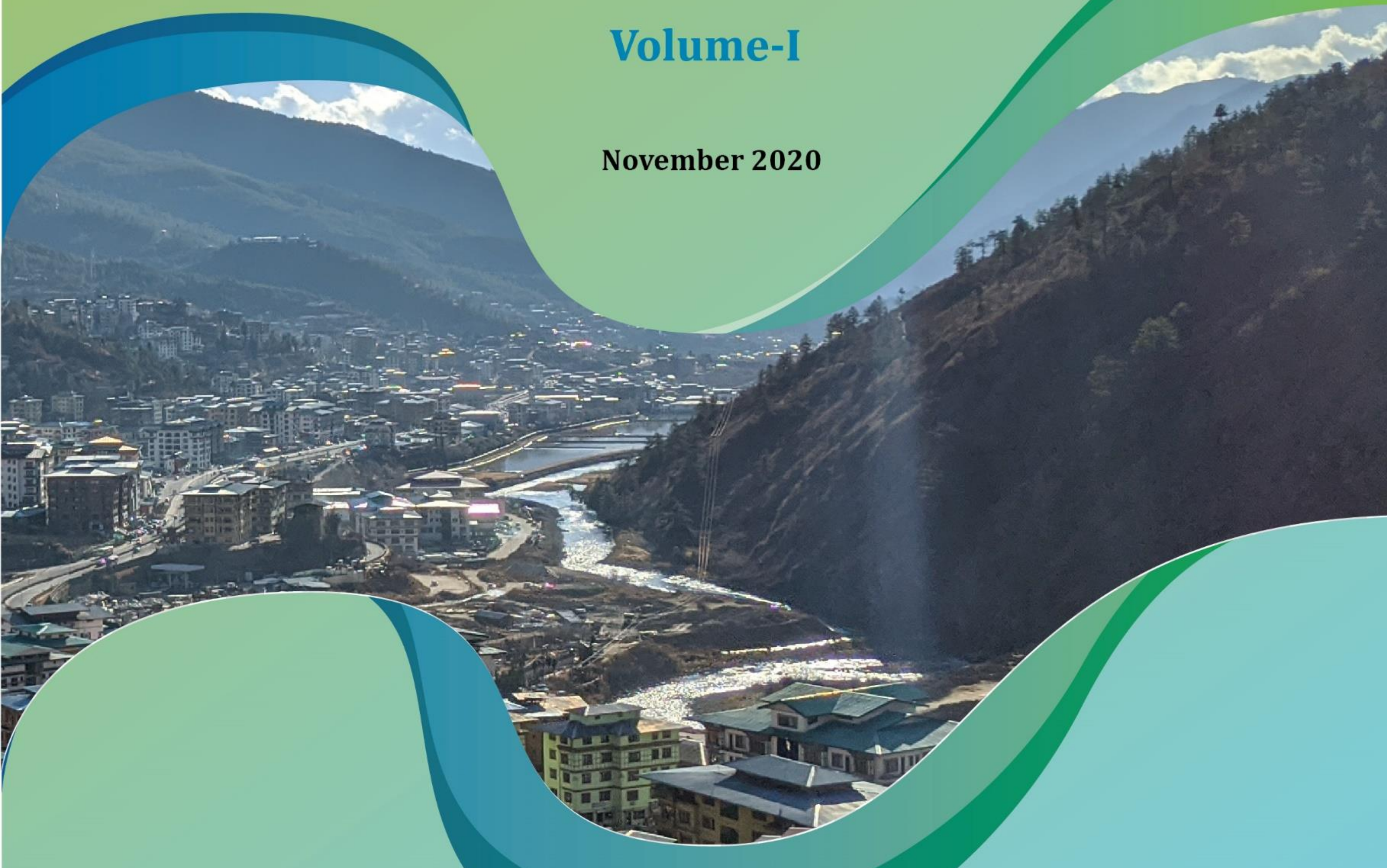
Department of Engineering Services
Ministry of Works and Human Settlement
Royal Government of Bhutan

Integrated Stormwater Management Plan for Thimphu Thromde (2021-2030)

Volume-I

November 2020



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In Association with

APECS Consultancy, Bhutan

Final Report

Integrated Stormwater Management Plan for Thimphu Thromde (2021-2030)

Acknowledgements

The Center for Environmental and Geographic Information Services (CEGIS), Bangladesh and M/s APECS Consultancy, Bhutan- JV expresses their gratitude to the Department of Engineering Services (DES) under the Ministry of Works and Human Settlement (MoWHS), Bhutan for entrusting CEGIS-APECS JV with the responsibility of conducting the project titled "Preparation of Stormwater Management Plan for Thimphu Thromde".

CEGIS-APECS JV is thankful to Mr. Karma Dupchuk, Director of Department of Engineering Services (DES) under the Ministry of Works and Human Settlement (MoWHS), Bhutan for offering his kind attention and guidance to initiate this study. CEGIS-APECS JV acknowledges the valuable suggestions, close coordination and sincere co-operation of Ms. Dago Zangmo, Chief Engineer, Flood Engineering and Management Division (FEMD), Department of Engineering Services (DES) under the Ministry of Works and Human Settlement (MoWHS), Bhutan.

CEGIS-APECS JV is especially thankful to Dasho Mr. Kinlay Dorjee, Thrompon, Thimphu Thromde for his kind cooperation and offering every possible support through engineers and planners of the Thimphu Thromde for smooth completion of this study. CEGIS-APECS JV expresses sincere gratitude to Mr. Karma Namgyel, Executive Secretary of the Thimphu Thromde for his kind cooperation and directions to enrich the study. CEGIS-APECS JV is also grateful to divisional Heads of Infrastructure Division, Environment Division, Development Control Division and Urban Planning Division of Thimphu Thromde for extending their help and guidance to finalize the study. The support provided by the zone engineers and other officials of the Thimphu Thromde was also very praiseworthy.

CEGIS-APECS JV expresses heartiest gratitude to Mr. Tayba Buddha, Chief, Hydrology and Water Resources Services Division and Dr. Singye Dorji, Chief, Weather and Climate Services Division of National Center for Hydrology and Meteorology (NCHM) for their kind suggestions, recommendations and extending their support to collect available data and information.

Besides, CEGIS-APECS JV is thankful to Ms. Kunzang Chhoden, Deputy Executive Engineer, Flood Engineering and Management Division (FEMD) for providing extensive technical guidance and input to improve and finalize the study. The relentless effort, coordination and cooperation by two project focals Mr. Kedhar Kumar Adhikari, GIS Officer and Mr. Ugyen Phuntsho, Engineer of Flood Engineering and Management Division (FEMD) in different stages of the study made the strong teambuilding effort. CEGIS-APECS JV is thankful to their kind support and cooperation.

CEGIS-APECS JV is also thankful to Mr. Pema Cheda, Deputy Executive Engineer of FEMD, MoWHS for his relentless support and feedbacks to understand the project site situation and taking part in consultations.

Last but not the least, CEGIS-APECS JV expresses their earnest gratitude to all community people and stakeholders of the Thimphu Thromde to take part in consultation and give their opinion during field validation and site visit.

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Abbreviations and Acronyms

APECS	APECS Consultancy Ltd.
BMP	Best Management Practices
CEGIS	Center for Environmental and Geographic Information Services
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DES	Department of Engineering Services
DHS	Department of Human Settlement
DoFPS	Department of Forest and Park Services
DoGM	Department of Geology and Mines
DoR	Department of Roads
FEMD	Flood Engineering and Management Division
GIS	Geographic Information System
GNHC	Gross National Happiness commission
GNP	Gross National Product
ISWMP	Integrated Storm Water Management Plan
LID	Low Impact Development
MoWHS	Ministry of Works and Human Settlement
MSL	Mean Sea Level
NCHM	National Center for Hydrology and Meteorology
NEC	National Environment Commission
PHCB	Population and Housing Census of Bhutan
SWMM	Storm Water Management Model by US EPA
WB	World Bank
WMD	Water Management Division

Executive Summary

Thimphu, the capital, and the biggest, city of Bhutan, is situated at the western central part of Bhutan. The city is spread out laterally in a north-south direction on the east-west bank of the valley formed by Wang Chuu. The city stretches 15 km long & 3 km wide with the area of 26 Sq.km. Thimphu is an economic development hub of the country. It contributes to 45% of the country's GNP (Gross National Product). Since the inception of this metropolis in 1960, urban development activities have been rapidly increasing in this city. Thimphu Thromde is expanding at a very high rate compared to other parts of the country. The population of Thimphu city was 43,479 in 2001 and 114,551 according to PHCB 2017. By 2027, it will increase to 162,327 (Kezang et al., 2017). The annual urban growth rate of 4%-5% is therefore increasing manifold problems. Among them, stormwater drainage problem is one of the prominent ones.

The Wang Chhu River which flows through Thimphu Thromde is named Thimphu Chhu which is the principal river of the Wang Chhu basin, one of the four principal river basins in the country. The river flow varies from a low of 3 to 5 m^3/s in January/February, to around 135m^3/s in some years in August/September. Several numbers of tributaries join and discharge into this river collecting surface runoff of the city through natural gullies and storm drains. The general land cover map (2010) of Bhutan shows that urban area is the dominant land use in the Thimphu Thromde covering 44% of the area, along with 33% forest and vegetation, 19% open space, 3% waterbodies and only 1% agricultural land. A recent study revealed that 13% urban area has been increased since 1990 to 2010 mostly reducing shrubs area and slightly reducing forests cover (-0.73%) and agricultural land (-1.5%). However, built up areas have substantially increased in course of time since 2010 and found 35% increase of settlements during last 8 years from 2013 to 2020.

The city is facing the storm water drainage problem very frequently due to a lack of coverage of network, loss of connectivity, inadequate capacity of existing urban drainage infrastructures, poor quality workmanship, lack of operation and maintenance work, poor planning with no outlet, lack of awareness of waste management etc. Drains constructed on an ad hoc basis are also not smooth and conducive for surface run-off, aggravating the situation. Some alignments also have discontinued drains along the roads, leading to overflow and deterioration of road conditions. The changed policy decisions that allowed the number of floors and ground coverage to be increased triggered the problem, on most cases. In addition to the increased surface runoff from the population and booming ongoing constructions, high intensity rain attributable to climate change also puts extra pressure on the existing drainage infrastructure.

Therefore, the Ministry of Works and Human Settlement (MoWHS) of the Royal Government of Bhutan through the Department of Engineering Services (DES) initiated the preparation of an Integrated Stormwater Management Plan (ISWMP) which will meet future demands of Thimphu Thromde (2020-2030). This plan would be the guiding tool for the decision makers aiming to alleviate the urban drainage problem and for the engineers to maintain the stormwater management system for the Thimphu Thromde in an efficient and sustainable way.

The ISWMP (2021-2030) has set aspirations to achieve the Vision of *Development of a Sustainable, Climate Resilient and Environmentally Sound Stormwater Management System for Thimphu Thromde* and the Goal of *Minimizing the Potential Threats of Urban Flooding and Protecting Natural Drainage Features Considering Urban Sprawl and Uncertainties of Climate Change by 2030*.

To achieve this vision and goal, the specific objectives considered are as follows:

- Assessment of adequacy of existing drainage system using SWMM modelling tool and stormwater management practices
- Provide sufficient infrastructure capacity to meet the future needs of the Thimphu Thromde (2020-2030) ensuring protection of the natural drains and streams
- Devise practically implementable economic and environmentally sound solutions incorporating Low Impact Development (LID) or Best Management Practices (BMP)

This ISWMP has been formulated in such a way that the envisioned stormwater management system will offer deliberative response by the responsible authority in case of any interventions need to undertake. On the other hand, the SWM system will be stakeholder responsive to ensure desired services from the Thromde. ISWMP focused on devising strategies maintaining coherence with the development vision of the RGoB and formulating no or low regret, adaptive and robust measures to tackle future uncertainties pose by climate change. Inclusion of environment friendly LID measures in stormwater management practices will attribute efficiency and sustainability of SWM interventions and allow flexibility for incremental adaptation. The successful implementation of ISWMP will enhance urban resilience of the Thimphu Thromde through climate proofing of major SWM initiatives.

The ISWMP has been formulated with very rigorous stocktaking and comprehensive technical analysis through SWMM modeling using US EPA SWMM tool. Recommendations and feedback of stakeholders i.e. local engineers and planners from the Thromde, engineers from DES and DoR, scientists from NCHM and community people have been taken into consideration throughout the plan preparation process. Future uncertainties of climate cange through dynamic downscaling and projected urban development scenario have got utmost importance to devise different alterntaives of SWM solutions. Field validation and manual cross check of design discharge estimation and adequacy checking has been performed to overcome of anomalies generated by the SWMM modeling and gain confidence on proposed measures. Finally strategies and measures have been prioritized from different alternatives taking preferences of experiences of local engineers from the Thimphu Thromde.

The issues, challenges, and recommendations of the 12th Five Year Plan (2018-2023) and Thimphu Structure Plan (2002-2027) relevant to stormwater management have been explicitly considered for the preparation of ISWMP. The plan has considered the future anticipated issues and concerns of 13th Five Year Plan (2023-2028) to address future challenges with holistic and prudent strategies. The global agenda of Sustainable Development Goals (2030) has also been considered for setting the planning horizon and targets. The interventions have been proposed thus in three timeframes i.e. short term (until 2023), medium term (2024-2030) and long term (beyond 2030). However, there would be provision of update and monitoring of plan in certain frequency, thereby the targets have been set in line with the three major milestones i.e. by 2023, 2028 and 2030 inside the planning period 2021-2030 and beyond. Seven major targets have been set in this ISWMP which are:

- Improved performance of existing drainage: 80% by 2023, 95% by 2028 and 100% by 2030.
- Reduce site specific stormwater drainage infrastructure related problems completely by 2025.
- Expansion of drainage coverage addressing future needs; 70% by 2023, 90% by 2028 and 100% by 2030.
- Establish functional monitoring mechanism for stormwater management by 2023.
- Enhance urban resilience through establishing emergency response and recovery mechanism by 2028.
- Strengthen human resources, institution, finance and coordination by 2025 and beyond.

- Promotion, popularize and Implementation of Low Impact Development measures by 2028.

The climate change analyses carried out in this study reveals that,

- Monsoon rainfall may change up to 15%-30% under RCP 4.5 and 20%-40% under RCP8.5 by 2050s with respect to present climate. Additionally winter rainfall would decrease slightly.
- Dry season may become dryer and highest maximum temperature may increase up to 1.5°-2.3° C by 2050s and highest minimum temperature may increase up to 2.0°-3.2° C by 2050s considering both RCPs.
- The intensity of short duration hourly rainfall would be increased from 25 mm/hr to 27 mm/hr for 20-year return period, 31 mm/hr to 37 mm/hr for 50-year return period and 36 mm/hr to 38 mm/hr for 100-year return period under RCP8.5 and by 2050s due to climate change. This means that, 100-year return period hourly rainfall event would become 50-year return period event while 50-year return period event would become 20-year return period event in future days.

Several principles have been set to formulate the strategies and conceptualization of measures, which are as following but not limited to:

- Maintaining alignment with the national and international development agenda
- Utilizing the existing resources and infrastructures
- Principles and recommendations of Thimphu Structure Plan for future urbanization
- Consideration of prevailing drainage pattern and characteristics
- Promotion of Environment friendliness or low impact development
- Innovative and IT based solutions
- Consideration of deep uncertainties due to climate change or pandemic like COVID-19
- Low cost, local materials oriented and durability
- Sustainability
- Standard SWMM Guidelines and Best Management Practices (BMPs)

Based on these principles the strategies for the stormwater management have been set, which are:

a. *Promote Climate resilient, sustainable stormwater drainage system*
b. *Promote Low Impact Development measures*
c. *Ensure regular and periodic cleaning and maintenance of the stormwater drainage system*
d. *Ensure cost-effective, nature-based and locally sourced solutions*

Following these strategies specific structural and non structural measures have been proposed. The structural measures include; Dimension increase and expansion of draiange structure, Construction of new drains in combination with LID measures, Changing type of drain (from L shape to Rectangular), Installation of stair/baffled drop structure with vegetation swale, Construction of catch pit at foothill outfall location, Construction of major drains instead of L-section, To use RCC drains with fixed cover along with changes in dimension for road crossing structure, Garbage Collection Sump, Drain top covered gutter, Periodic and Deep cleaning of drains before starting of monsoon season etc. The LID measures proposed include, Disconnecting rainwater from the roof and diversion , Low Cost Rainwater Harvesting, Reuse and Discharge through Infiltration Trench, Green landscaping, Increasing and maintaining natural vegetation in parks and other areas, Converting paved areas e.g., parking lot, footpath to permeable pavements or traditional Dolep pathways to allow for increased infiltration, Proper cleaning mechanism and waste management, Pollution control from source rather than construction of WWTP, Collection of waste through installing trash rack and garbage collection sump before outlet, infiltration trench, bio retention etc. in low lying areas before discharging into the river to allow infiltration and settling of pollutants in the conveyance system, Discharging domestic waste water into locally installed infiltration trench before discharging into the storm drains directly etc.

The identified non-structural measures are: Institutional Reform: Setting 'Emergency Response Unit', Development and implementation of standard operational procedure for emergency response Recovery, Procurement of Machineries and Equipment for Emergency Response, Integration of Explicit 'Regulatory Framework for Stormwater Management' into the Existing Standard Operational Procedure, Enhancement of Inter and Intra Institutional Coordination, Establishment of Financing Mechanism for Stormwater Management and Mainstream into Existing Budgeting System, Establishment of Functional Monitoring Mechanism for Stormwater Management, Monitoring, Review and Update of Stormwater Management Plan, Development of Stormwater Drain Design and Management Guideline, Capacity Building and Skill Development of Engineers and Planners, Campaign for Citizen Behavior Change and Awareness Building, Recruitment of skilled manpower for operation, maintenance, emergency response and recovery, Popularization of LID measures or Best management practices at community level, Update of Stormwater Drainage infrastructure geo Inventory, Explicit Clause of SWM on Occupancy Certificates and other Inspection Form DCR, Explicit Clause of LID Measures in city regulations etc.

Following these activities, several programs have been considered for storm water management in Thimphu Thromde under which 25 separate activities or projects have been outlined. These 4 programs are:

- P1: Development of Sustainable and Climate Resilient Stormwater Infrastructures
- P2: Emergency Response and Recovery
- P3: Strengthening Institutions, Coordination and Monitoring
- P4: Capacity Development

In accordance with these programs, tentative mitigation maps of areas needing specific measures and their tentative costs and detailed designs have been prepared. A total investment of 1366.3 million Nu is proposed to be required to implement the plan throughout 10 years. Based on the study overall institutional/ coordination guidelines and monitoring and evaluation framework have been proposed along with targets for the future. These mechanisms are expected to result in sustainable and climate resilient stormwater management for the city if implemented accordingly.

1. Introduction

1.1 Context

Thimphu, the capital city of Bhutan is an economic development hub of the country. Thimphu contributes to 45% of the country's GNP (Gross National Product) as the political and economic center of Bhutan. Since the inception of this metropolis in 1960, urban development activities have been rapidly increasing in this city. Thimphu Thromde is expanding at a very high rate compared to other parts of the country. The population of Thimphu city was 43,479 in 2001, 79,185 with density of 3029 persons per sq km in 2005, 91,000 in 2011 and 114,551 according to PHCB 2017. The population of Thimphu Thromde is estimated to grow further 162,327 by the year 2027 (Kezang et al., 2017). The annual urban growth rate of 4%-5% is therefore increasing manifold problems. Among them, stormwater drainage problem is one of the prominent ones.

The city is facing the storm water drainage problem very frequently due to a lack of coverage of network, loss of connectivity, inadequate capacity of existing urban drainage infrastructures, poor quality workmanship, lack of operation and maintenance work, poor planning with no outlet, lack of awareness of waste management etc. Drains constructed on an ad hoc basis are also not smooth and conducive for surface run-off, aggravating the situation. Some alignments also have discontinued drains along the roads, leading to overflow and deterioration of road conditions. The changed policy decisions that allowed the number of floors and ground coverage to be increased triggered the problem, on most cases. In addition to the increased surface runoff from the population and booming ongoing constructions (almost 300 buildings/year), high intensity rain attributable to climate change also puts extra pressure on the existing drainage infrastructure.

Figure 1.1: Recent Photographs of Havoc due to Stormwater Drainage Problems in Thimphu Thromde

Therefore, the Ministry of Works and Human Settlement (MoWHS) of the Royal Government of Bhutan through the Department of Engineering Services (DES) has entrusted JV of CEGIS, Bangladesh-APECS, Bhutan to conduct this assignment to prepare an Integrated Stormwater Management Plan which will meet future demands of Thimphu Thromde (2020-2030). This Integrated Storm Water Management Plan (ISWMP) would be the guiding tool for the decision makers to invest aiming to alleviate the urban drainage problem and for the engineers to maintain the stormwater management system for the Thimphu Thromde in an efficient and sustainable way.

1.2 Vision, Goal and Objectives

The ISWMP (2021-2030) has set aspirations to achieve the Vision of a *Development of a Sustainable, Climate Resilient and Environmentally Sound Stormwater Management System for Thimphu Thromde* and the Goal of *Minimizing the Potential Threats of Urban Flooding and Protecting Natural Drainage Features Considering Urban Sprawl and Uncertainties of Climate Change by 2030*.

To achieve this vision and goal some specific objectives have been taken into consideration in this very first comprehensive stormwater management plan for the Thimphu Thromde. They are as following:

- Assessment of adequacy existing drainage system using US EPA SWMM and stormwater management practices
- Provide sufficient infrastructure capacity to meet the future needs of the Thimphu Thromde (2020-2030) ensuring protection of the natural drains and streams
- Devise practically implementable economic and environmentally sound solutions incorporating Low Impact Development (LID) or Best Management Practices (BMP)

1.3 Principles and Formulation Process of the ISWMP

This ISWMP has been formulated on the laid foundation of 8 major principles as shown in the figure below. This plan has been formulated in such a way that the envisioned stormwater management system will offer deliberative response by the responsible authority in case of any interventions need to undertake. On the other hand, the SWM system will be stakeholder responsive to ensure desired services from the Thromde. ISWMP focused on devising strategies maintaining coherence with the development vision of the Royal Government of Bhutan (RGoB) and formulating no or low regret, adaptive and robust measures to tackle future uncertainties pose by climate change. Inclusion of environment friendly Low Impact Development (LID) measures in stormwater management practices will attribute efficiency and sustainability of SWM interventions and allow flexibility for incremental adaptation. Last but not the least, successful implementation of ISWMP will enhance urban resilience of the Thimphu Thromde through climate proofing of major SWM initiatives. These adopted principles may be theoretically idealistic, but made this plan inclusive and practically implementable devising some down to the earth structural and non-structural stormwater management measures considering in situ condition.

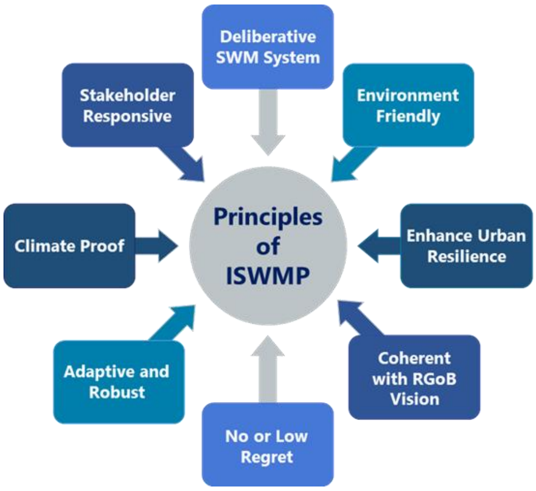


Figure 1.2: Principles of ISWMP

The ISWMP has been formulated with very rigorous stocktaking and comprehensive technical analysis through SWMM modeling using US EPA SWMM tool. Recommendations and feedback of stakeholders i.e. local engineers and planners from the Thromde, engineers from DES and DoR, scientists from NCHM and community people have been taken into consideration throughout the plan preparation process. Future uncertainties of climate change through dynamic downscaling and projected urban development scenario have got utmost importance to devise different alternatives of SWM solutions. Field validation and manual cross check of design discharge estimation and adequacy checking has been performed to overcome of anomalies generated by the SWMM modeling and gain confidence on proposed measures. Finally, strategies and measures have been prioritized from different alternatives taking preferences of experiences of local engineers from the Thimphu Thromde. Following figure illustrates overall process of the ISWMP formulation:

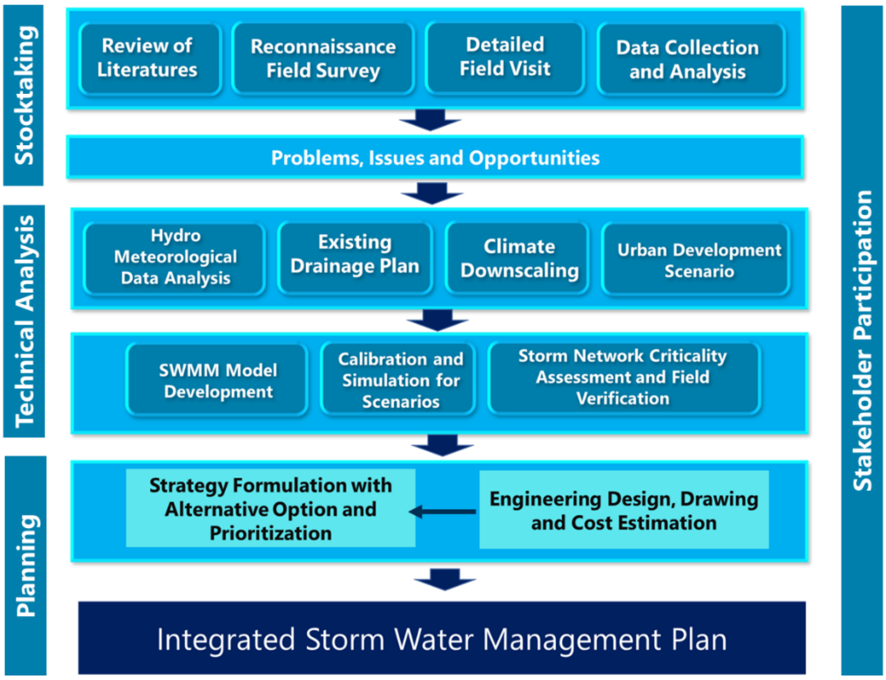


Figure 1.3: ISWMP Formulation Process

1.4 Planning Domain

1.4.1 Geographic Location

Thimphu, the capital, and the biggest, city of Bhutan, is situated at the western central part of Bhutan between 27°28′00″N 89°38′30″E and 27°28′00″N 89° 38′30″E. The city is spread out laterally in a north-south direction on the east-west bank of the valley formed by Wang Chuu. The city stretches 15 km long & 3 km wide which starts from Dechencholing from the North and ends at Babesa in the South with the area of 26 Sq.km.

Thimphu Thromde has been divided into 7 Demkhongs namely Babesa, Changbangdu-Olokha, Changangkha, Dechencholing, Jungshina- Kawajangsa, Motithang and Norzin. Figure 1.4 shows the map of the planning domain and Figure 1.5 to Figure 1.11 illustrate Demkhong's map inside the domain i.e. Thimphu Thromde. Among the Changabangdu Olakha and Babesa are the two largest Demkhongs in the central to southern portion of the city.

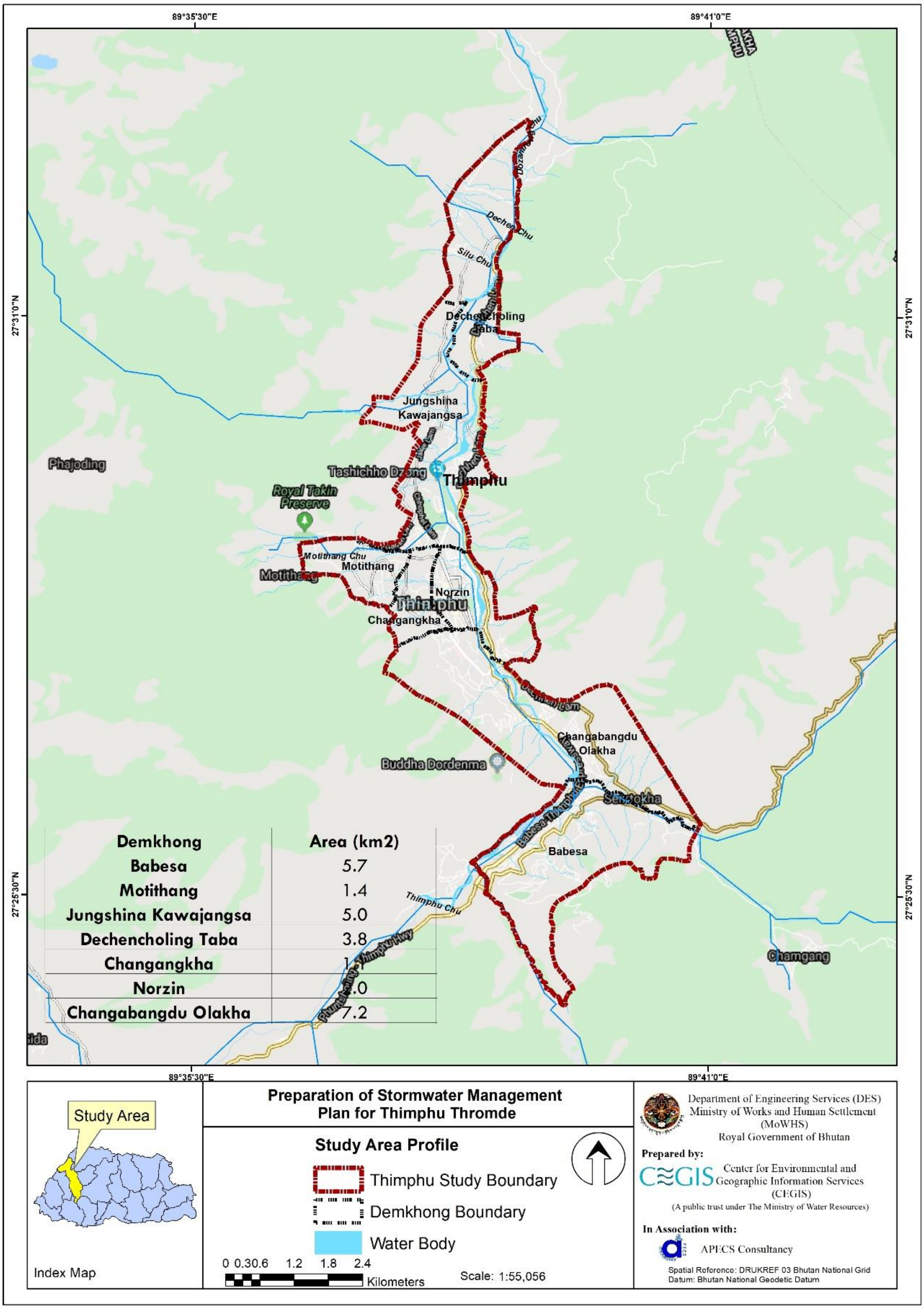


Figure 1.4: Geographical Location of Thimphu Thromde

Figure 1.5: Babesa Demkhong of Thimphu Thromde

Figure 1.6: Changang Kha Demkhong of Thimphu Thromde

Figure 1.7: Dechencholing Taba Demkhong of Thimphu Thromde

Figure 1.8: Jungshina Kawajangsa Demkhong of Thimphu Thromde

Figure 1.9: Motithang Demkhong of Thimphu Thromde

Figure 1.10: Norzin Demkhong of Thimphu Thromde

Figure 1.11: Changabangdu Olakha Demkhong of Thimphu Thromde

1.4.2 Topography

The Thromde spreads over an altitudinal range between 2,257 meters and 2,750 meters. Almost 75% of the area of Thromde lies under the elevation ranges of 2250-2350 m above mean sea level (MSL) and rest (25%) of the area beyond 2350m above MSL. Figure 1.12 shows the topography map of the study area. The Raidak River raises in the snow fields at an altitude of about 7,000 meters (23,000 ft). It has many tributaries that flow from the Himalayan peaks largely dictating the topography of the Thimphu valley. The Thimphu valley, so formed, is delimited by a steep eastern ridge that rises from the riverbed and a valley formation with gradually sloping topography, extending from Dechencholing and Simtokha, on the western banks of the Raidāk (Thimphu Dzonkhag Website). The north-south orientation of the hill ranges of the valley means that they are exposed to moist monsoon winds which engulf the inner Himalayas and its lower valleys. However, the windward and leeward sides of the hill ranges have different vegetation patterns depending on the varying rainfall incidence in the two sides. Thimphu valley lying in the leeward side of the mountains is comparatively dry and contains a different type of vegetation as compared to the windward side. Hence, the coniferous vegetation in the valley is attributed to this phenomenon.

