 2012 to 2018 is presented in

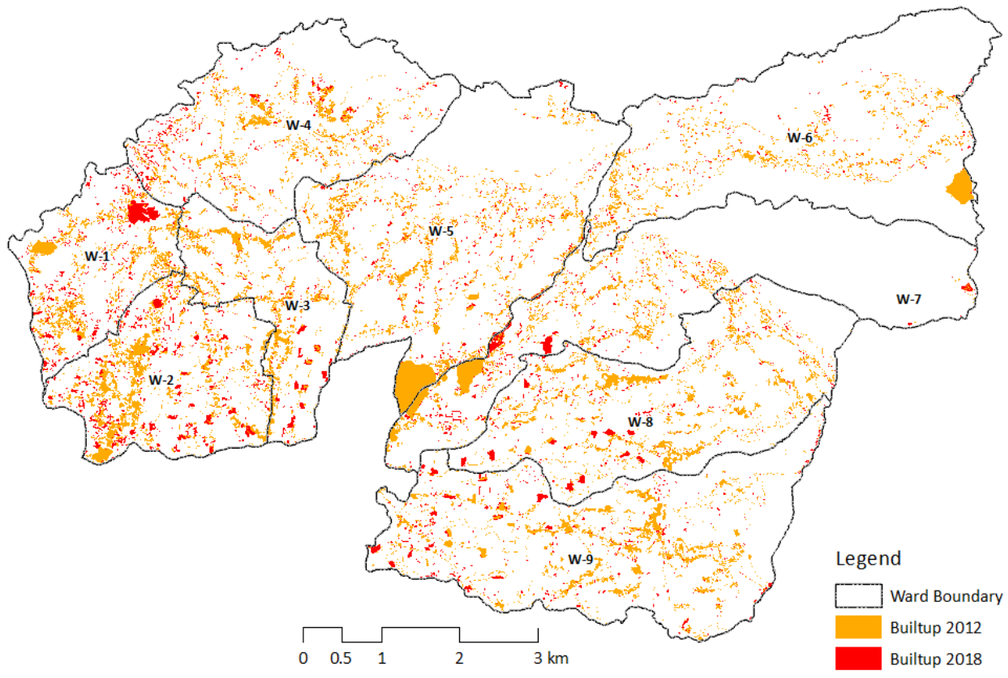


Figure 28 Built-up area change in Changunarayan municipality (2012 to 2018)

Table 13 Built-up area change in each ward (2012-2018)

Ward	Built-up 2012 (ha)	Built-up 2018 (ha)	Change (ha)	Annual growth rate (%)
1	40.24	62.49	22.25	0.06
2	65.27	92.90	27.63	0.07
3	43.28	51.63	8.35	0.02
4	42.87	56.70	13.83	0.04
5	86.01	99.38	13.37	0.04
6	47.06	54.24	7.19	0.02
7	51.36	67.97	16.61	0.04
8	62.74	77.18	14.44	0.04
9	69.56	86.27	16.71	0.04
Total	**508.38**	**648.77**	**140.39**	

New settlements were observed near to the existing settlements and roads. Spatial pattern of growth shows an outward expansion of the existing built up. The growth trend map Figure 29 shows the growth trend concentrated in the west.

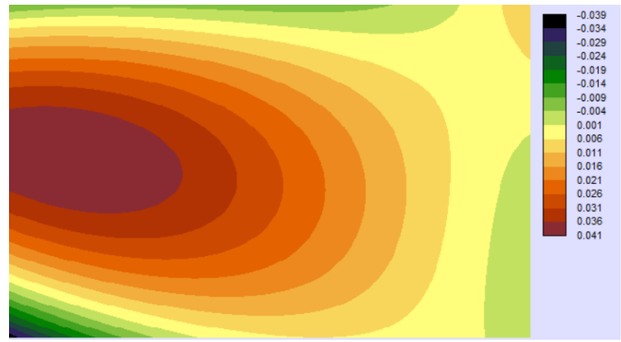


Figure 29 Trend map from all land cover to built-up (2012-2018)

4.2. Drivers of Growth

There are number of factors that influence the growth rate. These factors are also called as "drivers of urban growth" or variables responsible for change. The drivers of urban growth were identified from ward level focus group discussion and extensive literature review. The major drivers are discussed in following sections. The summary of drivers discussed in the focus group discussion is provided in Table 14.

[1] Annual Growth Rate (AGR) is calculated as $AGR = \frac{UA_{n+i} - UA_i}{n\,TA_{n+i}} \times 100\%$, where UA_{n+1} and UA_i are urban areas at time *n+I* and *I* respectively, *n* is the number of year and $TA_{n+i}$is the total land area of the target unit (administrative unit) calculated at the time *i+n Xiao, J., et al. (2006). "Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing." Landscape and Urban Planning **75**(1–2): 69-80.*

4.2.1. *Biophysical Condition*

Bio-physical characteristics refer to characteristics and process of the natural environment such as landforms, topography, soil type, natural resources and drainage pattern. These characteristics usually affect settlement growth pattern based on the suitability of land for specific purpose. Parameters such as slope, reserved forest and water bodies are taken as site specific characteristics, which can either restrict or accelerate the growth rate. Settlements are generally discouraged in the slopes greater than 30 degree, areas vulnerable to liquefaction, landslides and other natural hazards. Therefore, slopes greater than 30°, water bodies and areas vulnerable to natural hazards have been identified as constraint for growth.

4.2.2. *Road Network*

It is assumed that whether a place is urban or not is highly correlated to accessibility of that place. Therefore, transport related variables such as roads are included as predictors of urban growth. This variable is widely mentioned in most of the literatures because of the fact that the area which is at closer proximity of transport related variables have greater tendency to grow in future due to potential benefits such as ease of access, economic opportunities and social services. In Changunarayan Municipality, most of the settlements are located in close proximity to the roads, and possible settlement growth can also be expected in areas that are in proximity to the roads.

4.2.3. *Access to Market, Infrastructures and Services*

The level of urbanization and level of development is closely related with accessibility to market, infrastructure and services such as drinking water, electricity, education, market, health facilities. Therefore, settlements in areas facilitated with proper infrastructures tend to grow. The presence of infrastructures and services is also likely to affect the future growth pattern of a place because it enhances the thrust towards urbanization of rural-urban fringes, which eventually increase the settlement areas at their proximity.

4.2.4. *Urban Nodes*

Urban nodes are urban centres, where development activities are promoted. In these

areas, investments in urban infrastructure and services are prioritized for a planned growth. There are high possibilities of settlement growth in the vicinity of the urban nodes due to the presence of infrastructures and services.

4.2.5. *Political Scenario*

Political condition has an important role in determining the settlement growth as they determine the migration trend. Political situation in the country in the last decade influenced the migration pattern from rural areas to the district headquarters and more significantly from district headquarters to major cities for safety and security reasons. This had a negative impact in settlement growth in the region. Though political condition governs social and commercial growth attributing to the settlement growth, it is not included while modelling the growth due to complexity of modelling political situation into spatial form

Table 14 Summary of drivers of urban growth discussed in the focus group discussion in each ward

Ward	Drivers	Rank
1	Accessibility to road	1
	NEC	2
	Proposed Bir hospital	3
	Religiously significant place (Saraswatisthan)	4
	Sand mining	5
2	Proximity to Highway	1
	Market Centre	2
	KMC hospital	1
	Natural Disaster	3
	Ease of access to housing plot	3
4	Main road linking Sakhu and Changu	4
	Establishment of Susma Memorial hospital	5
	Establishment of NEC	1
	Linkage to Kathmandu city	2
	Proximity to city area	3
5	Economic opportunities	1
	Accessibility to road	2
	Population growth	4
	Accessibility to urban services-health, water supply, drainage etc	2
	Institutional Buildings	3
	Urban development projects	3
	Political situations	5
	Earthquake	4
6	Commercial centre	1
	Access to infrastructure	3
	Tourist destination	4
	Access to road	2
7	Migration	
	Establishment of hospital (Transplantation centre)	
	Grave	
	Employment opportunities	
8	Accessibility to public transportation	2
	Proximity to market centres	3
	Land value	4
	Population growth	1
	slope	5
9	Uncontrolled migration/relocation	1
	Demand of construction materials	2
	Nepal earthquake 2015	3
	Uncontrolled land and housing development	4

4.3. Urban Growth Projection

Potential area of settlement growth for the years' 2028 and 2038 were projected to forecast the scenario of growth considering the current and prevailing regulations/norms and practices the "business-as-usual scenario" model and a "controlled scenario model" considering the regulated growth. The projections modelling was done using *Markov Chain (MC)* algorithm*,* in which the state of system can be determined by knowing its previous state and the probability of transitioning from each state to each other state(Eastman 2012). Based on the earlier (2012) and later (2018) land use/cover map, influence of variables for determining future change (drivers), projection of the transitional potential into the future, the *MC* project's how much land would be expected to transition from the later date to the prediction date. The model also has the capability to include constraints and incentives for projecting land use.

4.3.1. Business as Usual Scenario

The projection of built-up area in Changunarayan Municipality is based on the probabilistic growth pattern, which relies on dominant drivers (variables) for the growth witnessed over time. Although there are different variables responsible for the growth, variables'-slope, distance from roads, urban nodes, institutions, commercial areas, market centers, cultural and archaeological sites and existing built up -were used to model settlement growth for the year 2028 and 2038, without consideration of any regulating or controlling factors such as built-up restrictions, setback and other forms of built-up byelaws.

Based on the mapping of the land use in 2012 and 2018, the total built-up area was 508.38 ha and 648.77 ha respectively, an increase of 140.39 ha (27.61%). In 2025, the total built-up area was projected to be around 867.44 ha, which is an increase of 33.70 percent (218.67 ha) from the baseline of 2018. Lower growth rate was projected for the year 2038, with projected built-up area of 1068.33 ha, i.e. 23.16 percent increase from the baseline of 2028. The *annual growth rate (AGR)* from the subsequent decade seen was 0.37 percent in the decade of 2012-2018, 0.35 percent in the decade of 2018-2028; and 0.32 percent in the decade of 2028-2038.

Table 15 Built-up projection for BAU Scenario Model

Year	Built-up (ha)	Change (ha)	Increase (%)	Annual Growth rate (%)
2012	508.38			
2018	648.77	140.39	27.61	0.37
2028	867.45	218.67	33.71	0.35
2038	1068.34	200.89	23.16	0.32

4.3.2. Controlled Scenario

Controlled scenario takes into consideration not only the dominant drivers (variables) considered in BAU scenario, but also considers variables that control or restrict the growth of settlement in certain area. The controls are the physical constraints for growth considering the factors like hazards (landslide, earthquake, floods, fire etc.), terrain slope, water body, environmental considerations, conservation and others that needs to be implemented for safe and sustainable growth of the city. These are the pertinent factors for risk sensitive land use planning and urban development. In terms of land use simulation and modelling, constraints are boolean image that do not provide space for degree of suitability (Eastman 2012). The constraints used in this study have been categorized into following types- land use restrictions, physical constraints, development constraints (constraint by-laws) and environmental constraints.

Under the controlled scenario, in 2025, the total built-up area was projected to be around 867.44 ha, which is an increase of 33.71 percent (218.67 ha) from the baseline of 2018. Lower growth rate was projected for the year 2038, with projected built-up area of 1068.35 ha, i.e. 23.16 percent increase from the baseline of 2028. The *annual growth rate (AGR)* from the subsequent decade was 0.35 percent in the decade of 2018-2028; and 0.32 percent in the decade of 2028-2038.

Table 16 Built-up projection for Controlled Scenario Model

Year	Built-up (ha)	Change (ha)	Increase (%)	Annual Growth rate (%)
2012	508.38			
2018	648.77	140.39	27.61	0.37
2028	867.44	218.67	33.71	0.35
2038	1068.35	200.90	23.16	0.32

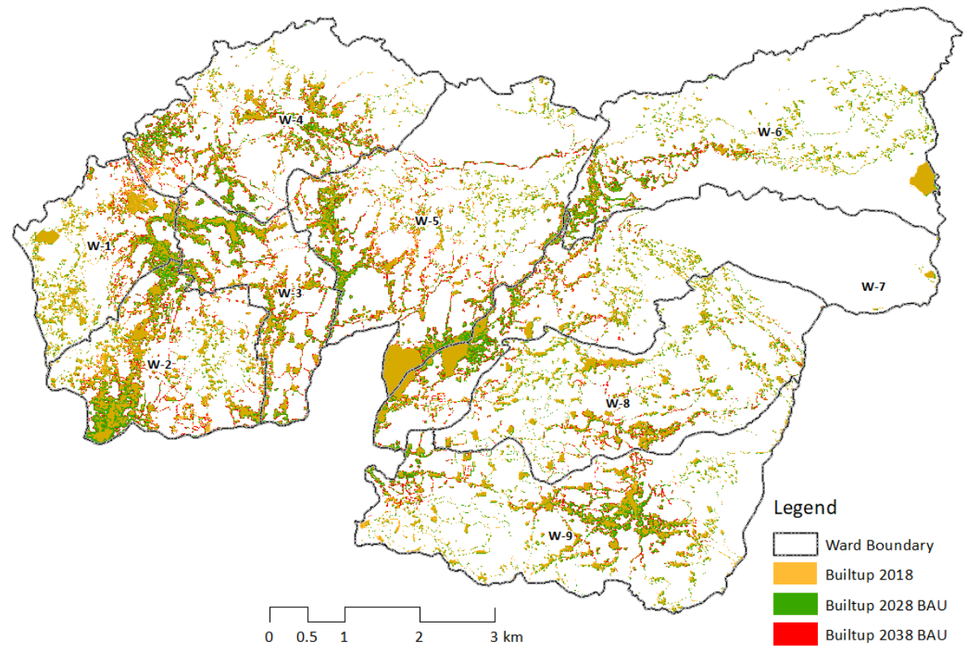


Figure 30 Built-up area projections for the year 2028 and 2038 for BAU Model

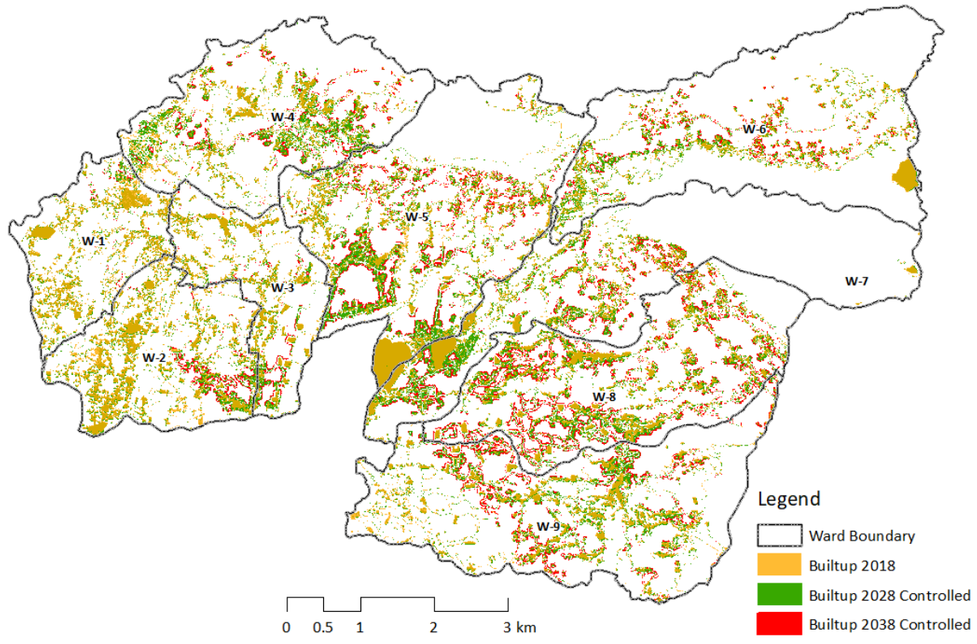


Figure 31 Built-up area projections for the year 2028 and 2038 for Controlled Scenario Model

4.4. Regional Growth Trend

Bhaktapur is one of the smallest district in Nepal with only 119 square kilometers. With the declining agricultural primacy in the district, it has been facing urban expansion in its peripheral settlements where abundant amount of prime agricultural land has been converted to the built-up area. According to National Census 2011, it has altogether 304651 population which will rise up to 436553 in 2031. With this remarkable acceleration in population, the pressure on infrastructure and services will certainly rise. Although the districts has lots of economic opportunities including tourism, agriculture and other services, it has still not been able to trap the total benefit from these sectors. In order to grab the maximum benefit from these sectors it needs to develop the infrastructure considering the local resources and environment.

4.5. Population Growth

As an urban periphery of Kathmandu valley, Changu Narayan Municipality is most likely to grow as a socio-economic hub which could attract number of people from surrounding districts. Moreover, Ward 1 and Ward 2 has been proposed as potential central business district (CBD) by different planning projects such as- JICA and KVDA. According to National Census 2001 and 2011, ward 1 and ward 2 has highest population with 5.04% and 6.87% growth rate. If the same trend continue in later decades, it is expected that the municipality will have 63997, 73888 and 8508 population[1] in 2021, 2031 and 2041 respectively.

Table 17 Population projection

Ward	Area (km2)	POP 2001	POP 2011	Growth Rate (%)	Population Density	Pop 2021	Pop 2031	Pop 2041
1	3.42	3877	5830	5.04	1704.88	9649	15967	26424
2	4.72	3871	6532	6.87	1382.82	12990	25831	51366
3	3.42	5220	5820	1.15	1703.26	6529	7325	8217
4	6.62	5858	6211	0.60	938.39	6597	7007	7442
5	9.55	7674	8129	0.59	851.43	8626	9153	9712
6	9.46	4247	4571	0.76	483.15	4934	5325	5747
7	8.78	5013	5385	0.74	613.38	5800	6247	6728
8	7.70	7053	7254	0.28	941.67	7464	7680	7902
9	9.24	5652	5698	0.08	616.94	5745	5792	5839
Total	**62.91**	**48465**	**55430**	**1.44**	**881.16**	**63997**	**73888**	**85308**

Source: National Census 2011

However, according to Municipal Profile 2017, most of the Wards in municipality have negative population growth trend (See table 3) which contradict with projected population of 2018 based on 2001 and 2011 census. The result seems controversial but could be possible because the municipality has surveyed only 88% buildings in average (ChangunarayanMunicipality 2017). Moreover, there is also the possibility of out-migration of people into other major cities for better opportunities and livelihood since most part of the municipality still have rural characteristics with limited access to infrastructure and services.

Table 18 Actual population growth and Projected population growth

Ward	POP 2011 (CBS)	POP 2018 (Municipality)	Growth Rate	Projected Pop 20182
1	5830	6101	0.66	8723
2	6532	6020	-1.12	11321
3	5820	5702	-0.29	6381
4	6211	6024	-0.43	6518
5	8129	6398	-3.04	8524
6	4571	4024	-1.71	4859
7	5385	5723	0.90	5714
8	7254	8295	2.05	7421
9	5698	6264	1.42	5735
Total	**55430**	**54551**	**-0.23**	**62184**

[1] [$P_t = P_0 * \exp^{rt}$], where P_t is latter year population, P_0 is Earlier year population , r is the rate of annual increase of population and t is the time interval.

[2] Projected Population 2018 is based on growth rate between 2001 and 2011 census population.

5. Strategic Spatial Planning

The federal restructuring has decentralized the governance and the municipalities are empowered to execute most of the government related activities. The Clause 8 of the Constitution of Nepal states that the municipalities have the power to take decision for improving the environment and socio economy of their area. They have rights to prepare and implement local level development plans and projects. Such plans will not only help to increase the economy but will also help urbanization.

Changunarayan municipality has an immense potential for rapid growth brought by urbanization. Further, it has high potential for tourism. It's location adjacent to Kathmandu and Bhaktapur municipalities also makes it a potential hub for urbanization. However, proper planning and control is required to avoid haphazard urbanization. In absence of proper planning and control, urbanization in Changunarayan Municipality can lead to higher vulnerabilities to hazards, especially seismic and landslides as well as negatively impact the environment resulting in adverse effects to the local economy.

5.1. Development Vision

The long-term development vision of the municipality is guided by its aspiration to achieve sustainable economic, social and physical growth, catalysed by guided development of urban form through land use planning. The development vision also aspires to conserve the environment and heritage as-well-as to mitigate the impacts of hazard risks through disaster risk management activities. The municipality has envisioned its long-term vision and mission as:

Vision

"उत्थानशील समुदायको निर्माणको लागी सुरक्षित बसोबास तथा एकीकृत वस्ती बिकास"

"Building Resilient Communities through Safe Settlements and Integrated Urban Development"

Mission

"विपद् जोखिम तथा वातावरणीय प्रभावलाई न्युनिकरण गर्दै योजनाबद्ध क्रमागत विकास"

"Minimizing Disaster Risk and Environmental Impacts through Planned and Integrated Development"

5.2. Guiding Principles

The guiding principles of the vision and the mission are:

- **Heritage Conservation –** Conservation and protection of UNESCO World Heritage site enlisted Changunarayan Temple and Temple Complex. Conservation and protection of traditional settlements, buildings; local culture, festivities, arts.
- **Environment Conservation –** Conservation of forests, agriculture area, urban greenery, water bodies. Sustainable use of natural resources such as soil, sand, surface water and ground water; protecting these resources from excessive and uncontrolled exploitation.
- **Safe and Integrated Development of Settlements –** Development of integrated compact settlements and provision of urban infrastructures and services in hazards risk free or low risk areas.

- **Planned Urban Development** envisioning the future urban form for achieving sustainable physical, social and economic development goals.

The future urban form and physical development of the municipality has been conceptualized and proposed based on the aforementioned guiding principles.

5.3. Strategies for Spatial Planning and their Context

Based on the development vision and the guiding principles, the strategies or Risk Sensitive Land Use Plan are proposed. These strategies were developed in consultations with ward secretaries and representatives from civil society in each ward. These strategies also takes due considerations of the guiding strategies of the National Urban Development Strategy 2017 (GoN/Ministry of Urban Development 2017).

Strategies	Spatial Context
Strategy 1: Conservation of Natural Environment and Cultural Heritage and Promotion of area as Eco-Tourism Destination	Designate ecologically sensitive region in the northern area from Changunarayan to Nagarkot as a "Conservation Zone".
	Conserve World Heritage Site Changunarayan Temple Complex and surrounding forests, settlements as "World Heritage Site Village"; to promote Local Economic Development.
	Conserve traditional settlements as "Cultural Village" to promote Local Economic Development.
	Promote touristic areas in Nagarkot as Eco-Village.
Strategy 2: Conservation and Sustainable use of Natural Resources	Designate "Agriculture Zone" to conserve prime agriculture land and arable soil and promote "urban agriculture".
	Create a "buffer zone" between settlement and natural forested areas to protect excessive extraction of forests and protect settlements from potential forest fires, wildlife.
	Designate "Green Belt" and "River Corridor" to conserver urban greenery, river networks and natural water sources.
	Control excessive extraction of construction materials (soil, sand and rocks) by designating "quarry/construction material extraction area" and strictly regulating the extraction.
	Control excessive extraction of surface and ground water through regulating the unauthorized extractions.

Strategy 3: Integrated Development of Safe Settlements	Minimize disaster risks and environmental impacts thorough designation of "compact safe settlements".
	Conserve and promote public space and neighbourhood.

5.4. Development Constraints and Opportunities

Based on the spatial context of these strategies, physical planning and subsequent zonation in the municipality is done by delineating the '*spatially constrained*' areas as restrictions for development and '*opportunities*' as '*developable areas*.'

Spatial Multi-Criteria Evaluation (MCE) is used to identify spatial constraints and opportunities. MCE is a powerful tool for decision makers to make land development process more efficient and attractive. It is "concerned with the allocation of land to suit (Eastman 2012) a specific objective on the basis of a variety of attributes that the selected areas should possess".

5.4.1. Spatial Constraints

Constraints are spatial conditions restricting the horizontal and vertical expansions of built-up area. Constrains are either physical constraints attributed due to the geo-physical conditions of the terrain, development restrictions (to be) enacted by the regulations or bye-laws and environmental constraints considered for safety and ecological conservation context. Constrains could be due to one of these factors or the combination of any of these. The constraining factors of the growth are natural hazard prone areas such as seismically hazardous areas, flood plains, liquefaction susceptible areas, landslide and erosion prone areas, fire hazard areas etc. The different constraints used in this study are presented in following sections.

Land Use Constraint

Existing land use built-up, forest, water bodies and others (mainly abandoned land, river bank, grassland, shrubs/bushes, cremation area, religious sites etc.) are not suitable for future settlement growth.Built up area is not suitable because once buildings are constructed, it remains there for long time, and there will not be enough space for settlement growth (Kumar and Biswas 2013). Forest areas are also not suitable for development as they provide habitat for floral and faunal species and various other ecosystem services, including recharge of the ground water. Water bodies are also not suitable as settlement cannot be built on water bodies or in the vicinity of rivers with potential of flood/flash floods.

Physical Constraint

Slope

Probability of occurrence of landslides and erosions are high in steep slopes, and strong engineering measures have to be taken to combat this, which can be costly. Therefore, flat areas are recommended for constructing infrastructures and housing projects (Dai, Lee, and Zhang 2001), and areas above 30^{o} slope is not suitable for settlements (Singh et al. 2014).

Development Constraint

Open space

Open space has an important role during natural disaster like earthquake because it provides emergency shelter during and after disaster. Knowing where open spaces are beforehand can save lives during disaster, and increase communities resilience to disasters as well (Manandhar and Joshi 2015). During the April 2015 earthquake, open spaces provided refuge to many people, therefore open space should be preserved, and restricted for any settlement growth.

Government of Nepal also has been emphasizing in delineating and preserving public open spaces. NUDS 2017 has set a milestone for allocating at least 2.5% of land as open space at ward level in old municipalities and 5% in new municipalities by 2031 (GoN/Ministry of Urban Development 2017).

According to Sphere Standard, the total area required for all camp functions including accommodation, cooking, hygiene, agriculture and school is 45m^2 per person. However due to lack of large open space in the municipality; the planning figure of 3.5 m^2 per person is used as it would allow space for basic hygiene and cooking functions. Using standard of 3.5 m^2 per person, the available open spaces could accommodate approximately **34,530 people** in Changunarayan Municipality area.

The selection criteria used for designating open space are:

- Only areas which are safer in terms of natural hazards are considered.
- Areas of national importance (such as helipads and army barracks) are not considered as suitable location.
- Only areas which have direct access to road will be considered.
- Only governmental areas and institutional areas with whom government could enter into an agreement are considered.

Right of way

The Right of way (ROW) is a "land corridor designed or constructed for the use of public access, vehicular traffic circulation and the location of public utilities such as pathways, roads and highways, regardless of the ownership of the land". Right of way is quite common in urban planning and management across the country. It helps to ensure mobility efficiency and desirable land use outcomes. Municipal Transport Master Plan of Nagarkot Mahamanjushree municipality and Changunarayan Municipality has been referred to assign ROW and building setbacks. Following ROW and buildings Set back has been considered in the study.

Table 5-1 Proposed ROW for different type of roads

Type of road	Total RoW (m)	Setback from road on either side (m)
Strategic road	20	1.5
Collector road (main)	14	1.5
Collector road (other)	10	1.5
Local	6	1.5

River Corridor/Water Body Buffer

Manohara and Hanumante Khola are the major rivers flowing in the municipality. To protect infrastructures from inundation and conserve the natural course of surface water, a buffer distance/set back of 100 m and 20 m has been considered from major rivers and streams respectively.

World Heritage Site/Historical/Religious/ Archaeological Sites

There are several historical, religious and cultural sites in the municipality. Among them, Changunarayan Temple is listed in UNESCO World Heritage Site. These sites should be preserved as culture assets as well as for local economic activities including tourism. A setback of 20 m is considered from the historical, religious, archaeological and world heritage sites for settlement expansion.

Industrial area

There are not any major industries, however there are some small-scale industries, therefore a setback of 20 m has been considered from the industrial area.

Transmission line

There are high voltage transmission lines passing through human settlement and agriculture land in the municipality. Area below and within 9 m of the transmission lines are considered to be unsafe for settlement as there are high chances of fire hazard. Nepal electricity regulation has proposed a setback of 9 m from transmission line of 132 KV.

Security Force

Building constructions are prohibited near the security force's barracks due to security issues; therefore a setback of 100 m has been considered from such areas.

Environmental constraints

Ecological sensitive areas

Forest and wetlands are ecological sensitive areas as it is habitat for floral and faunal species, therefore such areas should be preserved. Planning Norms and Standard (DUDBC 2015), has proposed a setback of 20 m from these sensitive areas for settlement development. It prescribes protection of 'Urban forests' and has stipulated "no permanent construction within the forest area shall be allowed and there will be buffer area".

Hazard Prone Areas

Hazard prone areas are areas that are prone to natural hazards. Flood prone areas, areas vulnerable to seismic activity, liquefaction, and areas with possibility of mass movement and erosion due to geomorphic and hydrological causes are considered as hazard prone areas. Therefore, areas that are highly vulnerable to hazard are not suitable for settlement areas.

Fault line

To reduce casualties and property losses during earthquake, active fault should be avoided. Zhang (2012) recommends a setback of 100 m from the active fault areas for settlements, which have incidence of historical earthquakes of more than 7 magnitude. This was based on report of Construction and Planning agency of Taiwan, 1998.

5.4.2. Spatial Multi-Criteria Evaluation for Constraints and Opportunities

A Spatial Multi-Criteria Evaluation (SMCE) approach was adopted to assess spatial criteria which includes constraints and factors (or opportunities that influences the growth). For suitability analysis nine constraints and seven factors were identified. The constraints discussed in Section 5.4.1 were used as the constraints for performing SMCE. The constraints were subcategorized, and suitable areas were given value of [1], whereas unsuitable areas were given value of [0]. The factors were subcategorized and weights (degree of suitability) were given to the sub categories of each factor. The factors and weights assigned to their subcategories are defined hereunder.

Slope

Flat areas are recommended for constructing infrastructures and housing projects (Dai, Lee, and Zhang 2001), and areas above 30 degree slope is not suitable for housing projects (Singh et al. 2014). However, in mountainous terrain area, it is hard to find flat areas; therefore, slopes less than 10 degree are considered as highly suitable for settlement area.

Table 2 Degree of suitability of slope

Slope (in degree)	Weight/value	Degree of Suitability
< 10	9	High
10-20	6	Moderate
20-30	3	Low
>30	0	Unsuitable

Distance to Existing Roads

Areas that are near to existing roads are highly suitable for settlement areas as it reduces traveling time and cost (Jain and Subbaiah 2007). Distance of 1,000-1,500 m from the existing road is acceptable distance as the walking time is around 15 to 20 minutes, however, shorter distance from existing road is preferred. Following weights were assigned to subcategories of distance to existing road.

Table 3 Degree of suitability of distance to existing roads

Distance to existing road (m)	Weight/value	Degree of Suitability
0-500	9	High
500-1000	6	Moderate
1000-1500	3	Low
>1500	0	Unsuitable

Distance to Existing Settlements

People prefer to stay near existing settlements for several reasons such as social bonding, security etc., therefore, areas that are near to existing settlement are highly suitable compared to areas that are far. Distance of 1,000-1,500 m from the existing settlement is acceptable distance (Ekanayaka 2014), however, shorter distance is preferred. Following weights were assigned to subcategories of distance to existing settlement.

Table 4 Degree of suitability of distance to existing settlements

Distance to existing settlement (m)	Weight/value	Degree of Suitability
0-500	9	High
500-1000	6	Moderate
1000-1500	3	Low
>1500	0	Unsuitable

Distance to Existing Commercial Areas

Closeness to commercial areas such as market centres, weekly market, department store or local shopping street also influences the preferences for settlement areas. People prefer to stay near commercial areas because of the easy access to local markets for daily needs, therefore, areas that are near to commercial areas are deemed suitable compared to areas that are far from commercial areas (Ekanayaka 2014). Distance of 1,000-1,500 m from the existing settlement is acceptable distance, however, shorter distance is better. Following weights were assigned to subcategories of distance to existing commercial area.

Table 5 Degree of suitability of distance to existing commercial areas

Distance to existing settlement (m)	Weight/value	Degree of Suitability
0-500	9	High
500-1000	6	Moderate
1000-1500	3	Low
>1500	0	Unsuitable

Distance to Existing Urban Nodes

Urban nodes are urban centres where development activities are promoted. In these areas, investments in urban infrastructure and services are prioritized for a planned growth. There are high possibilities of settlement growth in the vicinity of the urban nodes. Therefore, areas within 1000 m are highly suitable for settlement development. Following weights were assigned to subcategories of distance to urban node.***Error! Reference source not found.***

Table 6 Degree of suitability of distance to existing urban nodes

Distance to urban node (m)	Weight/value	Degree of Suitability
0-1000	9	High
1000-2000	6	Moderate
2000-3000	3	Low
>3000	0	Unsuitable

Distance to Existing Institutional Areas

People prefer to stay near institutions areas for several reasons, therefore, areas that are near to existing institutional areas are highly suitable compared to areas that are far. Distance of 1,000-1,500 m from the existing institutional areas is acceptable distance. Following weights were assigned to subcategories of distance to subcategories of existing institutional areas.

Table 7 Degree of suitability of distance to existing institutional area

Distance to existing institutional area (m)	Weight/value	Degree of Suitability
0-500	9	High
500-1000	6	Moderate
1000-1500	3	Low
>1500	3	Unsuitable

Distance to Cultural and Heritage Sites

In Hindu culture, people worship different gods. They worship gods in home at the family shrine or at the local temple. Some people go to temples daily to worship gods. During different festivals also, people visit different temples. Not only Hindus, people of other religion also visit holy shrines like monasteries, church. Therefore, people prefer to stay near the cultural area. Distance of 1,000-1,500 m from the cultural areas is acceptable distance. Following weights were assigned to subcategories of distance to cultural areas.

Table 8 Degree of suitability of distance to existing cultural sites

Distance to cultural area (m)	Weight/Value	Degree of Suitability
0-500	9	High
500- 1000	6	Moderate
1000-1500	3	Low
>1500	0	Not suitable

5.4.3. Assigning Weightage

Analytical Hierarchy Process (AHP) method (Saaty 1987), was used to determine the weight of each factor and check the consistency of the weight. AHP is a "theory of measurement through pairwise comparisons and relies on the judgement of experts to derive priority scales" (Saaty 2008). Comparisons are made using a scale of absolute judgement that represents how much one element dominates another with respect to a given attribute. There are possibilities for the judgement to be inconsistent. AHP helps to check such inconsistency and improve judgement (Saaty 2008).

Pairwise matrix was created based on the importance of each factor over another, and consistency ratio (CR)[1] was used to check the consistency of judgements. Since CR was acceptable, following weights were assigned to each factor: distance to road [0.2584], distance to settlement [0.1500], slope [0.409], distance to commercial area [0.0869], distance to urban node [0.0488], distance to institutional area [0.0285] and distance to cultural area [0.0184].

[1] To check the consistency of the judgement or comparison made, consistency ratio (CR) was calculated. If CR is greater than 10% i.e. > 0.10, then the weighted result indicates the presence of inconsistencies in the pairwise comparison matrix. If CR is less than 10%, then comparison is considered acceptable, and the eigenvector obtained for each factor can be used to assign weight to it. Here, the CR was 0.10. This shows there was consistency in the judgement and the eigenvector obtained for each factor can be used to assign weights to each factors.

5.4.4. *Weighted Linear Combination*

Weighted linear combination (WLC), one of the most commonly used multi-criteria decision analysis tool, was used to identify the suitable areas. In WLC, suitability (S) is identified by applying weight to each factor followed by summation of the result i.e. standardized factor map is multiplied by its factor weight, and the result is then summed. If constraint is applied, the suitability obtained from the factors is multiplied by the constraint to get the suitability map (Eastman 2012).

$$S = (\sum W_i X_i) \times C_j$$

where, Wi = Weight of factor i; Xi = Criterion score of factor i; Cj = Criterion score of constraint j

5.4.5. *Suitable Settlement Areas*

Suitable areas for settlement development or *Developable Areas (बस्न योग्य क्षेत्र/वस्ती विकास योग्य क्षेत्र)* are delineated using Spatial Multi Criteria Evaluation (SMCE) analysis of the aforementioned constraints. Using SMCE analysis, about 1145.96 ha of land was found highly suitable for settlement area, whereas 25.88 ha was moderately suitable, and 5099.82 ha was not suitable for settlement area in the municipal region. The details of suitable land for built-up area in different wards are presented in the table below and shown in ***Error! Reference source not found.***.

Table 9 Suitable areas for settlement in different wards

Ward	Unsuitable (ha)	Moderate (ha)	High (ha)	Total (ha)
1	329.72	0.00	9.95	339.66
2	437.92	0.00	33.17	471.09
3	310.71	0.00	30.46	341.17
4	525.94	1.39	131.30	658.62
5	751.88	0.00	200.42	952.30
6	758.57	18.08	166.09	942.74
7	744.02	0.00	132.50	876.52
8	493.15	1.82	274.93	769.90
9	747.92	4.59	167.14	919.65
Total	5099.82	25.88	1145.96	6271.67

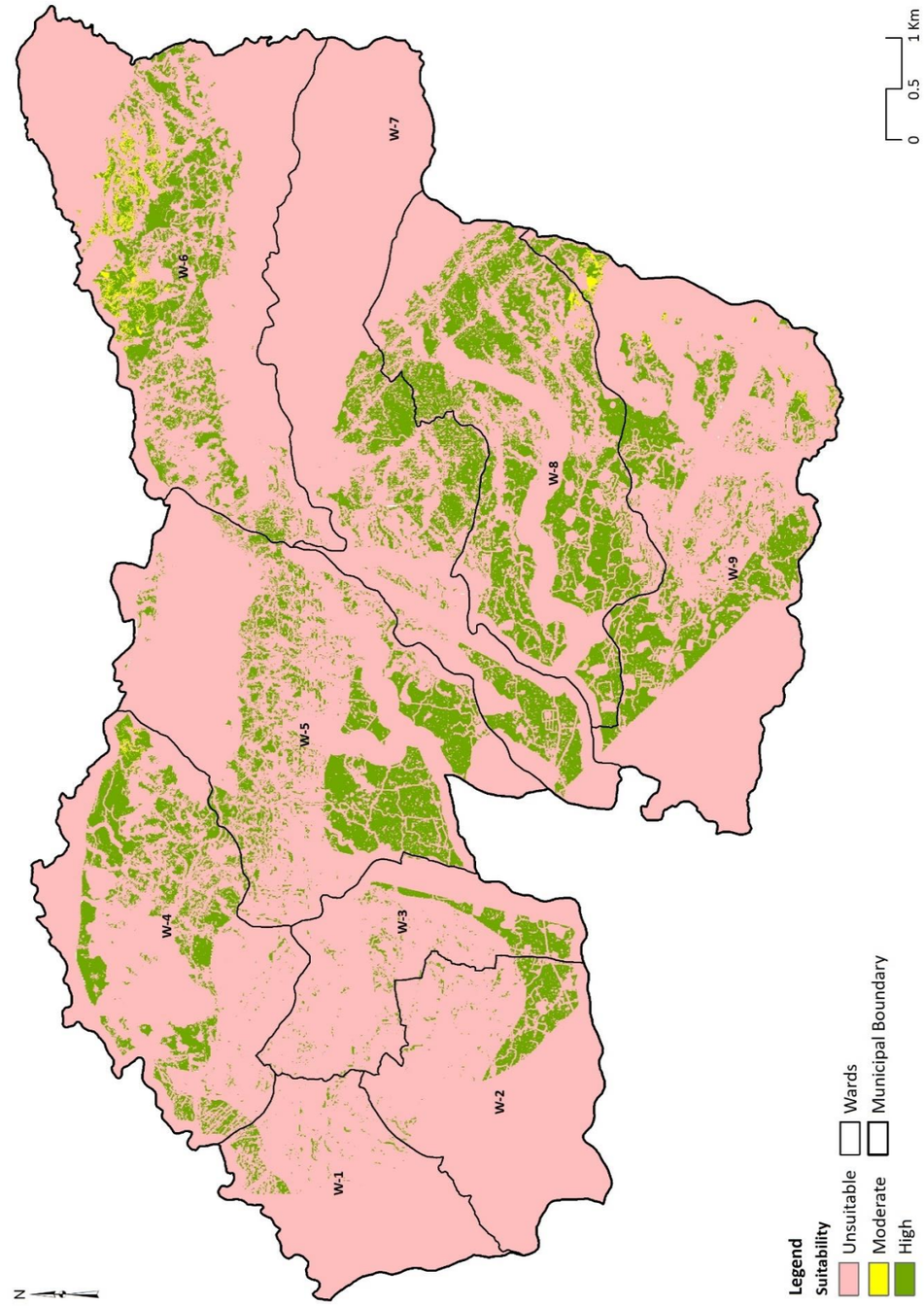


Figure 32 Suitable areas for settlement - 'Developable Area'

6. Risk Sensitive Land Use Plan for Changunarayan Municipality

6.1. Proposed Urban Form

Translating 'Strategies for Spatial Planning and their Context' into spatial form with due considerations of the 'Spatial Constraints and Opportunities', the envisioned '*Urban Form*' of Changunarayan Municipality is proposed as the following *'Physical Planning Zones'*.

6.1.1. Conservation Zone (संरक्षण क्षेत्र)

"Conservation Zone" is designated to protect and conserve UNESCO World Heritage Site, forests and greenery, watershed areas of surface and underground water sources and other natural resources.

- Northern region in the municipality above 1400 m elevation, densely forested area and area containing the UNESCO World Heritage Site is designated as the Conservation Zone covering an area of 20.6 km^2.
- The main objective of the Conservation Zone is to conserve natural form of the environmental sensitive area allowing regulated minimum density development of settlements and basic infrastructures.
- Conservation Zone is located in the norther region of the municipality in wards 4, 5, 6 7 and 8, covered by forested areas at higher elevation zone (above 1400m MSL).
- This region is also the watershed area for Manohara, Kashyang Khusung and Hanumante rivers of the region as well as ground water recharge area of entire Bhaktapur region.
- Existing settlements and potential Developable Area in Ward 4 within the Conservation Zone is proposed to be designated as "***World Heritage Site Village (विश्व सम्पदा क्षेत्र गाँउ)"*** with planned Traditional Settlement development, exhibiting its unique identity.
- Existing settlements and potential Developable Area in Ward 5 within the Conservation Zone is proposed to be designated as ***"Cultural Village (सांस्कृतिक गाँउ)"*** with the development of planned Traditional Settlement to promote local culture, art, craftsmanship etc. and to promote activities related to these.
- Existing settlements and potential Developable Area in Ward 6 within the Conservation Zone is proposed to be designated as ***"Eco Village (पर्यावरणीय गाँउ)"*** with the development of planned Traditional Settlement to conserve environment and ecology.
- Protect and conserve dense forest and green areas within the Conservation Zone.
- Establishment of Tertiary Node ***(तेस्रो तहको विकास केन्द्र)*** around existing tourist destination and market area in Nagarkot Ward 6 within the Conservation Zone to extend tourism businesses including hotels, restaurants, café, tourist information and service centre, bus park. Taxi park and other tourism related services. Promotion of eco-friendly tourism infrastructures and services in the designated Tertiary Node.
- Establishment of ward level Service Node ***(वडा स्तरको विकास केन्द्र)*** in Ward 6 around Gairigaun area for planned development of medium density (50-100 pph) settlement and provision of basic urban infrastructures and services.