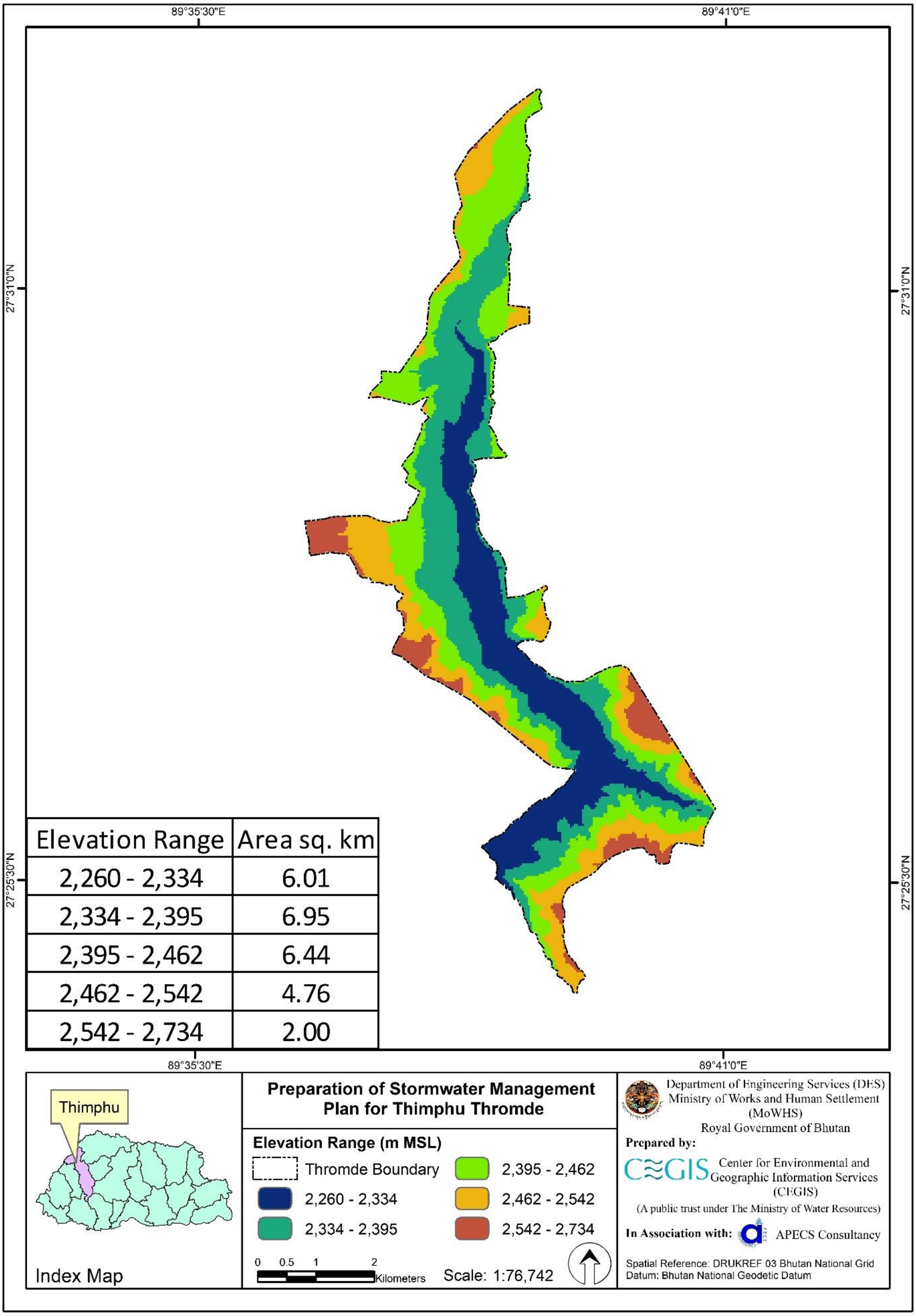


Figure 1.12: Topography of Thimphu Thromde

1.4.3 Climate

Thimphu's climate is characterized as cool and temperate. Temperatures here range from 0°C in winter to around 26°C in summer. The annual average minimum and maximum temperature ranges from 7°C to 23°C respectively. The highest temperature recorded in the city in 1997 was 29.8°C during the month of July while the lowest was recorded to be -4.6°C during the month of January. The highest average annual rainfall that the city received in 2002 was 867 mm with a maximum average of 254 mm during the month of July and minimum of 1 mm during the month of November. The average annual rainfall has been found 646 mm in MoEA complex station during the period of 1996-2019.

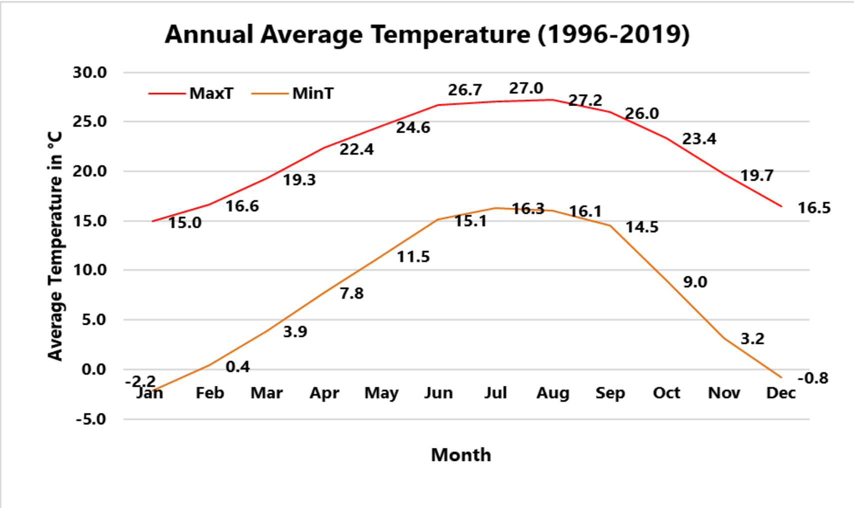


Figure 1.13: Annual Average Maximum and Minimum Temperature for Thimphu

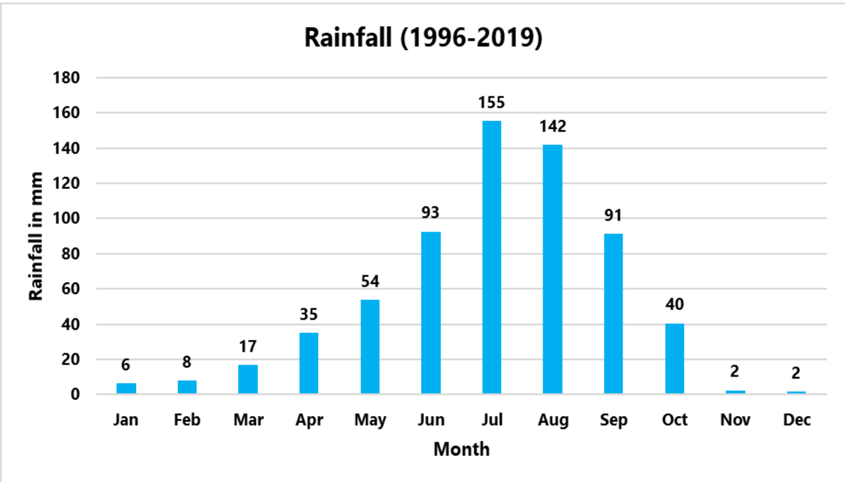


Figure 1.14: Annual Average Rainfall for Thimphu

1.4.4 Hydrology

The Wang Chhu River which flows through Thimphu Thromde is named Thimphu Chhu which is the principal river of the Wang Chhu basin, one of the four principal river basins in the country. The river flow varies from a low of 3 to 5 m3/s in January/February, to around 135m3/s in some years in

August/September. Several numbers of tributaries join and discharge into this river collecting surface runoff of the city through natural gullies and storm drains. Among them Olarang Chhu, Kabisa stream, Motithang Chhu, Chuba Chhu, Dechencholing Chhu, Lanjophakha, Taba Chhu, Changangkha Chhu, Ngarephu (RTC) Chhu and Samteling Chhu are noteworthy. Figure 1.15 shows the watershed boundary for the Thimphu.

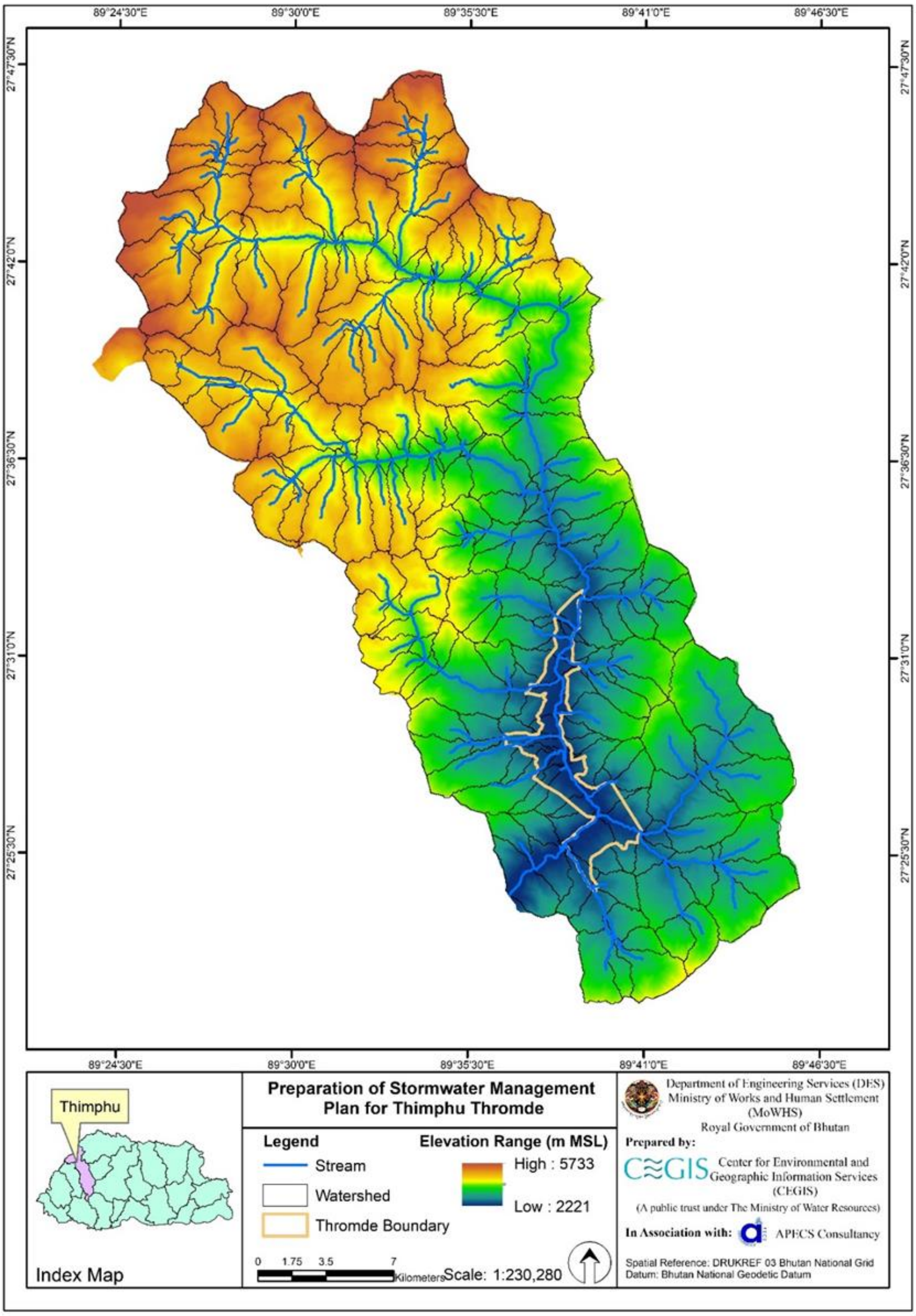
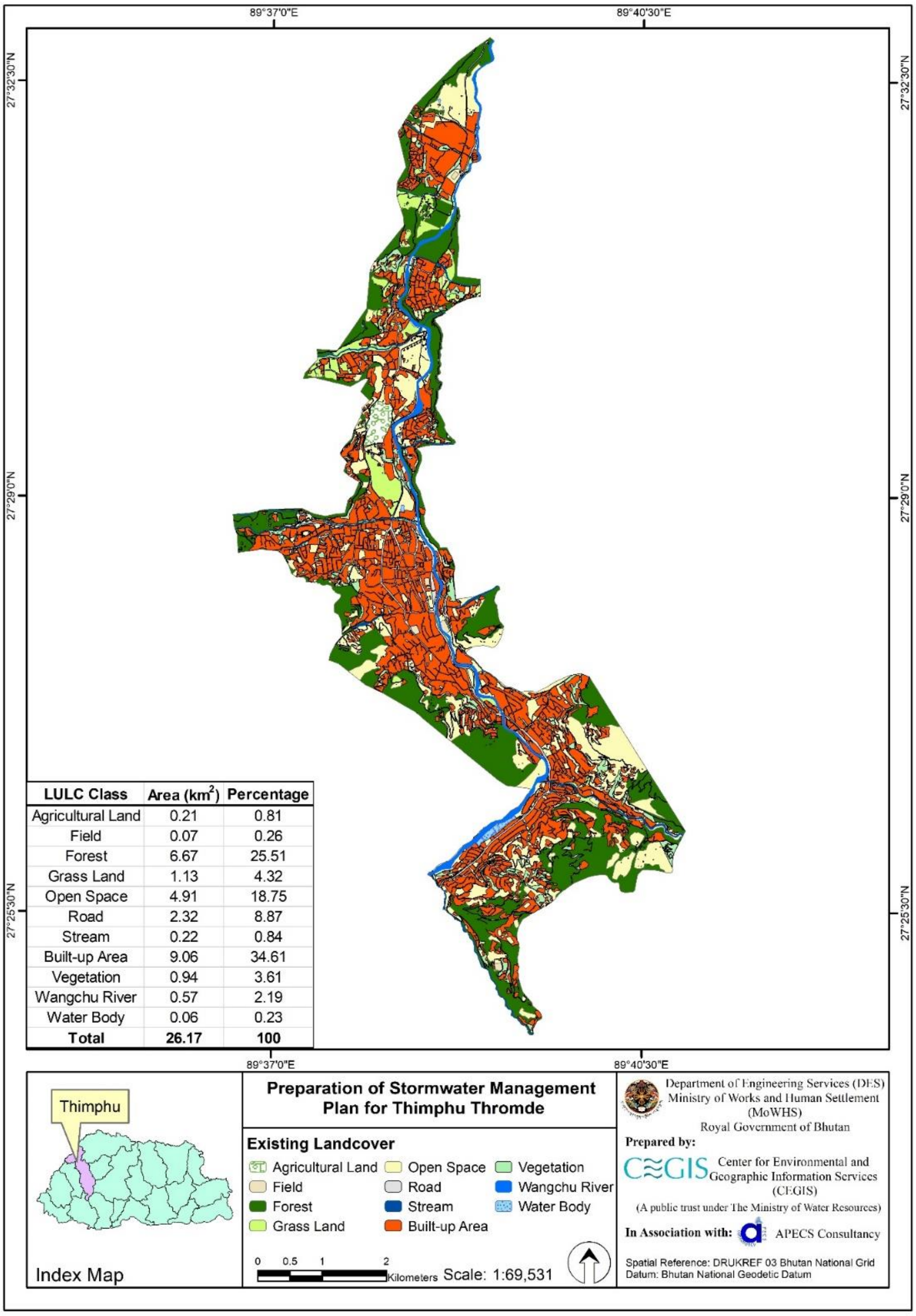


Figure 1.15: Watershed area of the Thmiphu basin

1.4.5 Land Cover

The general land cover map (2010) of Bhutan prepared by ICIMOD depicts that urban area is the dominant land uses in the Thimphu Thromde covers 44% of the area, along with 33% forest and vegetation, 19% open space, 3% waterbodies and only 1% agricultural land. The study (Giri and Singh, 2013) revealed that almost 13% urban area has been increased since 1990 to 2010 mostly reducing shrubs area and slightly reducing forests cover (-0.73%) and agricultural land (-1.5%). However, built up areas or urban areas have further substantially increased in course of time since 2010 and found 35% increase of settlements during last 8 years from 2013 to 2020. Figure 1.16 shows the land cover map of the Thimphu Thromde.



LULC Class	Area (km^2)	Percentage
Agricultural Land	0.21	0.81
Field	0.07	0.26
Forest	6.67	25.51
Grass Land	1.13	4.32
Open Space	4.91	18.75
Road	2.32	8.87
Stream	0.22	0.84
Built-up Area	9.06	34.61
Vegetation	0.94	3.61
Wangchu River	0.57	2.19
Water Body	0.06	0.23
Total	**26.17**	**100**

Figure 1.16: Land cover of the Thimphu Thromde

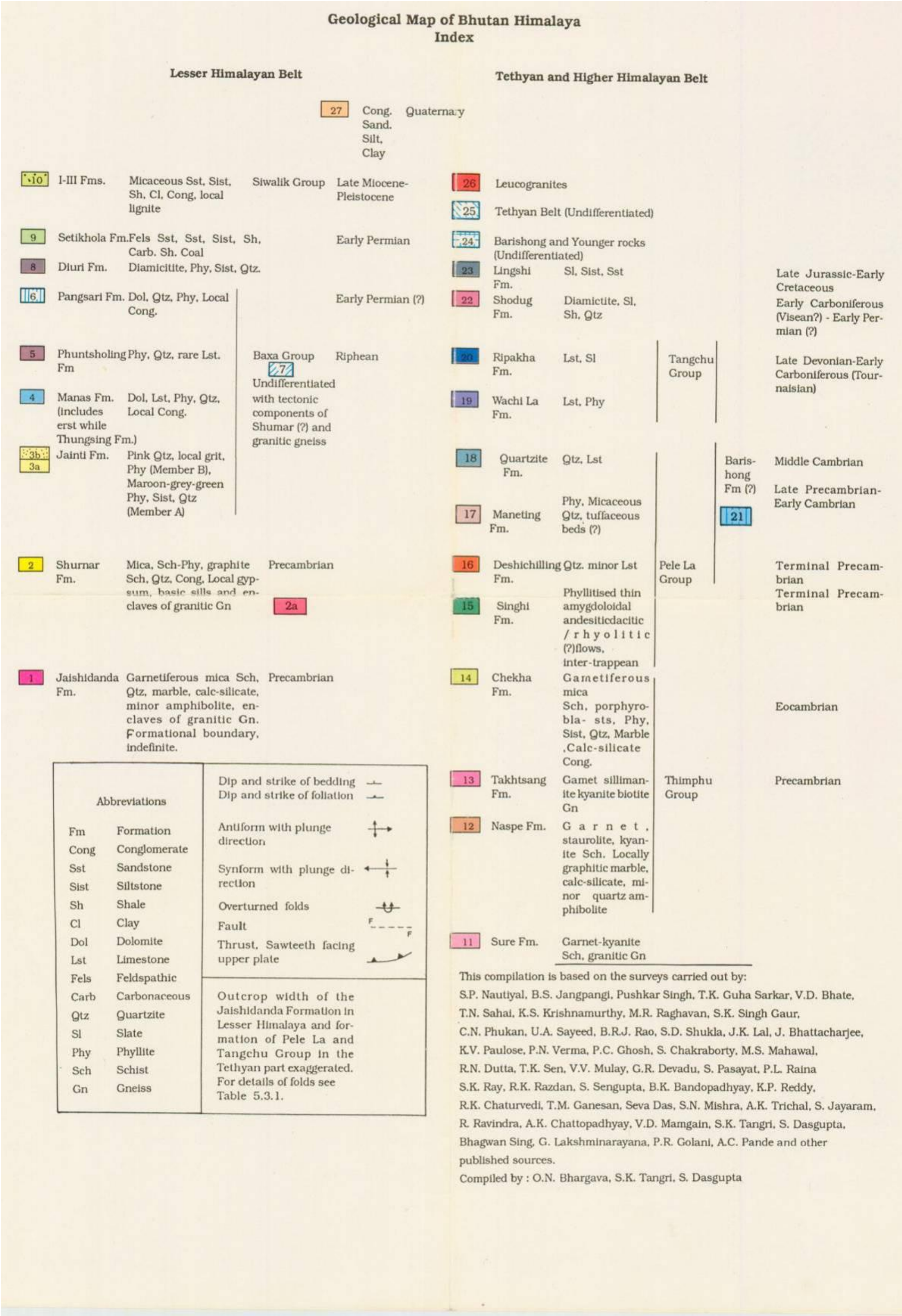
1.4.6 Lithology

Jangpangi (1968) maps the site as being as close to the boundary between quartzite and mica schist and more highly metamorphosed gneisses with mica schist. Gansser (1983) maps the area as the Paro Formation, which is moderately - highly metamorphosed and has a high proportion of schists.

The most recent geological description of the Thimphu area indicates that the area is wholly underlain by the Thimphu Gneiss formation (Bhargava 1995). This is a highly metamorphosed rock, with muscovite and biotite micas, plagioclase feldspars, and quartz as the main minerals. The rocks were formed by the folding and shearing that occurred in the thrusting from the north during the Himalayan orogeny.

The soils on the ridge are residual and have very shallow sola (<20 cm deep) overlying hard quartzite. The quartzite is inter-bedded with highly weathered biotite gneiss, which liberates considerable quantities of ferric iron compounds, on weathering, and gives bright red-orange-yellow soil colours. It is possible that the weathering was more intense during periods in the Pleistocene and/or Holocene when the climate of the area was warmer and more humid than it is now. On the lower side slope of ridge, the quartzite is underlain by schists. Some of these are also highly weathered giving strong brown soil colours. However, other ones are not so weathered and are more dark greyish brown. The colluvial deposits on the gentler, slightly concave lower slopes are thick in places but are mostly less than 2 m deep. These deposits are underlain by Thimphu gneiss, which is highly weathered.

As reproduced in the Bhutan Map by the Geological Society of America (Sean Long et. al), the study area has Lower meta-sedimentary unit (Neoproterozoic-Cambrian) which has dominantly amphibolite-facies (Gansser, 1983; Grujic et al., 2002; Daniel et al., 2003) metasedimentary rocks, including quartzite, and biotite-muscovite-garnet schist and paragneiss often exhibiting kyanite, sillimanite, or staurolite, and partial melt textures (Long and McQuarrie, 2010). As per their study, this area is placed under Structurally-Lower Great Himalayan section within the Great Himalayan Zone.



Geological Map of Bhutan Himalaya
Index

Lesser Himalayan Belt

27	Cong. Sand. Silt, Clay			Quaternary
10	I-III Fms.	Micaceous Sst, Sist, Sh, Cl, Cong, local lignite	Siwalik Group	Late Miocene-Pleistocene
9	Setikhola Fm.	Fels Sst, Sst, Sist, Sh, Carb. Sh. Coal		Early Permian
8	Diuri Fm.	Diamicitite, Phy, Sist, Qtz.		
6	Pangsari Fm.	Dol, Qtz, Phy, Local Cong.		Early Permian (?)
5	Phuntsholing Fm	Phy, Qtz, rare Lst.	Baxa Group	Riphean
4	Manas Fm. (includes erst while Thungsing Fm.)	Dol, Lst, Phy, Qtz, Local Cong.	7 Undifferentiated with tectonic components of Shumar (?) and granitic gneiss	
3b, 3a	Jainti Fm.	Pink Qtz, local grit, Phy (Member B), Maroon-grey-green Phy, Sist, Qtz (Member A)		
2	Shumar Fm.	Mica, Sch-Phy, graphite Sch, Qtz, Cong, Local gypsum, basic sills and enclaves of granitic Gn	2a	Precambrian
1	Jaishidanda Fm.	Garnetiferous mica Sch, Qtz, marble, calc-silicate, minor amphibolite, enclaves of granitic Gn. Formational boundary, indefinite.		Precambrian

Tethyan and Higher Himalayan Belt

26	Leucogranites			
25	Tethyan Belt (Undifferentiated)			
24	Barishong and Younger rocks (Undifferentiated)			
23	Lingshi Fm.	Sl, Sist, Sst		Late Jurassic-Early Cretaceous
22	Shodug Fm.	Diamictite, Sl, Sh, Qtz		Early Carboniferous (Visean?) - Early Permian (?)
20	Ripakha Fm.	Lst, Sl	Tangchu Group	Late Devonian-Early Carboniferous (Tournaisian)
19	Wachi La Fm.	Lst, Phy	Tangchu Group	
18	Quartzite Fm.	Qtz, Lst		Middle Cambrian
21	Barishong Fm (?)			Late Precambrian-Early Cambrian
17	Maneting Fm.	Phy, Micaceous Qtz, tuffaceous beds (?)		
16	Deshichilling Fm.	Qtz, minor Lst	Pele La Group	Terminal Precambrian
15	Singhi Fm.	Phyllitised thin amygdoloidal andesiticdacitic /rhyolitic (?)flows, inter-trappean		Terminal Precambrian
14	Chekha Fm.	Garnetiferous mica Sch, porphyroblasts, Phy, Sist, Qtz, Marble, Calc-silicate Cong.		Eocambrian
13	Takhtsang Fm.	Garnet sillimanite kyanite biotite Gn	Thimphu Group	Precambrian
12	Naspe Fm.	Garnet, staurolite, kyanite Sch. Locally graphitic marble, calc-silicate, minor quartz amphibolite		
11	Sure Fm.	Garnet-kyanite Sch, granitic Gn		

Abbreviations

Fm	Formation
Cong	Conglomerate
Sst	Sandstone
Sist	Siltstone
Sh	Shale
Cl	Clay
Dol	Dolomite
Lst	Limestone
Fels	Feldspathic
Carb	Carbonaceous
Qtz	Quartzite
Sl	Slate
Phy	Phyllite
Sch	Schist
Gn	Gneiss

Dip and strike of bedding
Dip and strike of foliation
Antiform with plunge direction
Synform with plunge direction
Overturned folds
Fault
Thrust, Sawteeth facing upper plate

Outcrop width of the Jaishidanda Formation in Lesser Himalaya and formation of Pele La and Tangchu Group in the Tethyan part exaggerated. For details of folds see Table 5.3.1.

This compilation is based on the surveys carried out by: S.P. Nautiyal, B.S. Jangpangi, Pushkar Singh, T.K. Guha Sarkar, V.D. Bhate, T.N. Sahai, K.S. Krishnamurthy, M.R. Raghavan, S.K. Singh Gaur, C.N. Phukan, U.A. Sayeed, B.R.J. Rao, S.D. Shukla, J.K. Lal, J. Bhattacharjee, K.V. Paulose, P.N. Verma, P.C. Ghosh, S. Chakraborty, M.S. Mahawal, R.N. Dutta, T.K. Sen, V.V. Mulay, G.R. Devadu, S. Pasayat, P.L. Raina, S.K. Ray, R.K. Razdan, S. Sengupta, B.K. Bandopadhyay, K.P. Reddy, R.K. Chaturvedi, T.M. Ganesan, Seva Das, S.N. Mishra, A.K. Trichal, S. Jayaram, R. Ravindra, A.K. Chattopadhyay, V.D. Mamgain, S.K. Tangri, S. Dasgupta, Bhagwan Sing, G. Lakshminarayana, P.R. Golani, A.C. Pande and other published sources.

Compiled by : O.N. Bhargava, S.K. Tangri, S. Dasgupta

Figure 1.17: Geological Map of Bhutan

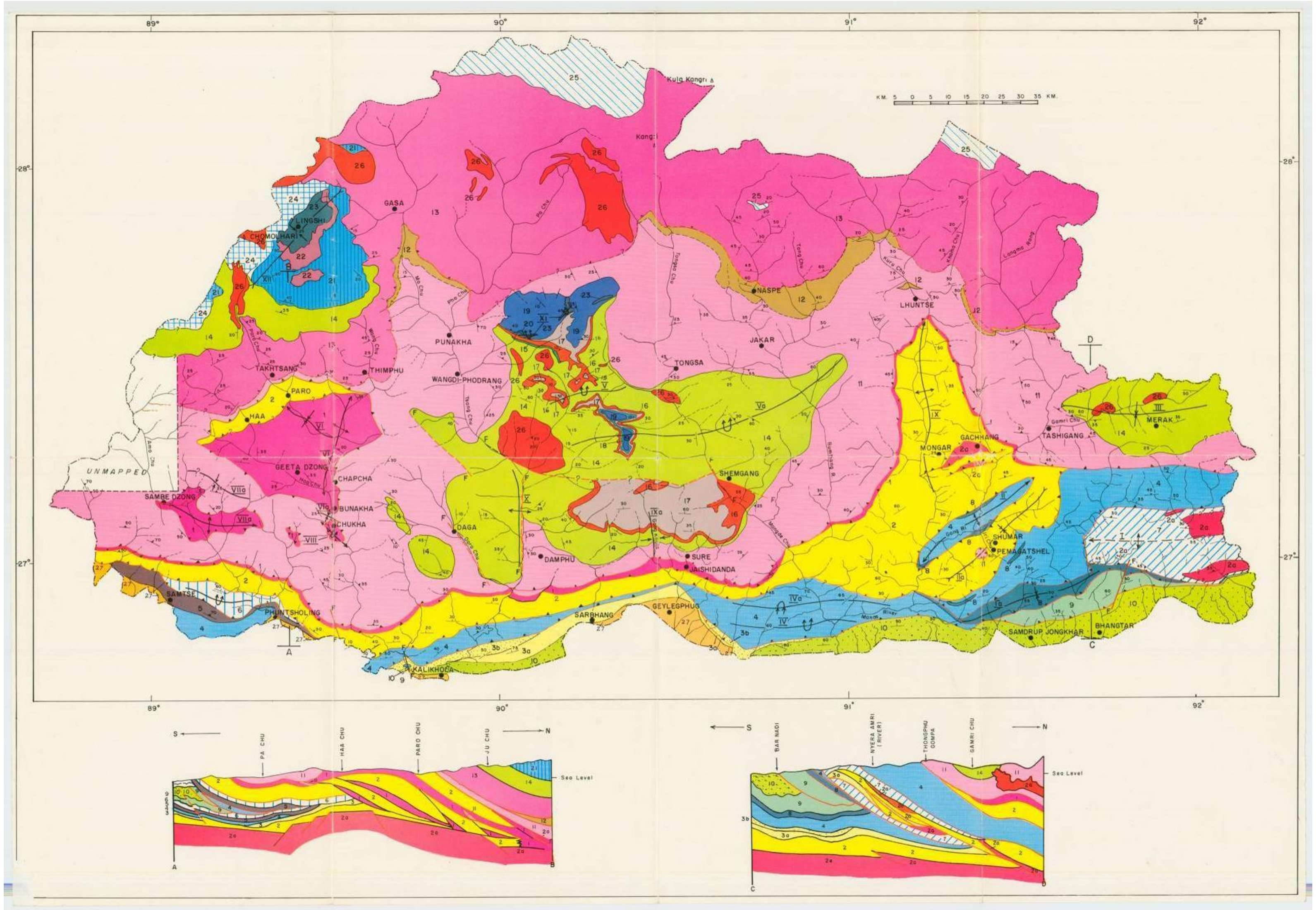


Figure 1.18: Lithological Map of Bhutan

1.4.7 Soil

According to a detailed soil survey of RNR-RC, Yusipang (SSU, 1998), the soils are formed in residual and colluvial materials on the hills, and in the fan alluvium of the valley floor. All the soil parent materials are derived from the Thimphu gneiss. The soils of the Centre are subdivided into three main geomorphic parent material groups, i.e. residual and colluvial soils of hill slopes, colluvial/slump soils of foot slopes, and depositional soils of the valley floor. The soils of the area span a narrow textural range, with sandy loams and sandy clay loams predominant. The soils are moderately acid and have generally low contents of available N and P.

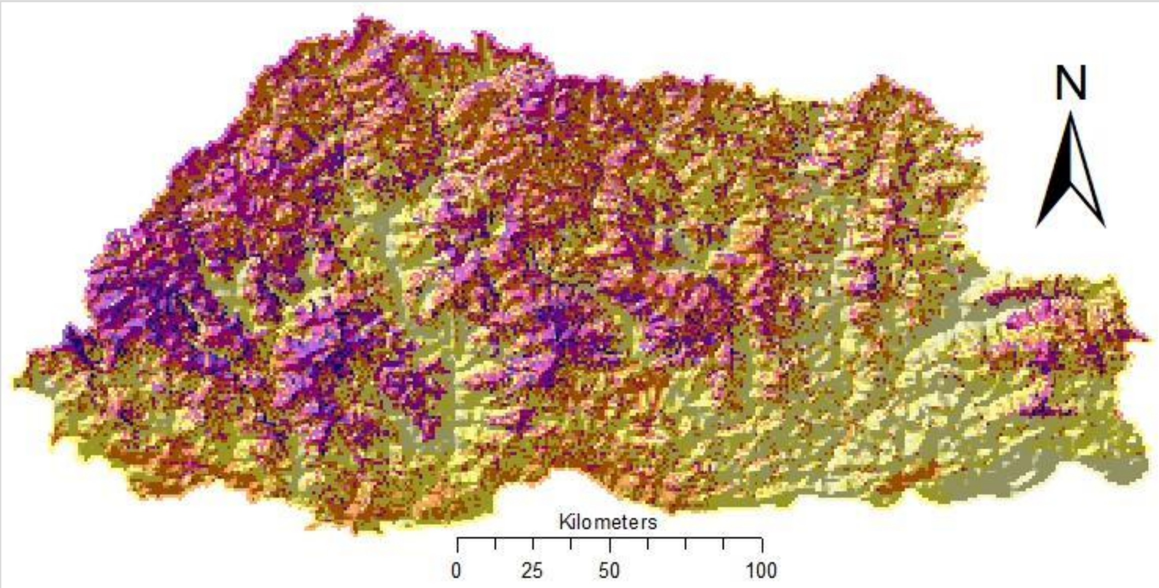


Figure 1.19: Soil Map of Thimphu1

1.4.8 Groundwater

Very little is known about groundwater in Bhutan. Given the steep terrain and deeply incised valleys, it is generally believed that there is no real groundwater aquifer to mention, although subsurface flow through fluvial deposits is believed to occur. The somewhat wider and flatter valleys of, for example, Paro, Punakha, Thimphu and particularly Samtse, Phuentsholing, Sarpang and Samdrup Jongkhar bordering the plains in India may well have groundwater reserves that could be exploited. By discussions with local experts, it has been revealed that the ground water table in Thimphu remains 15-20 m near the Thimphu Chhu, whereas it is more than 50 m in the higher elevation and very steep hills. Indeed, groundwater is being tapped in these areas on an individual basis but the government is generally reluctant to develop groundwater as a resource as long as the sustainability of its use has not been assessed.

[1] NSSC (2017). Digital Soil Mapping of Soil Organic Carbon Stock in Bhutan. National Soil Services Centre. Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan, Thimphu.