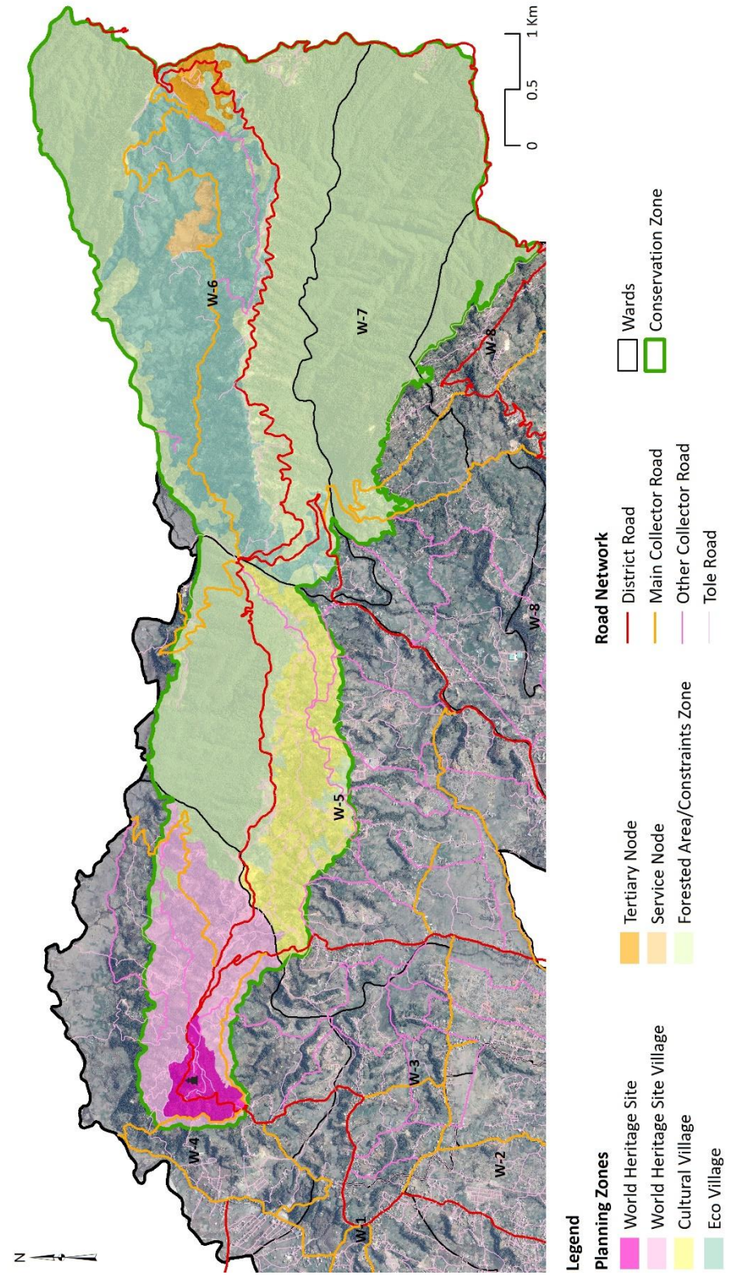


Figure 33 Conservation Zone and its Sub-Zones

Proposed land use regulations in the Conservation Zone and its Sub-zones are as under:

SN	Land Use Zones/Sub-Zones	Regulations
1	Conservation Zone (संरक्षण क्षेत्र) (Total Area: 2,060.46 Ha)	**Physical Form** ▪ Primarily open hilly landform (terrain), natural conservation, heritage conservation, agriculture land preservation ▪ Guided and planned development in designated 'Development Nodes' **Land Use** ▪ Land uses based on designated sub-zones ▪ Strict prohibition on any land use practices that can potentially impact the natural environment, culture and heritage **Built Density** ▪ Built density based on designated sub-zones
1.1	World Heritage Site (विश्व सम्पदा क्षेत्र) (Total Area: 34.74 Ha)	**Physical Form** ▪ UNESCO World Heritage Site Changunarayan Temple, Temple Complex, settlement in Changunarayan Town and surrounding forested area to be protected and conserved to retain in their existing forms **Land Use** ▪ Retain existing land use of low density settlement town and forested area surrounding Changunarayan Temple Complex, traditional agriculture land. ▪ Low density commercial activities, touristic services and facilities, home stay ▪ Strict prohibition on any land use practices that can potentially impact the UNESCO World Heritage Site **Built Density** ▪ Maintain up to 10 pph (gross density) in the old settlement
1.2	World Heritage Site Village (विश्व सम्पदा क्षेत्र गाँउ) (Total Area: 185.29 Ha)	**Physical Form** ▪ UNESCO World Heritage Site Changunarayan Temple, Temple Complex and surrounding forested area to be protected and conserved to retain in their existing forms ▪ To be designated as "World Heritage Site Village (विश्व सम्पदा क्षेत्र गाँउ)", promotion and place branding of the World Heritage Site Village, promotion of compatible land use activities **Land Use** ▪ Low density residential, home-stay facilities, commercial services/facilities for daily consumables, small markets ▪ Open natural area, public area, traditional agriculture land ▪ Various environmentally friendly usages related to vital facilities for religious and touristic services ▪ Public Use and Open Space Zone – Designated Humanitarian Open Space for emergency disaster risk management
		▪ Strict prohibition on any land use practices that can potentially impact the natural environment, culture and heritage **Built Density** ▪ Up to 50 pph (gross density) in Developable Area
1.3	Cultural Village (सांस्कृतिक गाँउ) (Total Area: 160.5 Ha)	**Physical Form** ▪ Forested area to be protected and conserved to retain its existing form and improve upon its condition ▪ Development of planned Traditional Settlement and promotion as a "Cultural Village" in developable area with provision of urban services and amenities ▪ Promotion of compatible land use activities with the concept of Cultural Village **Land Use** ▪ Low density residential, home-stay facilities, commercial services/facilities for daily consumables, small markets ▪ Open natural area, public area, traditional agriculture land ▪ Various environmentally friendly usages related to vital facilities for touristic services ▪ Promotion of activities related to small-scale industries, activities related to training and trade of arts, artisan related to the cultural heritage of the municipal area and Bhaktapur region ▪ Public Use and Open Space Zone – Designated Humanitarian Open Space for emergency disaster risk management ▪ Strict prohibition on any land use practices that can potentially impact the natural environment, culture and heritage **Built Density** ▪ Up to 50 pph (gross density) in Developable Area
1.4	Eco Village (पर्यावरणीय गाँउ) (Total Area: 371.5 Ha)	**Physical Form** ▪ Forested area to be protected and conserved to retain its existing form and improve upon its condition ▪ Development of planned Traditional Settlement with promotions of eco-friendly activities to develop and promote "Eco Village" in developable area with provision of urban services and amenities ▪ Promotion of compatible land use activities with the concept of Eco Village **Land Use** ▪ Low density residential, home-stay facilities, commercial services/facilities for daily consumables, small markets ▪ Open natural area, public area ▪ Various environmentally friendly usages related to vital facilities for touristic services ▪ Promotion of Horticulture (commercial fruit production) by identifying suitable fruits and locations ▪ Public Use and Open Space Zone – Designated Humanitarian Open Space for emergency disaster risk management

		▪ Strict prohibition on any land use practices that can potentially impact the natural environment, culture and heritage **Built Density** ▪ Up to 50 pph (gross density) in Developable Area
1.5	Development Nodes (वस्ती विकास केन्द्र) Total Area: 36.5 Ha)	▪ Two Development Nodes are proposed within the Conservation Zone. *(Regulation Clause 3.4)*

6.1.2. Agriculture Buffer Zone (कृषि बफर क्षेत्र)

"Agriculture Buffer Zone" is designated to protect and conserve fertile soil and prime agriculture land in the municipal area. Agriculture Buffer Zone is located especially in the high and medium risk areas due to soil properties and location along the river flood plain. Agriculture Buffer Zone is located in traditionally cultivated lower terraces, areas along the river flood plain and areas undergoing regular erosion.

- Agriculture Buffer Zone provides buffer area between existing traditional and unplanned settlements, newly proposed developable areas and Conservation Zone in order.
- Agriculture Buffer Zone is designated to prevent and mitigate the adverse impacts on environment, natural landscape and public health due to excessive extraction of soil from the prime agriculture land for production of bricks.
- Agriculture Buffer Zone is designated for the promotion of commercial agriculture, commercial fish farming (pisciculture), commercial cattle (cow, buffalo, goat) for dairy and meat production, commercial vegetable farming, commercial fruit farming, commercial cut flowers and floriculture with an aim to enhance the local economy through sustainable commercial agriculture.
- Agriculture Buffer Zone is designated to promote environmentally friendly small and medium scale agro-based industries for processing, storage and distribution to support commercialization of the agriculture sector.
- Agriculture Buffer Zone is designated in high and medium hazard risk zones, therefore strict adherence to Structural Building Code and safe construction practices should be made mandatory for any infrastructure, industries and other structures.
- Densification of existing settlements through strictly regulated development and safe building practices to control further spread and sprawl of unmanaged settlements.
- Control excessive excavation of soil and building materials through gradual displacement of existing brick kilns from the municipal area.

Proposed land use regulations in the Agriculture Buffer Zone are as under:

SN	Land Use Zones/Sub-Zones	Regulations
2	Agriculture Buffer Zone (कृषि बफर क्षेत्र) (Total Area: Ha)	**Physical Form** ▪ Primarily open agriculture land ▪ Infrastructure for commercial agriculture (green house/tunnel, small and medium scale industries for agriculture product processing, storage and distribution.
		Land Use ▪ Commercial agriculture-based usages ▪ Existing settlements and buildings ▪ Strict prohibition/displacement of any land use practices that can potentially impact the natural environment **Built Density** ▪ Low-density up to 10 pph (gross density)

6.1.3. Natural Resources Management Zone - Natural Corridor (प्राकृतिक श्रोत व्यवस्थापन क्षेत्र-प्राकृतिक कोरिडोर)

Natural Resources Management Zone (Natural Corridor) is designated to forested area, green area, rivers/streams/canals, ponds, riverbank corridor in the municipal area. This zone will be protected as a special natural conservation zone.

Forest Area (वन क्षेत्र)

Forested areas cover about 20.5 percent (1,287 ha) of the municipal region. Natural forests are located in Nagarkot, Bageshwori, Telkot, Changunarayan and Tathali Pipalbot area. Major tree species in these forests are Khari, Thulo Phalant, Dudhilo, Musure Katus, Chilaune, Uttis, Kattus, Kaffal, Salla are the major species present in the area. These forests hold religious values as well as are vital for surface and ground water sources in the entire region. There are around twenty community forests in the municipal region where the communities manage and protect their forests. However, there is increasing trend of encroachment and conversion of forested land. To protect the forested areas, 20 m setback from the forest boundary is recommended for any development activities in designated development nodes. This also helps to mitigate the risk of forest fire and its potential spread into the settlement area.

Physical Form
- Forested area to be protected and conserved to retain its existing form and improve upon its condition

Land Use
- Primarily maintain as natural forest
- Various environmentally friendly activities for recreation such as picnic, forest tour/walk
- Traditionally practiced religious activities restricting any activities impacting the environment and the forests
- Construction of temporary structures for tourism, recreational and religious activities purposes only, using eco-friendly construction materials. Strict regulations and permits by the municipal authority necessary for any such constructions.
- Restrictions of construction of any permanent structures using modern construction materials (cement, concrete, steel, bricks etc.)
- Use of forests for harvesting of Medicinal and Aromatic Plants (जदीवुटी), forest nursery
- Strict prohibition on any other land use practices that can potentially impact the natural forests

Built Density
- Residential and commercial development strictly prohibited
- Regulated development of eco-friendly facilities, structures for recreational, tourism and religious activities only.

Green Belt (हरित क्षेत्र)

Natural vegetation covers about 11 percent of the municipal area. Vegetation growing naturally along the rivers and streams, slopes of hillocks, in the periphery of settlements and farmlands as well as in public and private lands. These natural vegetation areas or corridors are zoned as Green Belt. Conservation of these vegetated areas in the public land is very important to maintain the natural aesthetics of the municipal area as well as to create a barrier from floods, erosion and landslide in the region. To protect these vegetated areas, 20m buffer setback is recommended for any form of development in designated areas.

Physical Form
- Natural vegetated Green Belt/Corridor in public land to be protected and maintained

Land Use
- Primarily maintain as natural vegetated green belt
- Various environmentally friendly activities for recreation such as picnic, park
- Traditionally practiced religious activities restricting any activities impacting the environment and the forests
- Strict prohibition on any other land use practices that can potentially impact the natural forests

Built Density
- Residential and commercial development strictly prohibited in public land

River Corridor (खोला कोरिडोर)

Corridor area within high flood levels of naturally flowing rivers and streams are designated as River Corridor. Areas within 100m buffer region from the high flood level of the major rivers and 20m buffer region from the high flood level of streams are designated as River Corridor.

Physical Form
- Natural vegetation and open area within the river corridor

Land Use
- Primarily maintain as natural vegetated or open area, agriculture area
- High flood level of river, frequently flooding area
- Strict prohibition on any other land use practices that can potentially impact the natural flow of river/stream and its ecology

Built Density
- Residential, commercial and industrial development strictly prohibited in corridor area

6.1.4. Development Nodes (विकास केन्द्र)

Development Nodes are *'urban centres'* where planned urban development activities are promoted through investments in urban services and physical infrastructures which catalyses planned growth. Development nodes are hierarchically categorized as primary, secondary, tertiary and ward level service nodes based on their designated functions. These development nodes are spatially planned at the most suitable location based on these criteria:

- strategically located near existing urban centres
- multi-nuclei development/growth nodes
- suitability of location based on multi-hazard risk sensitivity, availability or land and land natural resources
- compact and balanced settlements/development suitable for different functions exhibiting unique identity
- transit oriented primary and secondary nodes (, pedestrian oriented tertiary and service nodes (walkable radius of 250-1000m)

Functional characteristics of development nodes in Changunarayan Municipality are defined hereunder.

Primary Node (प्रथम तहको विकास केन्द्र)

Primary Nodes is the Financial and Business Hub (Central Business District - CBD) in the municipal region and contains mainly of financial, commercial, tourism and hospitality, entertainment, retail businesses; corporate, private, multi-national offices. Primary Node also consists of high density residential along with public and social amenities and urban infrastructures.

In Changunarayan Municipality, Primary Node is spatially planned in the southern part of Ward 5, in the east of Byasi-Changunarayan Road located in the region of Pakaune Pati, Kalikatar, Gaindagaun and Gundigaun (पकाउने पाटी, कालीकातार, गैंडागाँउ, गुण्डी गाँउ). The designated Primary Node is at a distance of 3 km from the centre of Bhaktapur City and spatially located at the centre of the municipal region, accessible and well-connected from all the wards.

This Primary Node can be promoted and developed as a tourist hub with hotels and other touristic services to cater for the tourists arriving in Bhaktapur. Alternative cycle route can provide an eco-friendly alternative connecting Bhaktapur to this node. This node can also be developed as the main commercial centre of the district. This node can be extended up to Nagarkot Road in the east as a Primary Node Extension. Proposed Outer Ring Road connects the Primary Node with the extension area. Planning norms for the Primary Node is proposed as under:

Physical Form
- Modern Central Business District with urban amenities
- Accessible from all the location of the municipality, good connectivity to surrounding, good internal vehicular mobility and pedestrian friendly
- Eco-friendly green zones and public spaces
- Total area about 100 Ha (about 1960 Ropani)[1] and total are of Extended Primary Node is about 43 Ha (840 Ropani)
- Radius of Primary Node: 950 m, radius of Extended Primary Node: 600 m
- Land uses – Mixed Land Use Zoning with high density residential

Land Use
- Commercial - Banks and Financial Institutions, Commercial Building, Hotel and Lodges, Retail Shops, Cinema and Theatre, Corporate Offices, other Tourism Services, Bus Park, Taxi Park, applied services related to tourism sector

[1] 1 Ropani = 5,476 sq.ft = 508.72 m^2

- Residential - High Density Residential and Apartments
- Public Use and Open Space – Open Public Space, Parks, Green Space and Gardens
- Public Use and Open Space – Designated Humanitarian Open Space for emergency disaster risk management
- Strict prohibition on any land use practices that can potentially impact the natural environment

Built Density
- High density with maximum of 300 pph (gross density)

Secondary Node (दोस्रो तहको विकास केन्द्र)

Secondary Node is proposed to be developed as the municipality's main administrative and institutional zone. Governmental institutions, education institutions, health services and other public infrastructures, various line agencies and institutions, vocation and technical training infrastructures are proposed in this secondary administrative node.

In Changunarayan Municipality, Secondary Node is spatially planned in the southern part of Ward 7, along the east of Army Camp-Nagarkot Road, crossed by Manjushree Road (District Road) and located in the region of Nayabasti and Bansbari (नयाँ वस्ती तथा बाँसबारी). The designated Secondary Node is at a distance of 1.5 km from the Primary Node and is accessible and well-connected from all the wards. Planning norms for the Secondary Node is proposed as under:

Physical Form
- Main Administrative and Institution Center with urban amenities
- Accessible from all the location of the municipality, good connectivity to surrounding, good internal vehicular mobility and pedestrian friendly
- Eco-friendly green zones and public spaces
- Total area about 60 Ha (about 1180 Ropani)
- Radius of Secondary Node: 500 m
- Land uses – Mixed Land Use Zoning with medium density residential

Land Use
- Public Use and Open Space – Governmental Agencies, Municipality Office, Administrative Offices, City Hall, Public Service Offices, Hospital and Health Services, Security and Emergency Response Agencies, Educational Institutions, technical and Vocational Education Institutions etc.
- Residential - Medium Density Residential and Apartments
- Public Use and Open Space - Open Public Space, Parks, Green Space and Gardens
- Public Use and Open Space– Designated Humanitarian Open Space for emergency disaster risk management
- Strict prohibition on any land use practices that can potentially impact the natural environment

Built Density
- Medium density with maximum of 200 pph (gross density)

Tertiary Node (तेस्रो तहको विकास केन्द्र)

Tertiary Nodes are proposed for ward level services and other specialized services/infrastructures for tourism sector, religious and cultural activities, agriculture extension, sports and entertainment activities. Tertiary Nodes also consists of planned compact settlement with access to basic urban infrastructures.

In Changunarayan Municipality, ten Tertiary Nodes are proposed in developable areas of Wards 2,6,7,8 and 9 covering total area of 418 Ha. These Tertiary Nodes have specialized functions and are planned accordingly. Following Tertiary Nodes are proposed:

Tourism Village (पर्यटकिय गाँउ) - Ward 6 Nagarkot

Existing tourism area in Ward 6 of Nagarkot, within the designated "Conservation Zone" is proposed to be developed as a "Tourism Village" to enhance tourism based economic activity of Nagarkot area in a planned and sustainable manner.

Physical Form
- Tourist Village as a main tourism hub with access to urban services, planned settlement, market centre and tourism services
- Promotion and development of "Eco-Friendly" tourism infrastructures and services
- Total area about 21 Ha (about 413 Ropani)
- Radius of Secondary Node: 300 m
- Land uses – Mixed Land Use Zoning with medium density residential

Land Use
- Residential - Medium Density Residential Buildings,
- Commercial - Tourism Services such as Hotels, Lodges/Bread and Breakfast, Restaurants, Café, Pubs, other tourism related services,
- Commercial - Banking and Financial Services, Money Exchange, Commercial and retail shops for daily consumptions
- Public Use and Open Space – Bus Park, Taxi Park, Open Spaces and Public Parks and other tourism related services
- Public Use and Open Space – Designated Humanitarian Open Space for emergency disaster risk management
- Strict prohibition on any land use practices that can potentially impact the natural environment

Built Density
- Medium density with maximum of 200 pph (gross density)

Eco-Tourism Village (पर्यावरणिय पर्यटन गाँउ) - Ward 6 Nagarkot

Developable areas in wards 7 and 8 in and around Banphedi, Majuwa, Padali, Habeli, Chareli, Lapro, Sunuwargaun, Adhikargaun, Kalamasi villages (वनफेदी, मजुवा, पदाली, हबेली, चरेली, लाप्रो, सुनुवारगाँउ, अधिकारीगाँउ, कलामसी) are proposed to be developed as low density ecofriendly "Eco-Tourism Village" to promote homestay for tourists and also to promote coffee and fruit plantations.

Physical Form
- Traditional settlements and open spaces to be protected and conserved to retain their existing forms
- Development of planned Traditional Settlement with promotions of eco-friendly activities to develop and promote "Eco-Tourism Village" in developable area with provision of basic urban services and amenities
- Promotion of compatible land use activities with the concept of Eco Tourism Village

Land Use
- Residential - Low density residential, home-stay facilities,

- Commercial - services/facilities for daily consumables, small markets
- Open natural area, public area
- Public Use and Open Space– Designated Humanitarian Open Space for emergency disaster risk management
- Promotion of Horticulture (commercial fruit production) by identifying suitable fruits, coffee plantations

Strict prohibition on any land use practices that can potentially impact the natural environment

Built Density
- Up to 50 pph (gross density) in Developable Area

Residential Areas (आवासिय क्षेत्र) - Ward 2, 7, 8, 9

Areas for safer future urban growth are designated in developable areas in wards 2, 7, 8 and 9 in the municipality. These designated Tertiary Nodes - Residential Areas

Physical Form
- Planned medium density settlement development with access to basic urban infrastructure and amenities in "Developable Areas" of wards 2, 7 8 and 9
- Ward level market and land uses/functions associated/required for market centre
- Eco-friendly development, green zones and public spaces
- Total area about 335Ha (about 6,575 Ropani)
- Land uses – Mixed Land Use Zoning with medium density residential

Map Index No	Ward	Area (Ha)	Area (Ropani)
3	8	40	785.00
4	7,8	52	1,020.00
5	7,8	42	822.00
7	8	71	1,394.00
8	8,9	49	958.00
9	8	20	397.00
15	6	21	416.00
20	2	40	783.00
	Total	**335**	**6,575.00**

Land Use
- Mixed Residential Commercial - Medium Density Residential Buildings, Daily consumable commercial services
- Public Use – Primary School, Health Center, Disaster management Center etc.
- Public Use and Open Space - Open Public Space, Parks, Green Space and Gardens
- Public Use and Open Space– Designated Humanitarian Open Space for emergency disaster risk management
- Strict prohibition on any land use practices that can potentially impact the environment

Built Density
- Medium density with maximum of 200 pph (gross density)

Ward Level Service nodes (वडा स्तरको विकास केन्द्र)

The primary function of Ward Level Services Nodes is to provide ward levels basic services to the population leaving in the vicinity.

Physical Form
- Planned medium density "compact-settlement" development with access to basic urban infrastructure and amenities in "Developable Areas"
- Ward level market and land uses/functions associated/required for market centre
- Eco-friendly development, green zones and public spaces
- Total area about 77 Ha (about 1,513 Ropani)
- Land uses – Mixed Land Use Zoning with medium density residential

Land Use
- Mixed Residential Commercial - Medium Density Residential Buildings, Daily consumable commercial services
- Public Use – Primary School, Health Center, Agriculture Extension Services etc.
- Public Use and Open Space - Open Public Space, Park etc.
- Strict prohibition on any land use practices that can potentially impact the environment

Built Density
- Medium density with maximum of 50-100 pph (gross density)

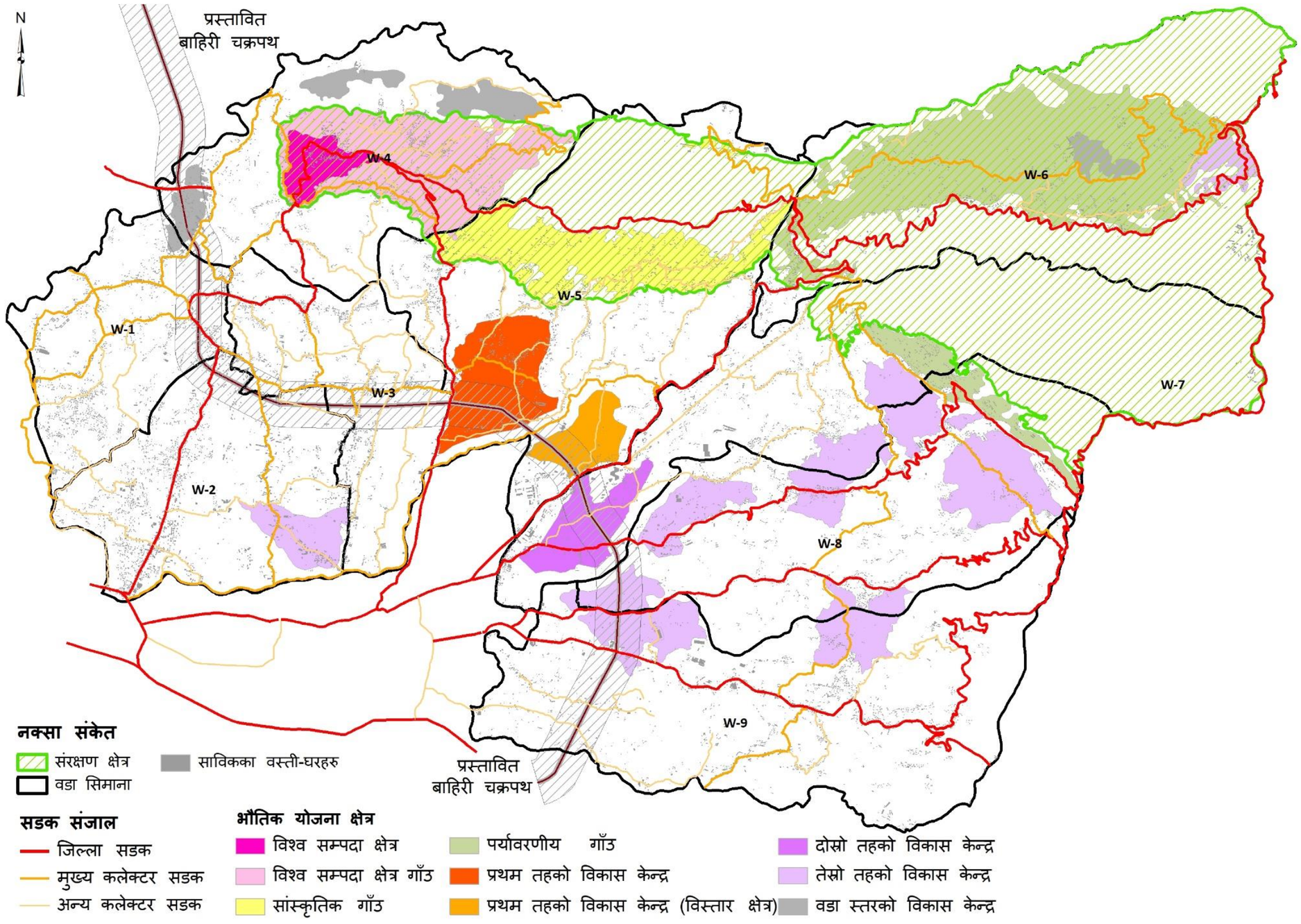


Figure 34 Proposed RSLUP Land Use Zones

6.2. Regulations for RSLUP

6.2.1. Land Uses

Land use categories are defined under the National Land Use Policy 2069 (GoN 2012) and revised under Nepal Gazette Part 65, 14 Ashoj 2072 Revision to the Land Act 2021, Land Categorization and Land Use Program Implementation. Under this act, the land use categories recommended are as under:

Land Use Zones	Descriptions
Agriculture Zone (A)	Agricultural Land may be defined broadly as land used primarily for production of food and fibre. Agricultural zoning is generally used by communities that are concerned about maintaining the economic viability of their agricultural industry. Agricultural zoning typically limits the density of development and non-farm uses of the land are restricted. The density is controlled by setting a large minimum lot size for a residential structure. Densities may vary depending upon the type of agricultural operation. By agricultural zoning, farming communities can be protected from becoming fragmented by residential development. Agriculture zone provides both market and non-market benefits to society e.g., crop production and open space.
Residential Zone (R)	Residential zone is intended for residential uses with high concentration of residential activities. The Residential land use designations provide for housing and other land uses that are integral to, and supportive of, a residential environment. Housing may take many forms ranging in density and scale from detached homes to high-rise apartment structures. To provide opportunities for the development of a broad range of residential uses that will satisfy housing requirements, and to provide for compatibility issues to be suitably addressed, different categories of residential land use have been identified. Areas designated Low Density Residential (Traditional and Modern Residential); Medium Density Residential (Paying Accommodations and care centres); and, High Density Residential (Group Housing and Apartments).A residential zone provides a supply of residential land that is sufficient to accommodate the anticipated demand for broad range of new dwelling types over the planning period. It also supports the provision of a choice of dwelling types according to location, size, affordability, tenure, design, and accessibility so that the broad range of housing requirement are satisfied. Within the residential zone building with architecturally and/or historically are encouraged for preservation and maintenance.
Mixed Zone (M)	Mixed use zone is the area in any municipality or VDCs where a single building blends a combination of residential, commercial, cultural, institutional or industrial uses; where those functions are physically and functionally integrated. Many part of Kathmandu Valley is predominantly mixed use.
Commercial Zone (C)	A commercial zone is any part of a city or town in which the primary land use is commercial activities. These activities include the buying and selling of goods and services in retail businesses, wholesale buying and selling, financial establishments, and wide variety of services that are broadly classified as "business". Commercial zone in a city can take up about 5% of a city's land. Even though these commercial activities use only a small amount of land, they are extremely important to a community's economy. They provide jobs and bring money into the community. Depending upon the nature of business, it could be neighbourhood commercial (C1), small (C2), medium (C3) and large (C4) commercial congregational units or hazardous and polluting commercial units (C5). A convenient commercial zone encourages the growth of residential population in new development areas.
Industrial Zone (I)	In order to recognize the needs of existing and future industry and to address concerns over land use compatibility, industrial land uses are separated into six categories: Household Industries (I1), Service Industries (I2), Small (I3), Medium (I4), and Large industries (I5) and Hazardous/Heavy Industries (I6). These categories are differentiated on the basis of the range of main permitted uses or industrial processes, the potential impacts of such uses or processes would have on adjacent areas, and the scale and intensity of development allowed. The intent of this categorization is to group industrial uses so as to maximize their compatibility and minimize any negative impacts on nearby residential or other sensitive land uses.
Forest (F)	This zone encloses all areas covered by Forests, shrubs, bushes, grasses and uncultivated areas. Forest zoning limits development that could conflict with forestry practices. It keeps forest lands from being divided into small plots for purposes other than forestry. Forest has to be preserved and shall be developed into eco parks without disturbing the natural features. These areas shall not be changed to any other land uses and should be retained as it is.
Public Utilities (PU)	The purpose of this zone is to provide for a system or works that is used to provide for public consumption, benefit, convenience or use such as water supply, sewage disposal, public transportation, irrigation, drainage, fuel, electric power, heat, waste management, and telecommunications and open spaces including Humanitarian Open Spaces for emergency evacuation and staging. The property on which the public utility facility is located shall be appropriately buffered or screened with fencing or landscaping to screen it from neighbouring zone or within a particular zone. Such screening and buffering shall be approved by concerned authority and such plan shall be submitted prior to the construction or installation of any such facility by a public utility. In case of new developments, these shall remain as non-buildable areas and remain as reservations and marked for the purpose intended. They may be considered for calculation of open spaces within the schemes while approving building/development and layout plans
Mines and Minerals (MM)	Mine and Minerals zone is designated for special areas with the existing/potential mines and minerals excavations/explorations, petroleum, natural gas, precious metals, gems and gemstones, rare earth minerals etc. that can be extracted from the earth's surface
Constructions Materials and Quarry (CQ)	Construction Materials and Quarry are designated for the areas with availability of constructions materials such as stone, stone aggregates, sand, sandstone, limestone, slate etc. used in construction industry

Cultural and Archaeological Zone (CA)	Cultural and Archaeological Zone is designated to the area with cultural, religious, historical and archaeological significance to various communities in the country. These include areas/sites designated under World Heritage; place of worship and religious activities for various religions; place of cultural identify, functions and activities; historic monuments, palaces, buildings, courtyards, forts/fortress etc.; archaeological sites, monuments, buildings etc.
Rivers and Water Bodies (R)	River and Water Bodies include rivers, streams, rivulets and other perennial/non-perennial flowing water sources. Water bodies are inland hydrological features such as lake, pond, etc. including fish pond, religious pond/lake, glacier lake
Hazard Zone (H)	Hazard zones are regions with existing hazards or susceptible to various geological, hydro-meteorological, environmental, anthropogenic and other hazards. These hazards may include hazards such as earthquake, landslide and erosions, flood, glacier lake out flow, dam burst, environment degradation, fire, lightening and industrial accidents, act of terror and war and others that can cause loss of life and properties, impact in economy, cultural and heritage and human wellbeing at the individual, household, community, regional and national and global levels
Other Zones	Other zones are designated areas as necessary besides the aforementioned zones.

These land use categories can be further sub-divided to adapt to the urban land use categories needed in various regions of the country. However, the basic definition must be in compliance with the above definitions by the Land Use Policy.

6.2.2. Land Parcels

Cadastral land parcels are the smallest unit of the land use planning and is the basis for implementation of RSLUP on the ground. Under the RSLUP implementation framework, individual cadastral land parcels are designated the above defined 'colour zone' based on its suitability and hazard risk with defined 'land use' class such that each parcels are categorized as defined land use zones.

The colour zone and the designated land use zone is reflected in the landownership and thus regulated under various planning programs.

Map of colour zones and designated land use zones at the land parcel levels are presented in

6.3. Regulations for Suitability Zones (Colour Zones)

Colour Zones reflect the suitability of land for development based on the availability of risks and constraint free non-built up area. Each colour zones is regulated by specific policies or bye laws to **Avoid** or **Contro**l or **Promote** uses based on the risks and constraints as mentioned below.

6.3.1. Red Zone (AVOID)

- Restrictions in any development of built-up and/or infrastructure
- Existing settlements, built-up and individual houses to be resettled in safer places
- Conservation of forestry and protection of landscape to be promoted
- Retaining of existing agriculture land and promotion of increasing agriculture productivity
- Hazardous land acquisition by government and provide alternative location
- Revealing the information to the owner related to hazards in their property

6.3.2. Orange Zone (AVOID)

- Restrictions in any development of built-up and settlements
- Limited use of lands for construction of hazard-resilient structures following stringent construction codes and practices
- Approval of the municipality and the related agency (DUDBC) required for any construction of infrastructure
- Existing settlements, built-up and individual houses to be resettled in safer places
- Conservation of forestry and protection of landscape to be promoted
- Creating of buffer zone of 15-20m from the forested area
- Retaining of existing agriculture land and promotion of increasing agriculture productivity
- Hazardous land acquisition by government and provide alternative location
- Revealing the information to the owner related to hazards in their property

6.3.3. Yellow Zone (CONTROL)

- All new construction shall conform to the new building bye-laws and the building code
- Retrofitting for strengthening identified structurally vulnerable building stocks
- Provision of emergency services and access
- No land fragmentation lesser than 3 aana[1] in core areas of wards 3,4 and 7 of the municipality, 4 aana in other areas of the municipality for residential sub-zone
- Identification/Allocation of humanitarian open spaces and staging areas along with alternative strategic and evacuation routes
- Restrict high rises and high occupancy residential and commercial buildings
- Creating of buffer zone of 15m from the forested area
- Planned development of residential zones with supporting infrastructures and services
- Promote medium density built-up through organized housing and land pooling
- Affordable housing scheme for low to middle income household

6.3.4. Green Zone (PROMOTE)

- Promote low density residential area development with necessary infrastructure and services

[1] 1 aana = 31.81 sq. m, 1 aana = 342.25 sq. ft

- Planned and regulated development through organized housing and land pooling scheme
- Promote urban greenery retaining/conserving existing vegetation, back garden, home orchards
- Affordable housing scheme for low to middle income household
- Subsidies/incentives for agriculture use
- No land fragmentation lesser than 4 aana
- Promotion of new mixed residential commercial zones, bus park, intuitional zone
- Identification/Allocation of humanitarian open spaces and staging areas along with alternative strategic and evacuation routes in every wards

6.4. Regulations for Land Parcels

Land parcels within above land use zones should be maintained with minimum area and frontage for various purposes as prescribed hereunder:

- Residential plot should have minimum size of 95 sq.m (0-3-0-0) in the Residential Subzone and 254 sq.m (0-8-0-0) in the Rural Settlement (Potential Development Subzone)
- Residential plot in other areas, should have minimum size of 50 sq.m (0-1-2-1) in the hilly region with minimum of 7 m of the frontage length.
- For residential land parcels being used through generations in the core commercial areas, conservation zones, above regulation may not be applicable. Similarly, for residential land parcels in other areas acquired through ancestral inheritance, the above regulation may not be applicable.
- However, land parcels should not be fragmented/divided smaller than 50 sq.m.
- Following regulations should be implemented for land parcel floor area ratio and ground coverage for residential plots

Table 10 Minimum land parcel requirements for residential

Residential Land Parcel Area (sq.m)	Maximum Ground Coverage (%)	Maximum Height (m)
50-150	90	10 m in Commercial Subzone, as defined in Conservation Subzone, defined by FAR in other subzones
150-250	75	
250-500	60	
> 500	50	

- Group housing should have minimum size of plots 1000 sq.m (1-15-1-3) with maximum ground coverage of 50 percent and maximum FAR of 2.
- For non-residential plots regulations should follow the bye-law provisions

6.5. Regulations for Open Spaces and Evacuation Route

Forty Two (42) open spaces were identified in the municipal region as Humanitarian Open Space (HOS) and Humanitarian Staging Area to accommodate estimated 34,530 population, based on minimum required area of 3.5 m^2/person including area for basic hygiene (WASH) and cooking.

- Land parcels for open spaces should be specially and specifically designated with proper signage showing the location and access route with estimated accommodating population
- Constructions of building(s) for emergency and essential services to allow humanitarian purposes is allowable in the designated open space for shelter, humanitarian storages and supplies, evacuation and support materials, WASH facilities etc. with strict safety considerations and building code.
- Access way to these open spaces must be specifically defined and their right of way strictly enforced.
- Open spaces allowable to be used as community spaces

Humanitarian Open Spaces are analysed and presented separately in Chapter 7.

6.6. Development Control Regulations in Hazard Prone Areas

Development regulations in the designated hazard prone areas needs special provisions and special enforcement/enactment regulations. Following regulatory mechanisms is proposed to be considered strictly in hazard prone areas.

I. General Requirements for Development	
Requirements of Site	No land shall be used as a site for the construction of building: ▪ If the site is found to be/designated as susceptible to liquefaction by the municipal authority under the certain earthquake intensity in the area, except where appropriate protection measures are taken. ▪ If the municipal authority finds that the proposed development falls in the area liable to landslides or erosion, except where protection measures are adopted to prevent any form/mechanism of landslide
Requirements of Site Plan	▪ In hilly terrain, the site plan should include location of land slide prone areas, if any, on or near the site, detected during reconnaissance. The municipal authority in such case shall cause to ensure that the site is away from such land slide prone areas. ▪ The site plan on a sloping site may also include proposals for diversion of the natural flow of water coming from uphill side of the building away from the foundation.
II. Provisions in Building Regulations/ Bye-laws for Structural Safety in Hazard Prone Areas	
Structural Design	All the construction should conform to the provision made under National building code. ▪ For general safety ▪ For windstorm protection ▪ For earthquake protection ▪ For protection of landslide hazard
III Regulations for Land Use Zoning for Hazard Prone Areas	
Land Use Zoning	▪ The objective of land use zoning is to regulate land use in hazard prone areas to minimize the damage caused to the habitat, as a result of natural hazards viz. earthquakes, cyclonic storms and floods which recur from time to time. Land Use Zoning, therefore, also aims at determining the locations and the extent of areas likely to be adversely affected by the hazards of different intensities and frequencies, and to develop such areas in a manner that the loss to the development is reduced to the minimum. ▪ Land Use Zoning envisages certain restrictions on the indiscriminate development of the "unprotected" hazard prone areas and to specify

	conditions for safer development by protecting the area from severe losses. In the former case, boundaries of different zones are to be established to prevent unrestricted growth there. ▪ Another objective of Land Use Zoning in the hill areas will be to ensure the forest cover and to preserve the green areas for environment protection.
Earthquake Prone Area Designation	▪ Intensities of VII or more on Modified Mercalli Intensity (MMI) scale are considered moderate to high. Therefore, all areas in these three zones will be considered prone to earthquake hazards. ▪ In these zones the areas which have soil conditions and the level of water table favourable for liquefaction or settlements under earthquake vibrations will have greater risk to buildings and structures which will be of special consideration under Land Use Zoning. ▪ Under these zones, those hilly areas which are identified to have poor slope stability conditions and where landslides could be triggered by earthquake or where due to prior saturated conditions, mud flow could be initiated by earthquakes and where avalanches could be triggered by earthquake will be specially risk prone. ▪ Whereas, earthquake hazard prone areas identified have to be determined specifically for the planning area under consideration through special studies to be carried out by geologists and geo-technical engineers. ▪ If an active fault trace is identified by Geological Survey, a structure for human occupancy should not be placed over the fault trace and must be set back by a minimum of 15 m on either side of fault trace.
Improving Resistant of Sites to Earthquake	▪ In those areas where there are no dangers of soil liquefaction or settlements or landslides, all building structures and infrastructures should be designed using the relevant Indian Standards as provided in the Building Regulations and the National Building Code ▪ Soils subjected to liquefaction potential under earthquake shaking can be improved by compaction to desired relative densities, so as to prevent the possibility of liquefaction. ▪ Buildings and structures could be founded on deep bearing piles going to non-liquefiable dense layers. ▪ Steep slopes can be made more stable by terracing and construction of retaining walls and breast walls, and by ensuring good drainage of water so that the saturation of the hill-slope is avoided. ▪ Any other appropriate engineering intervention to save the building structures or infrastructure from the fury of the earthquake. ***Note:*** *The protective action given under (ii) to (v) will usually involve large amount of costs and should only be considered in the case of large and costly structures. For ordinary buildings the cost of improvement of the site will usually be uneconomical, hence bad sites should be excluded by Land Use Zoning.*
Landslide Prone Areas	▪ Besides the existing landslide areas in slopes (dormant or active), other landslides can be triggered due to earthquake tremors or under conditions of heavy intensity rains, cutting and filling during construction of roads and infrastructures etc. ▪ Whereas, the landslide prone areas are to be identified on the available maps other areas have to be identified through local field survey and study of the landslide susceptibility of the planning area.
Planning in Hilly Areas	In order to ensure environmentally sound development of hill settlements, the following restrictions and conditions may be proposed for future activities. ▪ An integrated development plan should be prepared taking into consideration environmental and other relevant factors including ecologically sensitive areas, hazard prone areas, drainage channels, steep slopes and fertile land. ▪ Water bodies including underground water bodies in water scares areas should be protected. ▪ Where cutting of hill slope in an area causes ecological damage and slope instability in adjacent areas, such cuttings shall not be undertaken unless appropriate measures are taken to avoid or prevent such damages. ▪ No construction should be ordinarily undertaken in areas having slope above 30^0 or areas which fall in landslide hazard zones or areas falling on the spring line sand first order streams identified on the basis of available scientific evidence. ▪ Construction may be permitted in areas with slope between 10º to 30º or spring recharge areas or old landslide zones with such restrictions as the competent authority may decide.

7. Open Space and Evacuation Routing

7.1. Public Open Spaces

Altogether 49 open spaces were identified in municipality which includes, playground of school and colleges, football ground, open spaces inside military area, parking area, compound of government buildings and community open spaces. It also includes the Humanitarian open space identified by IOM, Nepal in Tapa Dumfo area of Ward 7. Most of these open spaces have primary access from paved or graveled road while few of them have secondary access from earthen road, foot-trails and stairs. Due to possibility of security issue 4 open spaces around/inside military area were considered unsuitable for emergency evacuation. Rather they were proposed as Stock-Piling area/ Staging area.

Figure 35 Open Spaces: a) Playground of Sunrise Boarding School, b) Open Space in Pipalbot, c) Nuldum Open Space and d) Existing IDP site in Lamatol, Nagarkot

7.2. Humanitarian Open Spaces (HOS)

The remaining 45 open spaces were overlaid with landslide hazard map to identify open spaces in high hazard area. It was found that 3 open spaces were located in high landslide prone zone. Therefore only 42 open spaces were considered as Humanitarian Open Spaces (HOS) that could be used as collection site, distribution site, Camp site, Humanitarian Co-ordination area, logistics area and vulnerable population assistance area according to their size, location and accessibility.

7.3. Access and Evacuation Route

To determine the travel time for a person to reach the nearest HOS, an average walking speed of 5km/hr was used based on the average walking speed of old and young people. Average walking speed of old people, above 60 years, is 4.5 km/hr, while of young people is 5.5 km/hr (Aspelin 2005). Network analysis was used to select the shortest path from settlements to HOS.

For the vehicular mode, the major roads such as- Main Collector Road, District road and Other Collector road were assigned with the speed of 40km/hr whereas local road such as Main Tole Road and Other Tole Road were assigned with 20km/hr.

In the municipality area, only 132 settlements have access to HOS within 30-minute walking distance. Remaining 12 settlements (Bkhrigaun, Nagarkot, Phedigaun, Paudeldada, Tallo Saudol, Chundevi, Nayabasti, Phuyalgaun, Dulalgaun, Karkigaun, Dandagaun and Timalsina tole) could not access the HOS within 30 minutes. The overall capacity of Open Space was determined from Sphere standard, with 3.5 m^2 per person for covered living and basic WASH function.

Table 11 Name of Settlement served by HOS within 30 minute walking distance

Name of HOS	Name of Settlement Served
Besigaun Open Space-1	Besigaun2
Football Ground-7	Damaigaun, Sunuwargaunn, Chareli, Habeli, Padali, Majuwa
FSCN-3	Gelalgaun, Nyaupanegaun
Ground of Janakpur Engineering College-9	Taikabu, Ngyabu, Ratopati
KMC Parking Area-2	Budathoki tole,Gakhu2,Fasintar,Phaidhoka2,Khatri tole,Gakhu1
Lamatol Open Space-6	Santi dada, Lamatol, Lamadada, Lamagaunn, Gairigaunn
Naag Thali Open Space-5	Gairapati,Bansghari,Ghumaune,Kuslamtar,Kaflegaunn,Pagaritol,Bhusundol,Bhajubhairav,Dahalgaun,Dobhane,Kharipati
Nawangal Open Space-4	Magan Tole ,Nawangalgaun
Nuldum Open Space-7	Nuldum
Om Santi Kendra_Park-5	Thapagaunn
Open Space-1	Somathali, Rokagaun
Open Space-2	Rashya Dol, Dobu Phant,Tripura Sundari, Tyatta Tole, Mahankal Chwok, Khadka Tole

Open Space-3	Milli, Kasula Tole, Thapagaunn, Lukundol
Open Space-4	Kapahiti,Halchap1
Open Space-7	Kalchagaun, Kaplegaun, Banphedi
Open Space-8	Tallo Nepalgaun, Purigaun, Nepalgaun
Open Space (3-4 ropanis)-3	Kotali,Dhimalgaun,Dahalgaunn1
Open Space of Mahadev Pokhari-7	Mahadev Pokhari
Open Space of Oldage Home-9	Piple, Bhetasi, Pipal bot
Open Space of Police Station-4	Pokhrelgaun, Mijal tole,Budathokigaun,Chhapdanda,Pauwa,Changunarayan,Chhap,Gurunggaunn,Khoregaun,Tatgal
Open Space of Shree Pancha Mahalaxmi Temple	Deurali Bhanjyang, Chayabasti
Playground of Shree Kalika Secondary School-6	Bastolagaun
Playground of Golden Sungava school-2	Dandipakha, Thado Dhunga, KMC chowk
Playground of Mitrashree School-2	Shakhal Basti, Pragya tole
Playground of NEC-4	Besigaunn1,Magargaun,Gamphedi,Sanchukcha
Playground of Phaidhoka School-9	Masandol,Phaidhoka1,Yangdol
Playground of Shining English boarding School-5	Gundigaun, Pakaune Pati, Gaindagaun, Kalikatar, Chhaling, Pikhel,Milan Tole, Tyattalgaunn
Playground of Shree Ganesh Madhyamik Bidhyalaya-9	Raut Tol, Sudal, Ghorsahi, Jitpur
Playground of Shree Kalika Basic School-8	Kalamasi, Adhikarigaun, Lapro
Playground of Shree Mahakali Madhyamik Bidhyalaya	Gadgade, Batase Dada, Lamidada
Sangdaha Open Space-4	Narayntar,Halchap2,Dhunganagaun,Sangdaha2,Sangdaha1
Saraswotikhel Open Space-1	ThapaTole, Saraswoti Khel
Saudol Open Space-9	Mathilo Saudol, Katritol, Halalgaun
SchoolGround-5	Dihigaunn,Gokulgaunn,Khatrigaunn,Tamanggaunn2,Karkigaunn1,Rahulgaunn,Mulakot,Tamanggaunn1
United Preparatory English School-3	Jhaukhel, Jagriti Chwok, Lakilagaun, Thekurigaun, Kolpakot, Duwakot

Table 12 Summary of HOS in Changunarayan Municipality

Number of HOS	42
Number of Settlement Served (30 minute)	132
Available open space (m^2)	120,855.45
Overall capacity (number of people @3.5m^2 per person)	34,530
Population demand (Shelter seeking population)	54,551

The time required for people of different settlements to reach nearest open space ranged from less than a minute to 32 minutes by walking. Similarly, the routing result of HOS to Staging area shows that the time required for four-wheeler to reach the nearest staging area from HOS ranges from 6 min to 150 min. And, the fire brigade which is located in Bhaktapur Municipality would take less than 3 min to 29 minutes to reach the HOS. The travel time for reach routing results are presented in Annex 3 and the maps in Annex 4.