1.5 Planning Horizon and Setting Targets

Any plan requires a timeframe to remain effective, which has been fixed for this study till 2030. The issues, challenges, and recommendations of the 12th Five Year Plan (2018-2023) and Thimphu Structure Plan (2002-2027) relevant to stormwater management of Thimphu Thromde have been explicitly thus considered for the preparation of ISWMP. The plan has considered the future anticipated issues and concerns of 13th Five Year Plan (2023-2028) to address future challenges with holistic and prudent strategies. The global agenda of Sustainable Development Goals (2030) has also been considered for setting the planning horizon and targets. The interventions have been proposed thus in three timeframes i.e. short term (until 2023), medium term (2024-2030) and long term (beyond 2030). However, there would be provision of update and monitoring of plan in certain frequency, thereby the targets have been set in line with the three major milestones i.e. by 2023, 2028 and 2030 inside the planning period 2021-2030 and beyond.

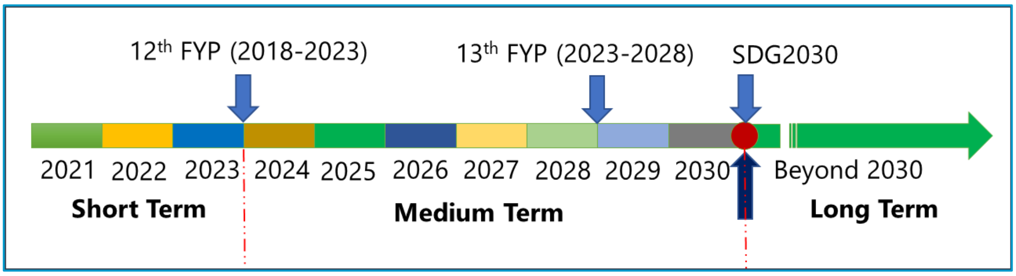


Figure 1.20: Planning horizon of the Integrated Stormwater Management Plan for Thimphu Thromde

Ambition to fulfill seven major targets have been set under this ISWMP analyzing existing level of service from SWMM modeling (Volume IV), future demands, national and global development agenda:

Figure 1.21: Targets set by the ISWMP

1.6 Contents of the ISWMP

Volume-I: Integrated Stormwater Management Plan for Thimphu Thromde (2021-2030)

This volume contains the main investment plan part of the Integrated Stormwater Management Plan for Thimphu Thromde including context and background of this plan, goals and objectives, situation analysis of present stormwater management system and level of services, future climate change, socio-economic and urban development scenario, identifying stormwater management challenges and assessment of priority needs followed by programme of actions to be implemented in this planning period. Each of the programs has a short concept paper including tentative cost, implementing agency and duration. Last but not the least, the implementation mechanism of the plan has been outlined to facilitate the successful implementation as per stipulated timeline and targets.

Volume-II: Stormwater Drainage Design and Management Guideline

This volume contains the preliminary guidelines prepared based on the findings of the technical study conducted during this planning period with a view to help and guide local engineers about possible planning and design considerations for storm water management particularly for the Thimphu Thromde.

Volume-III: ISWMP ATLAS

This volume contains all the maps that was generated for this Integrated Stormwater Management Plan for Thimphu Thromde to facilitate the local engineers to navigate the critical drains links and other information like design discharge, slopes, adequacy information etc. ISWM ATLAS also contains detailed design sections proposed for existing inadequate and proposed drains.

Volume-IV: Stormwater Modeling and Network Criticality Assessment

This volume contains the technical background studies and analysis performed to prepare this plan including the watershed modeling using SWAT, hydrodynamic modeling to assess future climate change impact, stormwater modeling using US EPA SWMM, stormwater drain network criticality from geo-spatial multi-criteria analysis.

Volume-V: Design, Drawing and Cost Estimation

This volume contains all detailed design, drawing and cost estimation required for ISWMP including a large set of different alternatives of structural solutions and site specific measures. Detailed cost estimation of formulated structural measures is also included in this volume.

Volume-VI: Geo-database of ISWMP (CD)

This digital volume contains all the related data, drawing AutoCAD files and GIS map layers in a geo-database that was generated during the plan preparation along with geotagged field visit pictures.

2. Present Stormwater Management System

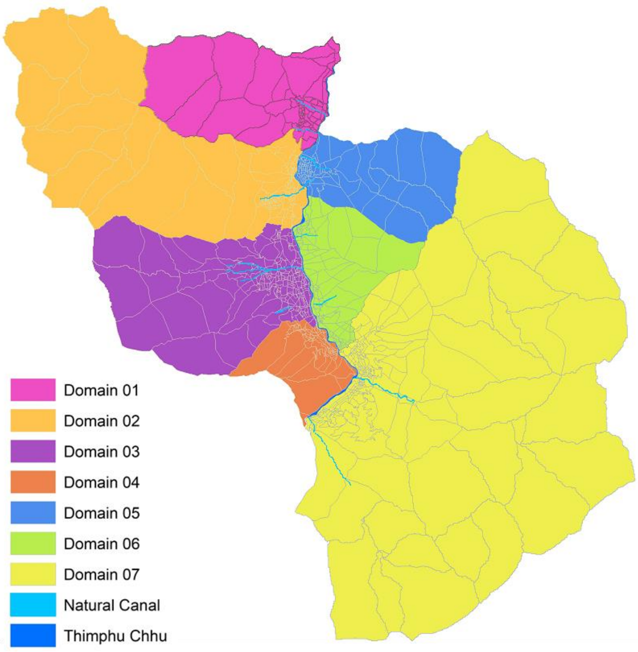
2.1 Introduction

It is imperative to understand the present stormwater management system and its current level of services, challenges, complexities, and gaps before identification of priority needs for structural and non-structural interventions considering future uncertainties posed by climate change. This chapter focuses on exploring the different aspects of present stormwater management system of the Thimphu Thromde.

2.2 Drainage Watersheds and its Characteristics

The Thimphu watershed encompasses around 813 sq km area, among which the territory of the Thimphu Thromde stretched over the valley of the Thimphu Chhu laterally carries surface runoff volume of 294.4 sq km drainage watersheds.

These drainage watersheds can be classified as the ***Primary Watershed***, which is the virgin and fully natural watersheds on the upstream of the basin comprised of mostly dense forest coverage, springs and glaciers in some cases. This type of watershed carries huge volume of flow through natural springs or canals and surface runoff from the top of the hill towards downstream; the ***Semi-Urban Watershed*** which is mostly governed by the natural characteristics as like as the primary watershed but have urban development potentials, connected directly with the urban watershed and thus the land cover contains certain percentage of impervious surfaces. These watersheds relay the surface runoff from the upstream to the ***Urban Watershed***, which are the mostly impervious lands with large dendritic artificial drains to carry stormwater to its ultimate destination the Thimphu Chhu.



Watersheds of Thimphu Thromde Carry Runoff Laterally

In total 911 sub-watersheds passes flow through 114 outlets, around 136 km artificial drainage and more than 400 km total drainage paths.

In general, drainage pattern of the Thimphu watersheds is governed by its steep slope and highly undulated topography. Elevation varies drastically, it lies approximately in between 5%-15% in lower valley, 15%-40% in upper middle valley and beyond 40%-70% in fully natural or primary watersheds. The generated runoff from primary watersheds basically travels from hill top towards the Thimphu Chhu valley over the urban watersheds following the natural streams, depressions, and gullies. From western side watersheds it drains towards down to the east and from eastern side watersheds it drains towards down to the west side and finally falls freely into the Thimphu Chhu through multiple outlets. The roads in the upper region of the primary watersheds work as surface runoff collector through a hill side L-section drain and the road itself works as a longitudinal drainage to carry the runoff using the gravity. Some portions of runoff travel down vertically to the next stair of road layers losing the longitudinal drainage paths of the roads or L-section drains. Gradually the runoff gets the inlet of large conveyance system entering the Semi-urban watershed area. Finally, it travels towards the outlet on Thimphu Chhu collecting additional surface runoff generated from the urban watersheds or areas. In this process of drainage, water gets very little chance to infiltrate into the soil due to steepness of the topography, higher changes in elevation and very short runoff travel time from the furthest point of watersheds.

Although the major part of the runoff from primary watersheds are carried by relatively large sized natural streams, yet, significant portions of contribution of runoff from primary watersheds are transferred to the urban watersheds as lateral flow. Further, most of natural streams do not have any outlet of urban watershed due to the topography and slope aspect of the urban watersheds towards Thimphu Chhu rather to the north or even southern direction to the downstream. Therefore, drainage pattern is fully controlled by the elevation and slope of the watersheds in the Thimphu Thromde. Following Table shows the natural streams in different drainage zones as per model domain.

Table 2.1: Dominant Natural Streams for Drainage of Thimphu Thromde

Model Domain	Natural Streams	Average Width (m)
1	Dechencholing stream	20.0-30.0
	Dangreyna stream	2.8-3.2
2	Samteling stream	20.0-30.0
3	Motithang Chhu	3.5-4.5
	Chuba Chhu	9.0-10
	Changanhkha stream	2.2-3.5
4	-	-
5	Kabisa stream	3.0-3.5
	Taba stream	4.0-5.0
6	Lanjophakha stream	3.0-5.5
7	Ngarephu (RTC stream)	4.4-5.0
	Olarong Chhu	8.0-10.0

Sometimes, maintaining slopes during construction of artificial drains become critical so that the flow becomes super critical with high velocity and hydraulic jump occurs very frequently. Consequently, the chances of failure of structures increases due to the rapid and frequent thrust of stream power. This phenomenon also causes unexpected flooding with short duration but intensive rainfall.

This plan divides the whole Thimphu watershed into 7 drainage or model domain. Seven model domains all together have 911 watersheds among which 666 are found urban watersheds. The western valley has 4 domains from model domain 1 to model domain no 4 towards north to south and the eastern valley has 3 domains from model domain no 5 to model domain no 7. The basic features of each model domain are following-

Table 2.2: Basic features of selected model domain

Domain	No. of Watersheds			Area (Sq. Km.)	Outlets No.	Conduits No.	Artificial Conduit Length (km)	Demkhong(s)
	Primary	Semi Urban	Urban					
1	15	8	48	23.4	12	142	9.78	Dechencholing Taba
2	16	19	91	53.6	14	293	13.64	Jungshina Kawajangsa, Samteling Chhu
3	18	12	200	33.7	19	559	47.47	Motithang, Changangkha, Jungshina Kawajangsa, Norzin
4	5	8	69	8.9	12	218	12.15	Changabangdu Olakha
5	24	8	54	17.4	9	171	11.61	Jungshina Kawajangsa, Dechencholing Taba
6	42	13	67	13.6	34	249	12.80	Jungshina Kawajangsa, Norzin, Changabangdu Olakha
7	46	11	137	144.6	13	527	28.77	Changabangdu Olakha, Babesa
Total	**166**	**79**	**666**	**294.4**	**113**	**2159**	**136.23**	

The spatial distribution of primary, urban and semi-urban watersheds for each of the model domain are illustrated in the ISWMP-ATLAS 1 to ISWMP-ATLAS 7 in Volume III.

2.3 Existing Stormwater Drainage Infrastructures

The primary survey conducted by the Flood Engineering and Management Division (FEMD) identified total 524 drainage links among which 119 are primary and 405 are secondary comprising approximately 136 km existing artificial drainage network. Following pie charts illustrate distribution of surveyed drainage under different types and categories, section type and material type. It has been revealed that most of the surveyed drains are rectangular in size, made by either PCC or stone masonry material due to their relatively cheap price and readily availability. Around 394 drainage connections are found open section drain, which depicts more tendency to dumping of household waste into the drainage system.

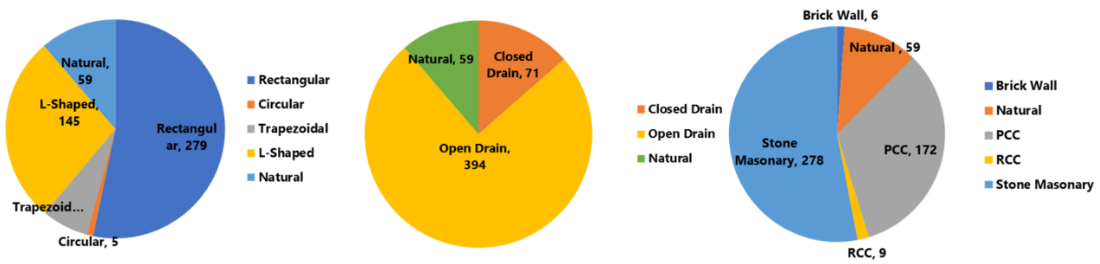


Figure 2.1: Surveyed Drainage Information of Thimphu Thromde

The comprehensive modeling study (Appendix: Volume IV) of this ISWMP further scrutinize using google maps ad ArcGIS, reduces topological digitizing error digitized and identified in total 2159 drainage links instead of 529 among which more than 1300 drainage links are attributed from surveyed 465 artificial drainage links. Remaining 850 drainage links are either natural drain or proposed drains which should be in place for smooth passage of surface runoff but absent in practical. These 2159 drainage links comprised of more than 400 km drainage network covering the whole watersheds area of the Thimphu Thromde. Following table shows quantity of total artificial and natural drainage paths identified in the modeling study under different domains. As per the modeling study, total 171 km primary, 175 km secondary and 88.5 km tertiary drainage paths have been identified.

Figure 2.2: Length of Different Types of Stormwater Drains in the Thimphu Thromde

Domain	Primary Drain(km)		Secondary Drain (km)		Tertiary Drain (km)	
	Natural	Artificial	Natural	Artificial	Natural	Artificial
Domain 01	12.6	4.8	1.4	9.2	-	4.4
Domain 02	19.4	8.6	10.7	11.1	0.4	5.0
Domain 03	13.8	13.3	10.3	24.3	4.5	18.6
Domain 04	5.4	6.2	1.9	9.5	0.7	6.9
Domain 05	16.2	5.7	7.6	6.1	-	2.6
Domain 06	18.6	10.3	7.1	6.9	0.8	0.4
Domain 07	29.1	7.3	38.3	30.8	22.0	22.0
Sub-Total	**114.9**	**56.2**	**77.3**	**98.0**	**28.3**	**59.9**
Grand Total	**171.1**		**175.3**		**88.2**	

Spatial distribution of identified different types of drainage have been presented in the ISWMP ATLAS (Appendix: Volume III).

2.4 Site Specific Problems

Low Lying Outlet Near Centenary Vegetable Market

Very few critically problematic areas are found during the physical inspection and consultation. One of the major critical areas is found near the Centenary Vegetable Market, where transition of slopes was not maintained very well, drains were clogged with plastic bottles, drains were almost perpendicular turned with sharp edge bend and most importantly a long length of drains pass a very flat slope in low lying flat areas before discharging into the Thimphu Chhu. The outlet sill levels are found very low in respect to the elevation of the river bed.



Near the Underpass

Another critical area is found near the underpass, where storm drains flow down from upstream and intersects with the road with a very narrow cross drain, which triggers to overflow the area. That steel grating covered cross drain was almost filled up with wastes. The adequacy of cross drain just beside the underpass is also needed to be checked as flows from three sub-watersheds meet there with very high velocity and the opening of the cross drainage is with very sharp bend.



Low Lying Area under Highway Flyover

Another low-lying problematic area was found under the flyover after Olakha, where slope lowers from both sides of roads and makes a depressed area. This depressed area passes through a huge amount of upstream surface runoff, but to improper drainage paths this area inundates frequently. Further, very small road side hole is kept to pass the collected runoff in a very less frequent interval.

Jushina Pamtho

This is newly developed area and local level road construction is ongoing, but nor proper drainage paths have been demarcated yet. This area thus requires proper drainage paths for smooth passage of surface runoff.

Beside New Land of Bangladesh Embassy

This portion of the area gets open surface runoff coming down from upstream and the lands just beside the Bangladesh embassy becomes marshy over the period. This area thus demands immediate interventions for ensuring smooth passage of drainage and reduce vulnerabilities to surrounding infrastructures.

In front of Primary School (Opposite of Golden Roots Hotel)

Runoff from school football ground is discharged into street. Inadequate surface drains, only small weep holes are available to discharge from the school. Moreover, main problems found in the school front drain beside the road, which is a L-drain basically and inadequate to carry the upstream surface runoff.

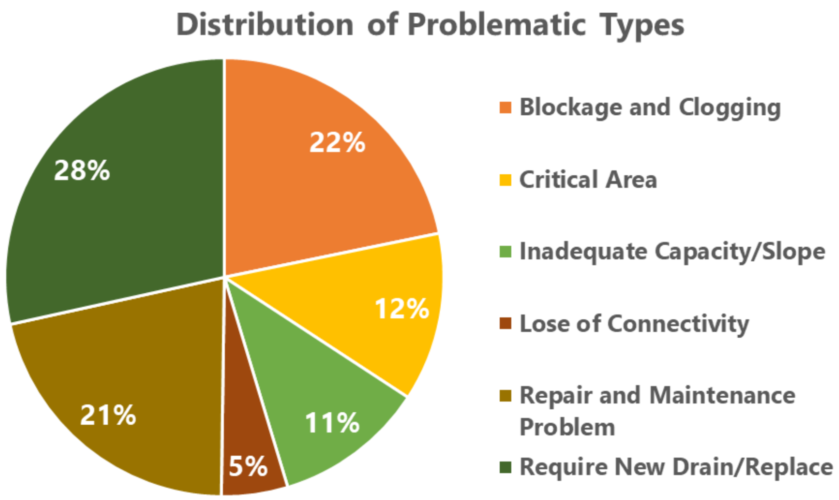
Near RBP and Memorial Chorten

Another very critical area was found in front of RBP and memorial chorten, where transition from natural drainage to artificial drainage occurs, narrowed down the natural drainage after transition and again replaced the open and wide enough stair case drain with two 1.2 m dia hume pipe, which is found inadequate from SWMM modeling study for future climate change scenarios. Therefore, this area needs proper interventions to alleviate mentioned challenges.

Near Babesa STP

According to the Thromde Engineers, another critically problematic area is near the Sewerage Treatment Plant (STP), where huge volume of soils has been dumped from different parts of the city and thereby the main drainage path has been blocked.

Apart from these site-specific problems, some other problems are also found like flash floods vulnerable locations due to sudden transition of slope at the foothill or stormwater quality problems just after the government staff quarter. There were many other areas where most of the drains have been blocked due to dumping of wastes, irregular maintenance, inadequate opening without considering the flow of watershed area and urban development. The identified problem areas which needs either cleaning or repair and maintenance have been illustrated in ISWMP ATLAS (Appendix III).



The distribution of problem types reveals that almost 40% problems are either related to blockage and clogging due to dumping of wastes or require repair and maintenance. Therefore, these challenges are also required to resolve with emergent actions apart from site specific measures.

2.5 Storm Water Quality

Thimphu Thromde being the capital city has been facing rapid population growth and numerous social and environmental issues which caused diversions to the natural watercourse. In addition to that, the main issue with storm water in Thimphu Thromde is the non-existent and ad hoc drainage infrastructures. The drainage systems are also used for grey water discharge from residences due to a lack of awareness and in some cases overflows from septic tanks being discharged into drainage. Since most of the drainage system passes through the core area where the drains are open channels, pungent odors are emitted. As agriculture expands upstream, farm runoff could become a consideration for water quality downstream. Much more significantly, urban growth and industrial processing expansion in parts of river catchments will have consequences on water quality downriver. Impacts on downstream users and ecosystems could mean water quality challenges for tourism and agriculture, depending on their locations.

Comparison of both chemical and physical properties of water quality based on sample data (33 sampling points of streams and drains) collected from the National Environment Commission (NEC) with the WHO and Bhutan Ambient Water Quality Standard, 2006 reveals that the storm water quality in the drains are deteriorating. In most of the drain location, PH, water temperature, dissolved oxygen, resistivity, and zinc are found exceeding the environmental standards. Other than this river and streams the water is found quite clean and does not contain any significant levels of pollutants. Levels of sulphate, nitrate and phosphate in stormwater drains suggest some household wastewater enters the drains. Concentrations of pollutants are likely to rise in the winter. Therefore, storm water quality issues are still not major issues in respect to storm water management but the process of prevention control of pollution from the source should start to avoid any further exacerbation of river water quality. Following figures illustrate location of different sampling points where either physical or chemical properties of water has exceeded the standard limit.

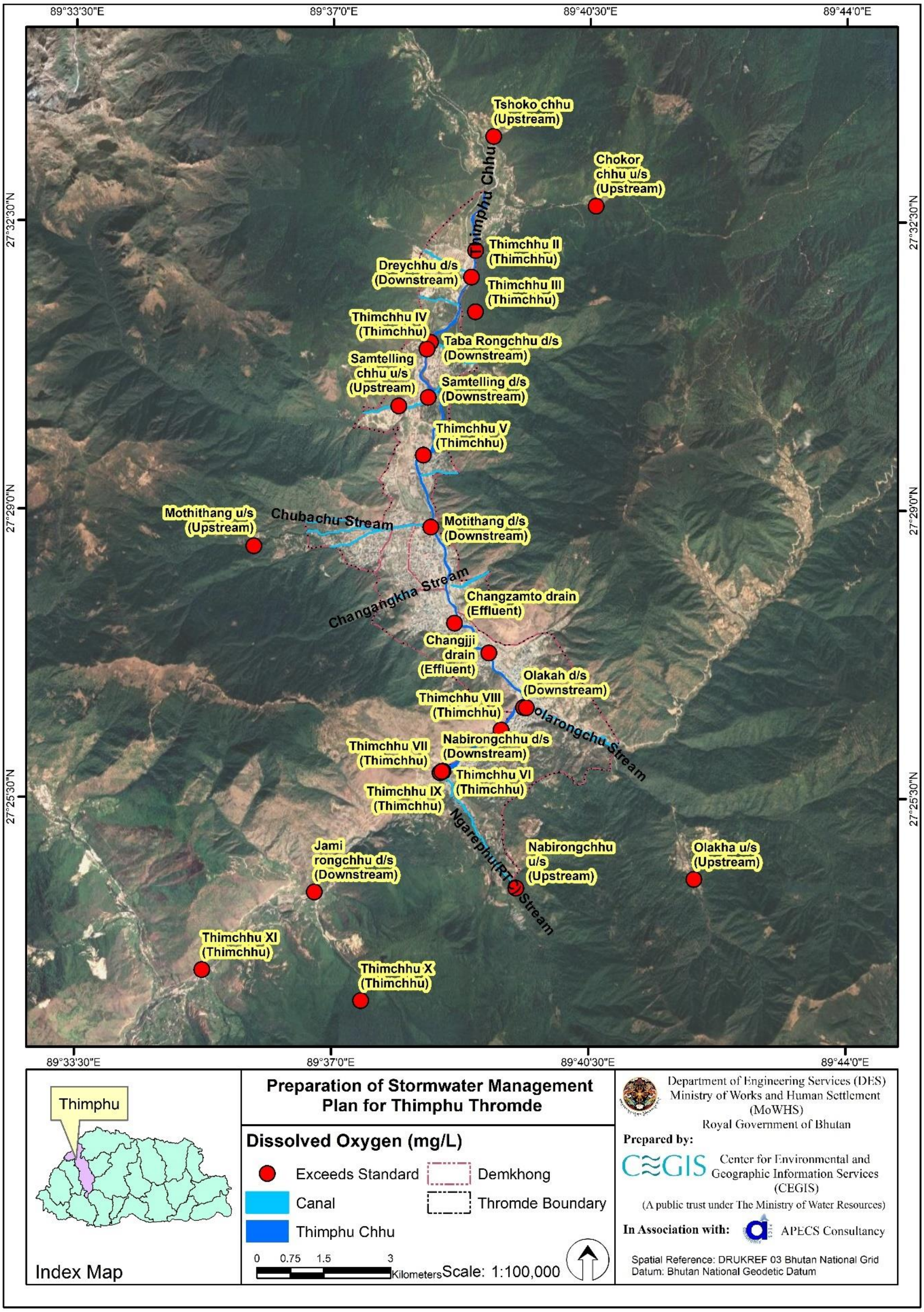


Figure 2.3: Dissolved oxygen where exceed standard environmental limits in Thimphu Thromde

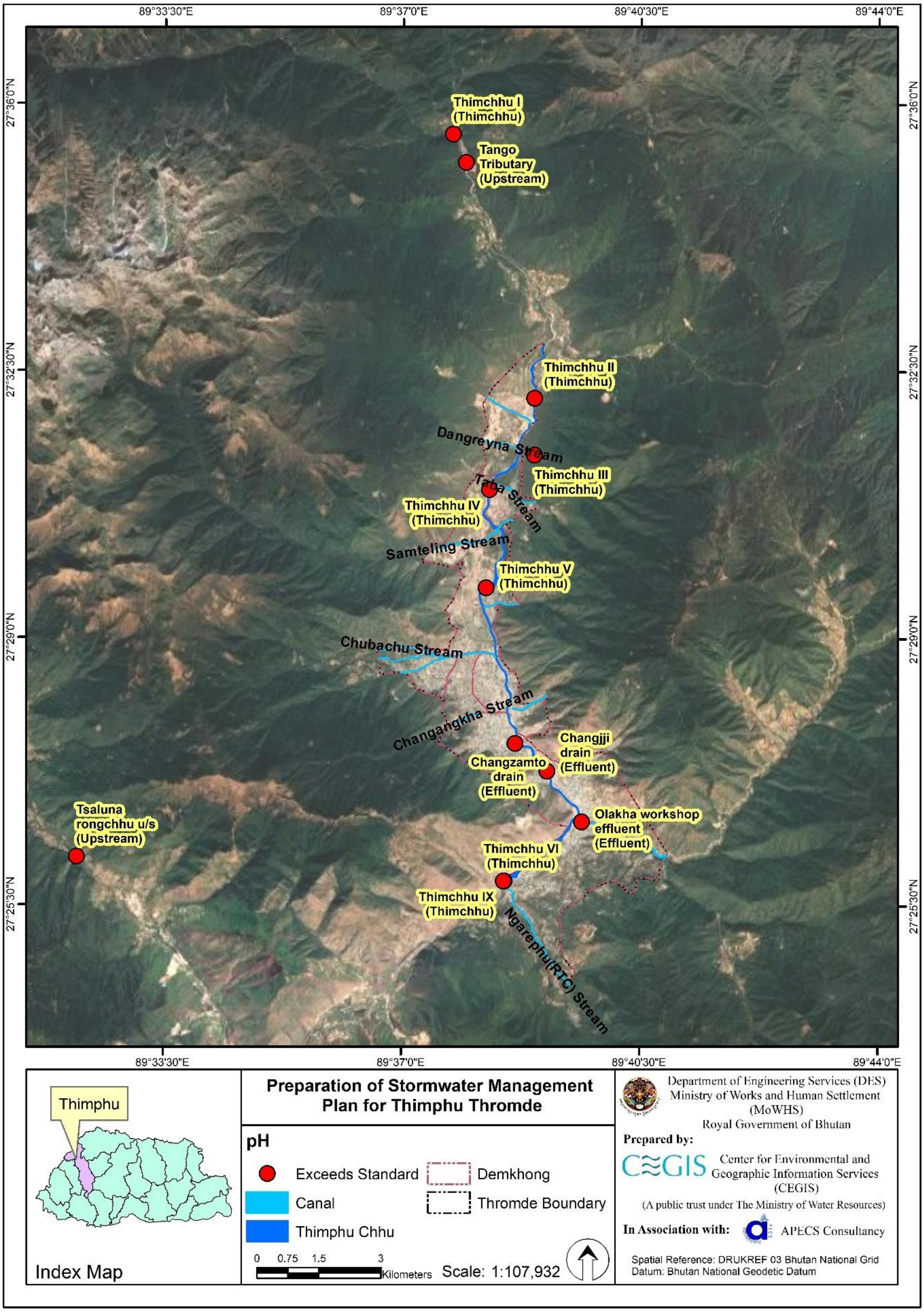


Figure 2.4: pH where exceed standard environmental limits in Thimphu Thromde

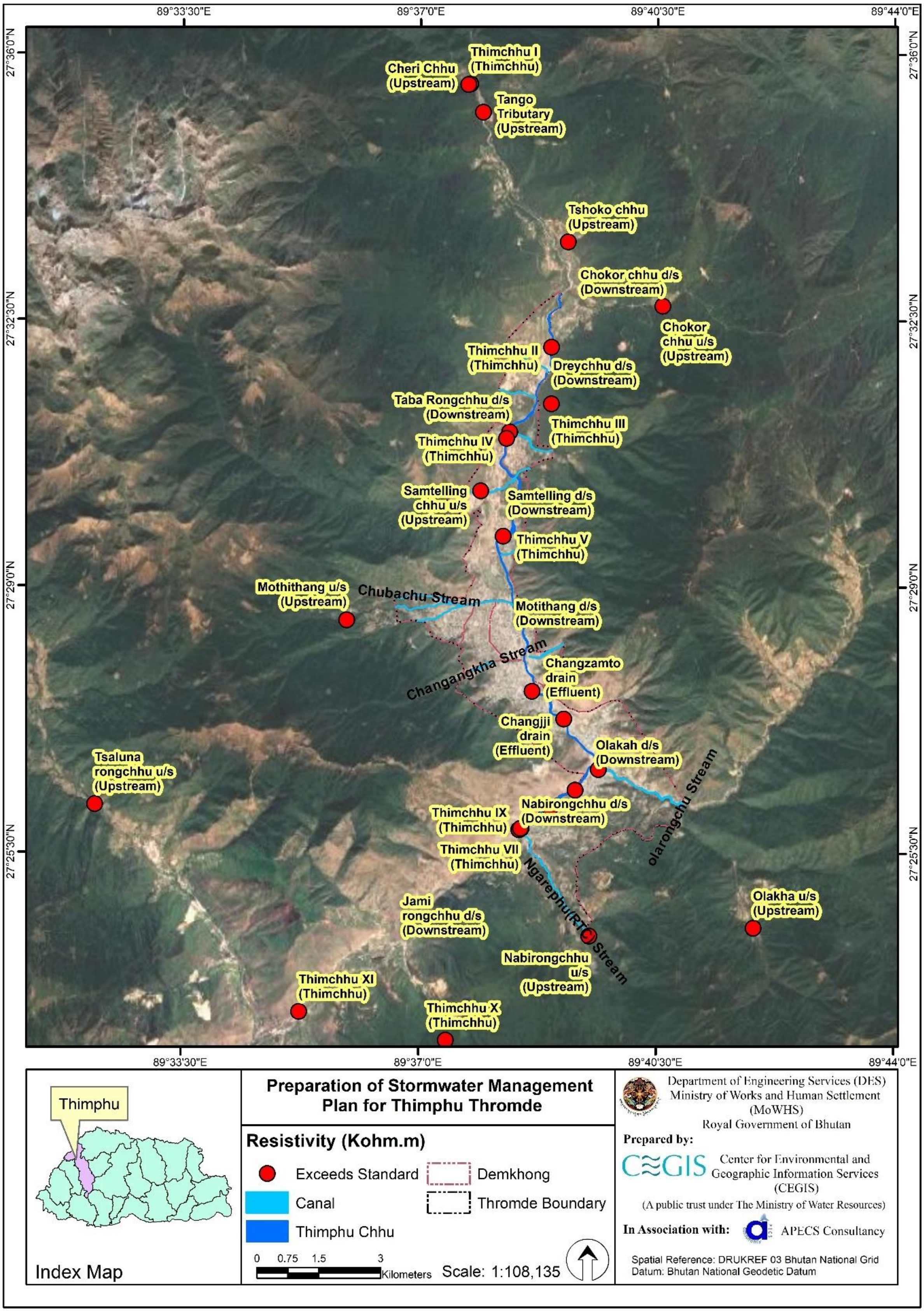


Figure 2.5: Resistivity where exceed standard environmental limits in Thimphu Thromde

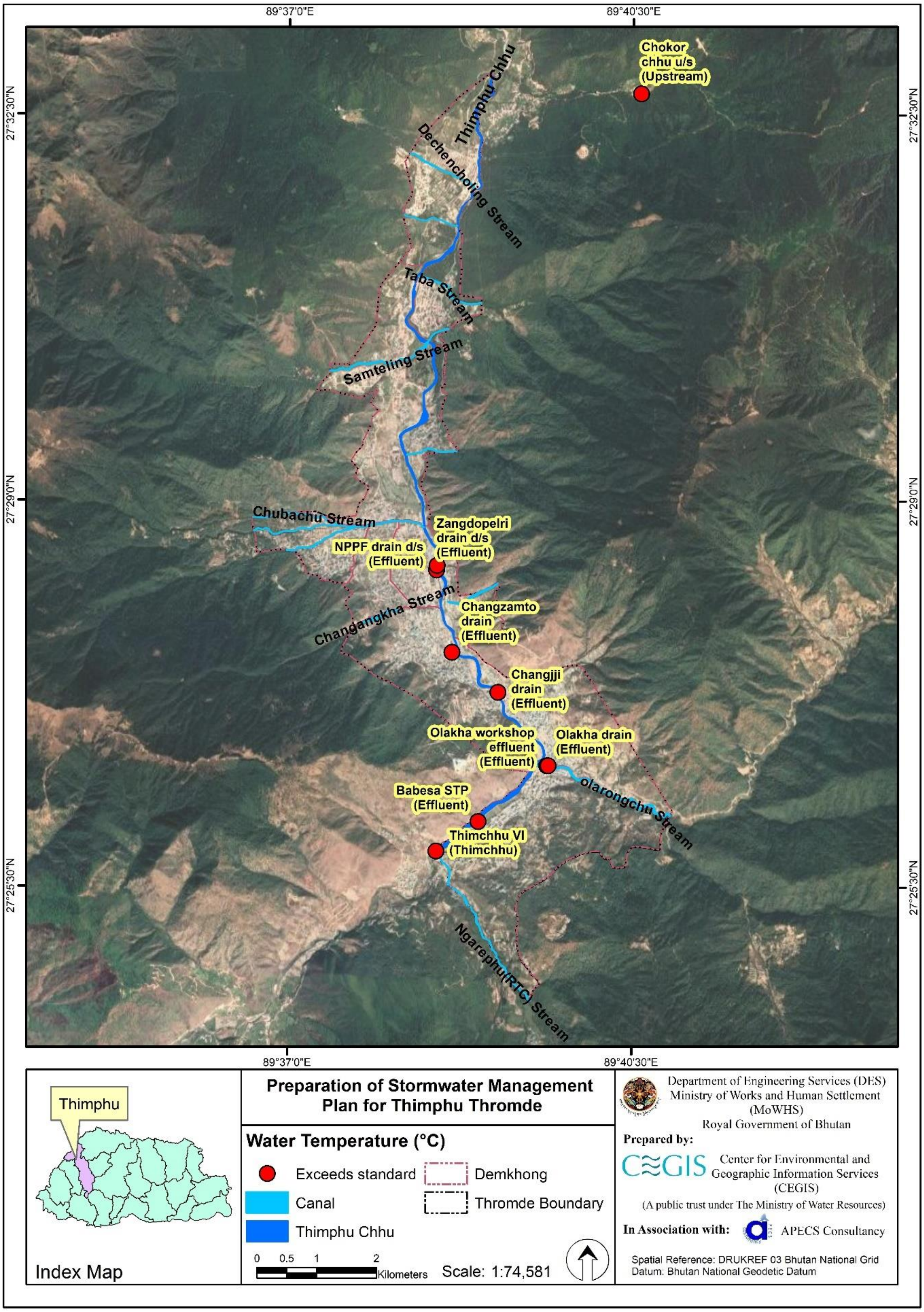


Figure 2.6: Water Temperature where exceed standard environmental limits in Thimphu Thromde

2.6 Regulatory Framework

Rigorous review of available literatures, policy and legal framework relevant to the stormwater management of the Thimphu Thromde reveals well organized regulatory framework already in place which are supporting present stormwater management system in manifold ways, but mostly in implicit manner with weak enactment practices. Summary of the key policies, strategies and plan guiding the urban development of the Thimphu Thromde and stormwater management system are as following:

Policy and Legal Framework	Key Findings
Gross National Happiness (GNH)	• Sustainable and equitable socio-economic development and environmental conservation among 4 pillars • Emphasized Living standards, Ecological diversity and resilience among 9 domains
12th Five Year Plan (2018-2023)	• Transformative platform for graduation from LDC • 17 NKRAs and several number of LGKRAs • NKRA 5, 6,9 and 15 particularly focus on sustainable infrastructure, healthy ecosystem, climate resilience and sustainable human settlements • 9 LGKRA have been set for Thimphu Thromde where LGKRA 2 and 7 emphasize storm water management and climate resilience issues • Target of 90% Roads without potholes and without running water has been set • Associated programs like storm water drains construction, waste management, landscape plan, green infrastructure development etc.
Sustainable Development Goals, 2030	• Bhutan focuses on 3 SDGs as a priority among 17 • Climate action, life on land and sustainable cities and communities are relevant to stormwater management • 12th FYP aligned with these SDGs and reflected through NKRA or LGKRA
Thimphu Structure Plan (2002-2027)	• Guiding tool for Thimphu city development • 14 LAPs have been prepared • Proposed specific precincts and different physical infrastructures layout
Thimphu Thromde Development Control Regulations, 2016	• Supersedes the Bhutan Building Regulations, 2002 and the Development Control Regulations, 2004 (DCR, 2004) • Specifically, applicable for Thimphu Thromde • Guided by TSP and controls any infrastructure development, interventions in precincts as per TSP • Mandated for stormwater management • Driven by Standard operation procedure • Couple of enforcement tool available like building application form, site inspection form, green channel, occupancy certificate application form etc. • Stormwater drain addressed with sanitation, enhances chances of being overlooked • Improvement of these tool may be required to integrate stormwater management related issues separately
Thimphu City Development Strategy, 2008	• Access environmentally conscious modern city with basic infrastructure • Prevent localized flooding • Establish coordination between agencies to prevent cross connections of utility lines • Improve solid waste disposal • Expanding stormwater coverage with road side drains is one of the primary strategies
Bhutan Urban Policy Note, 2018	• Emphasize regional development, municipal governance and finance, housing affordability and urban resilience • Focuses on stormwater quality control
Behavioral Change Strategy for Better Waste Management in Thimphu City, 2017	• Change the mindset of people to eliminate the root cause of the waste littering • Includes regulatory measures, awareness campaigns, collaborations among different institutions, and other urban design recommendations • Discourages consumerist behavior • Recommends that waste management should be practiced in school • Encourages program which will offer economic benefits from waste management • Suggests economic incentives for waste management

This plan exclusively mapped four key policy and strategic documents to facilitate the existing stormwater management system from the apex. They are:

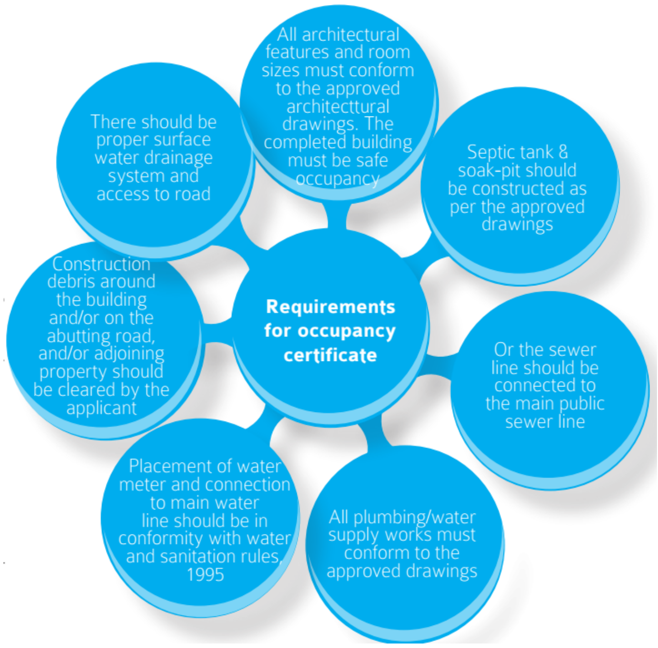
- The Thimphu Structure Plan (2002-2027)
- Development Control Regulations for the Thimphu Thromde (2016)
- The Bhutan Green Building Guidelines, 2013
- Citizen Behavior Change Strategy, 2017

The Thimphu Structure Plan, 2002-2027, framed the fate of the capital city Thimphu in planned way considering a well-balanced synergy with the environmental sustainability. The Strategic Environmental

Assessment (SEA) of TSP clearly recommends to formulate Integrated Storm Water Management Plan, considering the fact that the natural watercourses not be disturbed and channelized for draining storm water, but should be protected and restored to its natural course. Creating awareness and advocating behavioral change among the general public have been emphasized. It outlined the preliminary layout of the stormwater drainage of the Thimphu. Successively, Local Area Plan (LAPs) came in place with more detailed anticipated precincts to guide the infrastructure development of this city.

On the other hand, **Thimphu Thromde (TT) Development Control Regulations (DCR, 2004 which updated in 2016)** is facilitating the proper implementation of LAPs with some specific regulatory tools through the Standard Operation Procedures (SOP) of the Thimphu Thromde like Building Application Form, Site Inspection Form, New Water Connection Form, Building Foundation Inspection, Occupancy Certificate, Waste Disposal etc. By practice, these tools are being used to inspect, monitor and approval of any development activities inside the Thromde. Among those tools, following three tools are found very important and anticipated as most effective tool to devise sustainable and integrated stormwater management system:

- **Occupancy Certificate-** where Development Control Division, Urban Planning and Design Division, Infrastructure Division, Environment Division usually verify some checklists and in which infrastructure division verify the things that is related to stormwater management to some extent like damages to waterline, drainage, sewer line.



- **Access Road Application Form-** consists of a section where provision has been made to assess environmental impact due to the proposed road which include effect on natural stream or water body as well
- **Waste Disposal Form-** where the information related to type of waste, project details, applicant details are collected and provided some terms of condition like applicant shall dump only in designated areas as indicated in the waste disposal permit, use designated route specified in waste disposal permit etc.

The Bhutan Green Building Guidelines, 2013 is another anticipated effective guiding document which was prepared by the Engineering Adaptation and Risk Reduction Division (EARRD) of Ministry of Works and Human Settlement (MoWHS) with a primary objective to encourage the adoption and implementation of green design and construction practices in Bhutan. Some of the key recommendations of this guideline from the perspective of stormwater management are:

- Design shall be based on the hydrologic analysis of the building site
- Implementing an eco-roof or green parking design using permeable paving which reduces and filters storm water runoff
- Limit the amount of impervious surfaces in the landscape, using permeable paving surfaces such as wood decks, bricks and concrete lattice, swales, rain gardens, and bioengineered planting strips that can improve water quality and reduce runoff.
- Disconnecting the flow from storm sewers and directing runoff from impervious surfaces across vegetated area
- Recommends "thick" vegetation or "buffer strips" to grow alongside waterways to filter and slow runoff and soak up pollutants
- Restricts to install permeable pavement on storm water "hotspot" with high pollutant loads
- Rainwater use for flushing toilets

Traditional *Dolep* Pathways (Bhutan Green Building Guideline, 2013)

However, this green building guideline is found as a shelved document as this not has been integrated or mainstreamed into any relevant regulatory framework to make it success. Yet it has huge potential to accelerate the introduction of Best Management Practices (BMP) or Low Impact Development Measures (LID) for managing storm water runoff effectively.

Lastly, **Behavior Change Strategy, 2017** intended to establish some important strategies for better waste management very much applicable to the nature of people living in the city. It aims at changing the mindset of people to eliminate one of the major causes of stormwater management problems i.e. waste dumping and clogging of storm drains.

2.7 Institutional Arrangement

The responsible agency from RGoB for stormwater management is the Thimphu Thromde, which has mandate and Standard Operating Procedures (SOP) guided by the Development Control Regulations (DCR, 2016) to plan, design, construct, maintenance, monitor and finance any relevant actions in respect to the stormwater management issues. Thimphu Thromde mainly have four divisions which are mainly involved in storm water management from different perspectives under the spearhead of Thrompon and Executive Secretary. They are –

- **Infrastructure Division**- does the design, drawing and construction. There are no specific guidelines in place to follow for the storm water drainage design. Still they follow some typical sections for design and construction, which was not designed with proper hydrological consideration like design rainfall event, future urban growth, and climate change scenario etc.

- **Environment Division**- takes care of waste management issues and inform infrastructure division to o O&M work, if any drains are found clogged or blocked due to dumping of wastes.
- **Urban Planning Division-** mostly does planning upon getting application from peoples or assessment of needs. Usually they follow the Thimphu Structure Plan which only gives the idea of natural drainage only.
- **Development Control Regulatory Division-** is the authority to give the permission of constructing any development work changing land covers. There are many prescribed forms in place as part of the regulatory framework and the division do their routine work using those prescribed forms with the physical inspection by engineers or planners of other three divisions.

Stakeholder Meeting on Understanding Institutional Perspectives

2.8 Past Initiatives on SWM of Thimphu Thromde

Thimphu Thromde has very limited noteworthy initiatives in respect to the stormwater management issues and challenges. A large number of ad hoc basis small scale initiatives have been undertaken since the Thimphu Structure Plan (2002-2027). Among them, following two are most landmark initiatives:

Storm Water Drainage Master Plan (2015-2016)

- Very first initiative from the Thimphu Thromde to address stormwater issues
- Aims at guiding development of all the drains and related infrastructures
- Primary Natural, Primary Manmade, Secondary, Tertiary and Roadside and Household discharge drains have been identified with preliminary hydrological analysis
- Consequent cross section of drains and dimensions of catch pit and cross drains.
- A few Low Impact Development (LID) techniques have been recommended to explore
- Very preliminary recommendations without proper modeling, climate change considerations were missing and no implementation mechanism has been detailed out

Urban Infrastructure Development Projects

- Funded by the World Bank, ADB or other development partners
- To support Bhutan's municipal reform program by strengthening municipal finance and management systems improve infrastructure services in northern Thimphu

- Included construction and improvement of stormwater drains along with other urban infrastructures like water treatment plant, sewers, water supply network etc.

3. Climate Change, Socio-economic and Urban Development Scenario

3.1 Introduction

Thimphu Thromde is one of the most progressive cities of the Bhutan with rapid urban growth and development thrust to support the national economy, which is visibly creating multifaceted challenges in stormwater management. Global warming due to climate change and its uncertain consequences on climate variability on the other hand may exacerbate this situation further. For instances, climate change impact on stormwater like increased frequency of short duration but intensive rainfall will increase the runoff volume and hence the stormwater management problems. Understanding the future climate change along with future urban development scenario is thus essential to tackle those uncertainties. This integrated stormwater management plan for Thimphu Thromde thus exclusively takes consideration of future climate change and urban development scenario.

3.2 Climate Change Scenario

3.2.1 Climate Change Anomalies

National level projections by the National Center for Hydrology and Meteorology (NCHM) analyzing downscaled climate data of 6 ensemble GCM members under the CMIP5 experiments reveals, the whole country is expected to experience an increase in temperature with a larger increase in the high lands along with larger warming during MAM and DJF seasons. The overall increase under the RCP8.5 scenario found 0.8°C-2°C during 2021-2050 and about 3.2°C towards the end of the century (2070-2099).

On the other hand, Bhutan is likely to experience an increasing trend in rainfall which is 10%-20% during 2021-2050 and with more than 30% increase towards the end of the century under the RCP8.5 scenario, the projections also suggest increasing rainfall during the JJAS while the winter (DJF) seasons are likely to receive a decrease in rainfall in some parts of the country, especially in northwestern region of Bhutan.

This plan explicitly considers both statistically downscaled and bias corrected dynamically downscaled projections (Appendix: Volume IV) of climate data for Simtokha station of Thimphu Thromde to understand the local level climate change scenario and its range of uncertainties. Comparing both analyses, following climate change anomalies can be concluded for Thimphu Thromde, which shows almost similar trend to the national level projections:

- Monsoon rainfall may change up to 15%-30% under RCP 4.5 and 20%-40% under RCP8.5 by 2050s with respect to present climate.
- Dry season may become dryer as per future anomalies information.
- Highest maximum temperature may increase up to 1.5°-2.3° by 2050s and highest minimum temperature may increase up to 2.0°-3.2° by 2050s considering both RCPs.
- High rate of increment in minimum temperature than maximum temperature indicates gradual potential warming of the City.

3.2.2 Climate Change Impact on Stormwater

Assessment of impact of above mentioned anomalies on stormwater indicates the possible changes of rainfall intensity and frequency in the Thimphu Thromde for future periods. Figure 3.1 shows the IDF curve for extreme climate change event for 2050s time slices incorporating the future climate change anomalies. This IDF curve clearly depicts that rainfall intensity would be increased in near future due to climate change and thereby stormwater drainage problem would be more intensified and recurrent.

Findings from this IDF curve reveals that intensity of short duration hourly rainfall would be increased from 25 mm/hr to 27 mm/hr for 20-year return period, 31 mm/hr to 37 mm/hr for 50-year return period and 36 mm/hr to 38 mm/hr for 100-year return period under RCP8.5 and by 2050s due to climate change. Interestingly, 100-year return period hourly rainfall event would become 50-year return period event and 50-year return period hourly rainfall would become 20-year return period event in future days. It represents that extreme rainfall event would be more frequent in the near future due to climate change impacts, although the variation of event rainfall is a bit insignificant due to low amount of rainfall in the Thimphu watershed. Table 3.1 illustrate the rainfall intensity for different return periods extracted from the IDF curve for Simtokha station under present and future climate.

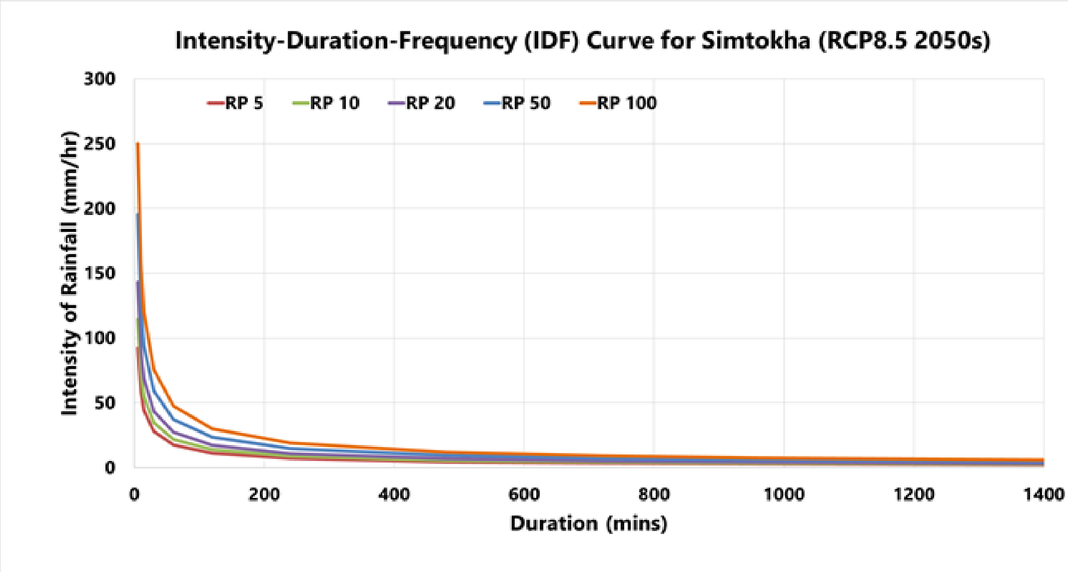


Figure 3.1: IDF curve for extreme rainfall event due to climate change under RCP8.5 for 2050s time slices in Simtokha station

Table 3.1: Changes of rainfall intensity due to climate change impact in Simtokha station

Mins	Rainfall Intensity (mm/hr)					
	Present Climate			Future Climate		
	10 yr	20 yr	50 yr	10 yr	20 yr	50 yr
5	113	133	163	114	143	195
10	71	84	103	72	90	123
15	54	64	78	55	69	94
30	34	40	49	35	43	59
60	21	25	31	22	27	37
120	14	16	20	14	17	23
240	9	10	12	9	11	15
480	5	6	8	5	7	9

Mins	Rainfall Intensity (mm/hr)					
	Present Climate			Future Climate		
	10 yr	20 yr	50 yr	10 yr	20 yr	50 yr
720	4	5	6	4	5	7
960	3	4	5	3	4	6
1440	3	3	4	3	3	4

3.3 Socio-Economic and Urban Development Scenario

3.3.1 Demographic Characteristics

Population

According to PHCB 2017, of the two towns in Thimphu Dzongkhag, Thimphu Thromde has 108,611 persons (99.0%) of the total regular household population living in urban areas, while Khasadrapchu Town has 966 persons (1.0%). Average household size for Thromde is 4.2 and literacy rate is as high as 90.3.

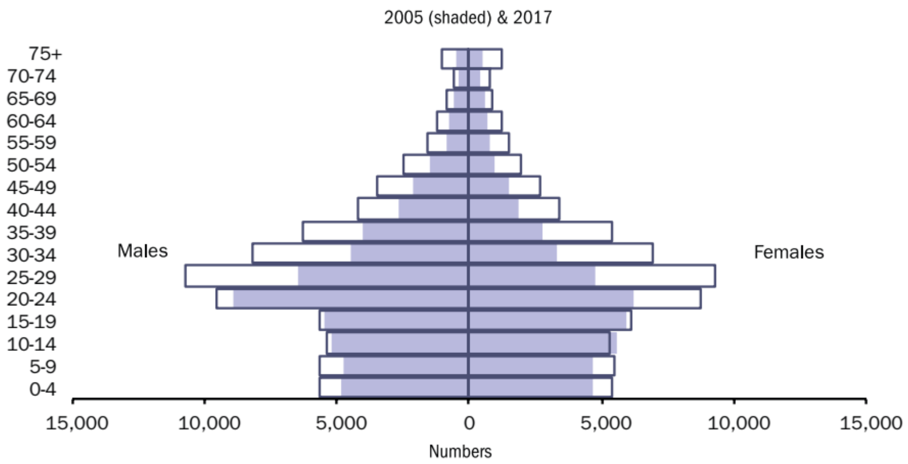


Figure 3.2: Comparison of population by sex between inter-census period

Both in 2005 and 2017, the population of Thimphu town was highest among other towns with 79185 and 114551 number of people. The population density was 3619 persons per sq. km of Thimphu in 2005, whereas in 2017 it has increased to 5336 people per sq.km. The change of population is 44% compared to 2005 and the growth rate by annum is 3.72%.

The projected population of Thimphu Thromde from the year 2017 to 2027 (PHCB) indicates that the population in Thromde will increase at a rate of 2.4% per year (Figure 3.3). Estimation of future population up to 2047 indicates that there will be more need of well-planned and well-coordinated urban development considering every sector as this will put strain on them through different ways. It will undoubtedly pose serious challenges to the city engineers and planners with respect to the stormwater management under climate change scenario.

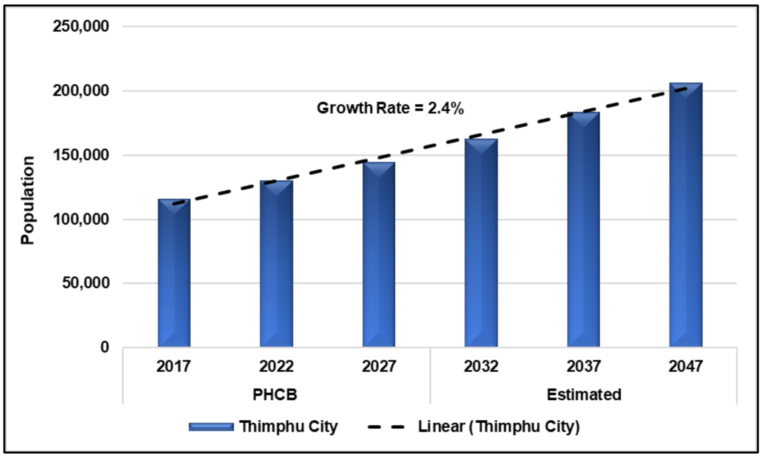


Figure 3.3: Population Projection for 2017-2047 of Thimphu Thromde

Household Characteristics

The escalated average household size in 2017 represents that, with the expanding urban population the demand of accommodation has increased specially in Thimphu Thromde (Figure 5.5). From Figure 3.4 it is evident that there is no significant increase in household size despite remarkable population increased from 2005 to 2017. It implies that people built large number of buildings and expand the city horizontally over the elongated valley to accommodate that population increase, which allows to maintain the average household size almost same. According to PHCB 2017, the average number of rooms is 3.3 and average household size is 4.3, but there is no such indicator mentioned in PHCB 2005 to justify this. This also points out to the incessant stress on drainage system from dwellings with more expanding population in recent years and the necessity to include its rectification within the urban development plan.

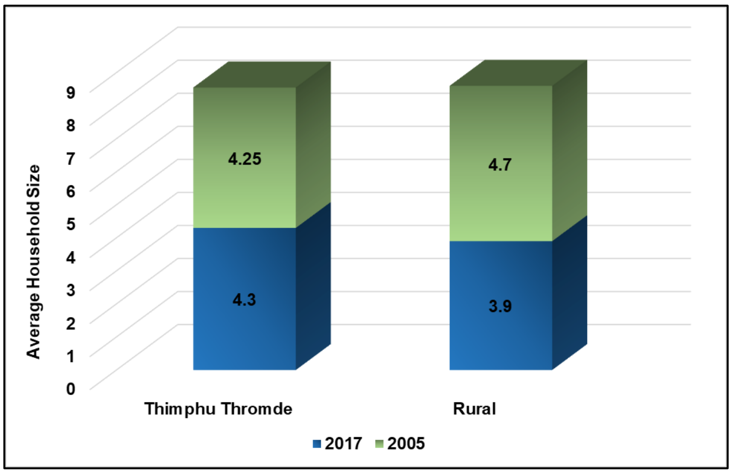


Figure 3.4: Change in average household Size from 2005 to 2017

A significant percentage (93%) of house in Thimphu Thromde has roof material made of concrete and slate, though the percentage of using slate and concrete decreased slightly from 2005. The surface of these materials can serve as clean container of potable rainwater for drinking water rather than any other material used for roof. Despite the advantage, the use of wood and straw as building material increased to 66% and 80% in 2017.

Most households in Thimphu Dzongkhag use electricity (98.3%) for lighting, while a few households still use kerosene (0.3%) and solar energy (0.7%) for the same purpose. There is a slight difference between urban (99.0%) and rural areas (94.7%) in the use of electricity for lighting.

Internal Migration

In terms of in migration, Thimphu has received the highest number (54,685) of people among other Dzonkhgas in 2005 whereas in 2017, Thimphu Thromde had alone received 68,310 migrants. The number of out migrants in Thimphu was 14,915 in 2005 which increased to 20,096 in 2017. The percentage of urban to urban migrants was 9.6% and rural to urban migrants is 54.0% for Thimphu Thromde in 2017. According to these data, the number of net migrants increased from 39,770 to 48,214 in Thimphu from 2005 to 2017.

3.3.2 Infrastructures and Social Services Facilities

Being an old and settled urban city Thimphu has well established connectivity with other parts of the country. The Thimphu Thromde has around 281 km roads, 45.7 km Geowg connectivity roads, 85.7 km Dzonkhag roads, 86.8 km farm roads, 16 motorable and 65 non-motorable bridges. Statistics reveals 43% increase in Dzongkhag roads and 5% increase in Farm roads since 2016, but no significant increase of Thromde roads. Similarly, the number of educational institutes (Appendix: Volume) and health infrastructure facilities are also found saturated and constant since last 5 years. Approximately 103.3 km underground sewer drain and 88.7 km footpath are presently existing in the Thimphu Thromde. No long-term historical data was found available in case of infrastructures to analyse the development trend. However, there would be significant changes in infrastructures development to accommodate stress of increased population.

3.3.3 Waste Generation and Management

The Royal Society for Protection of Nature's survey in 2005 (RSPN, 2006) found 36.7 tons of daily wastes collection from Thimphu Thromde. The inventory revealed that the maximum waste was generated from residential (69%), hotels (9%) and liquor bars (9%). Another study (B. Chakraborty. et.al., 2019) revealed that the generation of wet waste is increasing in Thimphu. According to the study, the amount of wet waste has increased from 250 tons in 2013 to 1590 tons in 2016. (B. Chakraborty. et.al.,2019), whereas it is seen that the amount dry waste has decreased by 2144 tons from 2013 to 2016.

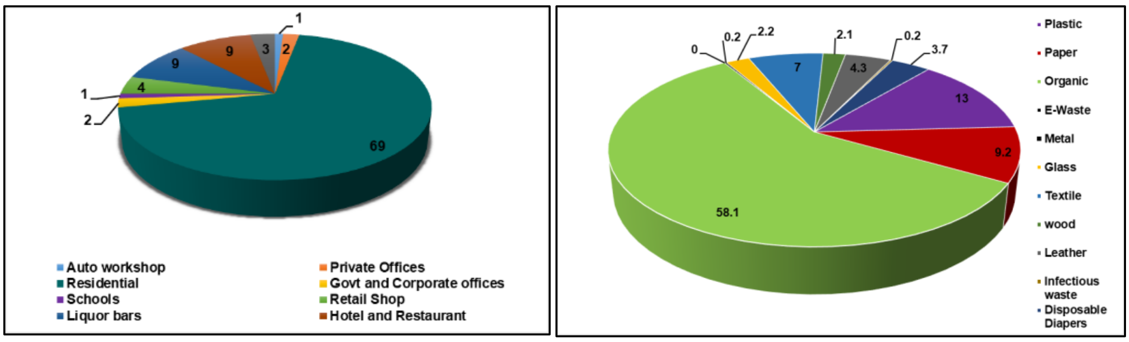


Figure 3.5: Percentage of source of waste and average composition of waste in Thimphu Thromde

The total waste generation at Thimphu Thromde was 40.3 Tons/day accounting to 0.35kg/capita/day in 2017 (NEC, 2018). In consideration to the projected population of Thimphu Thromde in 2032 which is

201,203 (NSB, Population Projection, 2017-2047), the waste generation is expected to be increased up to 67 Tons/day at this rate if it follows the current trend.

In response to the generated solid waste, Thromde has the solid waste management system includes the basic process of collection, transportation, and disposal at Memelakha. The service is door to door and communal collection by the municipality. The reuse and recycle of non-biodegradable waste prevail in such a way that, informal waste pickers, scavengers and municipal waste management laborers collect them and send them outside (MoWHS, 2007a). However, awareness and civic sense of citizens sometimes play very vital role to facilitate the proper solid waste management system.

Besides, the huge volume of wet waste has significant negative impact on the storm water quality, which will obviously increase in future. Although, Babesa and Dechenchholing STP are in operation with 3.2 MLD capacity since 2017 and after the commissioning of the proposed project the capacity will increase up to 16.5 MLD, it is still matter of concern. As, sometimes storm drainage system becomes mixed up with the sewer drains with grey liquid waste discharged from residence, it contaminates stormwater and spread bad odors passing through the core area. Dumping solid waste in open places and their leachate after decomposition drains into the stormwater drain which is also contributing towards wet waste generation. These in turn may put the aquatic health of the single major river Thimphu Chhu at stake in near future.

3.3.4 Urban Growth and Future Urbanization

Urban Development Initiatives

The urbanization and infrastructure development in Bhutan are expanding at a fast pace and it has been observed that these processes are causing a decrease in the forest cover, agricultural area and shrub lands in the Thimphu valley (Dema 2007, Burgi 2002, Dorji et. al., 2006, Rai 2007). Thimphu grew rapidly since 1955. The first massive initiative was undertaken in 1998, when the strategic plan influenced to expand the Thimphu City from 8 to 26 sq km and then the Cabinet's instruction to make Thimphu a dream city. Thimphu Structure Plan (2002-2027) was approved in 2003 to make the vision into reality and since then Thimphu is developing as per the guidance of TSP. Development Control Regulations (2004) was formulated to facilitate the implementation of TSP, which has been updated very recently in 2016. Fourteen Local Area Plan (LAPs) are prepared and being implemented now under the TSP following the DCR. The Local Area Plan deals with the practical detailing of the structural plan so that the overall strategic plan like Thimphu Structure Plan could be implemented at the ground level. Till date. almost all the LAPs are implemented except for Serbithang and E4 LAPs, which are yet to be implemented within a span of few years.

Table 3.2: Actions that has been taken from the past for Thimphu

Year	Action
1961	Bhutan's First Five Year Plan
1964	First Urban Plan which remained unimplemented
1986	Second Urban Plan that guided growth in 1990s
1998	Strategic Plan which influenced the expansion from 8 to 26 km^2
1999	Cabinet's instruction to make Thimphu a dream city
2003	Cabinet Approval of TSP 2002-27
2004	Development Control Regulations, 2004

Year	Action
2008	Thimphu City Development Strategy, 2008
2016	Development Control Regulations, 2016

Urban Growth

Urban density of Bhutan is projected to increase from 37.8 percent (2017) to 56.8 percent (2047) of the total population. Thimphu municipality comprises around 40% of the urban population, while the wider Thimphu district hosts 138,736 people (19.1 percent of the population) of Bhutan. Study revealed that almost 13% urban area has been increased since 1990 to 2010 mostly reducing shrubs area and slightly reducing forests cover (-0.73%) and agricultural land (-1.5%). However, built up areas or urban area has further substantially increased in course of time since 2010 and found 35% increase of settlements areas during last 8 years

Table 3.3: Demkhong wise distribution of buildings in 2013 and 2020

Demkhong	Settlements Count in 2013	Settlements Count in 2020	Settlements Area Increased in % (2013 to 2020)
Babesa	915	1608	43.10
Changabangdu Olakha	3095	3557	12.99
Changangkha	623	864	27.89
Dechencholing Taba	312	1585	80.32
Jungshina Kawajangsa	1229	2501	50.86
Motithang	625	945	33.86
Norzin	1162	1242	6.44
Grand Total	**7961**	**12302**	**35.29**

Source: DES and Open Street Map (OSM)

The expansion of urbanization was towards north direction as the core urban area was quite congested. Therefore, Dechencholing Taba had faced the highest expansion of urbanization and the increasing rate was 80.32% from 2013 to 2020. Jungshina Kawajangsa has already experienced the second highest urban expanded area and the expansion rate was nearly 51%. As the Thimphu Thromde area is bounded by high elevated hilly areas, therefore, expansion in east and west direction is difficult here. That is why the area expands towards the north and south direction. The southern Demkhong named Babesa now has nearly 700 new buildings from the past 7 years. Overall, every Demkhong is facing expansion of buildings at a tremendous rate.