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Annexes

Annex 1 Geotechnical Investigation in Changunarayan Municipality

Annex 2 SWOT Analysis for Risk Sensitive Land Use Planning

Annex 3 Humanitarian Open Space Time travel Analysis

Annex 4 Humanitarian Open Space Evacuation Maps

Annex 5 RSLUP Planning Zone Maps (in large scale A1 size)

Photo 2 Pit Sampling for lab tests of soil.

Photo 1 Sandy silt soil present at Duwakot, Changunarayan Municipality

Results of the lab test of soil samples from different locations within the Changunarayan Municipality

SN	Sample ID	Northing	Easting	Location
1	L1	27° 42 51.69”	85° 24’ 47.48”	Gamphedi, Ward 4
2	L2	27° 42 22.62”	85° 24’ 51.68”	Besigaun, Ward 1
3	L3	27° 41 12.23”	85° 24’ 37.63”	Duwakot, Ward 2
4	L4	27° 42 01.88”	85° 26’ 49.91”	Thapagaun, Ward 5

EMES Pvt. Ltd.

P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 7.12.2018
Sample No. L1
Standard : AASHTO T 88 - 81

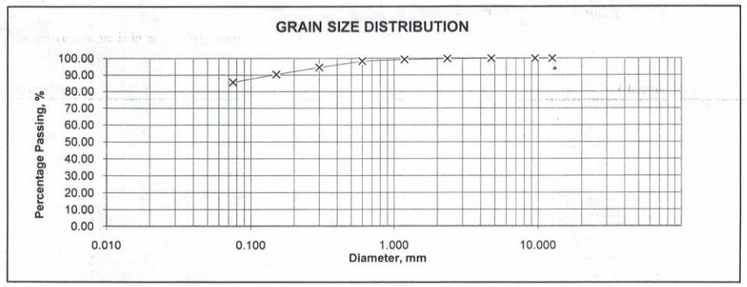
SIEVE ANALYSIS

WET	DRY

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Original Test Mass	767.1 gms	Riffled sample (< 4.75mm)		gms
Passing 4.75mm (# 4)	gms	Factor		

Test Sieve Sizes mm	Mass Retained Riffled Sam. gm.	Mass Retained Tot. Sam gm.	Cumu. Mass. Retained gm.	Cumulative Retained %	Total Passing %	SPECIFICATION LIMIT
50						
37.5						
25						
19.5						
12.5		0.0	0.0	0.00	100.00	
9.5		0.0	0.0	0.00	100.00	
4.75		0.0	0.0	0.00	100.00	
2.36		2.0	2.0	0.26	99.74	
1.18		4.2	6.2	0.81	99.19	
0.600		7.0	13.2	1.72	98.28	
0.300		28.3	41.5	5.41	94.59	
0.150		32.2	73.7	9.61	90.39	
0.075		36.7	110.4	14.39	85.61	
PAN		656.6	767.0	99.99		
Total		767.0				



Remarks:

The above sample is in ML (Silt) group as per ASTM soil classification

EMES Pvt. Ltd.

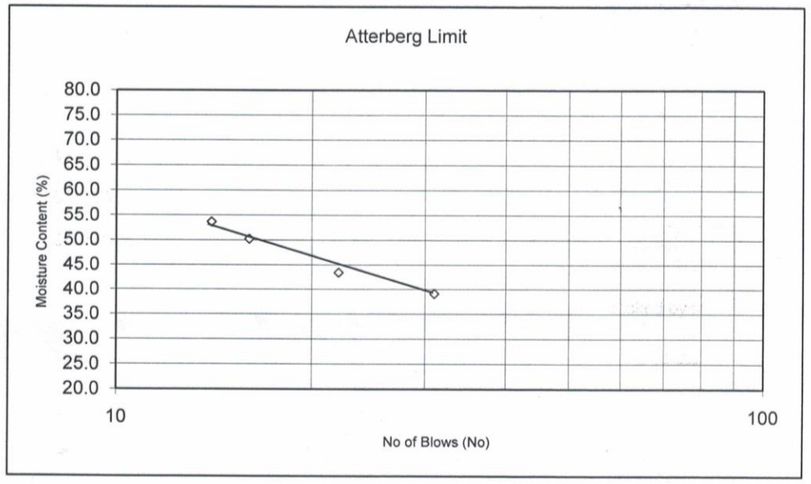
P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 9.12.2018
Sample No. L1
Standard : AASHTO T 89 - 81 & T 90 - 81

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Atterberg Limit Test Results

Number of blows	14	16	22	31
Water content %	53.71	50.26	43.42	39.11



LIQUID LIMIT(LL) = 42 %

PLASTIC LIMIT(PL) = NP %

PLASTICITY INDEX (PI) = NP %

Tested by :

Checked by :

EMES Pvt. Ltd.

P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

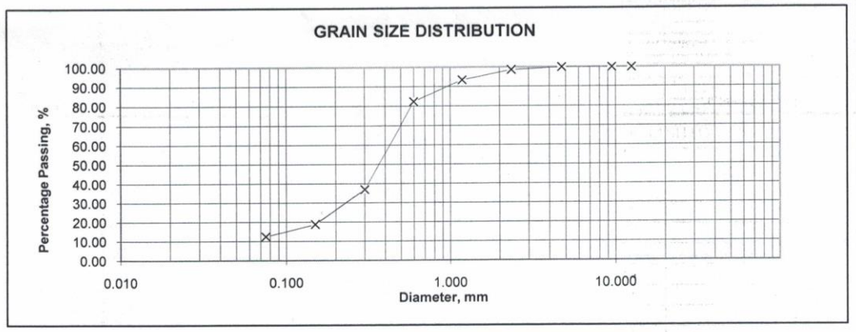
Date : 7.12.2018
Sample No. L2
Standard : AASHTO T 88 - 81

SIEVE ANALYSIS
WET | **DRY**

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Original Test Mass	**883.6**	**gms**	**Riffled sample (< 4.75mm)**	**gms**
Passing 4.75mm (# 4)		**gms**	**Factor**	

Test Sieve Sizes mm	Mass Retained Riffled Sam. gm.	Mass Retained Tot. Sam gm.	Cumu. Mass. Retained gm.	Cumulative Retained %	Total Passing %	SPECIFICATION LIMIT
50						
37.5						
25						
19.5						
12.5		0.0	0.0	0.00	100.00	
9.5		0.0	0.0	0.00	100.00	
4.75		0.0	0.0	0.00	100.00	
2.36		12.5	12.5	1.41	98.59	
1.18		45.7	58.2	6.59	93.41	
0.600		97.3	155.5	17.60	82.40	
0.300		401.2	556.7	63.00	37.00	
0.150		160.8	717.5	81.20	18.80	
0.075		56.1	773.6	87.55	12.45	
PAN		124.3	897.9	101.62		
Total		897.9				



Remarks:

The above sample is in ML (Sandy silt) group as per ASTM soil classification

EMES Pvt. Ltd.

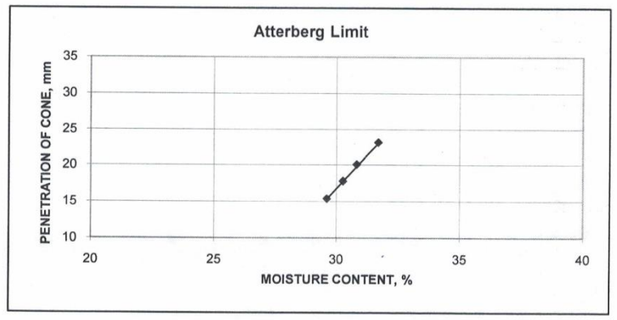
P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 9.12.2018
Sample No. L2
Standard : BS 1377 : 1975,Test 2 (A) & Test 3

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Atterberg Limit Test Results

Moisture Content %	29.61	30.27	30.82	31.71
Penetration of cone mm	15.4	17.8	20.10	23.2



LIQUID LIMIT %(LL) = 31

PLASTIC LIMIT % (PI) = NP

PLASTICITY INDEX (PI) = NP

Tested by:

Checked by:

EMES Pvt. Ltd.

P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 7.12.2018
Sample No. L3
Standard : AASHTO T 88 - 81

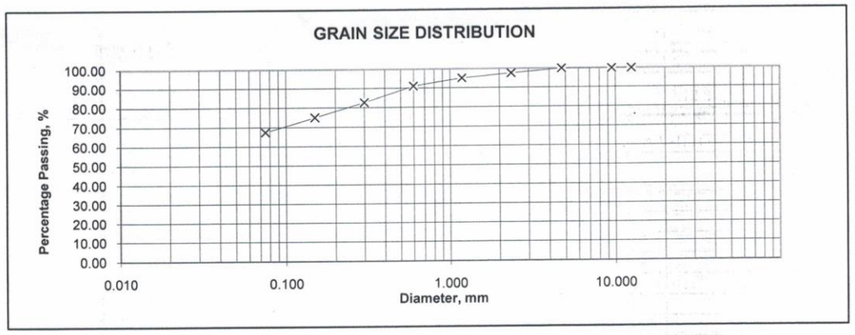
SIEVE ANALYSIS

WET	DRY

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Original Test Mass	**1175.7 gms**	**Riffled sample (< 4.75mm)**	**gms**
Passing 4.75mm (# 4)	**gms**	**Factor**	

Test Sieve Sizes mm	Mass Retained Riffled Sam. gm.	Mass Retained Tot. Sam gm.	Cumu. Mass. Retained gm.	Cumulative Retained %	Total Passing %	SPECIFICATION LIMIT
50						
37.5						
25						
19.5						
12.5		0.0	0.0	0.00	100.00	
9.5		0.0	0.0	0.00	100.00	
4.75		0.0	0.0	0.00	100.00	
2.36		28.9	28.9	2.46	97.54	
1.18		27.6	56.5	4.81	95.19	
0.600		49.5	106.0	9.02	90.98	
0.300		99.4	205.4	17.47	82.53	
0.150		89.5	294.9	25.08	74.92	
0.075		87.2	382.1	32.50	67.50	
PAN		793.4	1175.5	99.98		
Total		1175.5				



Remarks:

The above sample is in ML (Sandy silt) group as per ASTM soil classification

EMES Pvt. Ltd.

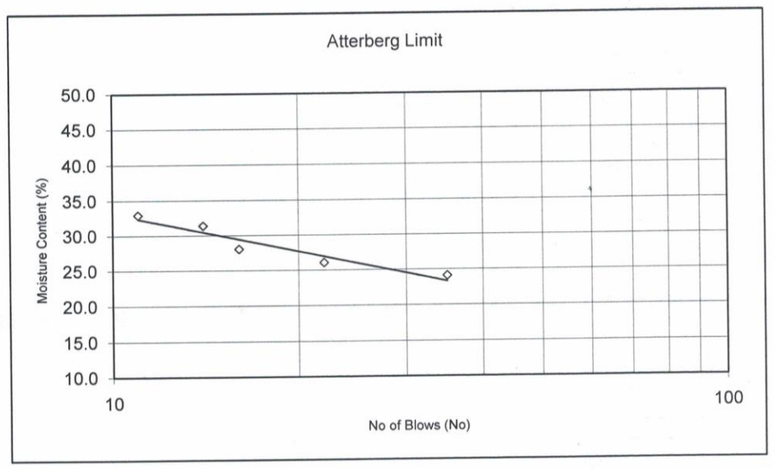
P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 9.12.2018
Sample No. L3
Standard : AASHTO T 89 - 81 & T 90 - 81

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Atterberg Limit Test Results

Number of blows	11	14	16	22	35
Water content %	32.94	31.42	28.04	26.06	24.07



LIQUID LIMIT(LL) = 26 %

PLASTIC LIMIT(PL) = NP %

PLASTICITY INDEX (PI) = NP %

Tested by :

Checked by :

EMES Pvt. Ltd.

P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

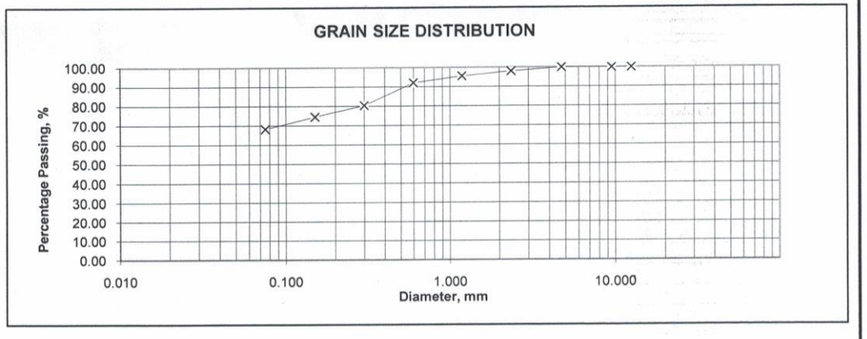
Date : 7.12.2018
Sample No. L4
Standard : AASHTO T 88 - 81

SIEVE ANALYSIS
WET | **DRY**

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Original Test Mass	**881.7**	**gms**	**Riffled sample (< 4.75mm)**	**gms**
Passing 4.75mm (# 4)		**gms**	**Factor**	

Test Sieve Sizes mm	Mass Retained Riffled Sam. gm.	Mass Retained Tot. Sam gm.	Cumu. Mass. Retained gm.	Cumulative Retained %	Total Passing %	SPECIFICATION LIMIT
50						
37.5						
25						
19.5						
12.5		0.0	0.0	0.00	100.00	
9.5		0.0	0.0	0.00	100.00	
4.75		0.0	0.0	0.00	100.00	
2.36		18.0	18.0	2.04	97.96	
1.18		21.9	39.9	4.53	95.47	
0.600		30.2	70.1	7.95	92.05	
0.300		102.5	172.6	19.58	80.42	
0.150		51.4	224.0	25.41	74.59	
0.075		56.3	280.3	31.79	68.21	
PAN		601.2	881.5	99.98		
Total		881.5				



Remarks:

The above sample is in ML (Sandy silt) group as per ASTM soil classification

EMES Pvt. Ltd.

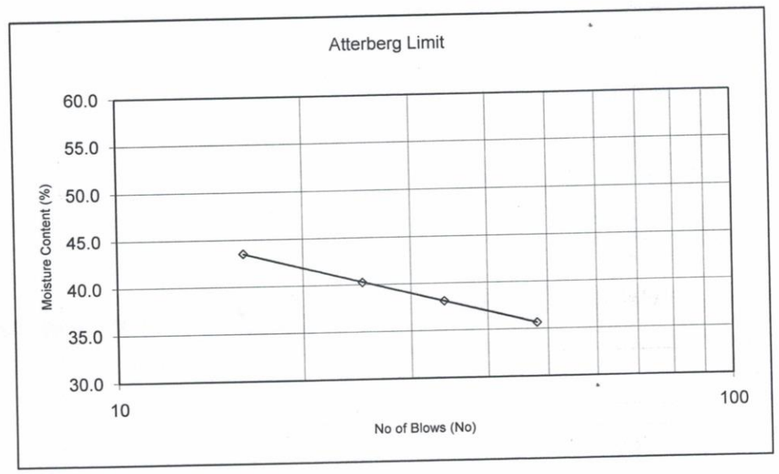
P.O.BOX 1192, Satdobato, Lalitpur, Nepal
PHONE NO : 5-538325
FAX NO. 977-1-5520242

Date : 9.12.2018
Sample No. L4
Standard : AASHTO T 89 - 81 & T 90 - 81

Client: Genesis Consultancy (P) Ltd
Source: Pit sample

Atterberg Limit Test Results

Number of blows	16	25	34	48
Water content %	43.52	40.26	38.12	35.66



LIQUID LIMIT(LL) = 40 %

PLASTIC LIMIT(PL) = 22 %

PLASTICITY INDEX (PI) = 18 %

Tested by :

Checked by :

Some photographs of erosion and land slide inventory

Photo 4 (a) Gully erosion damaging the road and wall in Duwakot (b) Tilting roadside structure indicating creeping along the road section to Changunarayan Temple

Photo 3 (a) Roadside slope stability structure to prevent the slides at the western slope of the hill of the Changunarayan Temple (b) Soft and fragile sediment prone to erosion present at the downhill slope of the road at Nagarkot

Photo 6 (a) Roadside failure damaging the road structure along the road at Nagarkot (b) Roadside failure and unstable land along the road section from Nagarkot to Muhanpokhari (c) Huge amount of soft sediment eroded and deposited continuously at the Duwakot area

Photo 5 (a)Unstable land along the Jitpur-Nagarkot road section prone to both erosion and slide (b) Erosion of soft sediment at the Tathali area (c) Roadside failure along the Jitpur-Nagarkot road

Annex 2 SWOT Analysis for Risk Sensitive Land Use Planning

Ward 1	
Strength	**Opportunities**
▪ Fertile agricultural land on the Manohara Riverbank can be used as Potential Cash crop area(Cauliflower, Carrot, Spinach, Tomato) ▪ Livestock farming can boost up local economy ▪ Sand mines and Clay excavation area ▪ Religious tourism at Saraswoti Temple during Shree Panchami ▪ Water source- Simko Dhara (Around 150-200 HH are served) and KUKL Deep Boring ▪ Bhanjyang and Saraswotikhel Area ▪ Proximity to Kathmandu and Bhaktapur ▪ Abundant amount of vacant and underutilized land that can be used for infill growth	▪ Local Market Center- Buspark area, Changu School Area, Mahankal Area, Saraswoti Temple Area, NEC College Area and Health post area ▪ Regional Market Center- Kalimati, Koteshwor, Naxal, SallaGhari and Thimi ▪ Potential site for religious park at Devithan Danda, Rupathali ▪ Promoting urban agriculture in vacant land for local food production ▪ Proposed Bir Hospital area can boost up local economy by creating employment opportunities
Weakness	**Threats**
▪ Irresponsible behaviour of local communities is harmful for biodiversity conservation ▪ Haphazard urban development and land fragmentation ▪ Flood plain area of Manohara river and other streams ▪ Fire risk due to High tension line ▪ Landslide risk at Saraswotikhel area and Saraswoti Basic School Area ▪ Infrastructure constraints such as- Solid waste, drainage and community services ▪ Lack of employment opportunities	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate funds for local development ▪ Environment pollution in surrounding communities ▪ Irresponsible behaviour of local communities is harmful for agricultural land and environment conservation

Ward 2	
Strength	**Opportunities**
▪ Potential Cash crop and unseasonal vegetables such as Mushroom, Cauliflower, tomato in Fertile agricultural land ▪ Potential Dairy product industries from Livestock farming ▪ Horticulture can boost up the local economy to certain extent ▪ Potential religious tourism at Tripurasundari temple complex and Ganeshsthan Temple area ▪ Water source- Simko Dhara (Around 150-200 HH are served) and KUKL Deep Boring ▪ Potential for Water Supply Industries ▪ Area under HTL can be proposed for Small scale industry ▪ Abundant amount of vacant and underutilized land that can be used for infill growth ▪ Sand mines	▪ Local Market Center-Duwakot chowk, KMC chowk, Phiadhoka area ▪ Regional Market Center- Kalimati, Baneshwor and Bhaktapur ▪ Potential Vegetable packaging industry ▪ Promoting urban agriculture in vacant land for local food production
Weakness	**Threats**
▪ Irresponsible behavior of local communities is harmful for biodiversity conservation ▪ Haphazard urban development and land fragmentation ▪ Earthquake risk at all settlement ▪ Fire risk due to HTL (Duwakot Height) ▪ Landslide risk at Pakho ▪ Road Accident risk at Sallaghari-Duwakot-Gelalgaun-Changu road section	▪ Haphazard urban development has increasingly negative impact on environment and ecology. ▪ Inadequate funds for local development ▪ Environment pollution in surrounding communities due to brick industries ▪ Clay excavation in fertile agricultural land have decreased the agricultural products

Ward 3	
Strength	**Opportunities**
▪ Potential Cash crop and unseasonal vegetables such as Mushroom, Cauliflower, tomato in Fertile agricultural land ▪ Potential Dairy product industries from Livestock farming ▪ Horticulture can boost up the local economy to certain extent ▪ Potential religious tourism at Tripurasundari temple complex and Ganeshsthan Temple area ▪ Sand mines and clay ▪ Abundant amount of vacant and underutilized land that can be used for infill growth ▪ Proximity to main urban centre of Bhaktapur	▪ Local Market Center-Neupane chowk, Gelal gaun chowk, Thapa Gaun ▪ Regional Market Center- Byasi, Kamalbinayak and Sukuldhoka in Bhaktapur ▪ Potential park at Jyotirlingeshwor temple area ▪ Potential religious tourism at Jyotirlingeshwor temple area
Weakness	**Threats**
▪ Haphazard urban development and land fragmentation ▪ Landslide risk- Dahal gaun, Dhimal gaun, Chundevi Area, Kolpakot, Thakuri Tole, Thapa gaun, Ganesh Primary School area ▪ Flood risk due to Kasan Khola (Jyotirlingeshwor to Kalighat river stretch) ▪ Fire risk due to electricity High Tension Line	▪ Haphazard urban development has increasingly negative impact on environment and ecology. ▪ Inadequate funds for local development ▪ Environment pollution in surrounding communities due to brick industries ▪ Clay excavation in fertile agricultural land have decreased the agricultural products

Ward 4	
Strength	**Opportunities**
▪ Rich biodiversity in the area due to presence of forest and River ▪ Presence of World Heritage site- Changunarayan Temple complex and its buffer area ▪ Sand mines and Clay excavation area ▪ Tourism- highest economic contribution in upper part of the ward ▪ Presence of Manohara river is the ecological importance ▪ Topography of the area ▪ Rich culture, cultural heritage, history and tradition ▪ Abundant amount of vacant and underutilized land that can be used for infill growth	▪ Important economic region of the municipality due to tourism ▪ Opportunities for cultural and eco-tourism ▪ Expanding the Water springs can provide drinking water for the ward ▪ There are tree clusters in the slope to control erosion ▪ Employment opportunity in the area by tourism services and infrastructure construction ▪ Local market at Changu and Pauwa ▪ Regional Market Center- Thamel, Bhaktapur, Khopasi, Melamchi, Naubise ▪ Probable Site for Cricket stadium on the north of Jyotirlingeshwor ▪ Promoting urban agriculture in vacant land for local food production
Weakness	**Threats**
▪ Ignorance of the reconstruction of ancient monuments ▪ Lack of hotels and tourist facilities ▪ Flood plain area of Manohara river and other stream ▪ River pollution due to negligence of local people and authorized body ▪ Landslide risk at Halchap ▪ Flood due to Manohara river ▪ Earthquake risk (Almost 90% HH were affected) ▪ Social risk (at Tamang Basti)	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate funds for local development ▪ Failure to introduce the region as one of the significant tourist destination ▪ Lack of spatial planning and zoning ▪ Lack of protection of cultural heritage and cultural landscape ▪ Degradation of nature and environment ▪ Lack of waste management

Ward 5	
Strength	**Opportunities**
▪ Rich biodiversity and Natural landscape ▪ Very good geographical location- central part of municipality and bridge Changunarayan and Nagarkot ▪ Abundant amount of tree clusters in sloppy area to prevent erosion ▪ Strong local support for developing the area as cultural tourism ▪ Presence of Manohara river is the ecological importance ▪ Topography of the area ▪ Variety and ethnic richness in indigenous area with traditional cuisine ▪ Abundant amount of vacant and underutilized land that can be used for infill growth ▪ Religious spot (Macche Narayan Temple complex)- Flow of internal tourist ▪ Presence of Municipality office and other administrative buildings is an opportunity for local people	▪ Ecotourism and cultural tourism will help local people in job creation ▪ Conserving natural landscape to decrease negative impacts ▪ Possibility to attract tourist by exploiting historical, cultural and traditional inheritance ▪ Existence of considerable amount of greenery and tree clusters will add panoramic view from Telkot (Possibility of view tower at Telkot) ▪ Employment opportunity in the area by tourism services and infrastructure construction ▪ Local market center at Kharipati-Nagarkot road section ▪ Regional market center- Kamalbinayak, Sankhu, Kathmandu ▪ Probable Site for Cricket stadium on the north of Jyotirlingeshwor ▪ Promoting urban agriculture in vacant land for local food production ▪ Potential area for herbs due to presence of forest ▪ Potential tourist route (Changunarayan-Telkot-Nagarkot road section) ▪ Potential Handicraft industry with local materials such as-bamboo products ▪ Potential Medicine factory for processing herbs ▪ Possibility of picnic spot and park
Weakness	**Threats**
▪ Lack of hotels and tourist facilities ▪ Flood risk at Manohara river and Gadgade river ▪ Landslide risk at Telkot ▪ Fire risk during dry season in Telkot Forest ▪ Lack of connectivity to the market due to transportation problem ▪ Lack of irrigation	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate infrastructures for tourism development ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Lack of spatial planning and zoning ▪ Degradation of nature and environment ▪ Lack of waste management ▪ Shortage of drinking water

Ward 6	
Strength	**Opportunities**
▪ Major tourist destination ▪ Abundance of natural and cultural environment locating in rural settings ▪ Connectivity to Kavre ▪ Tourism recognized as a key industry by public and private sector investment ▪ Existing park areas ▪ Government land at Santidanda (around 200 ropanies) can be proposed for Peace park ▪ Topography of the area ▪ Variety and ethnic richness in indigenous area with traditional cuisine ▪ Presence of cave at Gairigaun	▪ Ecotourism and cultural tourism will help local people in job creation ▪ Employment opportunity in the area by tourism services and infrastructure construction ▪ Panoramic view of mountains and valley ▪ Possibility of supporting services for hotels such as-handicraft, local products etc. ▪ Prime agricultural land ▪ Potential cash crop such as coffee, potato, cauliflower, radish and cucumber ▪ Potential area for herbs (Rodsalla, chiraito, lemon grass, ban kurilo) ▪ Livestock farming ▪ Possibility of homestay at Fedi and Lamatol area ▪ local market-Kharipati, Telcot and Nagarkot ▪ regional market-Kavre, Bhaktapur and Kathmandu ▪ Potential Handicraft industry with local materials such as-bamboo products ▪ Possibility of collection center and processing center for agricultural products
Weakness	**Threats**
▪ Lack of hotels and tourist facilities ▪ Fire risk due to Pine forest during dry season ▪ Landslide risk at Muhan Pokhari and Telcot Fedi ▪ Wild animal risk- leopard, monkey and wild boar ▪ Rapid land fragmentation	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate infrastructures for tourism development ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Lack of spatial planning and zoning ▪ Degradation of nature and environment

▪ Poor road condition ▪ Military area as a blockade for development ▪ Steep terrain ▪ Inadequate funding of resources for tourism promotion ▪ Rural populations are generally less benefited as most of the tourism services are ruled by outsiders	▪ Lack of public infrastructures such as dumping site and public toilets ▪ Bypassing the local participants in tourism sector could create tension between the leading investors and local people ▪ Possibility of uncontrolled tourism development

Ward 7	
Strength	**Opportunities**
▪ Rich environmental, natural and cultural area locating in rural settings ▪ Abundant amount of tree clusters in sloppy area to prevent erosion ▪ Topography of the area ▪ Variety and ethnic richness in indigenous area with traditional cuisine ▪ Cultural and religious spot (Mahadev pokhari) ▪ Presence of major water source- Muhanpokhari	▪ Potential Eco-Tourism (Hiking, Bungi Jump) will help local people in job creation ▪ Connectivity to Kavre ▪ Employment opportunity in the area by tourism services and infrastructure construction ▪ Panoramic view of mountains and valley ▪ Possibility of supporting services for hotels such as-handicraft, local products etc. ▪ Potential Cash crop- Potato, Cucumber, tomato and mushroom ▪ Possibility of Horticulture- Pear, Kiwi, Guava, Nepalese Hog Plum (Lapsi), Persimmon ▪ Livestock farming ▪ Local market- Nayabasti, Bansbari, Kharipati, Bageshwori Health post area, Muhanpokhari-Bageshwori-Sudal road corridor ▪ Regional Market- Kathmandu, Bhaktapur and Kavre ▪ Religious and cultural elements like- Muhan pokhari, Bagehitti, Balmikeshowr, Yattu mahadev ▪ Possibility of Herbs and medicine in forest area ▪ Main water source- Mahadev Pokhari and Gattekhola ▪ Wildlife and Watershed area (Forest) ▪ IOM Open Space at Tapa Damfo Land pooling site ▪ Possibility of cycling route in Gattekhola corridor connecting communities in Nagarkot, Sudal and Tathali
Weakness	**Threats**
▪ Lack of hotels and tourist facilities ▪ Earthquake risk mainly in Majhuwa and Pedali ▪ Flood risk on the river side area ▪ Landslide risk on Ghattapakha area ▪ Wild animal risk- leopard, monkey and wild boar ▪ Rapid land fragmentation ▪ Poor awareness in the market about tourism products ▪ Steep terrain ▪ Inadequate funding of resources for tourism promotion	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate infrastructures for tourism development ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Possibility of uncontrolled tourism development ▪ Lack of public infrastructures such as dumping site and public toilets ▪ Lack of spatial planning and zoning ▪ Degradation of nature and environment

Ward 8	
Strength	**Opportunities**
▪ Designated Pocket area of PM-AMP (Potato) ▪ Rich environmental, natural and cultural area locating in rural settings ▪ Religious and cultural elements like- Saraswoti Temple and Thuli Brahmayani area ▪ Abundant amount of tree clusters in sloppy area to prevent erosion ▪ Topography of the area ▪ Variety and ethnic richness in indigenous area with traditional cuisine	▪ Prime agricultural land ▪ Potential Cash crop- Potato, Cucumber, tomato and mushroom ▪ Possibility of collection center and processing center for agricultural products ▪ Employment opportunity in the area by tourism services and infrastructure construction ▪ Livestock farming ▪ Possibility of Herbs and medicine in forest area ▪ Potential Cultural Tourism and homestay at Bojheni, Sete pakho, Thuli Brahmayani area ▪ Potential Handicraft industry with local materials

	▪ Local market- Jitpur, Sudal, Saraswotisthan, Chareli, Kalamari and Ratopati area ▪ Regional Market- Kamalbinayak, Chyamasing, Kalimati ▪
Weakness	**Threats**
▪ Earthquake risk (Known as Sindhupalchowk area) ▪ Flood risk due to Ghatekhola and Gubhu khola (Inundation and Erosion) ▪ Air pollution due to Brick industries ▪ Rapid land fragmentation ▪ Steep terrain	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate infrastructures for tourism development ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Lack of public infrastructures such as dumping site and public toilets ▪ Environment pollution in surrounding communities due to brick industries ▪ Clay excavation in fertile agricultural land have decreased the agricultural products

Ward 9	
Strength	**Opportunities**
▪ Rich biodiversity and Natural landscape ▪ Abundant amount of tree clusters in sloppy area to prevent erosion ▪ Topography of the area ▪ Variety and ethnic richness in indigenous area with traditional cuisine ▪ Abundant amount of vacant and underutilized land that can be used for infill growth ▪ Economic Connectivity to major urban centers	▪ Prime agricultural land ▪ Potential Cash crop- Potato, tomato, Cauliflower and mushroom ▪ Livestock farming ▪ Stone mine area ▪ Possibility of Trekking route in Nalagumba-Halalgaun-Khawa route ▪ Possibility of Homestay area at Phaidhoka area and boarder area of ward 8 and ward 9 ▪ Panoramic view of Valley and mountains ▪ Possibility of Stone artifacts and handicraft industry ▪ Local market- Phaidhoka, Tathali ▪ Regional Market- Bhaktapur and Kathmandu ▪ Main water source- Bulbule and deep bore ▪ Local Jatra and festivals ▪ Possibility of religious tourism at Chundevi temple complex and Majhi Bhairav temple complex
Weakness	**Threats**
▪ Landslide risk in Saudol, Khawa, Raut tole, Ban devi Mandir area ▪ Flood risk due to Tabya Khusi River ▪ Fire risk ▪ Wildlife risk ▪ Air pollution due to Brick industries	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate infrastructures for tourism development ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Lack of spatial planning and zoning ▪ Degradation of nature and environment ▪ Lack of waste management ▪ Shortage of drinking water

Municipality SWOT Analysis	
Strength	**Opportunities**
▪ Major tourist destination-Nagarkot and Changunarayan temple complex ▪ Potential Cash crop and unseasonal vegetables such as Mushroom, Cauliflower, tomato etc. in Fertile agricultural land ▪ Livestock farming can boost up local economy of the Municipality ▪ Sand mines and Clay excavation area ▪ Different Religious and Cultural sites are Potential for religious tourism ▪ Abundant amount of vacant and underutilized land that can be used for infill growth ▪ Horticulture can boost up the local economy to certain extent ▪ Proximity to Kathmandu and Bhaktapur	▪ Important economic region of the municipality due to tourism ▪ Opportunities for religious, cultural and eco-tourism ▪ Promoting urban agriculture in vacant land for local food production ▪ Expanding the Water springs can provide drinking water for all wards ▪ Proposed Birhospital area can boost up local economy by creating employment opportunities ▪ Potential Vegetable packaging industry ▪ There are tree clusters in the slope to control erosion ▪ Employment opportunity in the area by tourism services and infrstructure construction ▪ Probable Site for Cricket stadium on the north of Jyotirlingeshwor

▪ Area under HTL can be proposed for Small scale industry ▪ Rich biodiversity and Natural landscape ▪ Presence of World Heritage site- Changunarayan Temple complex and its buffer area ▪ Tourism- highest economic contribution in upper part of the Municipality ▪ Topography of the area ▪ Rich culture, cultural heritage, history and tradition ▪ Abundant amount of tree clusters in sloppy area to prevent erosion ▪ Strong local support for developing the area as cultural tourism ▪ Presence of Manohara river is the ecological importance ▪ Economic Connectivity to the surrounding regional and local centers ▪ Existing park areas ▪ Government land at different locations can be proposed for park, open spaces, hospital area and so on ▪ Presence of cave at Gairigaun ▪ Presence of major water source- Muhanpokhari ▪ Designated Pocket area of PM-AMP (Potato)	▪ Ecotourism and cultural tourism will help local people in job creation ▪ Possibility to attract tourist by exploiting historical, cultural and traditional inheritance ▪ Existence of considerable amount of greenery and tree clusters will add panoramic view ▪ Potential area for herbs (Rodsalla, chiraito, lemon grass, ban kurilo) ▪ Potential trekkingt route (Changunarayan-Telkot-Nagarkot road section) ▪ Potential Handicraft industry with local materials such as-bamboo products ▪ Potential Medicine factory for processing herbs ▪ Possibility of picnic spot and park ▪ Panoramic view of mountains and valley ▪ Prime agricultural land ▪ Possibility of homestay area ▪ Possibility of collection center and processing center for agricultural products ▪ Wildlife and Watershed area (Forest) ▪ IOM Open Space at Tapa Damfo Land pooling site ▪ Possibility of cycling route in Gattekhola corridor connecting communities in Nagarkot, Sudal and Tathali
Weakness	**Threats**
▪ Irresponsible behavior of local communities is harmful for biodiversity conservation ▪ Haphazard urban development and land fragmentation ▪ Flood plain area of Manohara river and other stream line ▪ Fire risk due to High tension line ▪ Landslide risk ▪ Infrastructure constraints such as- Solid waste, drainage and community services ▪ Lack of employment opportunities ▪ Earthquake risk at all settlement ▪ Road Accident risk at Sallaghari-Duwakot-Gelalgaun-Changu road section ▪ Ignorance of the reconstruction of ancient monuments ▪ Lack of hotels and tourist facilities ▪ River pollution due to negligence of local people and authorized body ▪ Social risk ▪ Lack of connectivity to the market due to transportation problem ▪ Lack of irrigation ▪ Wild animal risk- leopard, monkey and wild boar ▪ Poor road condition ▪ Steep terrain ▪ Inadequate funding of resources for tourism promotion ▪ Rural populations are generally less benefited as most of the tourism services are ruled by outsiders ▪ Poor awareness in the market about tourism products ▪ Air pollution due to Brick industries	▪ Haphazard urban development has increased negative impact on environment and ecology. ▪ Inadequate funds for local development ▪ Environment pollution in surrounding communities due to brick industries ▪ Clay excavation in fertile agricultural land have decreased the agricultural products ▪ Failure to introduce the region as one of the significant tourist destination ▪ Lack of spatial planning and zoning ▪ Lack of protection of cultural heritage and cultural landscape ▪ Degradation of nature and environment ▪ Lack of waste management ▪ Transportation infrastructure not to the community standard and unsatisfactory ▪ Shortage of drinking water ▪ Lack of public infrastructures such as dumping site and public toilets ▪ Bypassing the local participants in tourism sector could create tension between the leading investors and local people ▪ Possibility of uncontrolled tourism development ▪ Inadequate infrastructures for tourism development ▪

Annex 3 Humanitarian Open Space Time travel Analysis

Table 13 Time required for people of different settlements to reach nearest open space

Ward No	Name of HOS	Settlement Name	Time (Minutes)
1	Besigaun Open Space	Besigaun2	2.59
7	Football Ground	Majuwa	2.86
		Padali	3.87
		Habeli	8.40
		Sunuwar gau	15.31
		Lapro	13.15
		Chareli	9.77
		Damai gau	14.34
3	FSCN	Nyaupane gau	9.31
		Gelalgau	2.72
		Dhimal gau	0.01
9	Ground of Janakpur Engineering College	Taikabu	6.15
		Ngyabu	16.01
7	IOM Open Space	Nayabasti	14.19
		Ratopati	14.31
		Dandagau	29.70
		Gairapati	21.38
2	KMC Parking Area	Phaidhoka2	9.41
		Fasintar	3.86
		Gakhu1	10.72
		Budathoki tole	7.16
		Khatri tole	8.11
		Gakhu2	9.36
6	Lamatol Open Space	Lamatol	19.20
		Santi dada	21.33
		Gairi gaun	26.25
		Lamadada	1.45
		Lama gaun	3.65
		Nagarkot	30.37
5	Naag Thali Open Space	Kharipati	18.11
		Dobhane	14.34
		Bhusundol	11.45
		Ghumaune	9.68
		Dahal gaun2	16.08
		Pagaritol	9.88
		Kuslamtar	7.65
		Bansghari	17.44
		Kafle Gaun	0.84
4	Nawangal Open Space	Magan Tole	8.75
		Nawangal gau	0.39
7	Nuldum Open Space	Nuldum	0.07
5	Om Santi Kendra_Park	Bhajubhairav	13.23
		Thapa Gaun	12.11
1	Open Space	Somathali	6.78
		Roka gau	4.75
		Khadka tol	13.49
2	Open Space	Duwakot	13.29
		Dobu phat	16.40
		Rashya dol	8.13
		Tyatta tole	9.47
		Tripura Sundari	6.12
		Mahankal Chwok	11.83
3	Open Space	Milli	15.02
		Lukundol	17.94
		Kasula Tole	17.85
4	Open Space	Kapahiti	5.20
		Halchap1	12.87
7	Open Space	Banphedi	2.30
		Kalcha gau	22.61
		Kaplegau	19.78
		Phuyal gau	35.27
		Timalsina tole	28.36
8	Open Space	Nepal gau	4.67
		Tallo nepal gau	5.20
		Puri gau	20.28
3	Open Space (3-4 ropanis)	Dahal gaun1	5.95
		Kotali	1.62
7	Open Space of Mahadev Pokhari	Mahadev Pokhari	0.27
9	Open Space of Oldage Home	Bhetasi	20.97
		Piple	17.55
		Pipal bot	7.46
4	Open Space of Police Station	Chhapdanda	17.38
		Pauwa	8.96
		Chhap	12.45
		Tatgal	12.57
		Pokhrel gau	17.41
		Mijal tole	13.91
		Khore gau	10.80
		Budathoki gau	10.27

		Changunarayan	3.79
		Gurung Gaun	18.79
5	Open Space of Shree Pancha Mahalaxmi Temple	Deurali banjyang	23.85
		Chayabasti	4.99
6	Playground of Shree Kalika Secondary School	Bastola gaun	15.22
		Phedi gaun	21.60
2	Playground of Golden Sungava school	Dandipakha	2.34
		Thado Dhunga	5.19
		KMC chowk	5.24
2	Playground of Mitrashree School	Shakhal Basti	1.43
		Pragya tole	1.34
4	Playground of NEC	Sanchukcha	17.21
		Gamphedi	7.84
		Magar gau	7.49
		Besigaun1	7.16
9	Playground of Phaidhoka School	Phaidhoka1	1.26
		Yangdol	7.17
		Masandol	25.83
		Chundevi	32.12
5	Playground of Shining English boarding School	Chhaling	16.64
		Gainda gau	7.04
		Gundi gau	10.03
		Pakaune pati	0.87
		Kalikatar	7.75
		Paudeldada	20.63
		Pikhel	10.06
		Tyattal gaun	18.04
		Milan tole	14.24
9	Playground of Shree Ganesh Madhyamik Bidhyalaya	Raut tol	2.03
		Katritol	3.76
		Sudal	18.60
		Dulal gau	33.41
		Jitpur	29.75
		Ghorsahi	29.13
		Karki gaun2	28.09
8	Playground of Shree Kalika Basic School	Kalamasi	0.99
		Adhikari gau	13.97
6	Playground of Shree Mahakali Madhyamik Bidhyalaya	Lamidada	4.32
		Batase dada	11.48
		Gadgade	17.43
		Bkhri gaun	24.35
4	Sangdaha Open Space	Narayntar	8.63
		Sangdaha1	7.46
		Dhungana gau	14.08
		Sangdaha2	1.49
		Halchap2	3.73
1	Saraswotikhel Open Space	Saraswoti Khel	10.97
		ThapaTole	12.75
9	Saudol Open Space	Halal gau	23.28
		Tallo saudol	9.76
		Mathilo saudol	5.28
5	SchoolGround	Khatrigaun	13.96
		Dihigaun	4.40
		Karki gaun1	8.53
		Tamang gaun1	12.90
		Mulakot	23.98
		Gokul gaun	16.72
		Rahul Gaun	16.59
		Tamang gaun2	11.34
3	United Preparatory English School	Thekuri gau	2.76
		Kolpakot	4.50
		Lakila gau	8.83
		Jhaukhel	1.98
		Thapagaun	5.11
		Jagriti Chwok	1.39

Table 14 Travel Time for Fire Brigade to reach different HOS

Ward No	Name of HOS	Time (Minutes)
6	Playground of Shree Mahakali Madhyamik Bidhyalaya	28.45
7	Military Open Space	25.48
7	Nuldum Open Space	24.94
7	Open Space near Military Area	24.24
7	Open Space of Mahadev Pokhari	23.16
6	Lamatol Open Space	22.00
6	Open Space near KUKL	21.67
6	Pipalbot Open Space	21.58
6	Playground of Shree Kalika Secondary School	20.55
5	Open Space of Shree Pancha Mahalaxmi Temple	19.84
9	Open Space near Kalika Basic School	19.67
8	Open Space	19.45
8	Playground of Shree Kalika Basic School	18.83
7	Football Ground	18.59
7	Open Space	16.25

9	Playground of Shree Ganesh Madhyamik Bidhyalaya	15.47
9	Playground of Devi School	15.05
9	Open Space of Oldage Home	14.90
7	Open Space/ Matadan Kendra	14.39
8	Football ground	14.26
9	Saudol Open Space	14.22
4	Nawangal Open Space	13.96
5	SchoolGround	13.58
9	Ground of Janakpur Engineering College	13.22
9	Open Space	12.18
9	Playground of Phaidhoka School	11.98
4	Open Space	11.47
4	Open Space of Police Station	11.42
5	Om Santi Kendra_Park	11.23
5	Naag Thali Open Space	11.03
1	Open Space near Military area	9.63
4	Open Space of Ward office	9.49
4	Sangdaha Open Space	9.00
1	Open Space	8.99
1	Besigaun Open Space	8.61
3	Open Space (3-4 ropanis)	8.52
7	IOM Open Space	8.50
4	NEC Bus Stand	8.43
4	Playground of NEC	8.34
3	FSCN	8.25
3	Nepal Medical College	7.61
1	Saraswotikhel Open Space	7.48
5	Playground of Shining English boarding School	7.39
3	United Preparatory English School	7.25
3	Open Space	6.78
2	Open Space	6.19
2	KMC Parking Area	5.92
2	Playground of Golden Sungava school	3.35
2	Playground of Mitrashree School	2.76