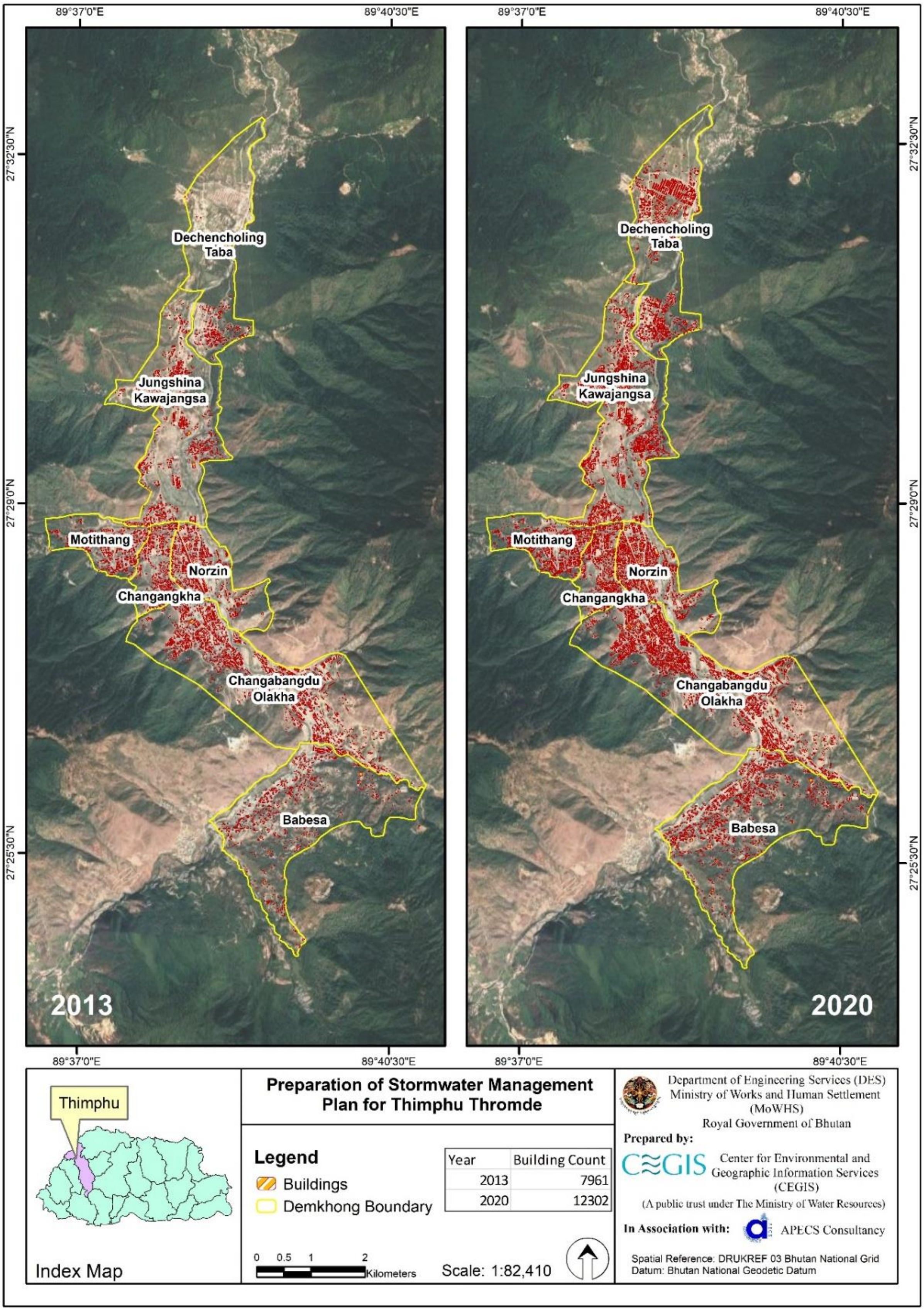
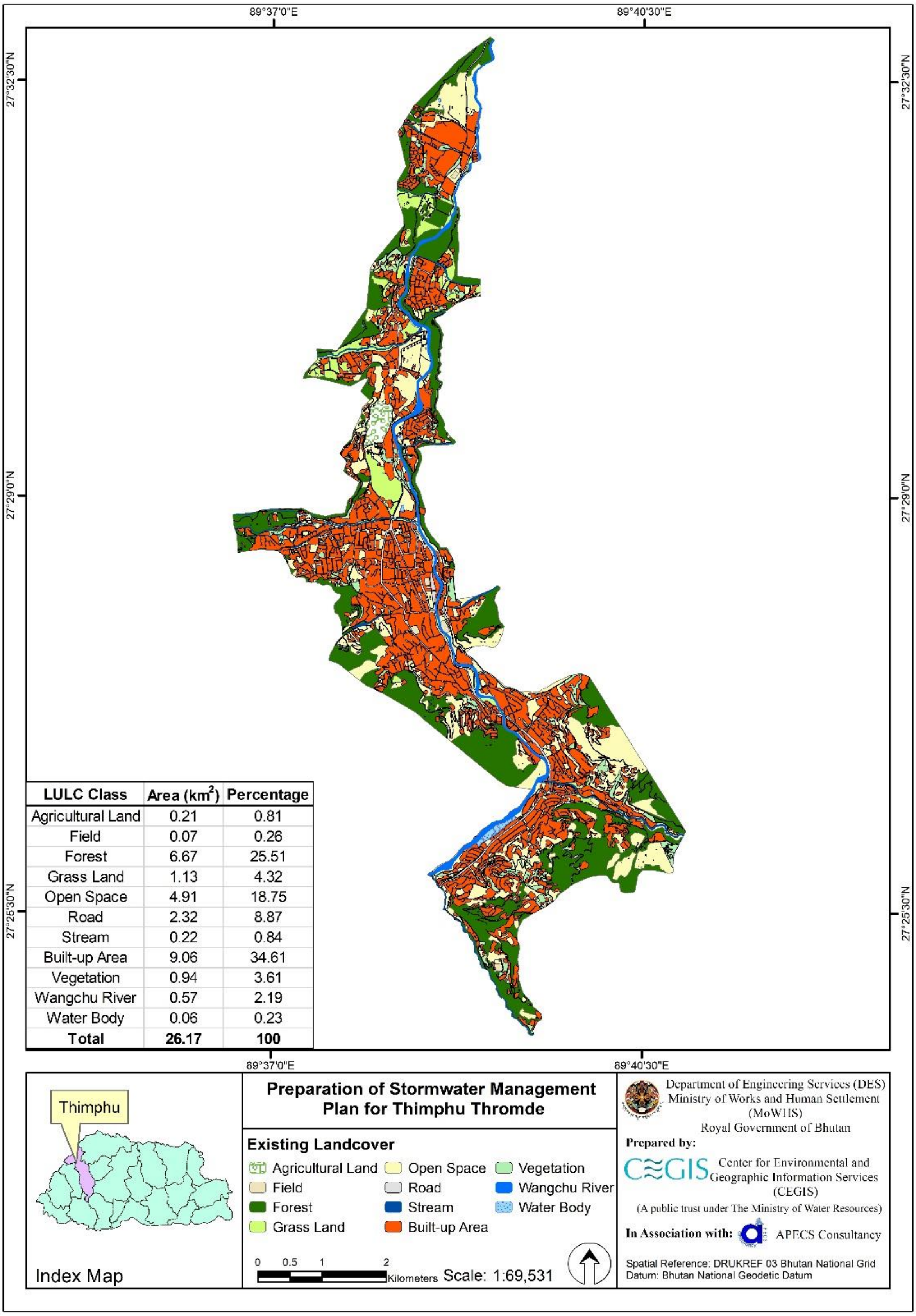


Figure 3.6: Distribution of settlements cover in 2013 and 2020

Future Urbanization

Existing land use and land cover map (LUCL) of Thimphu Thromde (Figure 3.7) reveals that around 26% of area are covered by forests, whereas 43% are impervious area comprising roads and built up areas. Earthen surface or open spaces are quite prominent 19%, homestead vegetation covers 4.32% and grass land area shows only 3.61%. Only a small provision of agricultural cover is found 0.81% behind the Tashichodzong and rest are waterbodies and fields.

A future LULC map (Figure 3.9) was generated during the preparation of this plan on the basis of this existing land use and land cover pattern and precincts map (Figure 3.8) of Thimphu Structure Plan (2002-2027) to understand the future urbanization patterns over The Thimphu Thromde. The detailed technical assumptions of preparation of this future LULC map are outlined in Appendix: Volume IV. As per future land cover, 12.5% area would be converted into urban area by 2027, which consequently would trigger increased stormwater runoff and additional pressure to existing drains. On the other hand, open space will be decreased drastically as 6.28% and most of the spaces will be consumed by built-up land cover. As Golf Course (pond) and Sewer Treatment facility are now in the process of converting into green zone, therefore this place was identified as grass land in future LULC. Urbanization will also impact the forest cover, and the decreasing rate in forest cover will be 3.4%. In a word, reduction in green cover and the subsequent growth in urban land cover will demonstrate pressures of modernization on the environment of Thimphu Thromde.



LULC Class	Area (km^2)	Percentage
Agricultural Land	0.21	0.81
Field	0.07	0.26
Forest	6.67	25.51
Grass Land	1.13	4.32
Open Space	4.91	18.75
Road	2.32	8.87
Stream	0.22	0.84
Built-up Area	9.06	34.61
Vegetation	0.94	3.61
Wangchu River	0.57	2.19
Water Body	0.06	0.23
Total	**26.17**	**100**

Figure 3.7: Existing LULC map of Thimphu Thromde

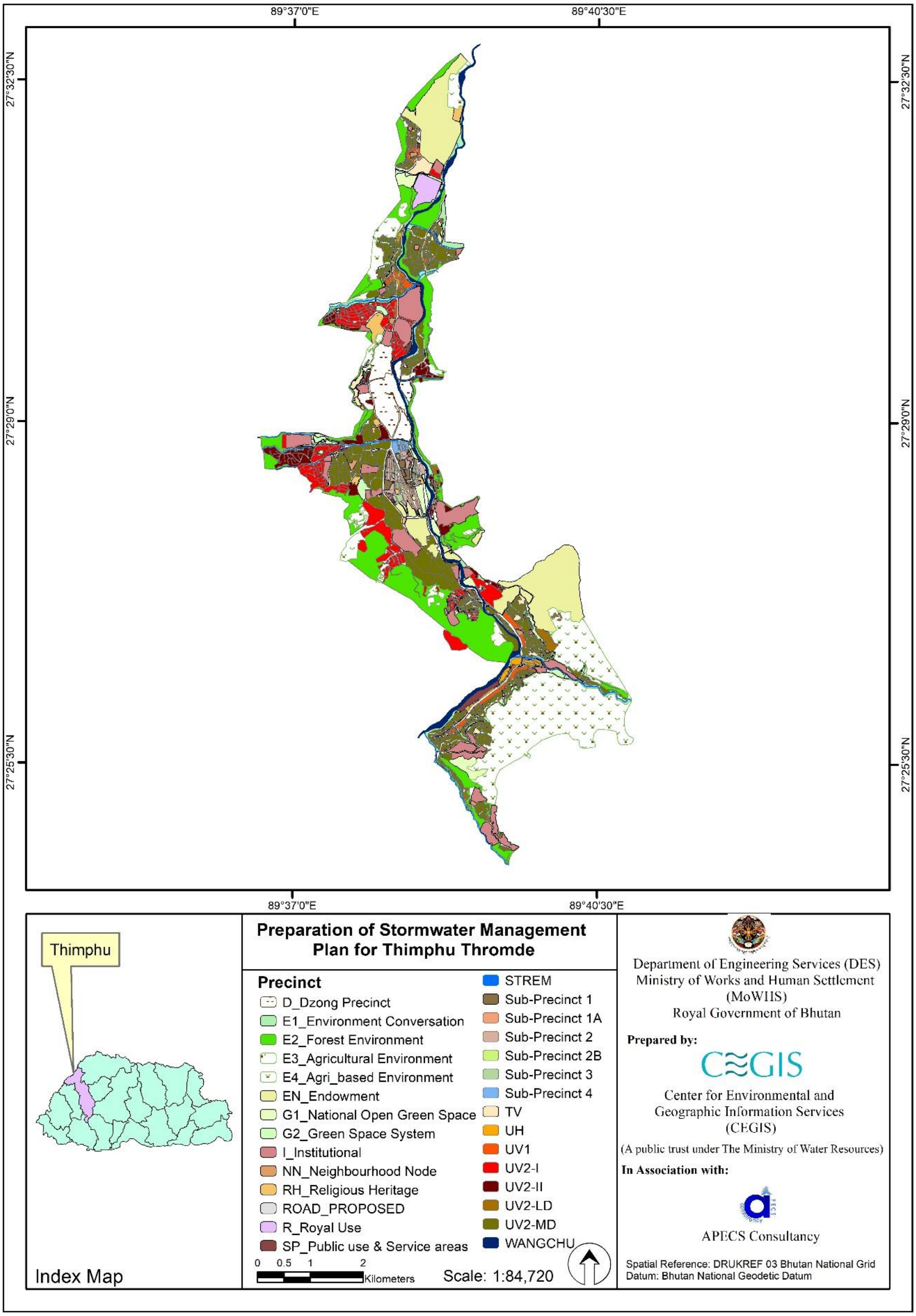
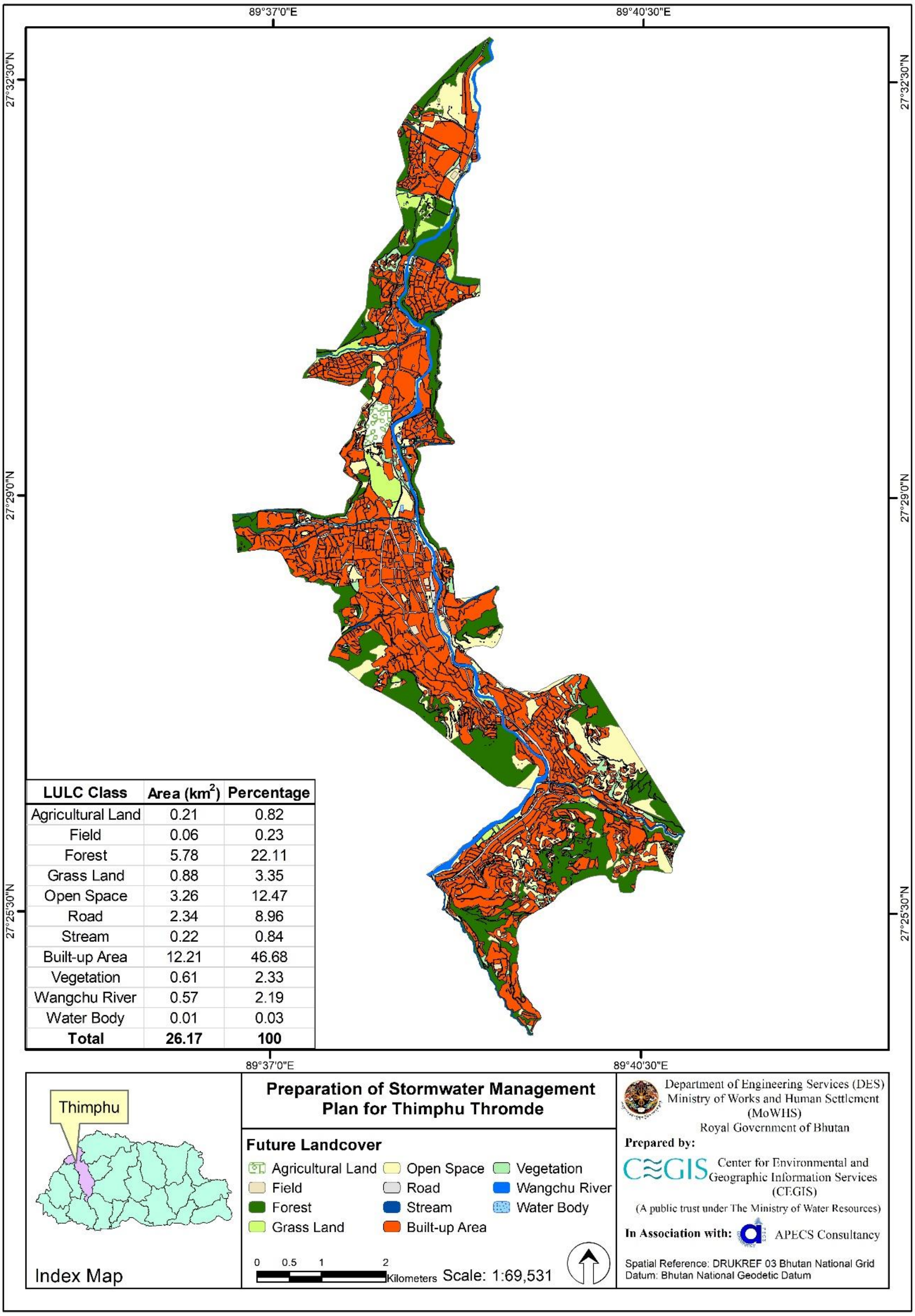


Figure 3.8: Precinct map of Thimphu Thromde



LULC Class	Area (km^2)	Percentage
Agricultural Land	0.21	0.82
Field	0.06	0.23
Forest	5.78	22.11
Grass Land	0.88	3.35
Open Space	3.26	12.47
Road	2.34	8.96
Stream	0.22	0.84
Built-up Area	12.21	46.68
Vegetation	0.61	2.33
Wangchu River	0.57	2.19
Water Body	0.01	0.03
Total	**26.17**	**100**

Figure 3.9: Future LULC map of Thimphu Thromde

4. Assessment of Priority Needs

4.1 Introduction

The ISWMP aims at alleviating the havoc resulted from stormwater management issues taking considerations of lesson learn from past initiatives, gaps, and mistakes. The earlier two chapters along with physical field visit during reconnaissance and inception, series of stakeholder consultations physically and virtually, field validation build the foundation of understanding the present and future scenarios on different aspects specially stormwater management challenges presently prevailing and intervention needs for future in the Thimphu Thromde. This chapter portrays the stormwater management challenges and identify priority intervention areas for future strategies and alternatives formulation.

4.2 Stormwater Management Challenges

4.2.1 Site Specific Criticality

Assessment of existing stormwater drainage infrastructures revealed presence of a few site-specific problems, which needs to be addressed immediately. In addition, some common problems such as blockage or clogging, repair and maintenance related problems are also found which sparsely distributed all over the city and around 40% of the problems are found due to these reasons which also demands emergent actions. Following Table 4.1 and Table 4.2 reveal overall site-specific criticality and distribution of finally identified either cleaning or repair and maintenance required related locations after field validation under different domains.

Table 4.1: Priority site specific criticality

SL No.	Domain	Site Specific Criticality
1	Domain 01	
2	Domain 02	Near Jushina Pamtho and Bangladesh Embassy
3	Domain 03	Near vegetable market outlet, RBP and memorial chorten, near underpass, near primary school, centenary park
4	Domain 04	Low-lying area under highway flyover
5	Domain 05	
6	Domain 06	Flash floods vulnerable locations, stormwater quality prevention
7	Domain 07	Near Babesa STP

Table 4.2: Identified Priority Problems

SL No.	Domain	Blockage and Clogging	Loss of Connectivity	Repair and Maintenance
1	Domain 01			1
2	Domain 02	1	2	1
3	Domain 03	14	5	22
4	Domain 04	4	1	7
5	Domain 05	4	1	1
6	Domain 06	7		9
7	Domain 07	14	3	11
Total		**44**	**12**	**52**

These are exclusively taken into consideration to formulate priority action areas of ISWMP. Spatial distribution of these criticality and problematic areas are illustrated in ISWMP ATLAS (Appendix: Volume III).

4.2.2 Impact of Land Cover Change and Future Climate Change

Developed SWMM model has been simulated for present scenario considering present land use and climatic condition; and for future scenario using future land use and considering climate change. It has been found that 12.5% urban area increase and 23% increase of rainfall due to extreme climate change would produce on an average 30% additional runoff than present condition.

Domain	Total precipitation (m)		Surface Runoff (Ha-m)		External Outflow (Ha-m)	
	Present	Future change (%)	Present	Future change (%)	Present	Future change (%)
Domain 01	90	23	163	36	141	37
Domain 02	90	23	370	37	354	36
Domain 03	90	23	230	34	181	31
Domain 04	90	23	57	34	25	28
Domain 05	90	23	122	39	107	29
Domain 06	90	23	95	34	74	31
Domain 07	90	23	985	29	781	26

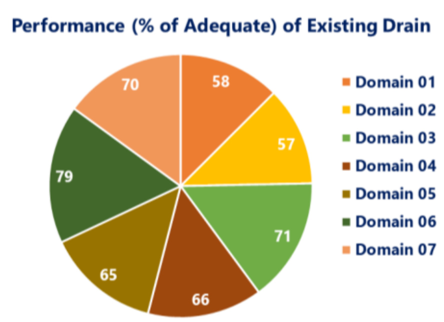
4.2.3 Waste Management and Stormwater Quality

Stormwater quality is gradually deteriorating specially during dry season, due to dumping of waste directly into the drain. Dumping of waste is also triggering urban drainage problems during heavy shower due to blockage or clogging of drains. Sometimes, smelly, and bad quality warm household water is directly discharging into the river carrying by storm drains posing the health of the Thimphu Chhu and its aquatic ecosystem at stake, which may be increased in near future with rapid urban growth. Changing the mind set of citizens on proper household waste management is a big challenge particularly for this case. These challenges are therefore unavoidable and should be addressed intensely to get a holistic solution for stormwater management system.

4.2.4 Existing Level of Service

Existing level of services have been assessed using the field and manually validated final SWMM model outcome and under two categories i.e. i) in terms of performance of existing drains under extreme climate change condition and ii) in terms of coverage of drainage network considering the future needs.

It has been revealed that on an average 68% of total artificial stormwater drainage network (136.9 km) of the total Thimphu Thromde are or will be performing well or adequate under future climate change and urban development scenario. Domain wise adequacy is shown in below pie chart and bar charts, where it has been found that inadequacy problem is higher in domain 3, domain 2 and domain 7.



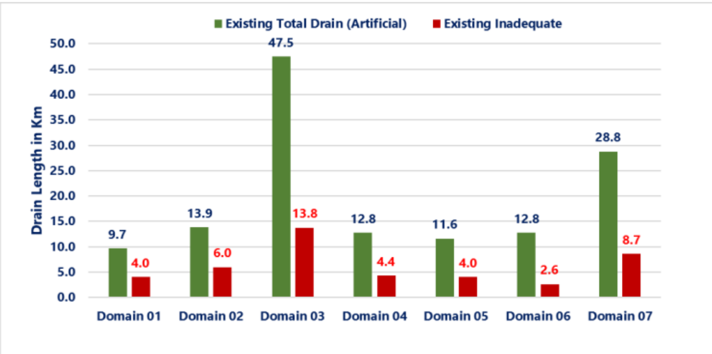


Figure 4.1: Performance of Existing Drain under Climate Change and Urban Development Scenario in the Thimphu Thromde

Further, the overall coverage of stormwater drainage network has been found around 64% considering the future needs. Following bar chart illustrates the status of the drainage coverage under different model domains:

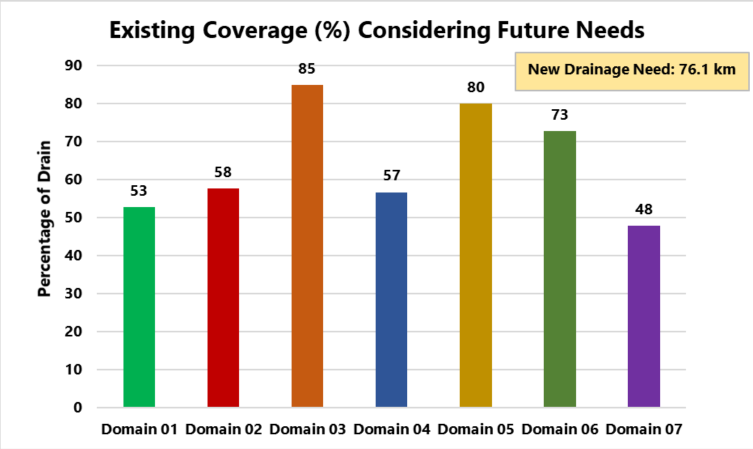


Figure 4.2: Coverage of Existing Drain Considering Future Development Needs in the Thimphu Thromde

This assessment depicts that in addition in total 76.1 km new artificial drains will need to be constructed gradually to meet the future demands, while highest drainage required drains are found under domain 7, which is around 31.4 km followed by domain 2 (10.2) in terms of length.

Summary of Level of Service

Domain	Existing Drain Length (km)		Proposed Drain length (km)
	Adequate	Inadequate	
Domain 01	5.6	4.0	8.7
Domain 02	7.9	6.0	10.2
Domain 03	33.7	13.8	8.4
Domain 04	8.4	4.4	9.8
Domain 05	7.6	4.0	2.9
Domain 06	10.1	2.6	4.8
Domain 07	20.1	8.7	31.4
Total	**93.4**	**43.5**	**76.1**

From existing level of service, it has been revealed that around 32% inadequate drain (43.5 km) should be improved immediately to make adequate enough considering the future climate change extreme event and 36% new drains should be constructed to accommodate future increased runoff.

4.2.5 Existing Design Practices

There is no specific guideline for stormwater drain design and construction. Some typical sections are being followed by practice without considering any design rainfall event or future urban growth scenarios. Figure 4.3 and Figure 4.4 show the usually followed sections during construction of storm drain in Thimphu Thromde. Storm water from road gutters are collected with L-section drain either on one side or both sides of roads, which has some small holes to pass the volume of water beneath the footpath into side storm drain which then carries the stormwater towards the Thimphu Chhu. The major storm drains are found mostly rectangular in shapes, which collect storm water as well as household water. The storm drains very frequently cross roads to maintain the slope of topography and gravity flow as well. Most of the cross-drainage structures include either hume pipe or box culvert (rectangular/trapezoidal), but not maintaining any specific rules, mostly designed on an ad hoc basis without any proper considerations from hydrological point of view. The openings of cross drainage are found very inconsistent from physical inspection, sometimes under designed and sometimes overdesigned. Most surprisingly, the opening size has been reduced from upstream to downstream, whereas the reverse of it would be logical. Also, apart from plain storm drain bed, some drains are found cascade or stair case type. This ad hoc design practices should be another area of concern to improve the design practices.

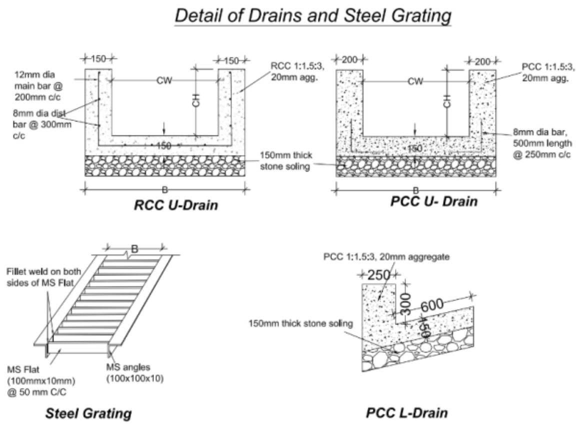


Figure 4.3: Details of storm water drains and steel grating

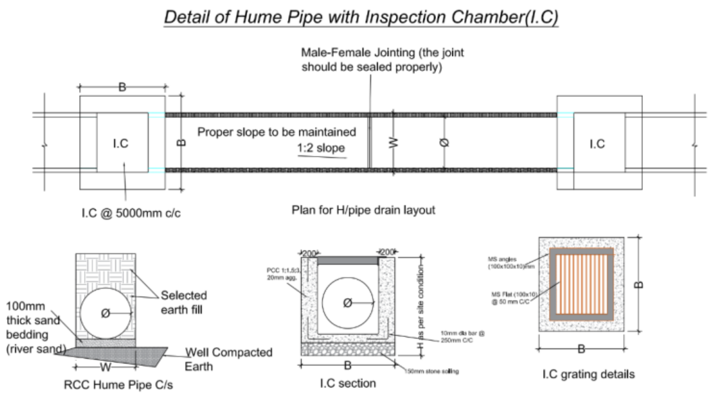


Figure 4.4: Details of Hume Pipe with Inspection Chamber

4.2.6 Emergency Response and Recovery

Thimphu Thromde has not yet established any institutional arrangement for any emergency response and recovery with respect to urban disaster or urban flooding problems after a sudden heavy shower. Stakeholder consultations urged that a well-structured institutional mechanism should be there to act on emergency promptly with adequate high-tech equipment to make recovery faster and alleviating havoc of life and properties. Urban Policy Note on Water and Climate Change developed by the World

Bank and RGoB officials also emphasized strengthening of emergency response and recovery for enhancing urban resilience considering uncertainties of climate change.

4.2.7 Low Impact Development (LID) Practices

No evidence of Low Impact Development (LID) practices has been found during the reconnaissance visit except the collection of rain water from roof-top through gutter. According to the Thromde engineers, almost 90% buildings of Thimphu Thromde contain these types of rain gutter, but it discharges directly to the stormwater drain without reusing this. Reuse of these rainwater for household purposes can reduce the stormwater volume significantly and enhance the efficiency of the stormwater drainage network. Reuse of collected storm water through rain gutter can be harvested in a tank. These types of rainwater harvesting practices have not been observed or reported during the visit. Moreover, no database has been found that contain the rain gutter provision related information. As ISWMP focuses on integration of environmentally nature based low impact development measures, exploring, research, piloting, and field level implementation of LID measures should be taken into consideration to address these challenges.

4.2.8 Implicit Regulatory Framework

The existing regulatory framework i.e. the Development Control Regulations, 2016 has implicitly considered the stormwater management issues under either water supply or sanitation or sewerage. The available inspection forms or occupancy certificates are also not including any explicit clauses on stormwater related issues, which is a major drawback inside the existing regulatory framework. Further, Bhutan Green Building Guideline (2013) was not integrated very well inside the DCR (2016), although it recommended very useful and beneficiary low impact development measures more than 5 years ago which might function very well for this city if it was mainstreamed and integrated inside the regulatory framework properly.

4.2.9 Protection and Conservation of Natural Streams

Protection and conservation of natural drainage is very important aspects as most of the surface runoff coming down from upstream are carried by natural streams or gullies. Rapid urban development is presently posing serious threats to these natural streams to be intervened and hinders the smooth passage of drainage flow, which may aggravate in future. Strict enforcement of DCR, 2016 can alleviate these problems, where any intervention is strictly prohibited inside the certain buffer zone of the natural streams.

4.2.10 Inadequate Drainage Survey Data

The technical background study of ISWMP reveals that high accuracy topography and longitudinal profile survey data of storm drains are very important for comprehensive assessment, especially for highly varied topography with steep slopes governing area. As a single percent change of slope may change design flow significantly. Unfortunately, these detailed level survey data of storm drainage network infrastructures are not available at this moment, which must be exclusively taken into considerations for priority actions.

4.2.11 Human Resources Development and Capacity Building

Inadequate manpower and insufficient skilled manpower are found key reasons to non responsive and less frequent repair, maintenance and cleaning program or initiatives. Adequate human resources development and their capacity building thus will have to be ensured.

4.2.12 Coordination and Monitoring

Infrastructure division does the monitoring of storm water drains not in periodic basis or before starting monsoon rather in an ad hoc basis upon getting information from the Environment division of the Thromde. Every day status of drains has been monitored and maintained through labor and thus lack of labors also hindrance the monitoring process of the drainage networks. In addition, there is also no major initiatives that have been taken to assess and monitor the storm water quality issues. For monitoring purposes, urgency of well coordination among divisions of the Thimphu Thromde is revealed. The inter agency coordination like with Department of Roads (DoR), Department of Human Settlement (DHS), National Center for Hydrology and Meteorology (NCHM) are also found essential, but not present in structured manner as part of the institutional arrangement.

4.2.13 Financing, Operation and Maintenance

Thimphu Thromde have no separate budget allocation for storm water management. The storm water drainage network is constructed by Infrastructure Division which they do from their annual development program (ADP) allocation. Besides no provision is found available for dedicated budget for construction, operation and maintenance works. In general, Administrative and Finance Division disburse the budget upon requisition by the concerned division which is subject to availability from allocations. Usually a few portions of combined budget of road construction and drains are being utilized every year for O&M, which is inadequate than present demand.