Table 15 Vehicular Travel Time to move from HOS to Staging Area

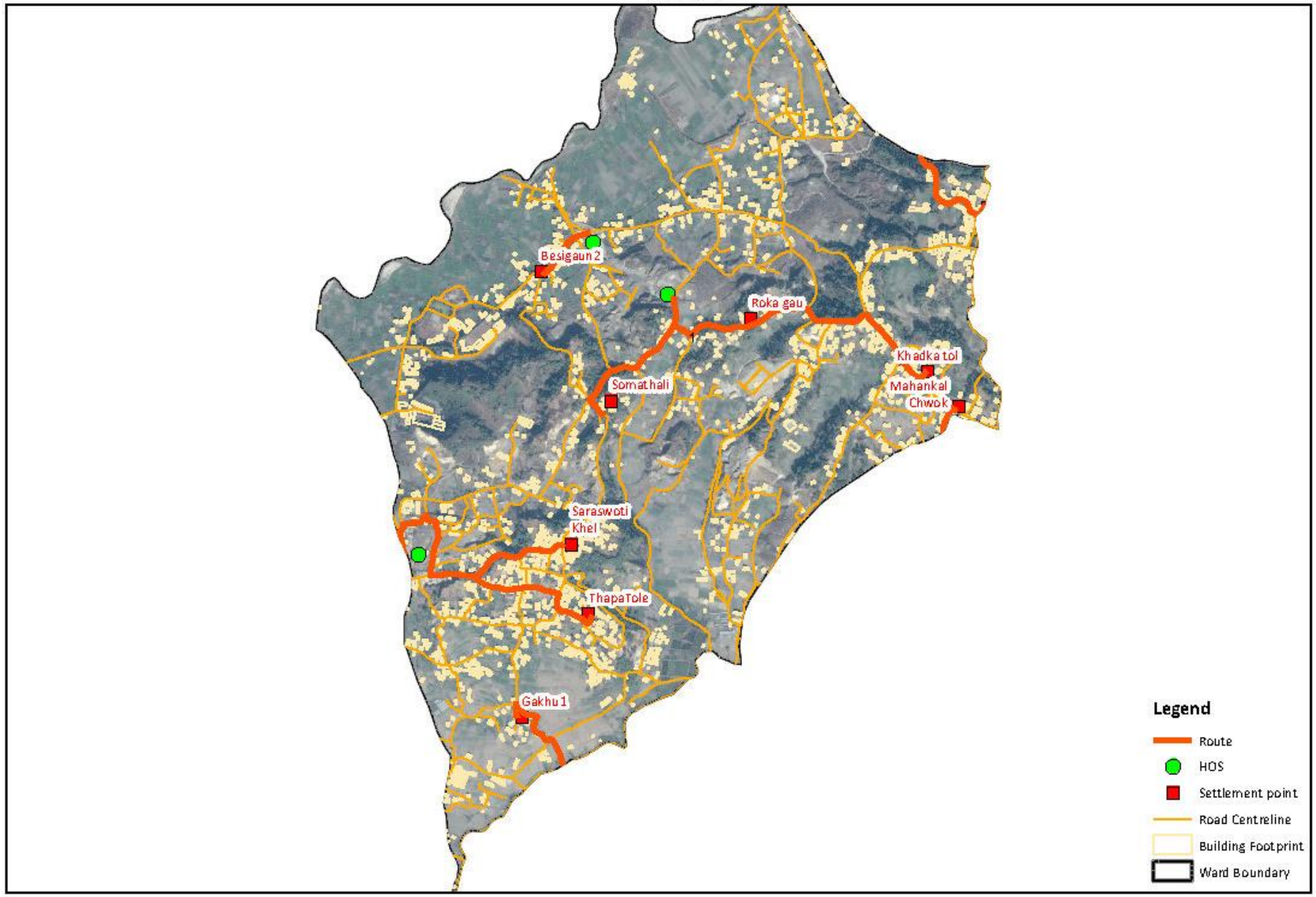
Name of HOS	Staging Area	Time (Minutes)
Playground of Devi School-9	IOM Open Space-7	55.42
Ground of Janakpur Engineering College-9	IOM Open Space-7	39.40
Playground of Shree Ganesh Madhyamik Bidhyalaya-9	IOM Open Space-7	47.70
Saudol Open Space-9	IOM Open Space-7	53.84
Open Space-9	IOM Open Space-7	44.04
Playground of Phaidhoka School-9	IOM Open Space-7	44.44
Open Space of Oldage Home-9	IOM Open Space-7	54.33
Om Santi Kendra_Park-5	IOM Open Space-7	46.59
Naag Thali Open Space-5	IOM Open Space-7	37.87
Playground of Shining English boarding School-5	IOM Open Space-7	60.53
SchoolGround-5	IOM Open Space-7	54.21
Playground of Shree Kalika Secondary School-6	IOM Open Space-7	95.92
Playground of Shree Mahakali Madhyamik Bidhyalaya* -	IOM Open Space-7	150.95
Lamatol Open Space-6	IOM Open Space-7	109.08
Open Space near KUKL-6	IOM Open Space-7	105.95
Pipalbot Open Space-6	IOM Open Space-7	104.15
Open Space-7	IOM Open Space-7	61.14
Open Space of Shree Pancha Mahalaxmi Temple -	IOM Open Space-7	90.09
Besigaun Open Space-1	Open Space near Military area-1	14.05
Saraswotikhel Open Space-1	Open Space near Military area-1	13.14
Open Space-1	Open Space near Military area-1	20.58
Playground of Golden Sungava school-2	Open Space near Military area-1	44.85
Open Space-2	Open Space near Military area-1	37.58
KMC Parking Area-2	Open Space near Military area-1	35.07
Playground of Mitrashree School-2	Open Space near Military area-1	46.24
United Preparatory English School-3	Open Space near Military area-1	51.30
Open Space-3	Open Space near Military area-1	60.04
Open Space (3-4 ropanis)-3	Open Space near Military area-1	46.38
Nepal Medical College-3	Open Space near Military area-1	46.54
FSCN-3	Open Space near Military area-1	45.30
Open Space of Police Station-4	Open Space near Military area-1	59.50

Playground of NEC-4	Open Space near Military area-1	33.56
Sangdaha Open Space-4	Open Space near Military area-1	46.69
Nawangal Open Space-4	Open Space near Military area-1	70.37
Open Space-4	Open Space near Military area-1	59.67
NEC Bus Stand-4	Open Space near Military area-1	34.27
Open Space near Kalika Basic School-9	Open Space near Military Area-7	49.26
Nuldum Open Space-7	Open Space near Military Area-7	5.64
Football Ground-7	Open Space near Military Area-7	68.01
Open Space of Mahadev Pokhari-7	Open Space near Military Area-7	18.45
Open Space-8	Open Space near Military Area-7	48.40
Playground of Shree Kalika Basic School-8	Open Space near Military Area-7	44.21