4.3 Prioritization of Action Areas

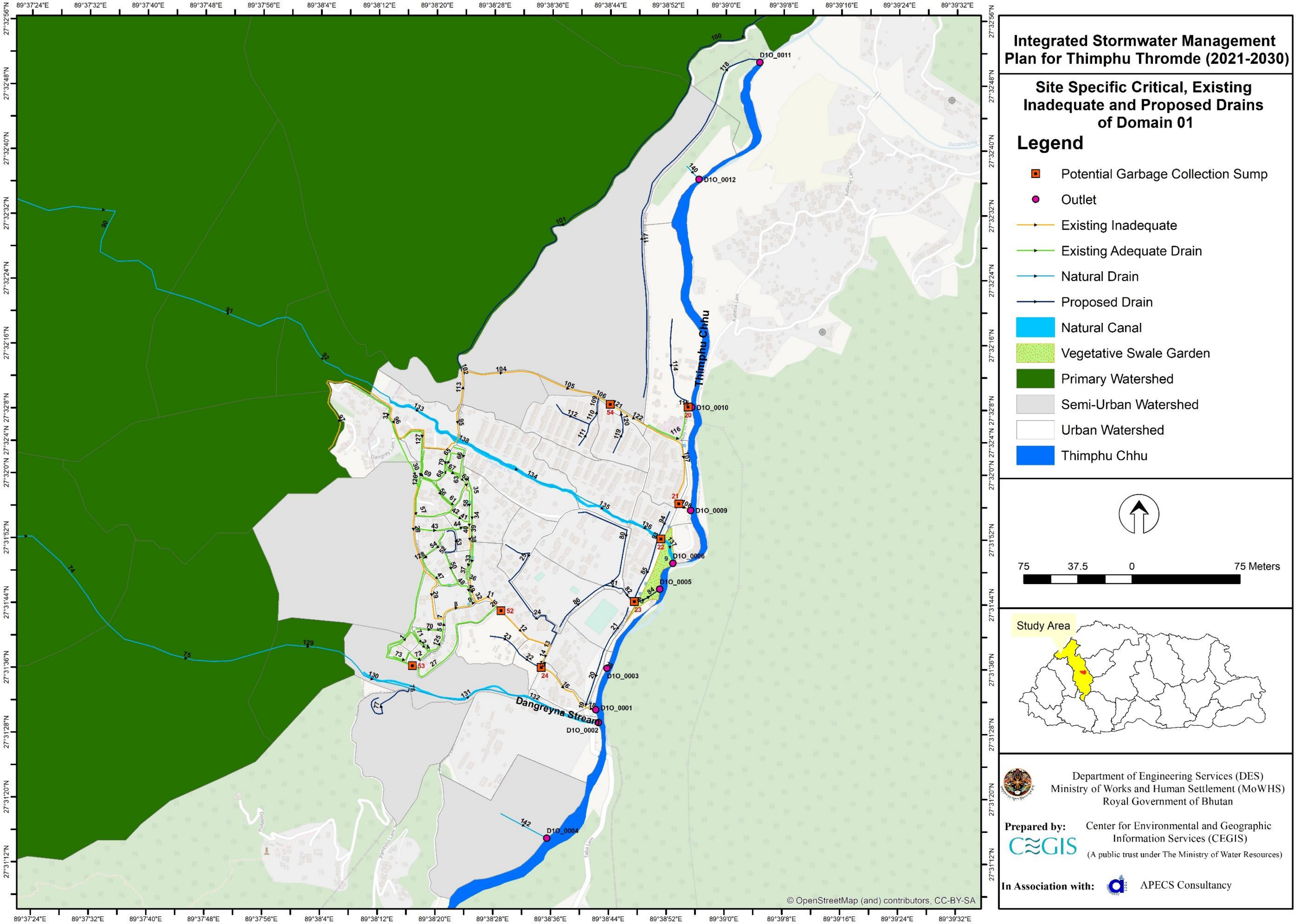
Analyzing all above mentioned key stormwater management related challenges attributed from SWMM modeling, site visit and stakeholder consultations, following priority action areas have been identified under structural and non-structural categories:

Table 4.3: Priority Action Areas of ISWMP, Thimphu Thromde

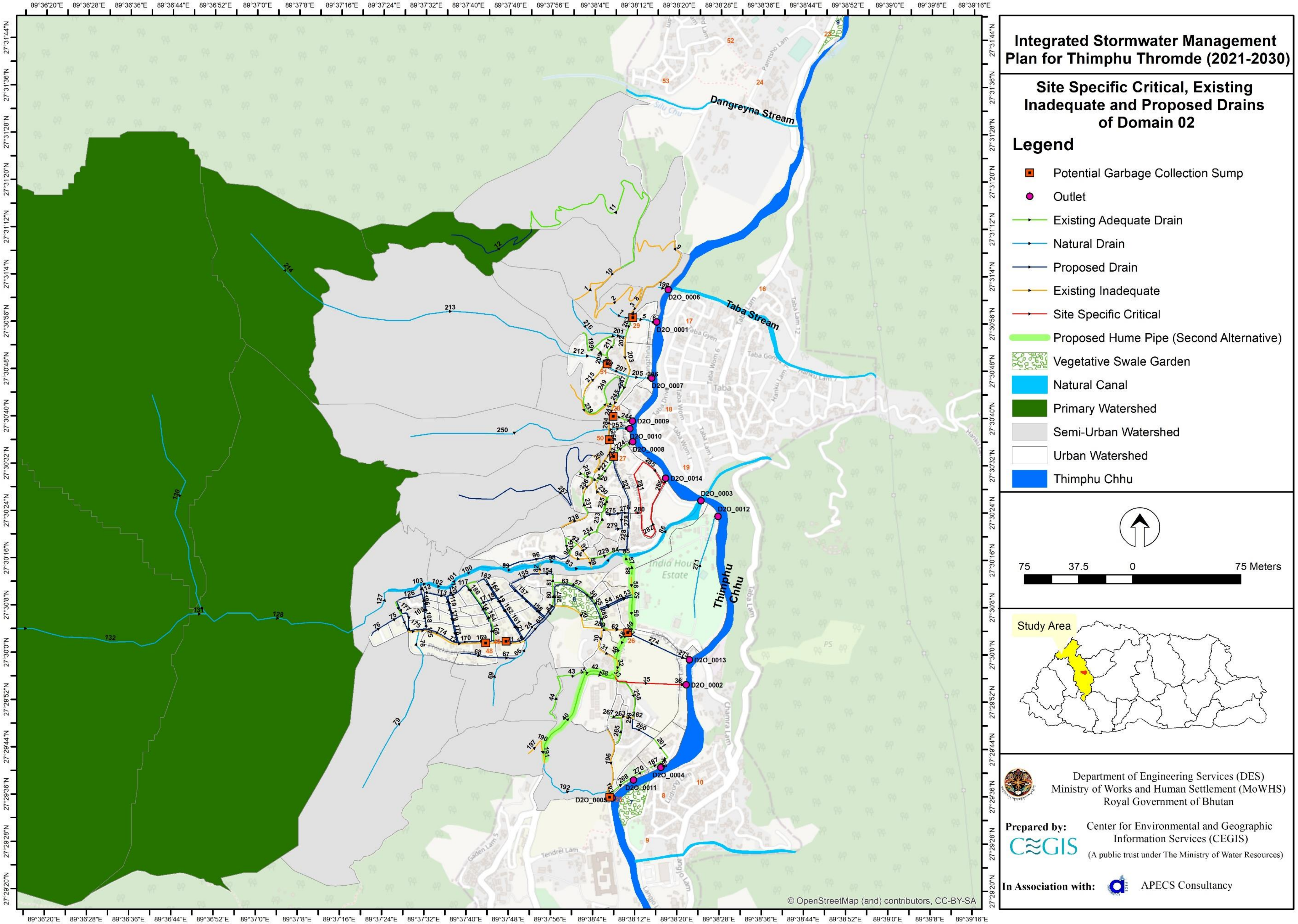
Structural	Non-Structural
Improvement of Existing Inadequate Drains (43.5 km)	Development of Emergency Response and Recovery Mechanism for Urban Resilience
Expansion of Drainage Coverage for Future Needs (76.1 km)	Enhance Coordination among Divisions and Agencies
Construction or Repair/Maintenance of Site-Specific Critical Problems (64 nos.)	Strengthening Operation and Maintenance
Cleaning of Blocked and Clogged Drains (44 nos.)	Dedicated Financing for Stormwater Management
Regular Repair and Maintenance	Human Resources Development

Research, Piloting, and Implementation of LID Measures	Capacity and Skill Development
Conducting Detailed Topography and Longitudinal Profile Survey of Storm Drains	Promoting IT based Monitoring System
Installing IT based Monitoring System	Popularization of Low Impact Development Measures for Implementation
Installation of Garbage Collection Sump for Waste Filtering and Cleaning	Protection and Conservation of Natural Streams or Drainage
	Preparation and Enforcement of Explicit Regulatory Framework for Stormwater Management

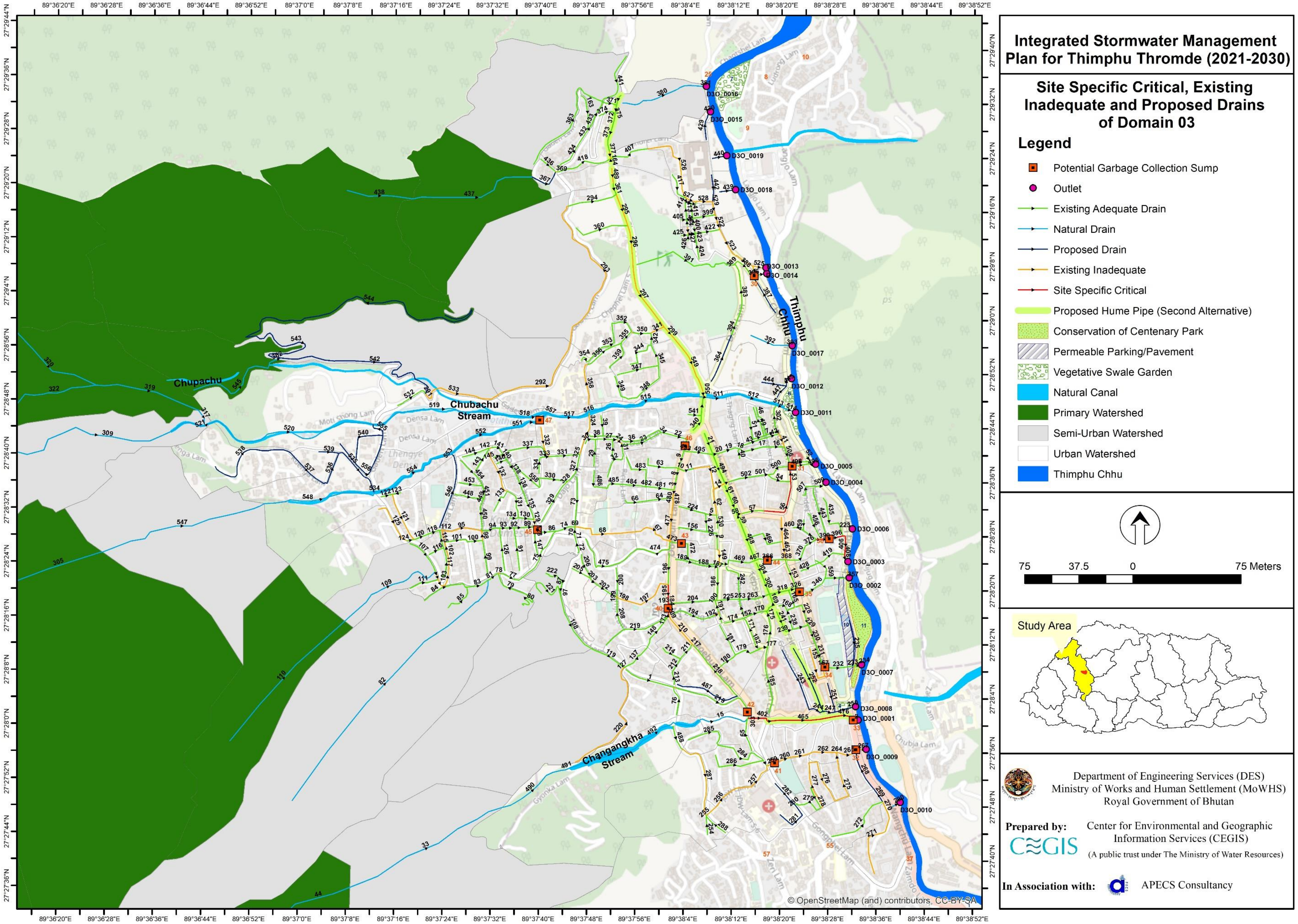
Following figures illustrate site specific criticality, existing coverage and inadequacy, natural drainage, and possible solutions like proposed drains, hume pipe as alternative solutions, potential location of garbage collection sump, etc. to portray structural part of the priority action areas.



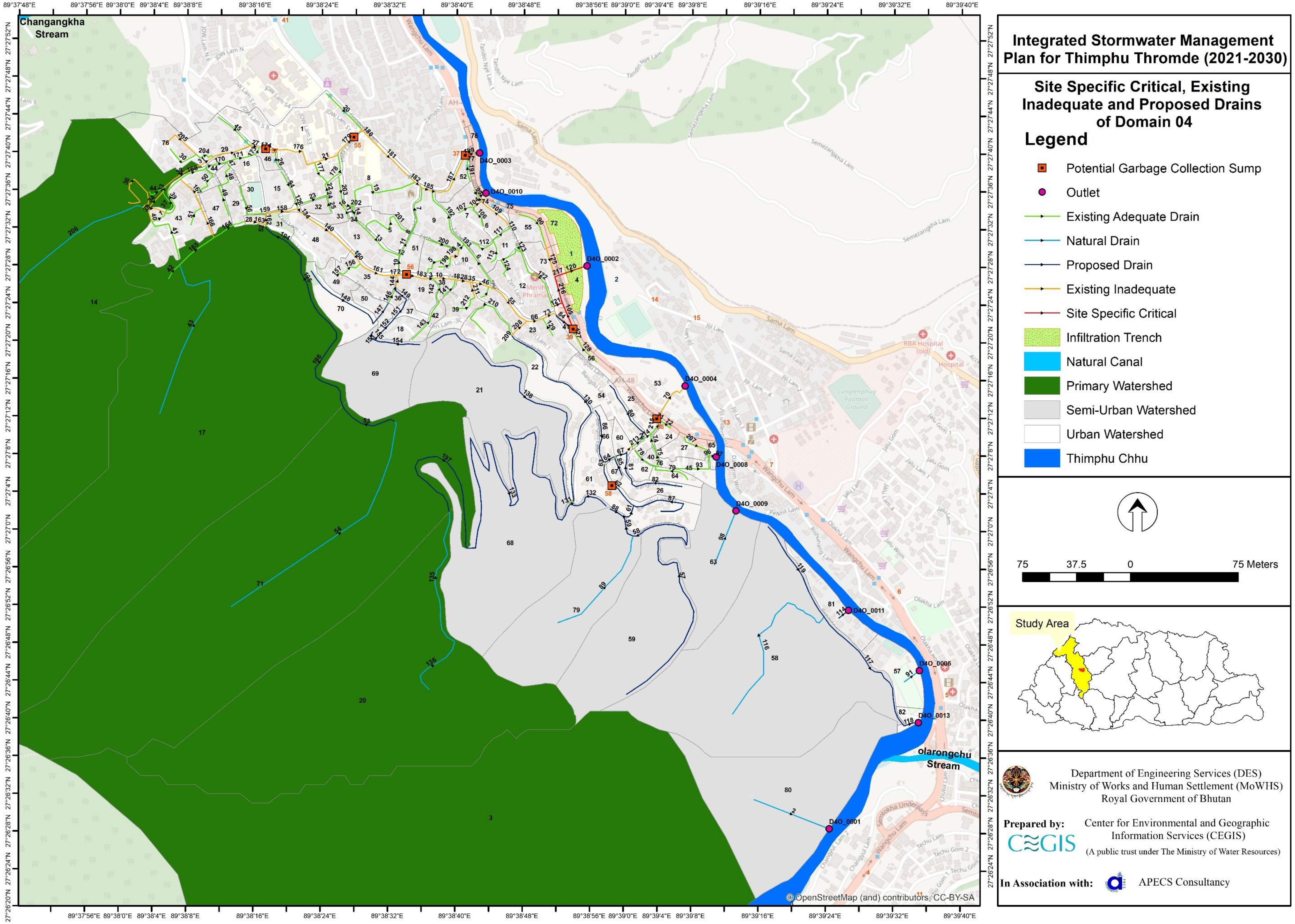
Site Specific Criticality and Proposed Measures for Model Domain 1



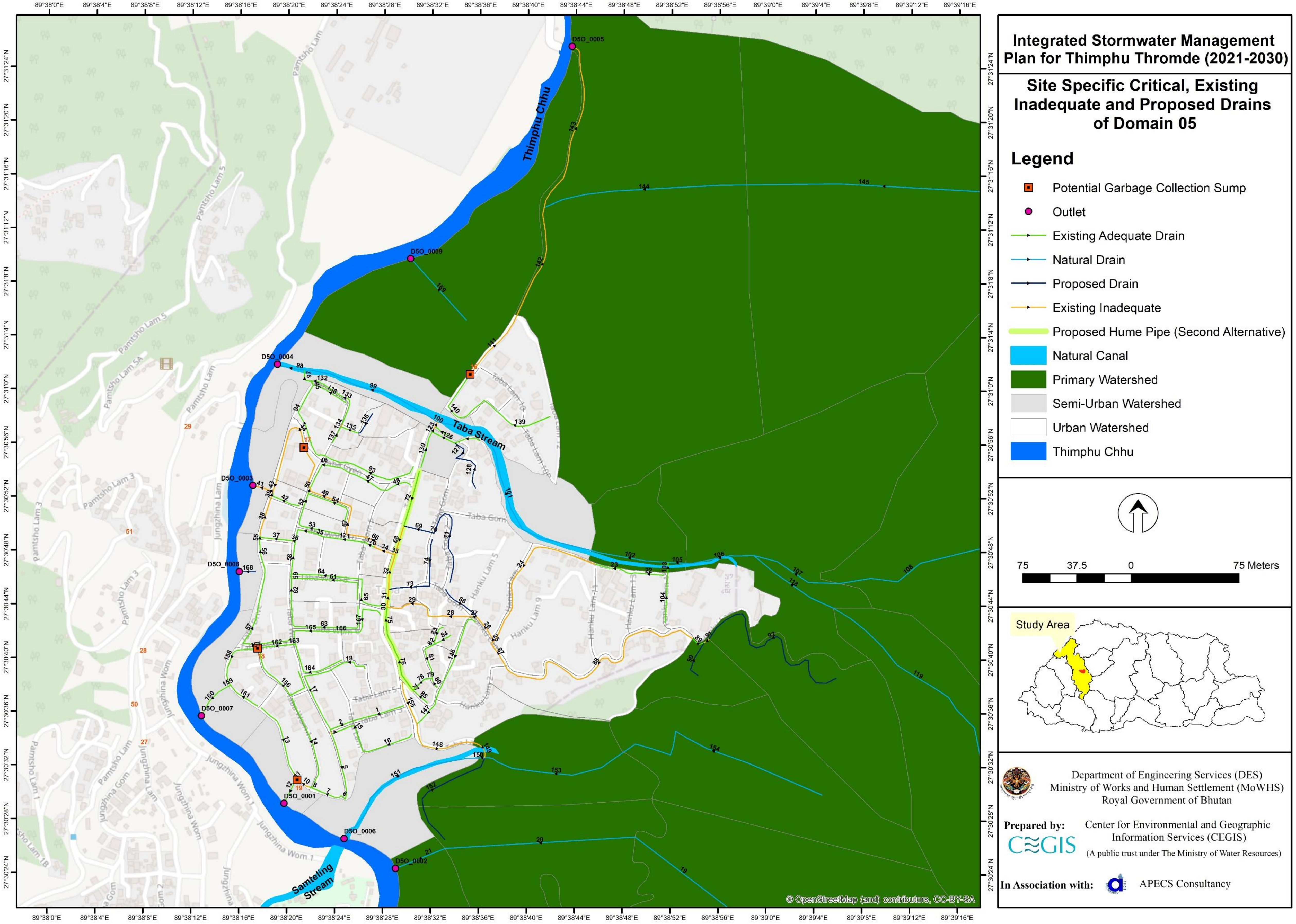
Site Specific Criticality and Proposed Measures for Model Domain 2



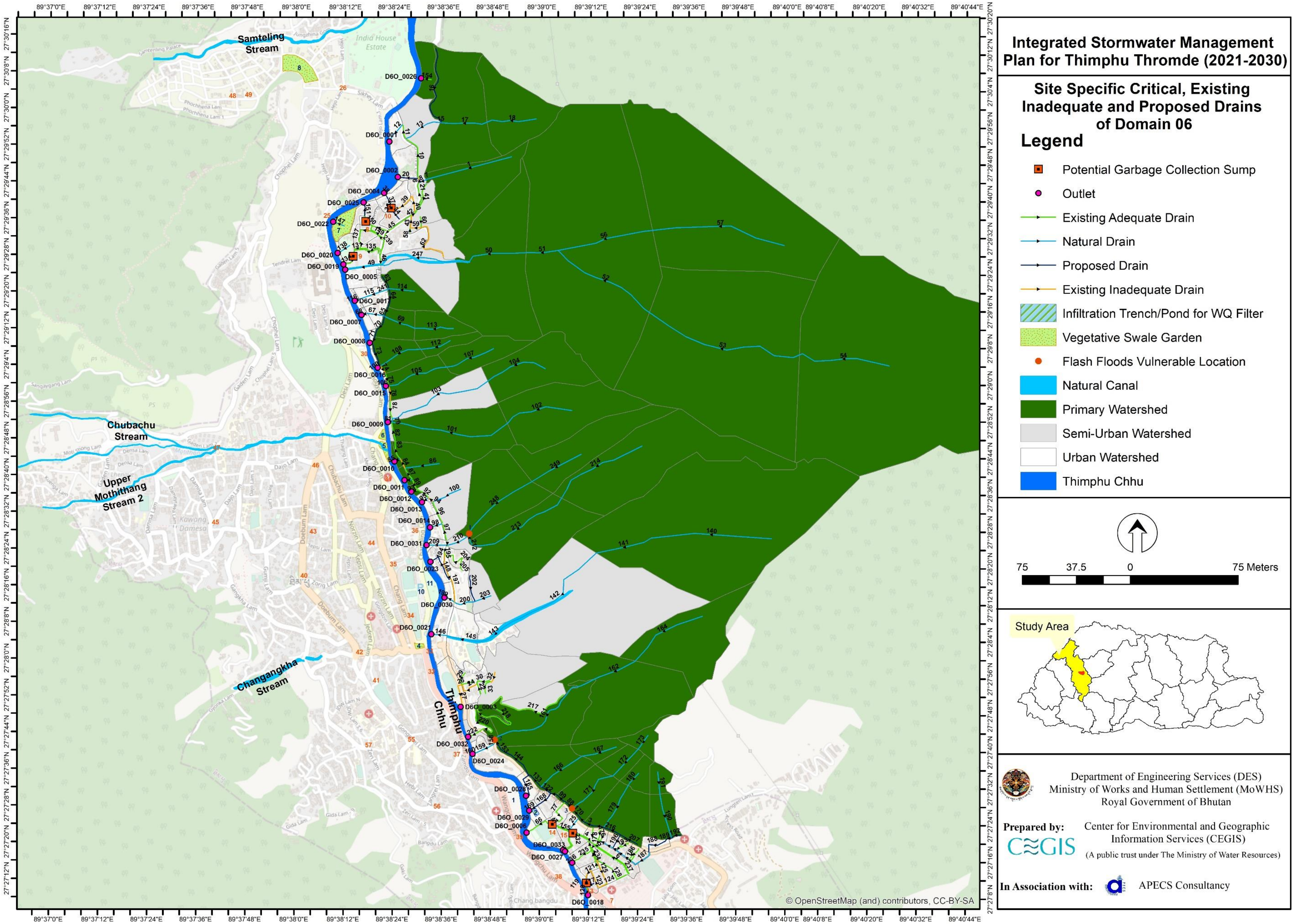
Site Specific Criticality and Proposed Measures for Model Domain 3



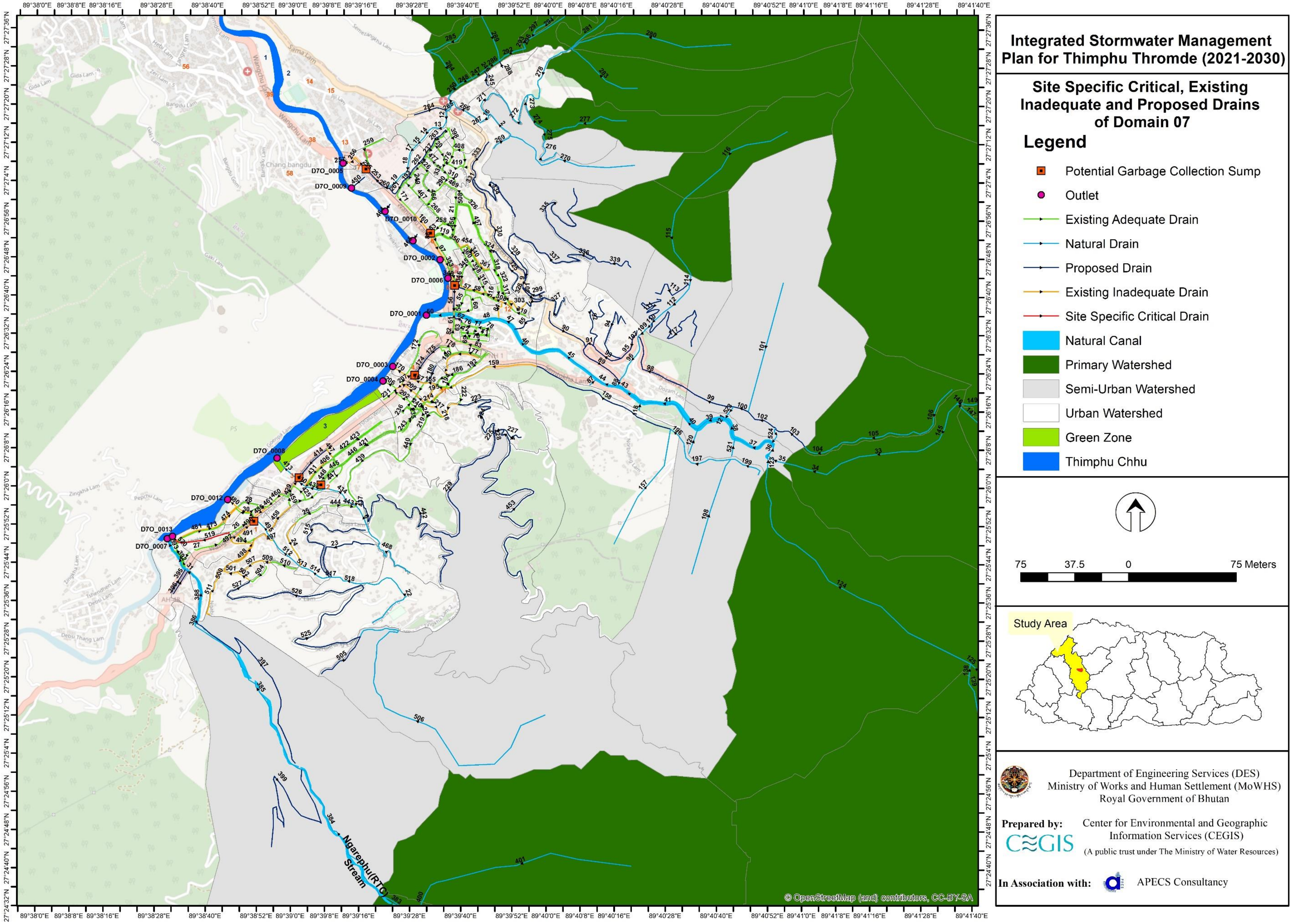
Site Specific Criticality and Proposed Measures for Model Domain 4



Site Specific Criticality and Proposed Measures for Model Domain 5



Site Specific Criticality and Proposed Measures for Model Domain 6



Site Specific Criticality and Proposed Measures for Model Domain 7

5. Stormwater Management Strategies and Measures

5.1 Introduction

This section details out the conceptualization of structural and non-structural measures to ensure proper and sustainable stormwater management system of Thimphu Thromde. The proposed structural and non-structural measures are outcome of detail analysis and consultation with experts. All structural and non-structural measures have been finalized upon rigorous discussion among the experts, DES and Thromde engineers. However, all proposed measures have been finalized after taking feedback from Thromde Engineers as well as other relevant stakeholders during finalization stage of the ISWMP.

5.2 Stormwater Management Strategies

Several principles have been set before fixing the strategies and conceptualization of measures, which are as following but not limited to:

- Maintaining alignment with the national and international development agenda
- Utilizing the existing resources and infrastructures
- Principles and recommendations of Thimphu Structure Plan for future urbanization
- Consideration of prevailing drainage pattern and characteristics
- Promotion of Environment friendliness or low impact development
- Innovative and IT based solutions
- Consideration of deep uncertainties due to climate change or pandemic like COVID-19
- Low cost, local materials oriented and durability
- Sustainability
- Standard SWMM Guidelines and Best Management Practices (BMPs)

Based on these principles the strategies for the stormwater management have been set. The strategies are:

e. ***Promote Climate resilient, sustainable stormwater drainage system:*** This strategy focusses on building on hydrologic analysis and stormwater model result based outcomes considering present and future needs for the city's stormwater system due to climate change impacts. The solutions will focus on sustainable and low maintenance measures – both structural and non-structural.

f. ***Promote Low Impact Development measures:*** This strategy focus on promotion of Low Impact Development that can reduce the stormwater peak flow and reduce the pressure on the city drainage network. Some possible examples are; rainwater harvesting, infiltration trench, vegetative swale, permeable pavement etc.

g. ***Ensure regular and periodic cleaning and maintenance of the stormwater drainage system:*** City stormwater system cleaning and maintenance is an important aspect of the system. Regular maintenance, monitoring and cleaning can ensure proper functioning of the system and prevent disastrous situations. This will focus on engaging emergency response teams and automated/ IT based monitoring system.

h. ***Ensure cost-effective, nature-based and locally sourced solutions:*** Cost effective solutions that are nature based and utilize locally available materials are the best options for sustainable development of the city drainage infrastructure. The measures should be focused on this approach.

5.3 Formulation of Structural Measures

Below sub-sections described the problem specific and site specific structural measures for the ISWMP:

5.3.1 Problem Specific Measures

Inadequacy Problem, Requirement of Drains/Replacement

Form the model results and survey data it was evident that a large number of drains/ pipes have limited capacity to store/carry stormwater. This leads to the overflow of the drains/ pipes and cause local urban flooding. Further, some areas may require additional drains or drainage capacity. To address these problems following structural measures have been proposed:

- Dimension increase and expansion
- Construction of new drains in combination with LID measures

Increased dimension and expansion of length where required will increase the storage capacity of the drainage system as well as draining conditions. Based on the detailed modeling results, design flows at each of the primary, secondary and tertiary drains have been identified. As, there is lack of data related to exact values of invert levels of drains, the designing of drain dimension has been done considering estimated invert levels from DEM land level values, design discharge and slope. For providing a sustainable solution for the implementation authorities, the designs are prepared for groups of drains with similar design discharge and slope. First, the adequacy check for each drain is done based on their existing condition. Later revised drain sections are proposed for each group. Typical sections for drains are provided in Figures 5.1-5.9.

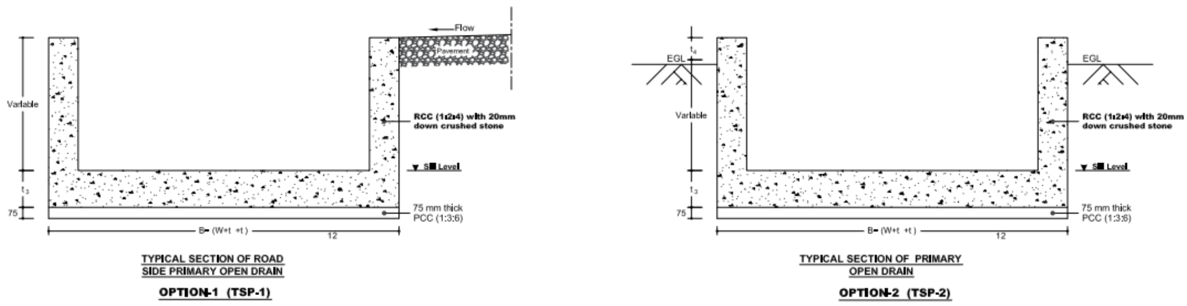


Figure 5.1: Typical section for Primary open drain

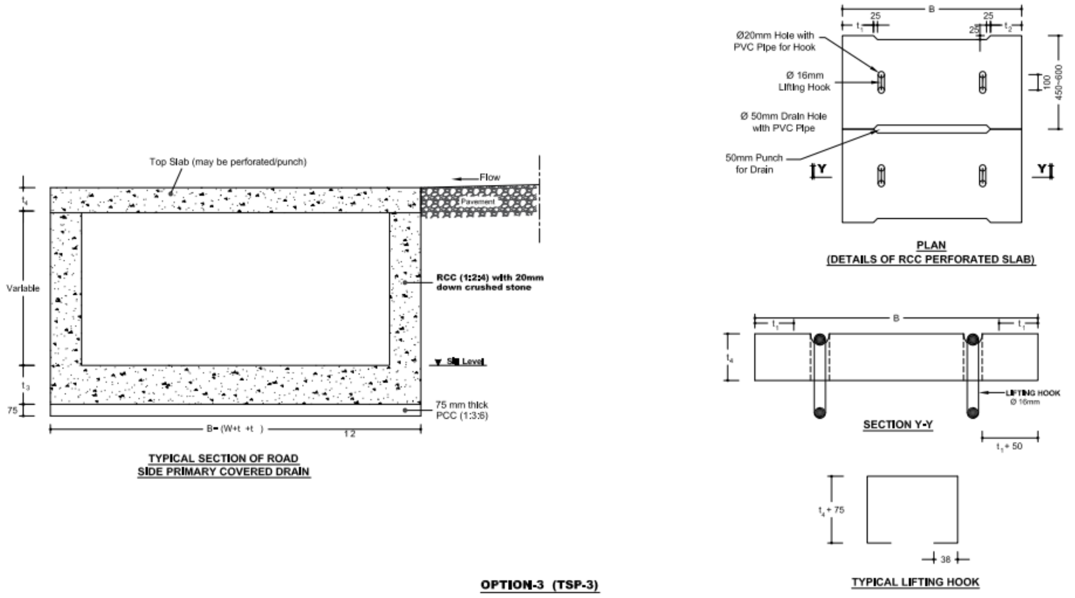


Figure 5.2: Typical section for Primary closed drain

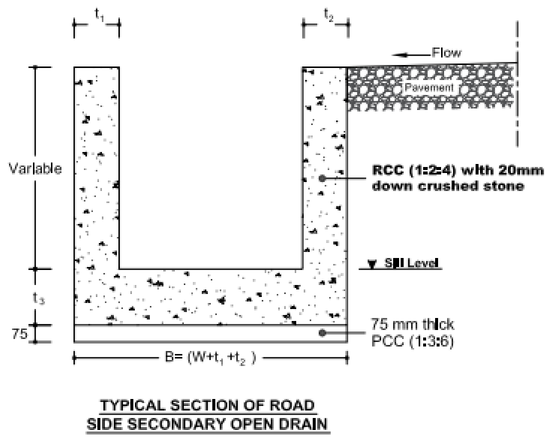
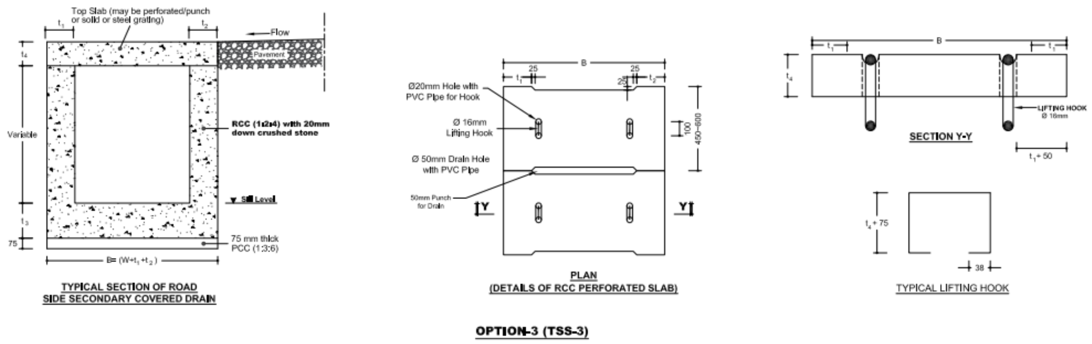
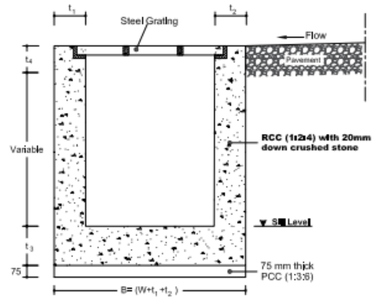