Annex 4 Evacuation Route Maps

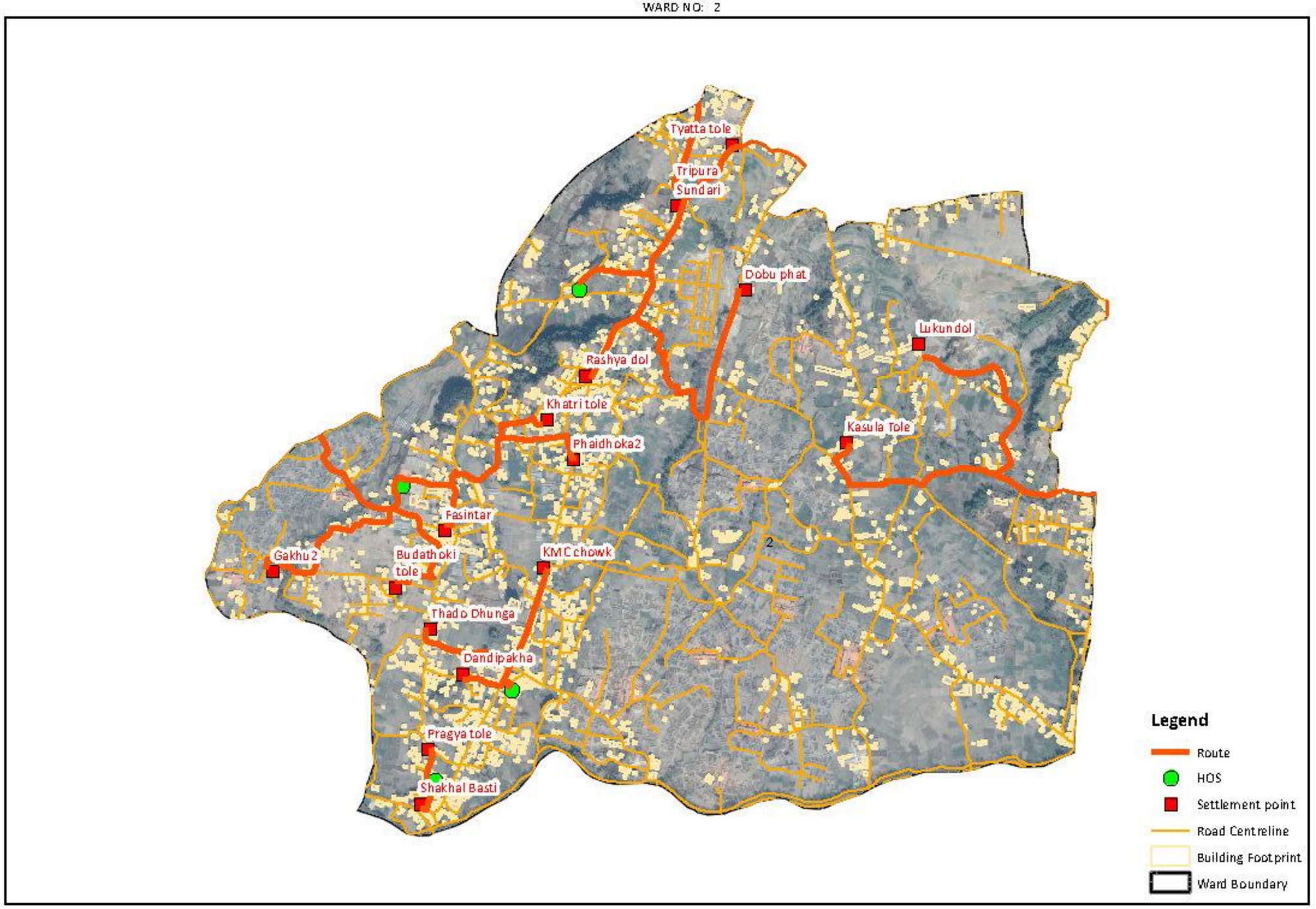
OPEN SPACE EVACUATION ROUTE

WARD NO: 1



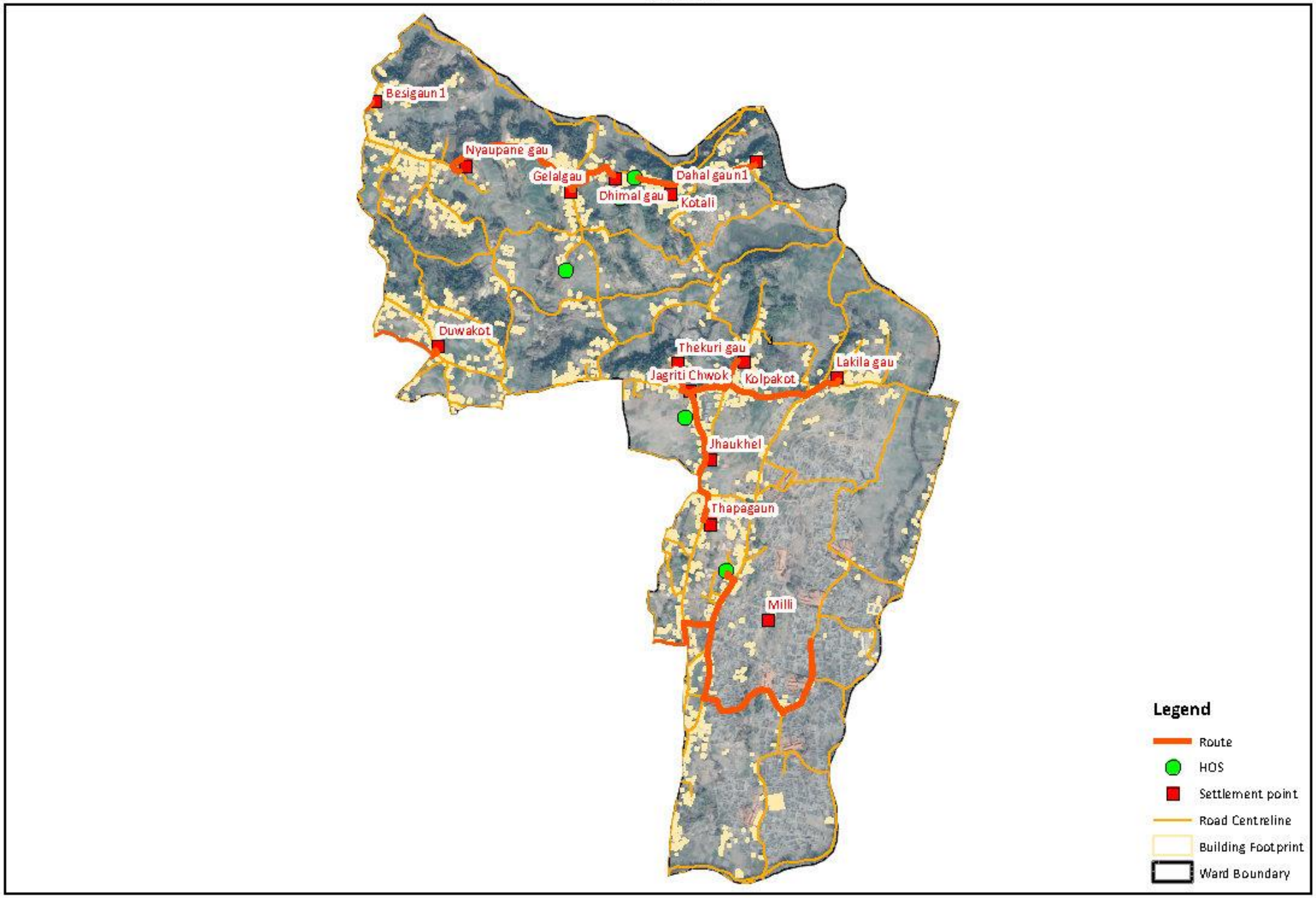
OPEN SPACE EVACUATION ROUTE

WARD NO: 2



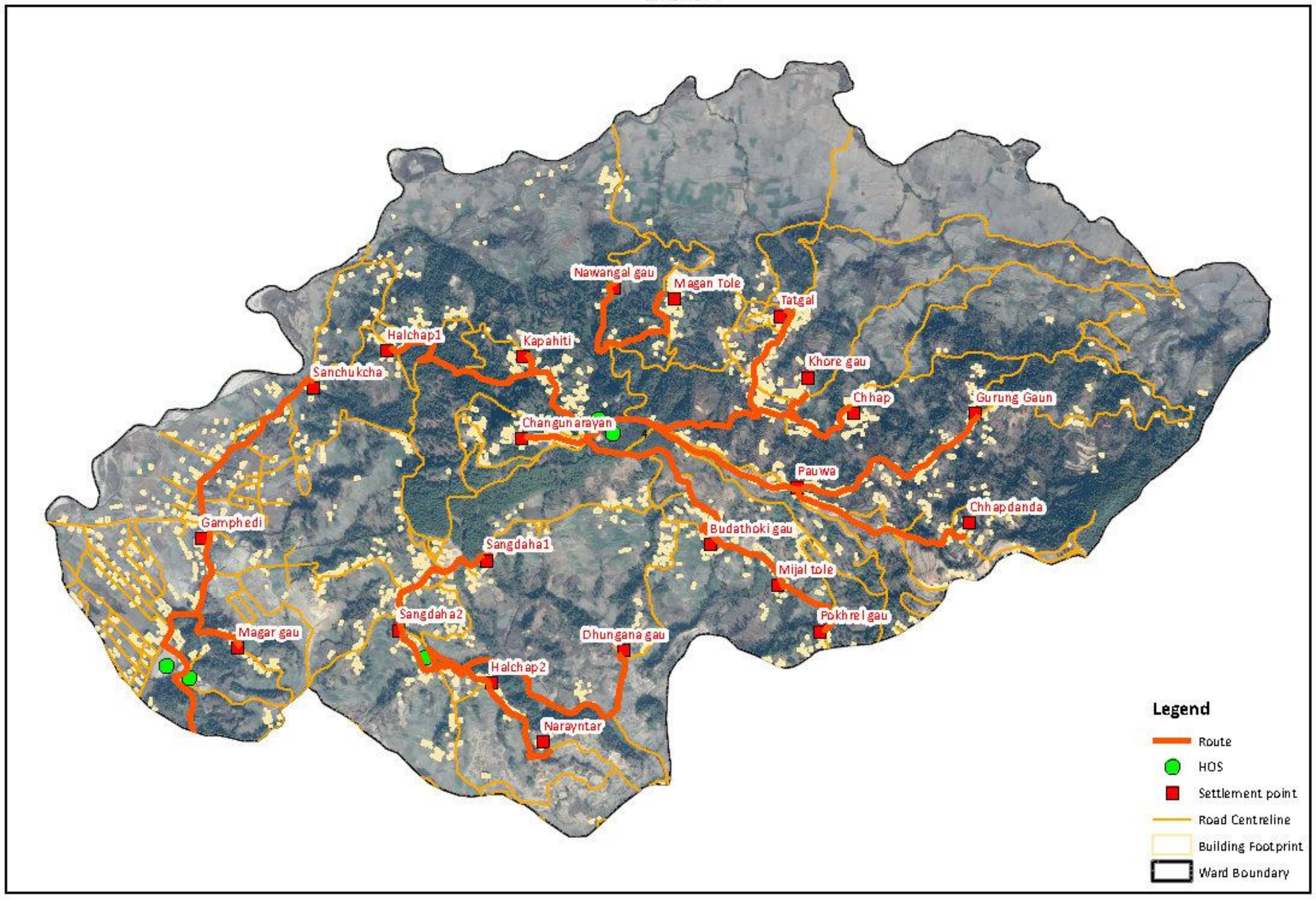
OPEN SPACE EVACUATION ROUTE

WARD NO: 3



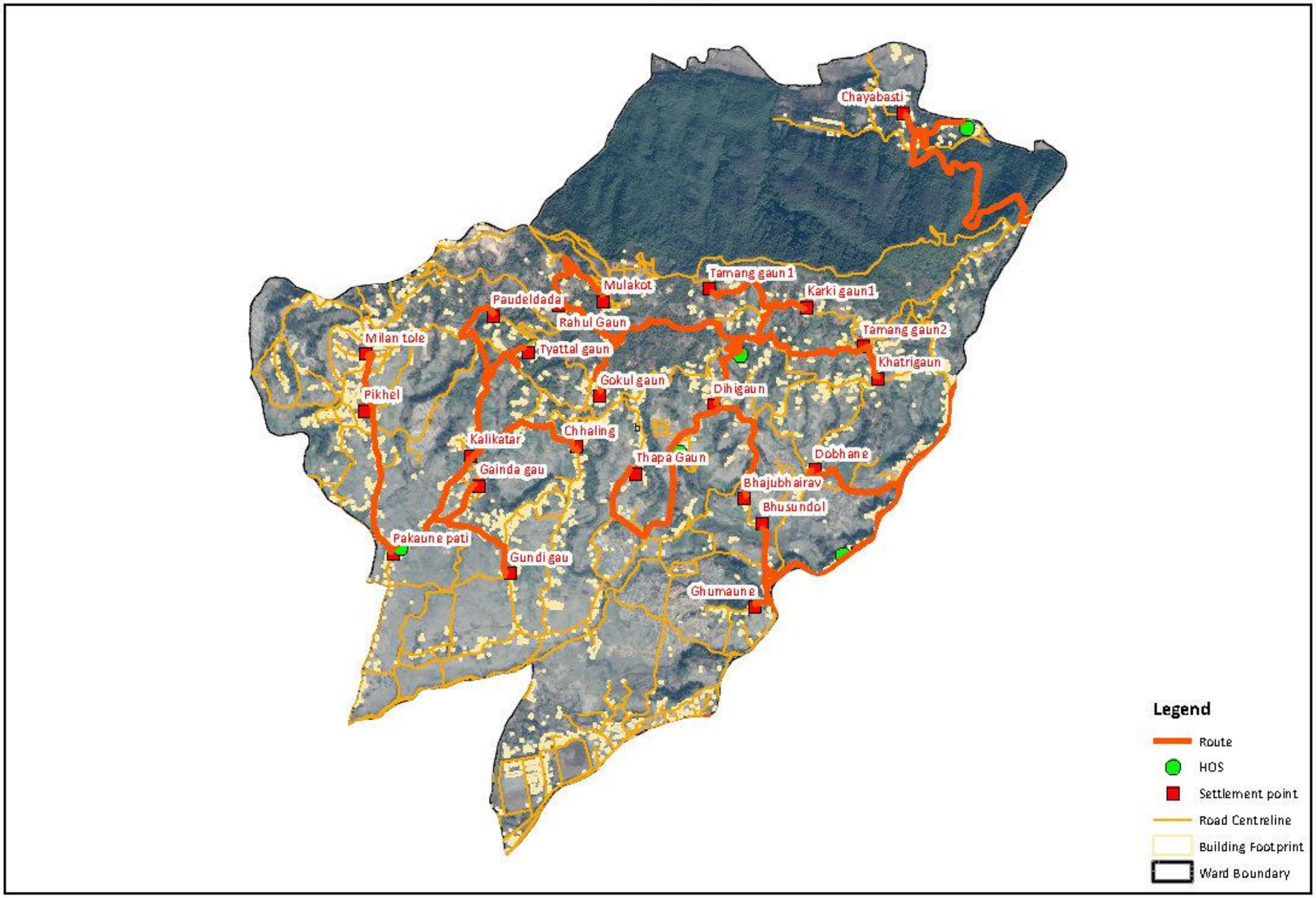
OPEN SPACE EVACUATION ROUTE

WARD NO: 4



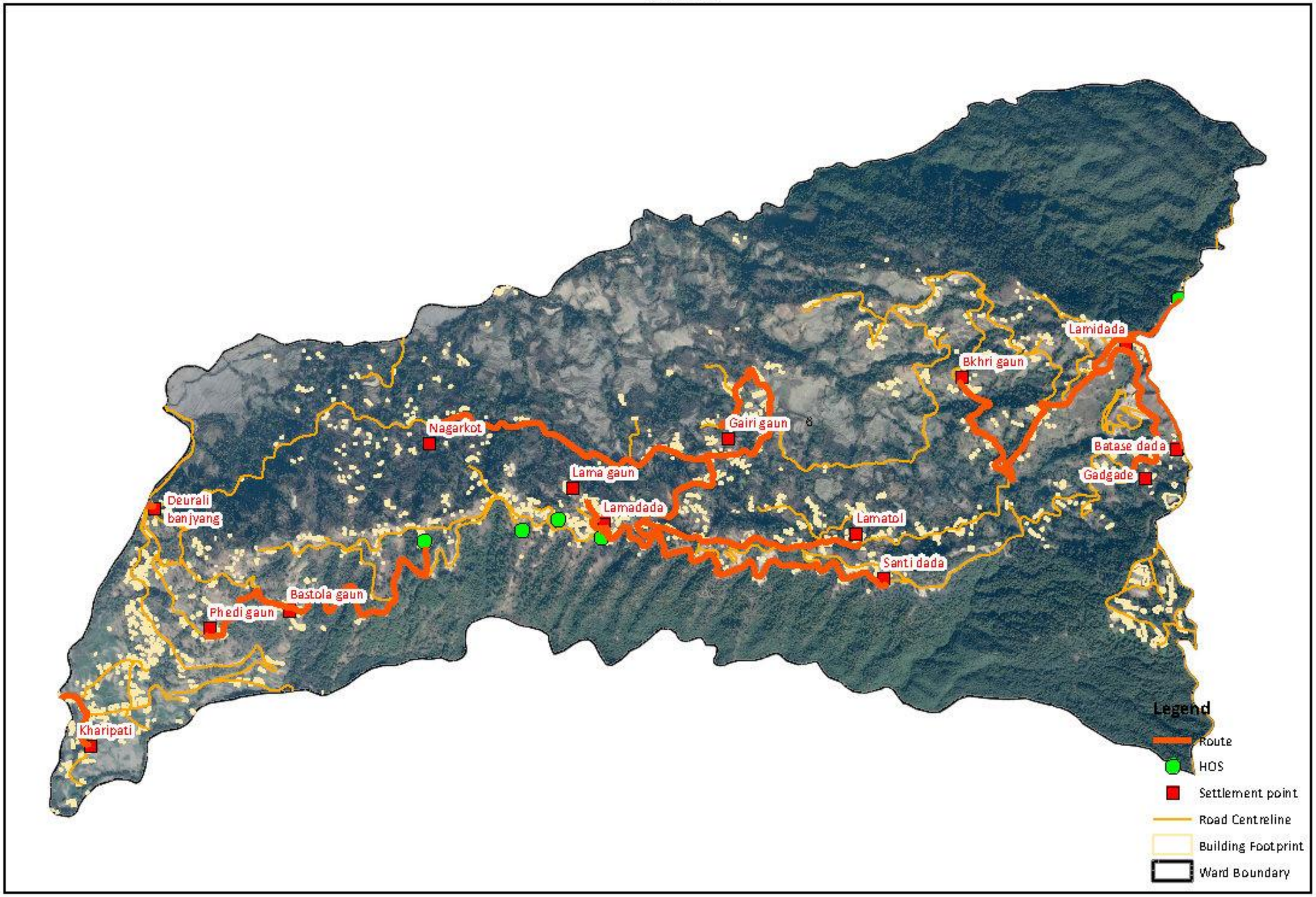
OPEN SPACE EVACUATION ROUTE

WARD NO: 5



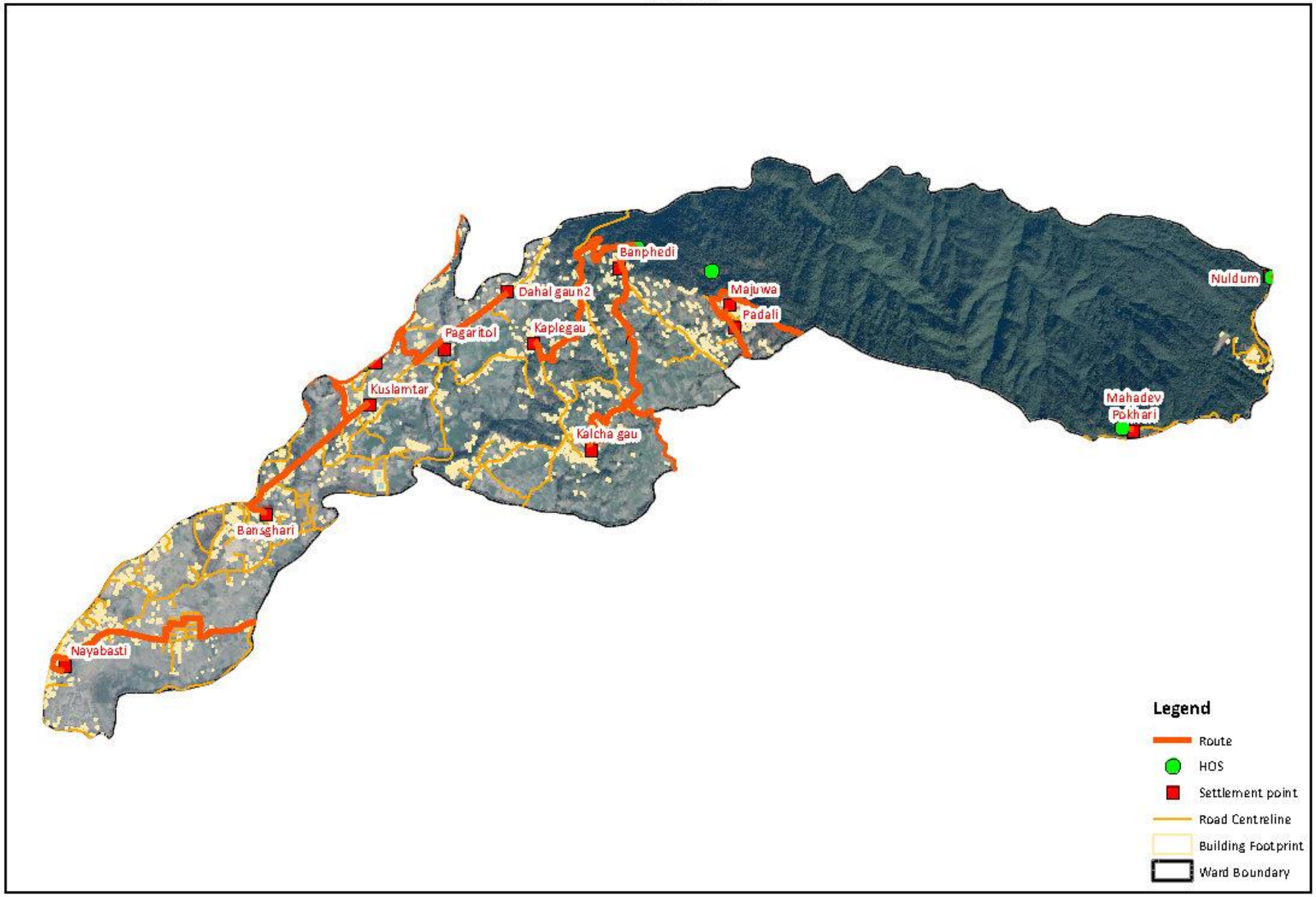
OPEN SPACE EVACUATION ROUTE

WARD NO: 6



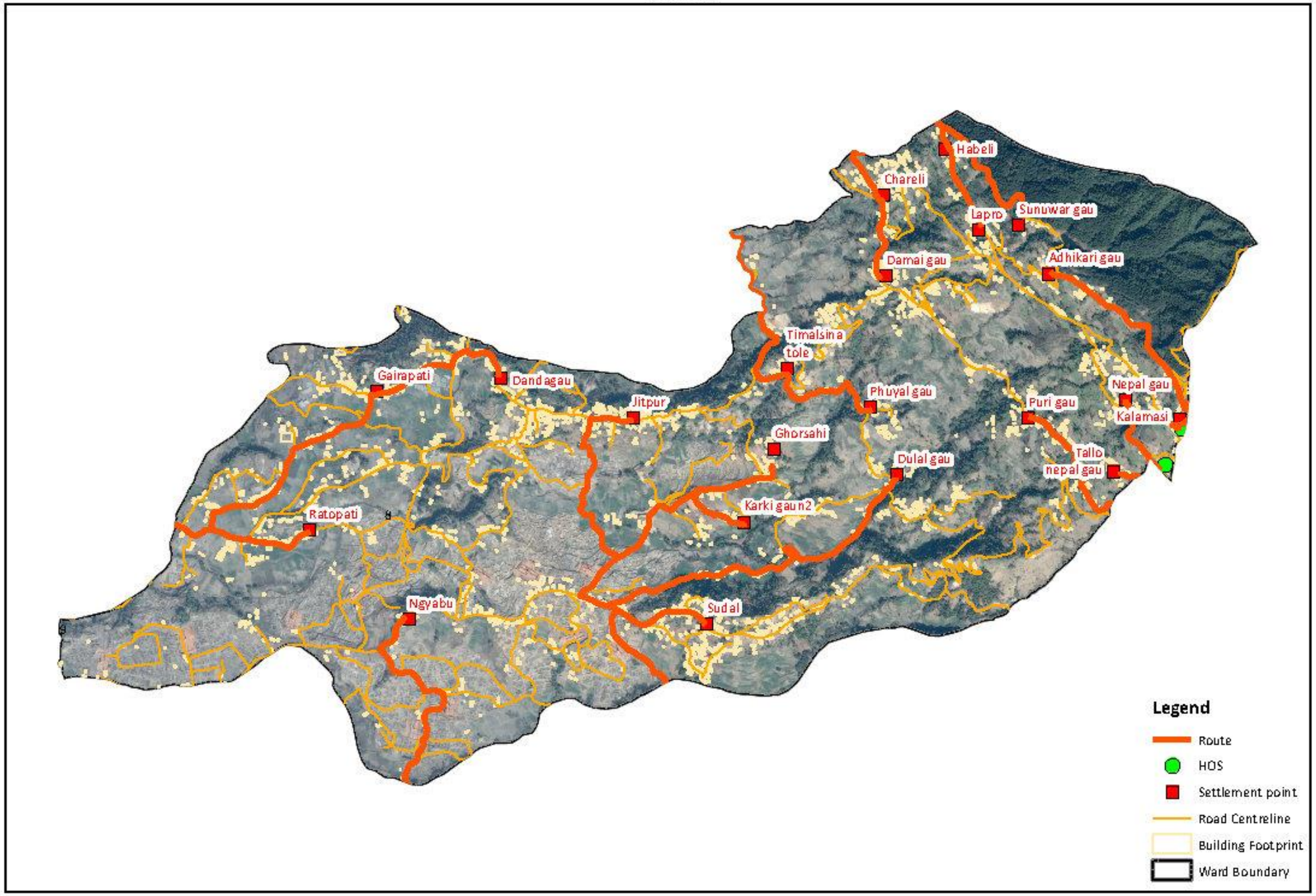
OPEN SPACE EVACUATION ROUTE

WARD NO: 7



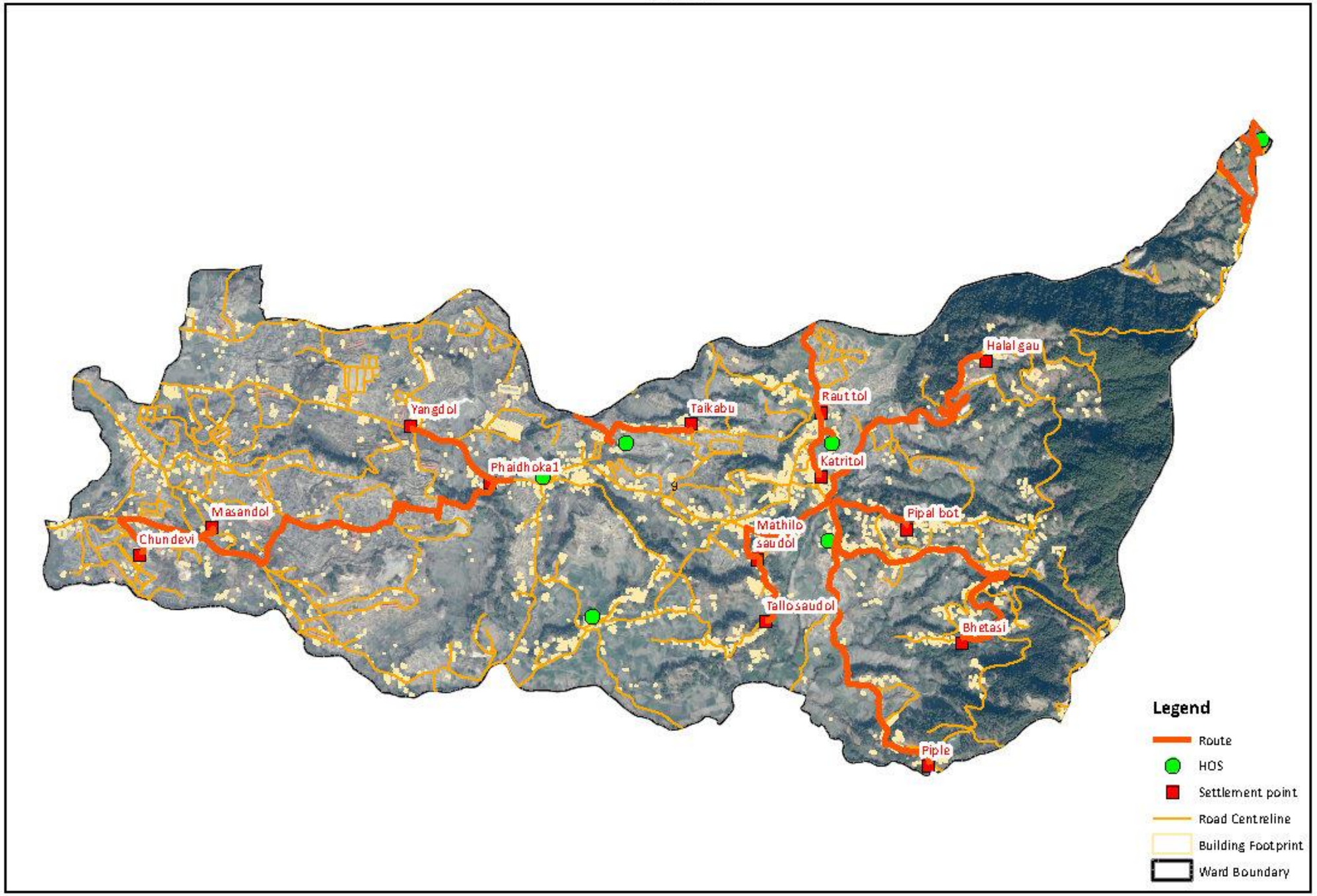
OPEN SPACE EVACUATION ROUTE

WARD NO: 8



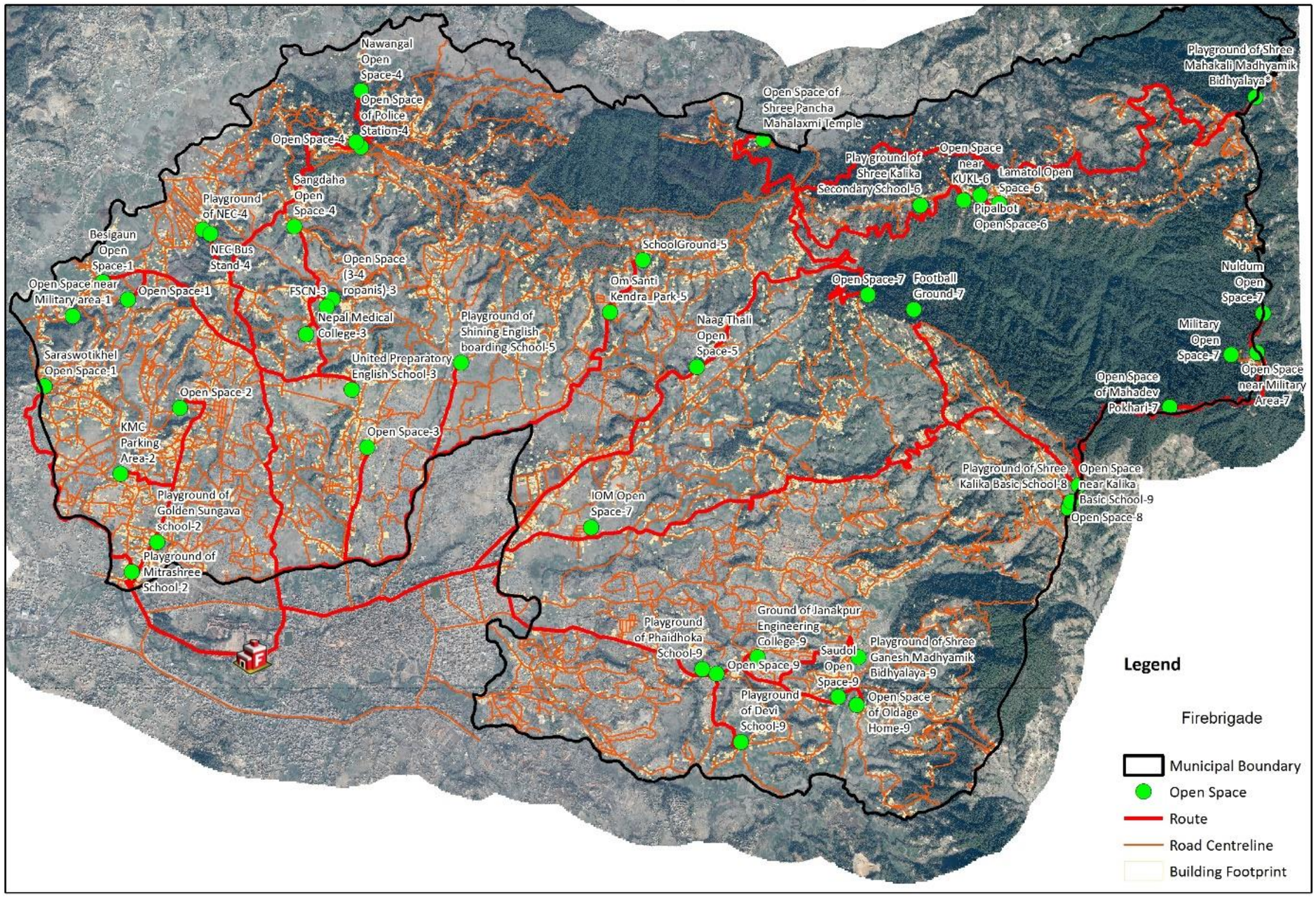
OPEN SPACE EVACUATION ROUTE

WARD NO: 9



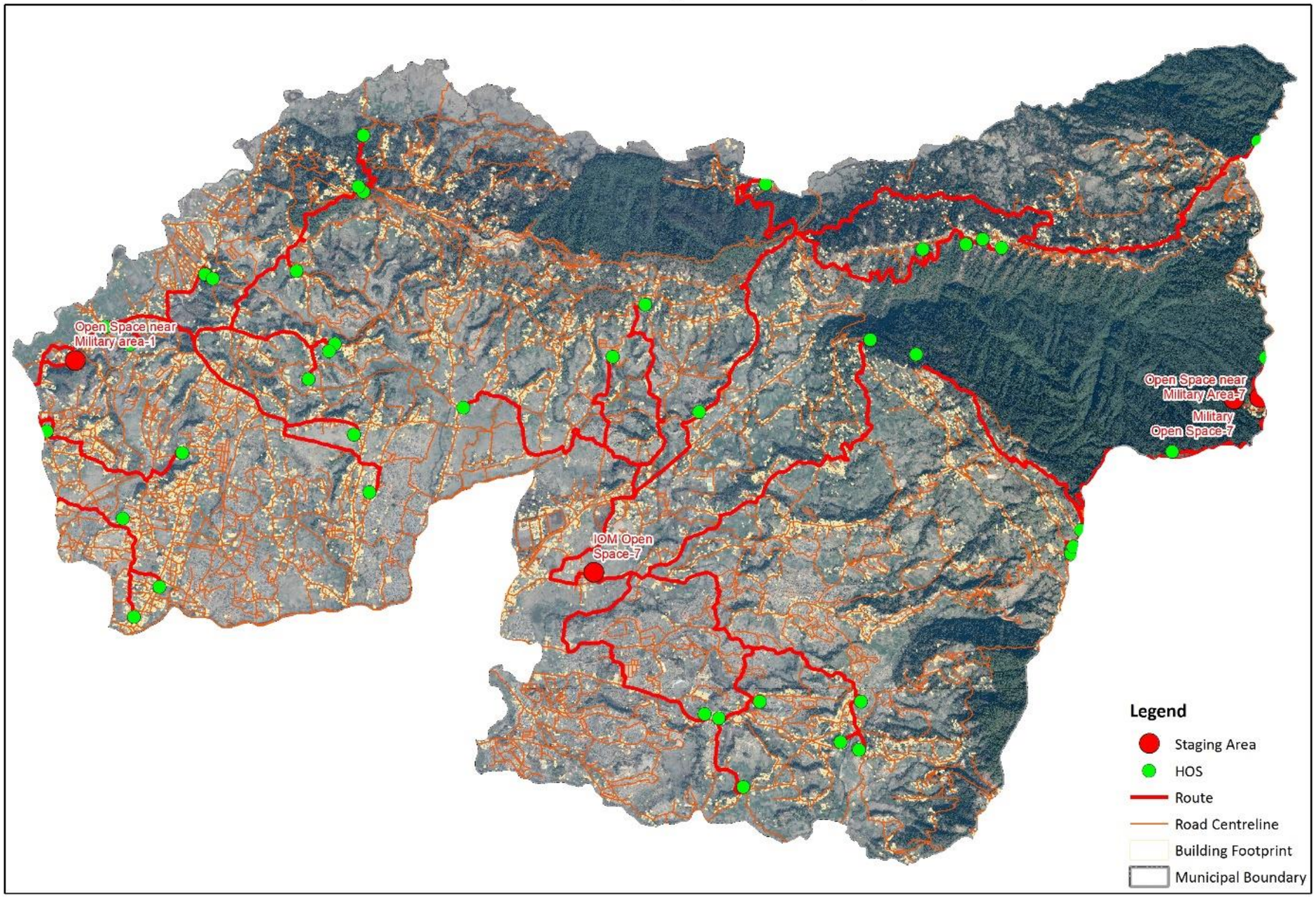
Evacuation Route from Fire Brigade to HOS

EVACUATION ROUTE (FIRE BIGADES TO HOS)



Evacuation Route from HOS to Staging Area

EVACUATION ROUTE (HOS TO STAGING AREA)



Annex 5 RSLUP Planning Zone Maps (in large scale A1 size)

<Attached separately>