Figure 5.3: Typical section for Secondary open drain

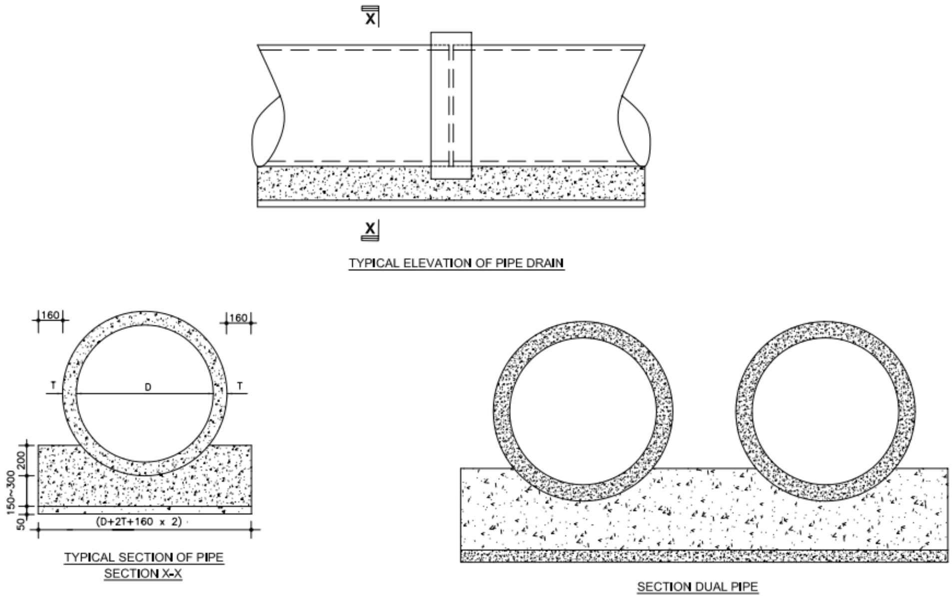




TYPICAL SECTION OF ROAD SIDE SECONDARY DRAIN COVERED WITH STEEL GRATING

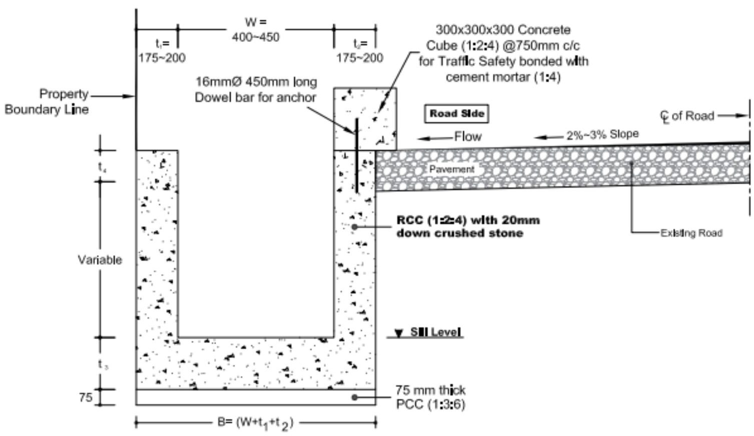
OPTION-2 (TSS-2)

Figure 5.4: Typical section for Secondary closed drain



OPTION-4 (TSP-4)

Figure 5.5: Typical section for Pipe drain/ Hume pipe for Primary or Secondary Drain



TYPICAL SECTION OF ROAD SIDE OPEN DRAIN

Figure 5.6: Typical section for Tertiary open drain

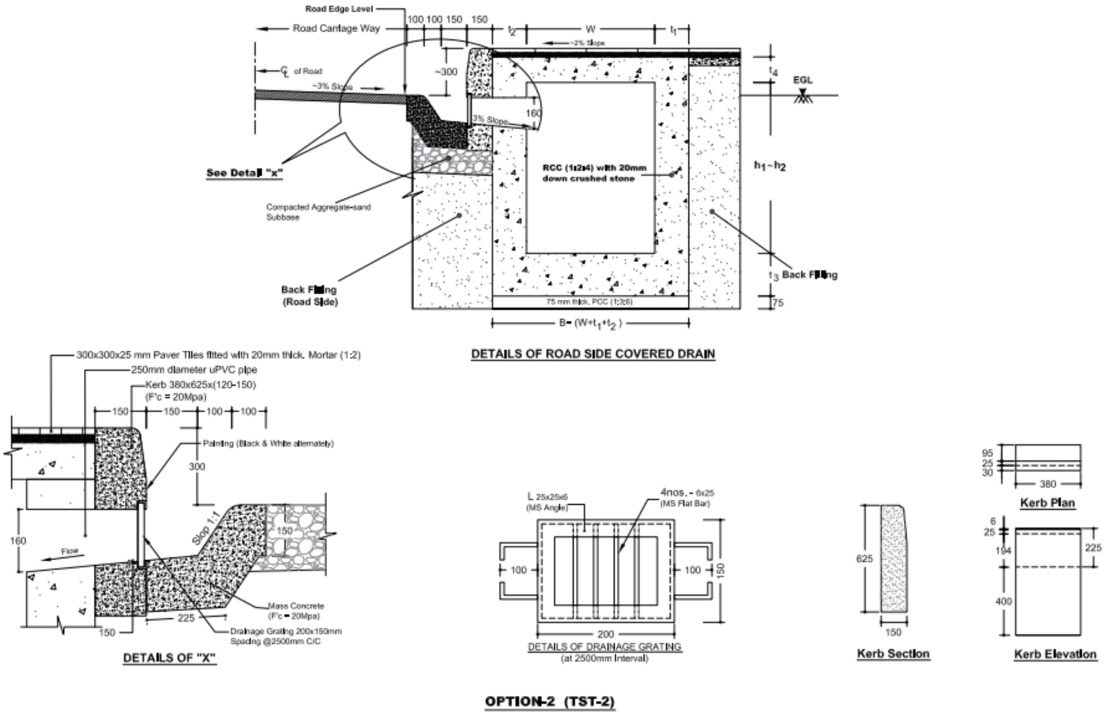


Figure 5.7: Typical section for Tertiary closed drain (type-1)

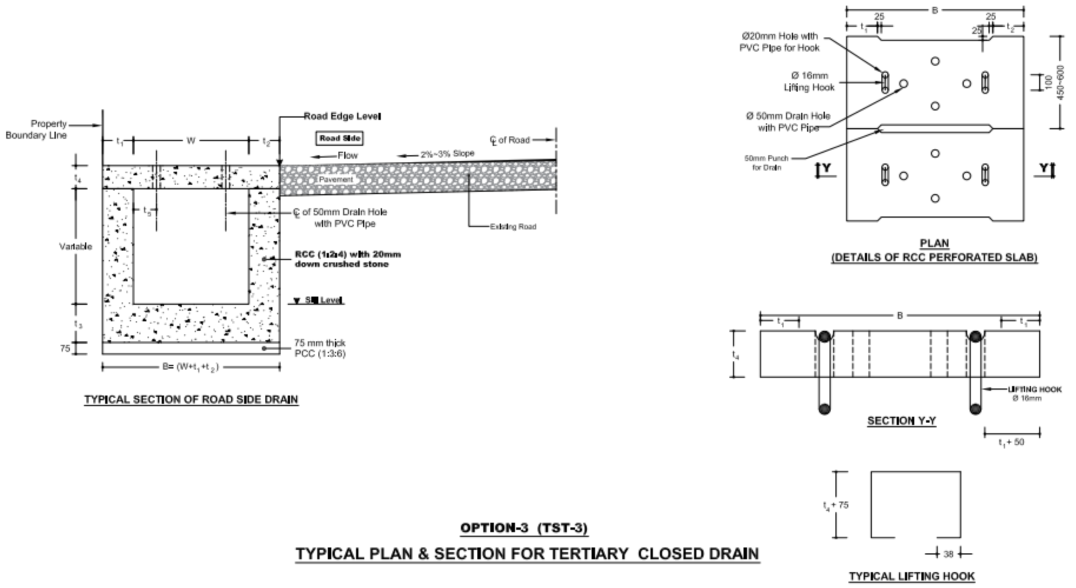


Figure 5.8: Typical section Tertiary closed drain (type-2)

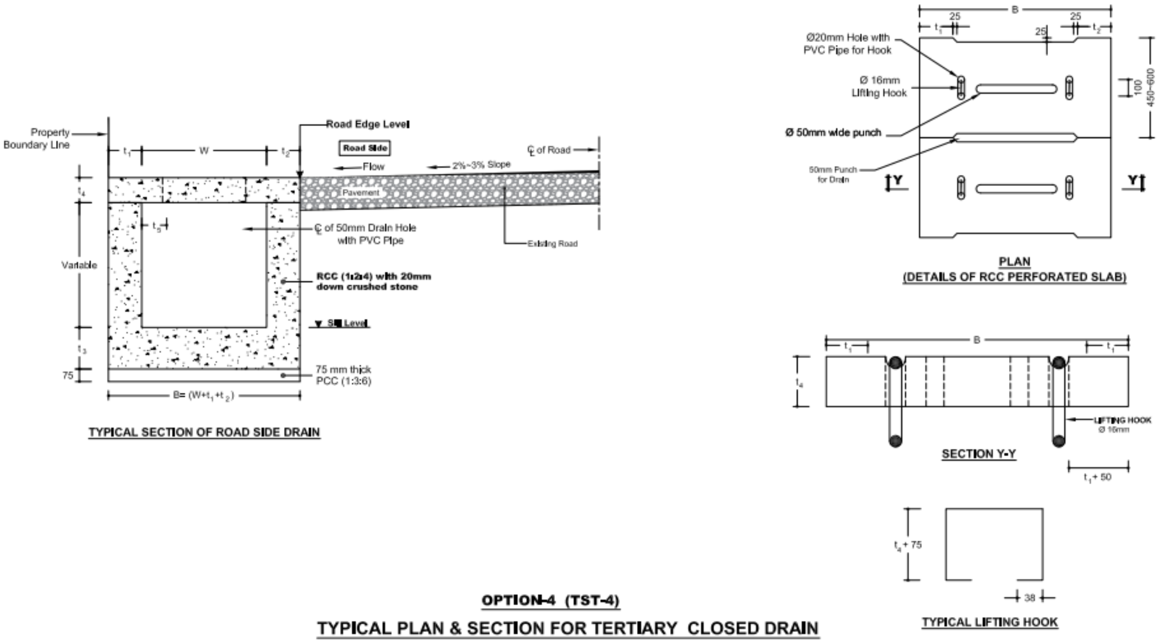


Figure 5.9: Typical section Tertiary closed drain (type-3)

Changing type of drain (from L shape to Rectangular) is suggested for many areas, as they were found inadequate. Based on model results, the design discharges for each L drain is estimated and have been checked with the available capacity of L drains which are quite frequent in the city. Based on this adequacy check, a set of rectangular drain sections have been proposed to cater the need of different discharges found in L drains. Figure 5.6-5.9 illustrates the typical sections for a rectangular drain to replace an L drain.

Slope Transition Problem

Due to a lack of smooth transition, congestions can occur at the inlet or outlet of adjacent conduits. When the gradient of a pipe changes from steep to mild or mild to steep, a hydraulic jump may occur at the transition. This hydraulic jump can create local flooding or congestion at the transition point. Some structural measures can alleviate this problem. Those measures include but not limited to –

- Installation of stair/baffled drop structure with vegetation swale
- Construction of catch pit at foothill outfall location
- Construction of major drains instead of L-section

A stair/ baffled drop structure with vegetation cover will not only lessen the steep gradient problem but also will address the capacity issue of the conduits. These structures are essential for ensuring smooth transition of slope in the topography. Typical sections of baffled/ stair/ vertical drop structures are presented in Figure 5.10 and Figure 5.12 for information. However, before implementation a proper survey of invert level, dimensioning of the design and long profile is mandatory.

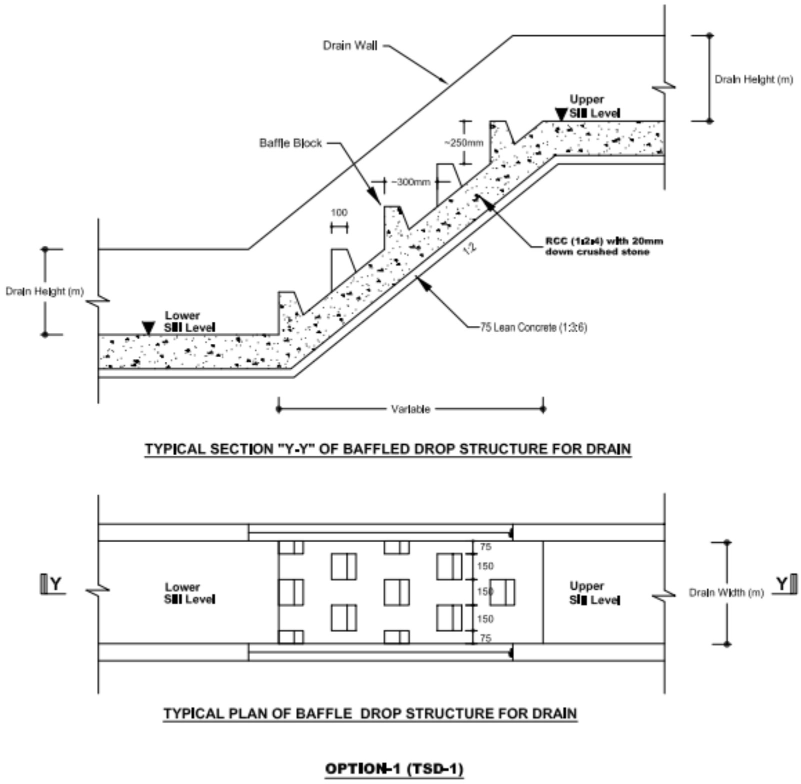


Figure 5.10: Typical section of baffled drop structure

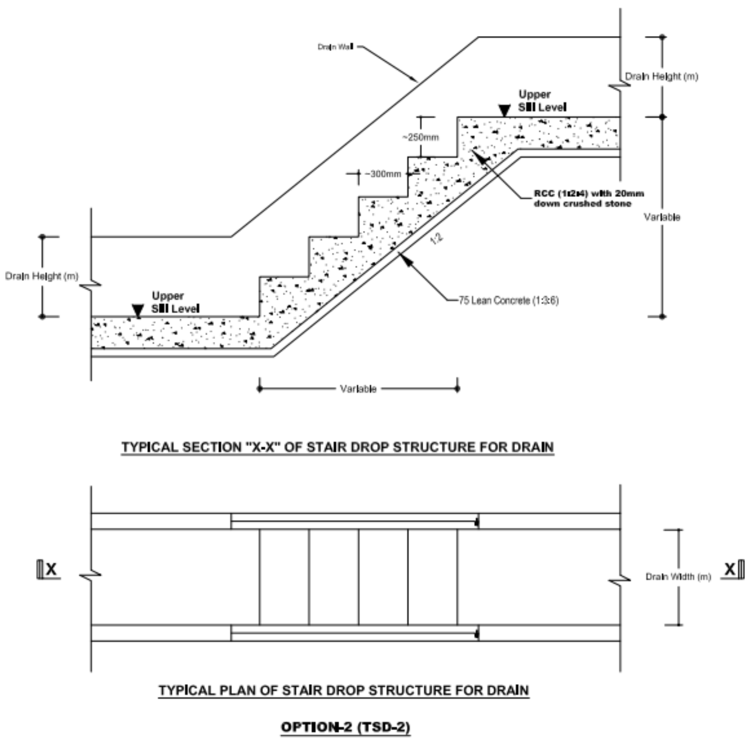


Figure 5.11: Typical section of stair drop structure

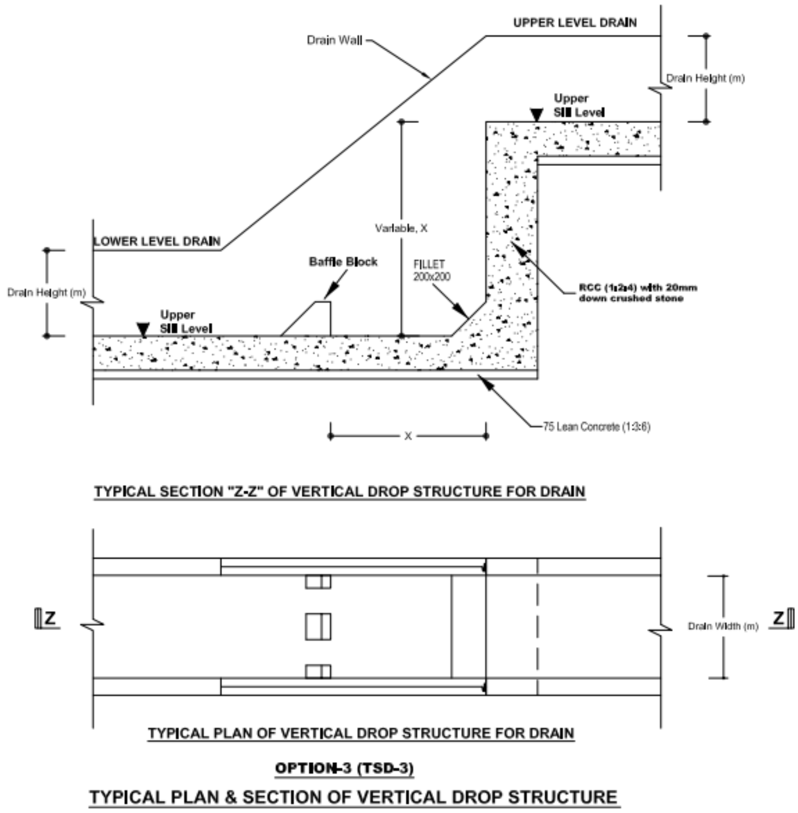


Figure 5.12: Typical section of Vertical drop structure

Construction of catch pit or shear wall at foothill will prevent road flooding and will route water to the conduit slowly as it can hold water for some time. This solution has been presented for several areas around the city where this type of problem is found. Figure 5.13 shows the typical layout of the road causeway that is proposed for the solution of this problem.

By increasing the size of the collector drain or transforming them into the major drain will increase the capacity as well as mitigate the slope transition problem. Similar issues also occur at drain outfalls to river/ canals. At these locations, a similar approach can be implemented along with trash rack to arrest the garbage. However, before implementation a proper survey of invert level and long profile is mandatory. Figure 5.14 and 5.15 show the typical layout of these solutions.

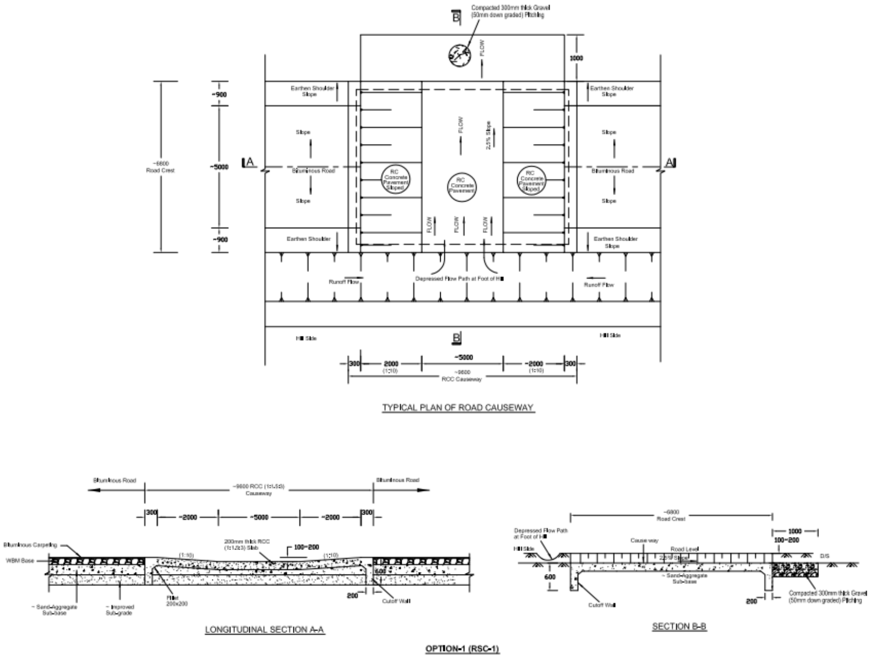


Figure 5.13: Typical section for road causeway

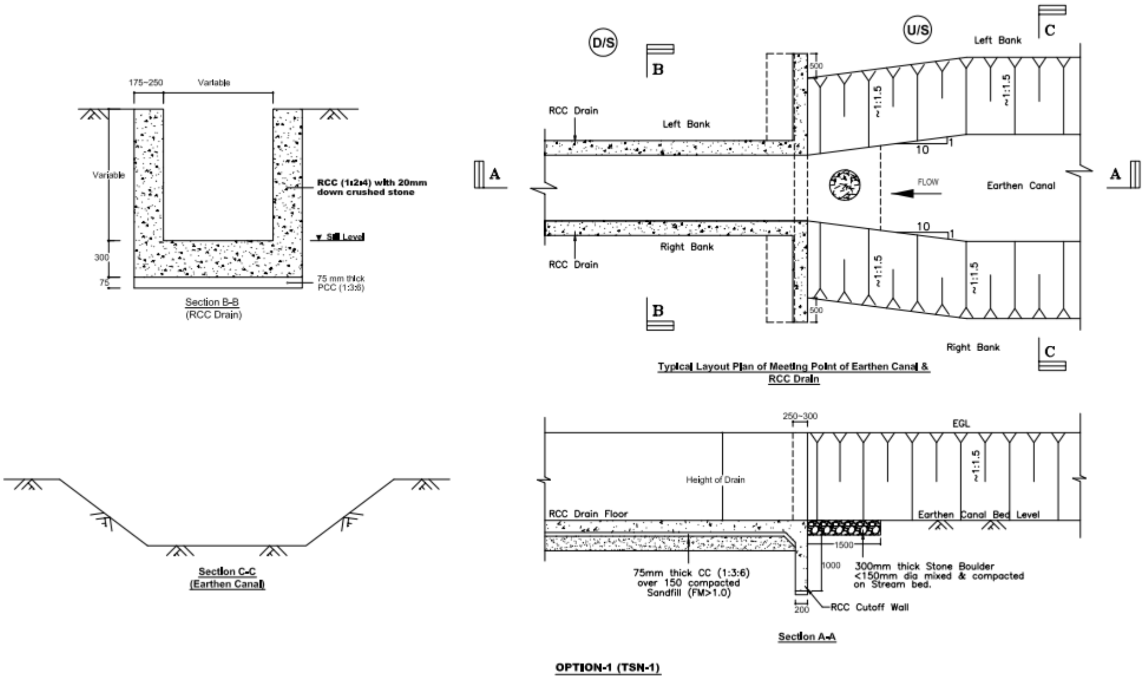


Figure 5.14: Typical section for natural to artificial transition drain

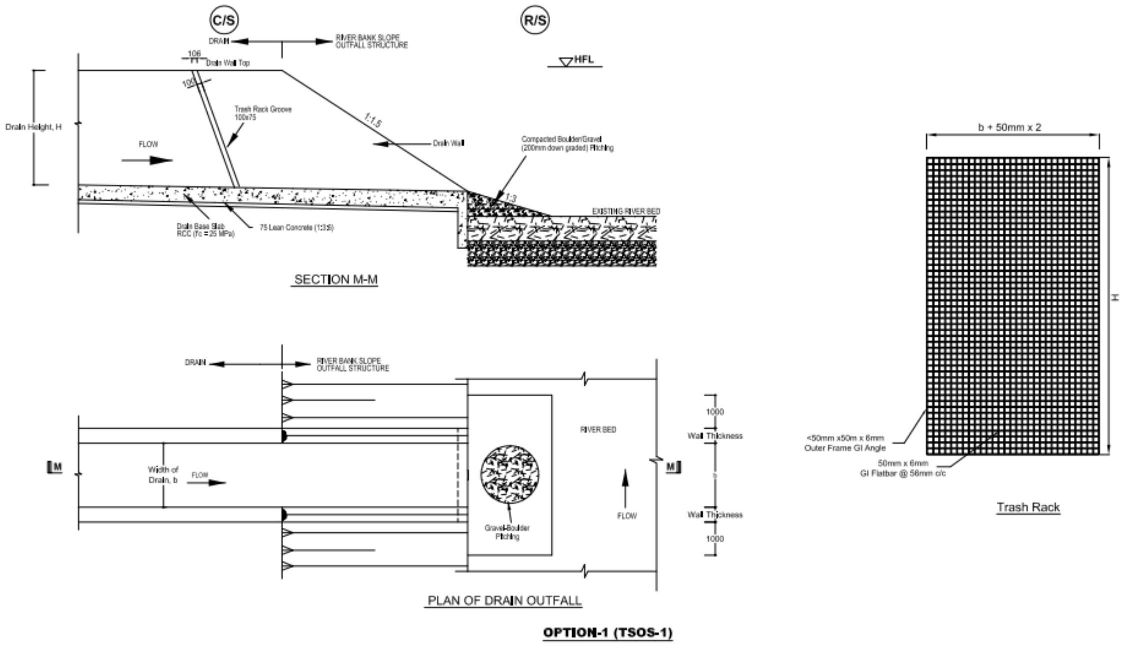


Figure 5.15: Typical section of drain outfall structure

Road crossing structures

Flooding in roads occur due to inadequate road crossing drain capacity in many places. As, mostly these drains are not properly planned currently, the study assessed the condition and suggests some typical solutions. The main suggestion for road crossing structure (RCS) is to use RCC drains with fixed cover along with changes in dimension when flow from two or more places merges. Besides, when a RCS has a 90-degree bend, the bend should be curved at mild curvature to facilitate smooth flow. Figure 5.16 and 5.17 shows typical sections for RCS.

Blockage, Clogging, Repair and Maintenance Problem

Dumping of waste in open space and directly to the drainage system contribute to drainage systems being congested. These congested drains have reduced capacity and cannot take the pressure of huge water accumulated due to heavy rain, leading to waterlogging. Each year this problem is being frequent and severe in the city. Therefore, following structural measures have been proposed:

- Garbage Collection Sump
- Drain top covered gutter
- Periodic cleaning
- Deep cleaning before starting of monsoon season
- Infiltration trench or Bioretention cell.

Garbage collection Sump can be installed near a critical/ problematic point or outlet. It will ensure water flow by filtering out macro garbage (i.e. Plastic bag, Water bottle, Forest litter, etc.). A typical section for a garbage collection sump is presented in figure 5.19. Potential locations of garbage collection sump have been included inside the ISWMP ATLAS (Volume III). An iron made gutter type drain cover will prevent the garbage from entering the system. It is suggested to implement such covers around important places where a lot of dumping occurs. However, for an efficient drainage system, periodic cleaning work, and deep cleaning before every year monsoon period must be done. To facilitate the cleaning process, in case of closed rectangular drain, steel grating cover has been suggested at 2-3 m interval in case of highly critical area and at 10-20 m interval in low critical area with respect to waste dumping. The cleaning can be performed either manually using a stick and push the clogged waste just pulling up the steel grating cover. In case of fully closed hooked top cover, excavator or pay loader may be used to pull up the top cover and then pull clogged waste with the bucket of the excavator. In case of tertiary closed drain, the top cover can be pulled up with hand.

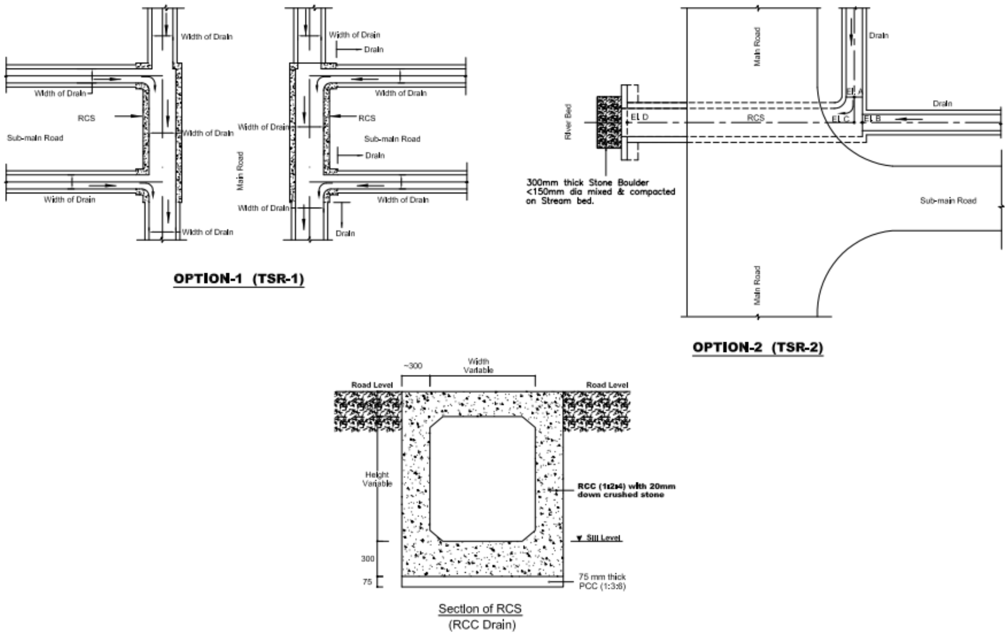


Figure 5.16: Typical section of Road Crossing Structure (option-1 & 2)

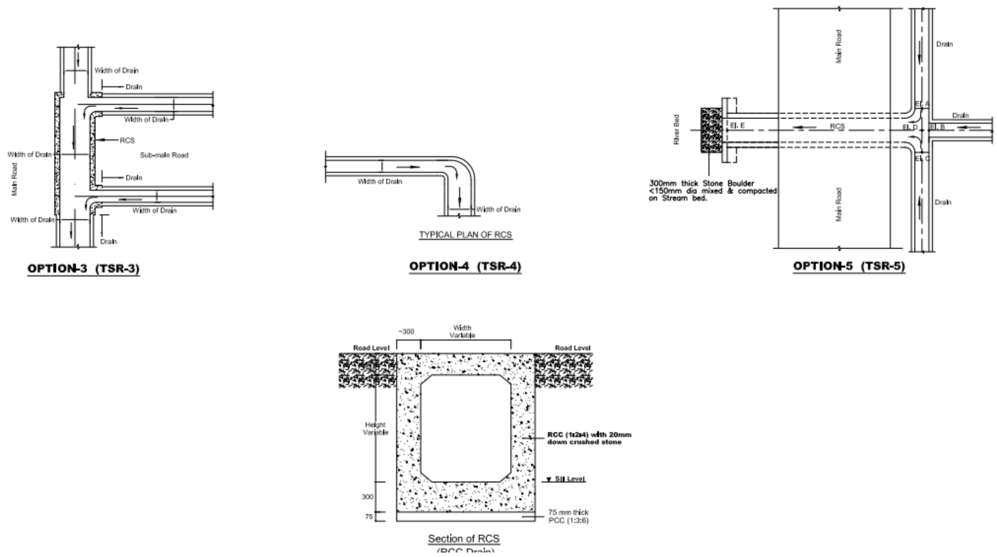


Figure 5.17: Typical section of Road Crossing Structure (option-3, 4 & 5)

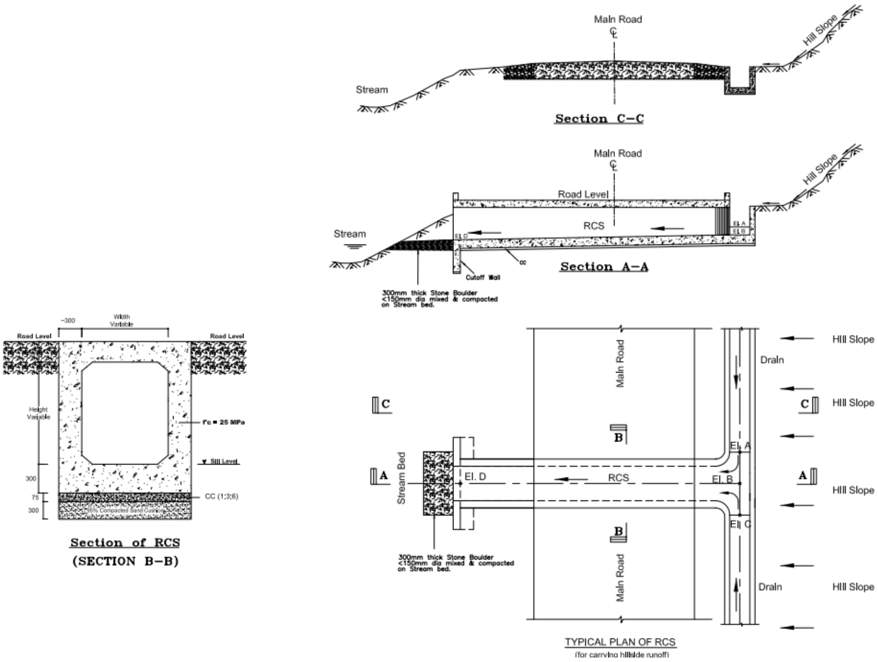


Figure 5.18: Typical Section for Hill Side Road Crossing Structures

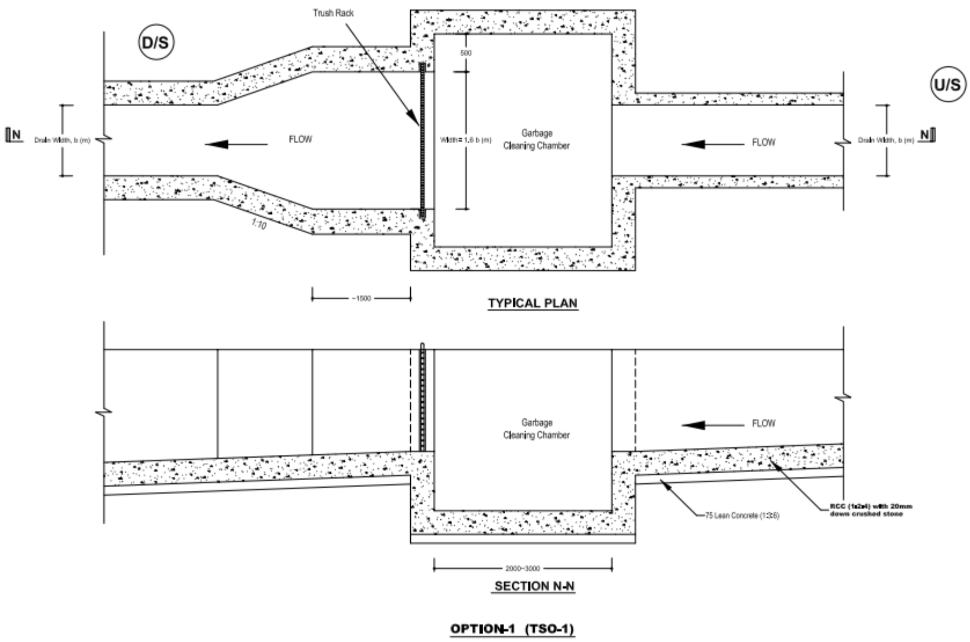


Figure 5.19: Typical design of garbage collection sump

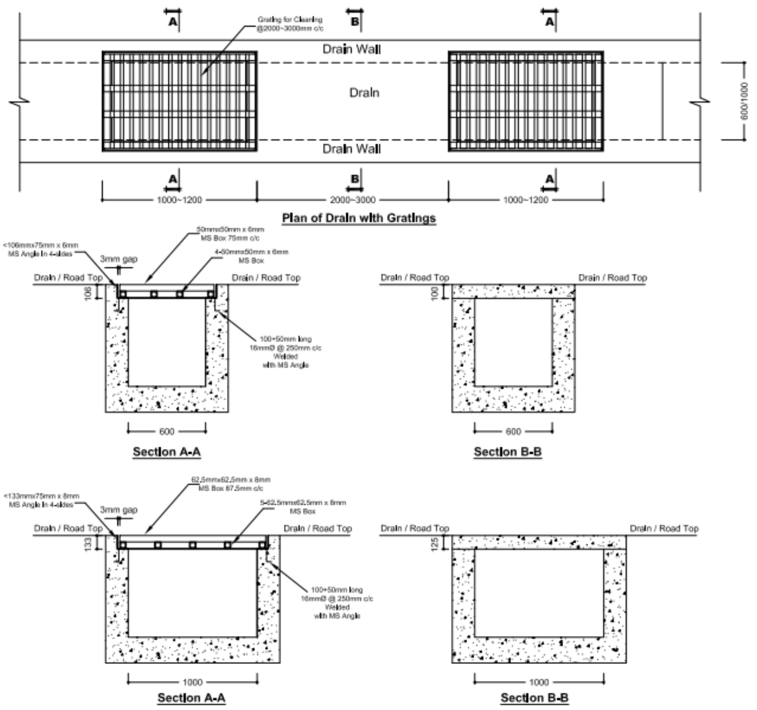


Figure 5.20: Typical section of steel grating to facilitate cleaning process in cased of closed rectangular drain

There were some places where the drain was congested by the service line. To remedy this problem, hotspot of service lines should be demarcated and a few service lines should be removed from inside the drains.

Blockage due to damaged drains require almost same measure i.e. repair before staring of monsoon and perform periodic maintenance with skilled labor.

To ensure improved functioning GIS and SCADA based monitoring systems can be implemented. Further, remote and IT-based monitoring mechanisms like the use of UAV, installing of IP based webcam, or CC cameras in the roadside lamp pole can be introduced for automation of data collection. Mechanization of cleaning storm drains (open as well as closed drains) through advanced technologies like jetting with high velocity and thrust will need to be introduced. In this regard, a professional and trained labor force is essential.

5.3.2 Site Specific Measures

Vegetable Market Outlet

For an outlet near the vegetation market, a special assessment was made. The drain network for this outlet come straight down to the market from upstream but just before crossing the road, it turns about 90 degrees to the south, and then after flowing about 100 m it crosses the road and eventually falls to the Thimpu Chhu. This Outlet is comparatively low lying with an invert of 2298.45 m where the highest flood level can be as high as 2298.96 m considering climate change. As a result, a backwater flow occurs during floods and makes congestion upstream. After a thorough analysis, the proposed solution for this is;

Improvement of existing drain from upstream side upto the bend, transfer the flow to next drain with curved bend, Pass the flow to widened drain beside the perpendicular road and then pass the flow to cross drainage structure with adequate dimensions toward outlet (Figure 5.21). The opening of the cross drainage should not be separated with RCC wall to reduce sedimentation problems.

Another alternate option of was initially thought to align the drain directly crossing the road towards river before taking that sharp bending. However, this option was not found feasible due to overflowing through back water flow in the outlet as that outlet is also very low and HFL considering climate change supersedes the danger level. To implement this option, installation of Installation of Flap Gate with small capacity pump and slope correction through drop structure is also needed. Typical section of flap gate has been illustrated in Figure 5.22. The team thus preferred option 1.

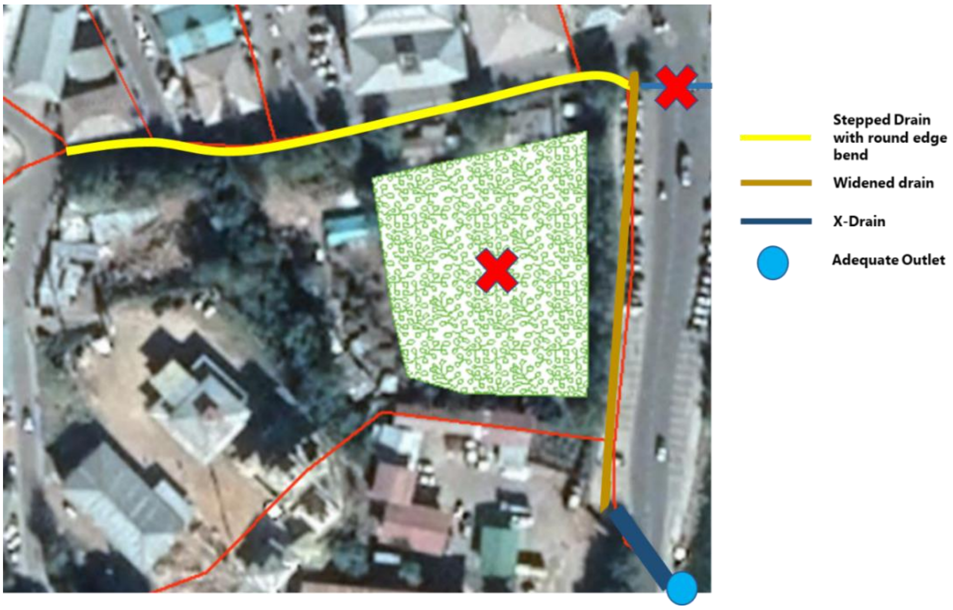


Figure 5.21: Possible Solution for vegetable market area

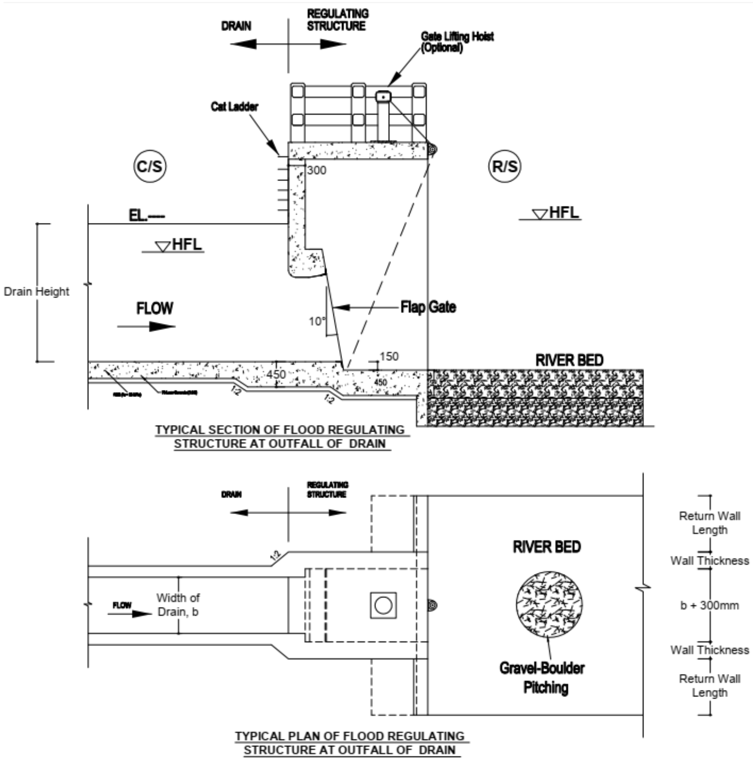


Figure 5.22: Typical section of flap gate for low-lying outlet

Near Underpass

Following site specific structural solutions for critical area near Underpass has been proposed:

- Construction of new adequate sized cross drainage structure as per the previous alignment and maintaining slope
- Re-sectioning of the roadside drain with adequate capacity
- Provide adequate grating structure to collect runoff effectively when collecting road runoff in later part and discharge through proper sized outlet.

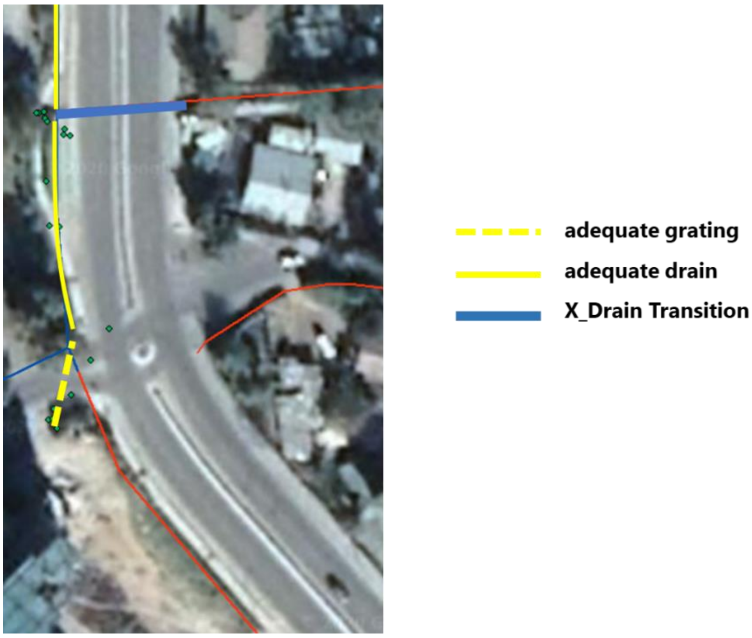


Figure 5.23: Possible Solution for area near underpass

Opposite to Golden Roots Hotel, Runoff Discharges from School

The road in front of the Golden roots hotel experience frequent local flooding due to the discharge from the School. So, to solve this issue, following measures has been proposed:

- Construction of new adequate sized cross drainage structure maintaining proper slope
- Re-sectioning of the roadside drain with adequate capacity

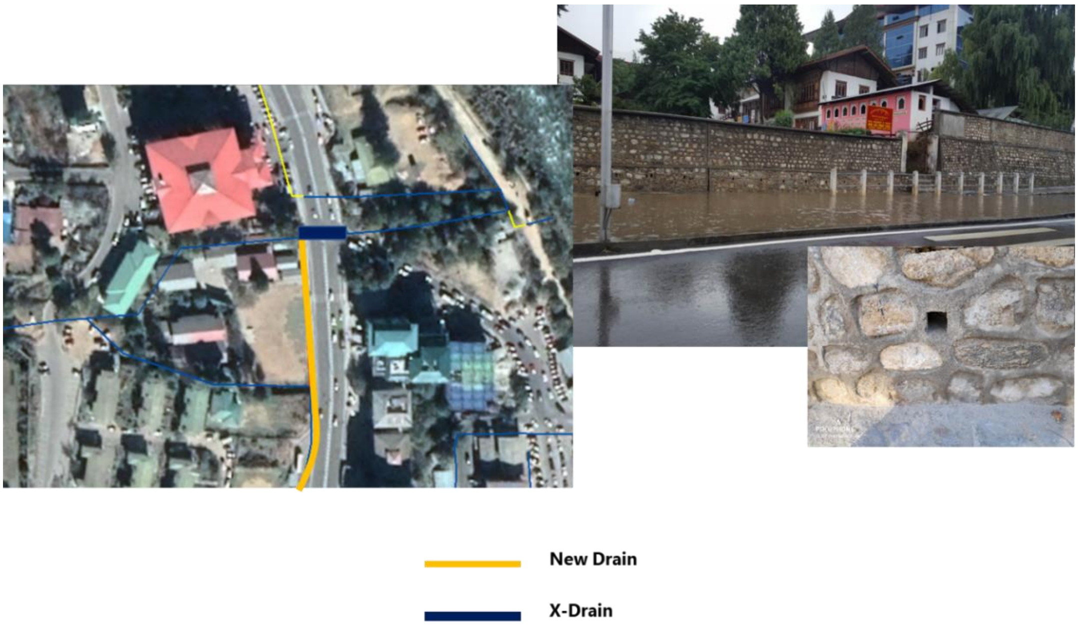


Figure 5.24: Possible Solution for road Opposite to Golden Roots Hotel

Jushina Pamtho area beside Indian Embassy

New local roads are going to be constructed soon beside the Indian embassy and particularly this area is in lower elevation than nearby major roads elevation. Therefore, following structural measures have been proposed to ensure smooth passage of drainage flow from this area towards Thimphu Chhu.

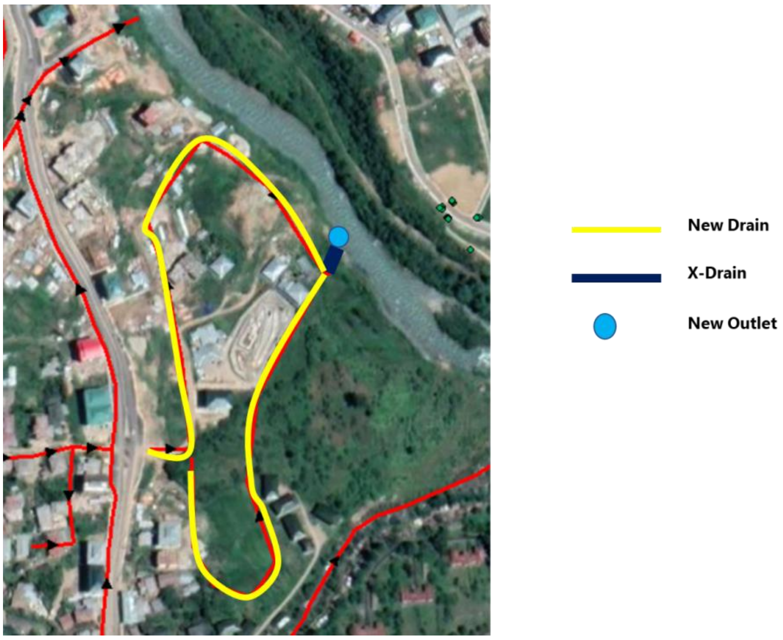


Figure 5.25: Possible Solution for Jushina Pamtho area near Indian Embassy

- Check adequacy and construct new drains
- Construct new outlet and cross drainage structure to carry flow from the new drains

To construct new drains responsibilities of land acquisition can be done through proper channel, if required and Thimphu Thromde should facilitate the process.

Near RBP and Memorial Chorten

For RBP area, the past wide rectangular open and stair case drain has been replaced with two 1.2 m dia hume pipe. From modeling exercise we have found out even that capacity is not adequate considering the future climate change scenarios. Therefore, study team suggested to go back to previous section again. Study team also explored the possibility of hume pipe, which increased to 5 barrel to accommodate future flow under climate change condition instead of current two 1.2 dia hume pipe. Thus study team strongly recommend to construct RCC rectangular stair case or baffle drop drain considering the field condition slope. Design guideline (Volume II) has elaborated on pros and cons for using hume pipe and RCC rectangular pipe to facilitate zone engineers further on selection or prioritize the design section type.

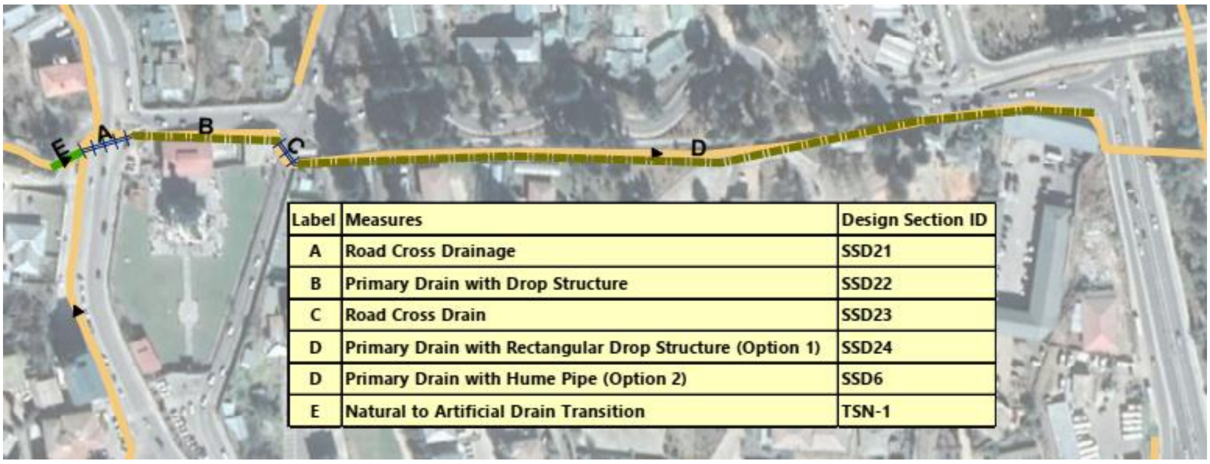


Figure 5.26: Possible Solution for RBP area

5.4 Low Impact Development (LID) measures

5.4.1 General LID Measures

Low impact development mechanisms are focused on alternate, natural process oriented measures that can help mitigating stormwater related issues. Figure 5.28 shows the major features that can be achieved with LID measures. Possible LID measures for the Thimphu thromde can be;

- Disconnecting rainwater from the roof and diversion
- Low Cost Rainwater Harvesting, Reuse and Discharge through Infiltration Trench
- Green landscaping
- Stormwater quality prevention

Disconnecting stormwater from roof and diversion is a possible LID measure for the city. The collected rainwater can be diverted towards permeable vegetative areas through constructing small vegetative swale or infiltration trench with small stones. This can reduce runoff to some extent.

Low cost rainwater harvesting can be done through the provision of placing multiple (at least 3) low-cost rain barrels. It will reduce runoff volume as those harvested water will be reused for domestic washing purposes or toilet flushes. This can substantially reduce the peak flow in stormwater drainage system and reduce capital costs for city authority if implemented properly. As per modeling exercise, three 80 gallon low cost PVC barrel will be able to fulfill the daily household demand during monsoon.

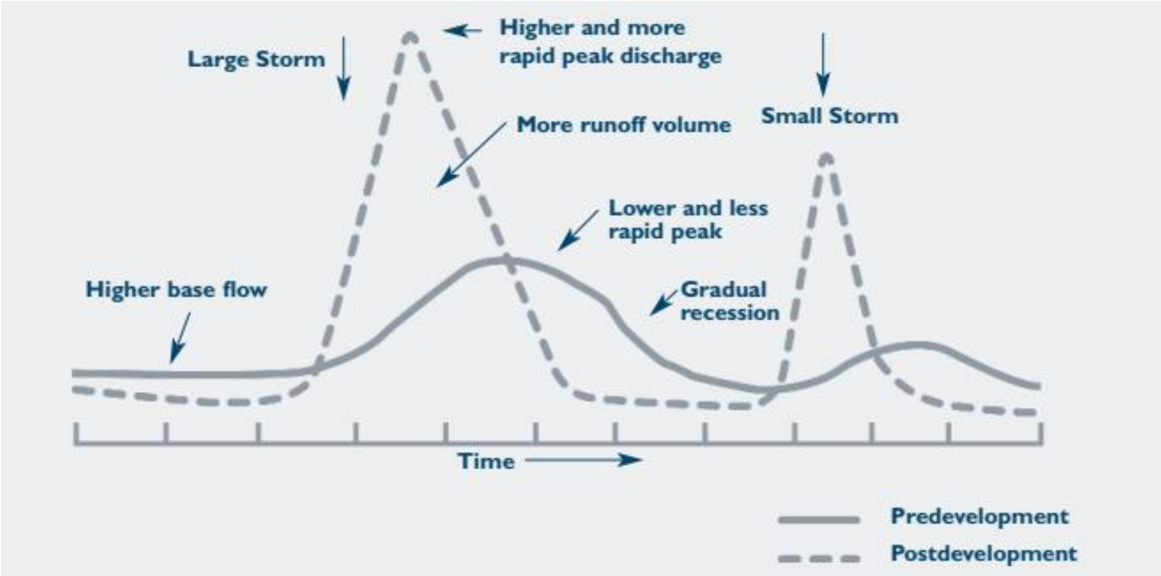


Figure 5.27: Effectiveness of LID measures to address stormwater issues

Green landscaping is suitable for open spaces nearby any problematic areas facing local flooding, parking areas, and footpath. This measure will also reduce runoff. This will include;

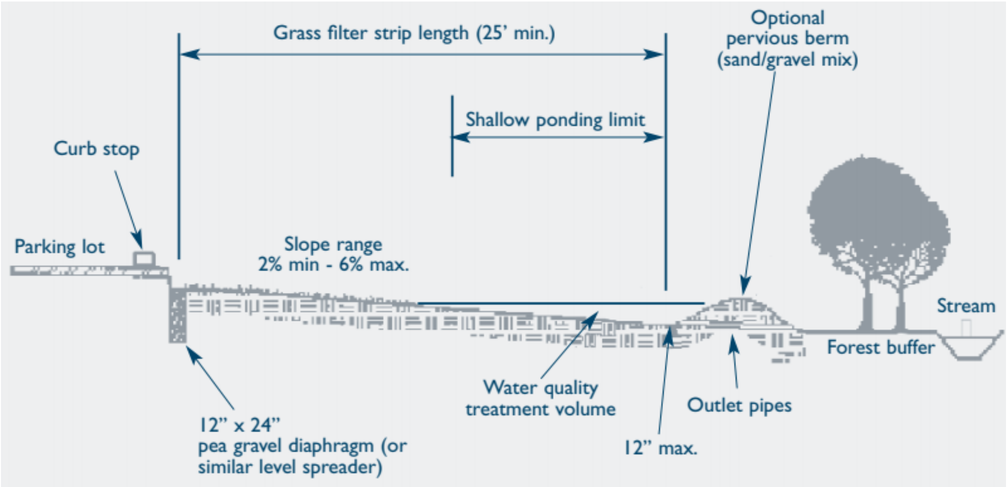
- Increasing and maintaining natural vegetation in parks and other areas,
- Converting paved areas e.g., parking lot, footpath to permeable pavements or traditional Dolep pathways to allow for increased infiltration and
- Infiltration trench or vegetative swale to replace drains and allowing increased infiltration

LID measures are very micro-scale intervention but can be very effective if implemented collectively. This can be done using locally available construction materials and typical design guidelines can be provided for the public sector agencies and private sector. Following figures illustrate some practical example of LID measures. Typical sections for some of these measures are presented in Figures 5.27-5.29.

Disconnection of Rooftop Water through Infiltration Trench

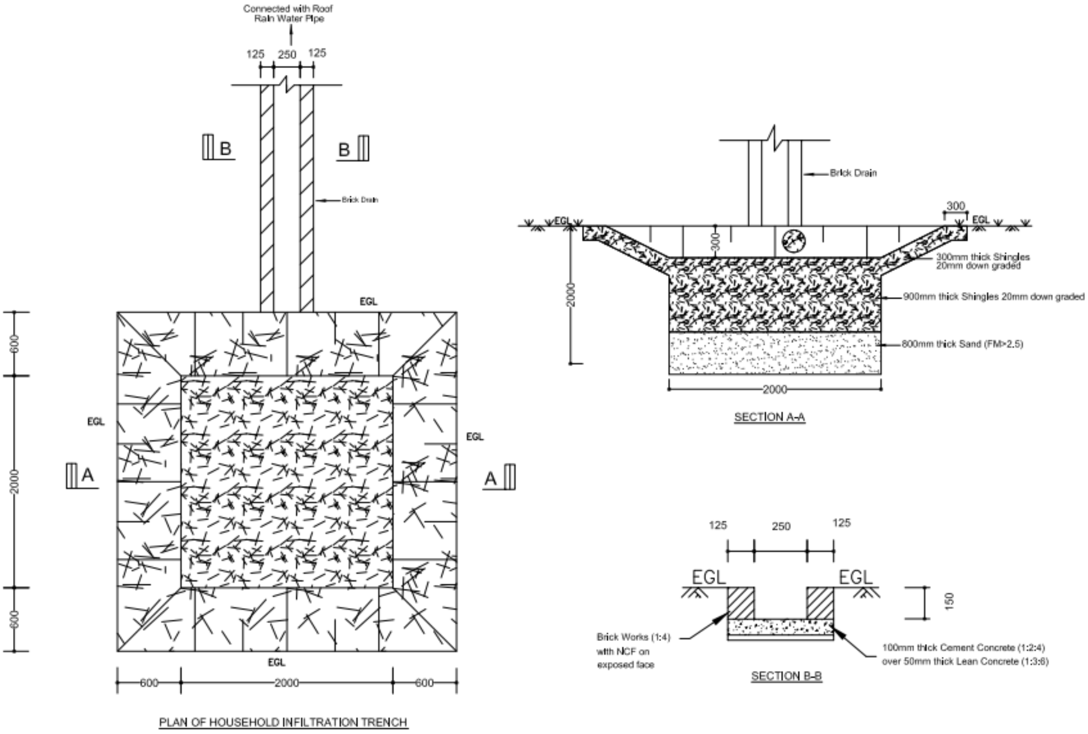
Low Cost Rain Barrel for Disconnection of Storm Water

Permeable Pavement for Parking or Footpath **Dolep Pathways**



Infiltration Trench

Infiltration Trench or Vegetative Swale



(TSHI-1)

Figure 5.28: Typical Section of Household level infiltration trench

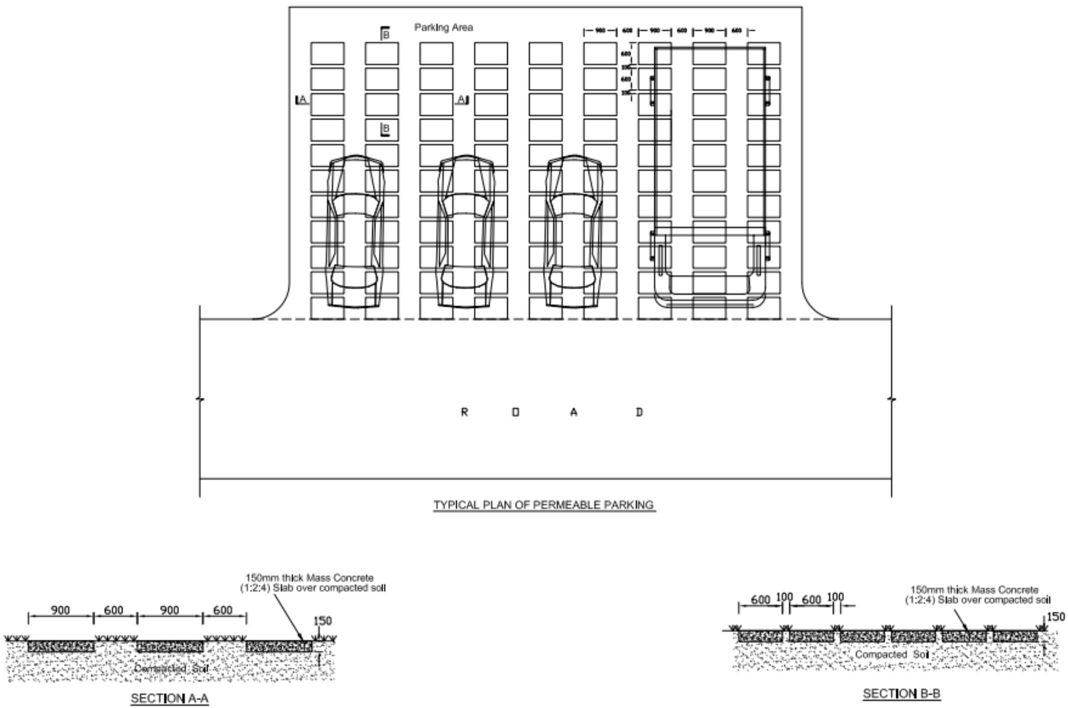


Figure 5.29: Typical design of permeable parking

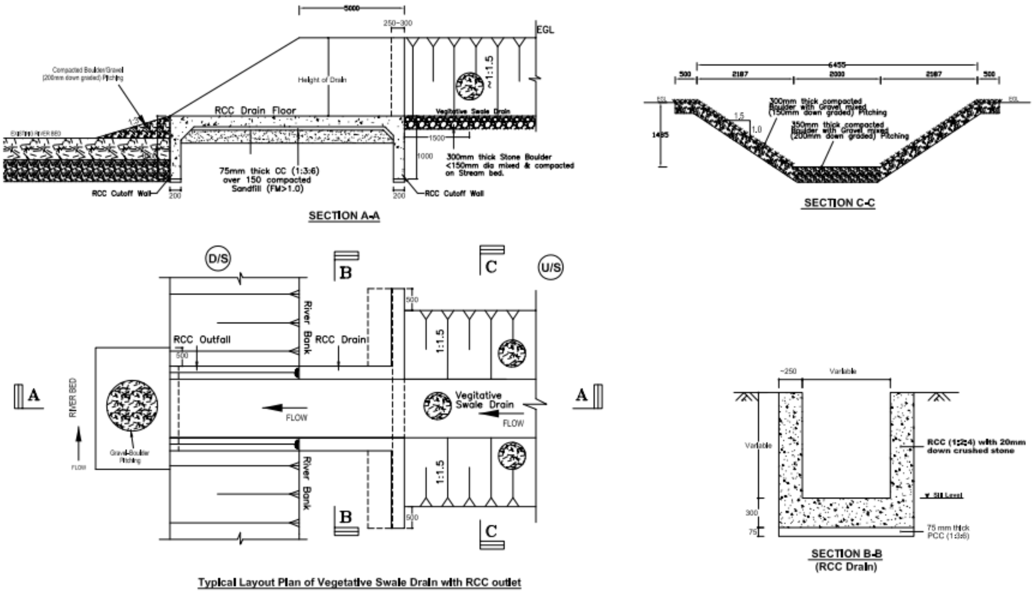


Figure 5.30: Typical section for vegetative swale drain

Water quality analysis depict that stormwater quality is gradually deteriorating as well as it is imposing negative impact on health of Thimphu Chhu. Therefore, proper stormwater quality preservation mechanism should be adopted. Waste Water Treatment Plant (WWTP) may be anticipated as an appropriate structural solution, but actually one treatment plant will not be able to serve the purpose, as due to topography and slope more than hundreds of outlets are discharging flows from watersheds towards Thimphu Chhu. Waste Water Treatment Plant may need to be installed in multiple outlets, which would be very expensive as well as connecting all drains flow and then converging into single WWTP are not technically feasible in the context of the Thimphu Thromde. Therefore. this plan mostly focuses on pollution control from source and in conveyance system through following structural measures:

- Proper cleaning mechanism and waste management
- Pollution control from source rather than construction of WWTP
- Collection of waste through installing trash rack and garbage collection sump before outlet
- LID techniques like infiltration trench, bio retention etc. in low lying areas before discharging into the river to allow infiltration and settling of pollutants in the conveyance system
- Discharging domestic waste water into locally installed infiltration trench before discharging into the storm drains directly

Different LID measures have different level of effectives for pollutant reduction. Following infographics illustrate the effectiveness of LID measures for stormwater quality prevention.

Category	Practice	Pollutant Reduction						Ground Water Recharge/ Runoff Volumn Reduction	Stream Channel Protection	Peak Flow Control
		Sediment	Total P	Total N	Metals	Hydro Carbons	Bacteria			
Stormwater Ponds	Wet pond	●	●	●	●	●	◍	❍	●	●
	Micropool ED pond							◍	●	●
	Wet ED pond							◍	●	●
	Multiple pond system							❍	●	●
Stormwater Wetlands	Shallow wetland	●	●	●	◍	●	●	❍	●	◍
	ED wetland							❍	●	●
	Pond/wetland system							❍	●	●
Infiltration Practices	Infiltration trench	●	●	●	●	◍	●	●	◍	❍
	Infiltration basin							●	●	◍
Filtering Practices	Surface sand filter	●	●	●	●	●	◍	◍[1]	◍	❍
	Underground sand filter							❍	❍	❍
	Perimeter sand filter							❍	❍	❍
	Bioretention							◍[1]	◍	❍
Water Quality Swales	Dry swale	●	◍	◍	●	◍	❍	◍[1]	❍	❍
	Wet swale							❍	❍	❍

Notes:
● Effective
◍ Somewhat effective
❍ Least effective

[1] If designed as exfilter
ED – Extended Detention

5.4.2 Site Specific Measures

Low Lying Flat Areas near Flyover

One of the critical area found from field visit was low lying flat area under the fly over after Olakha, where due to slope and low elevation certain portion of roads become very flat and like shallow depression area, which gets inundated during heavy storm due to inadequate size and number of road side gutter opening. Therefore, following measures have been proposed:

- Install roadside openings with big size and increased frequency (Proposed size is 9 inch opening at an interval of 2.5 m)
- Construct rain garden with green landscaping beside the road and open space
- Make existing parking space permeable paving
- Construct new drains or enlarge if required
- Construction of improved cross drainage structures
- Construction of several vegetative swale or earthen canal/nala in the low lying flat area beside the river to carry the stormwater from road drainage and allow infiltration

There is a large area like island just between that low lying flat area roads and riverbank (Figure 5.31), which can be utilized very fruitfully for constructing rain garden with green landscaping. In addition, there are three roadside parking lots where permeable pavement structure can be constructed to allow infiltration of stormwater to underground and towards the river.

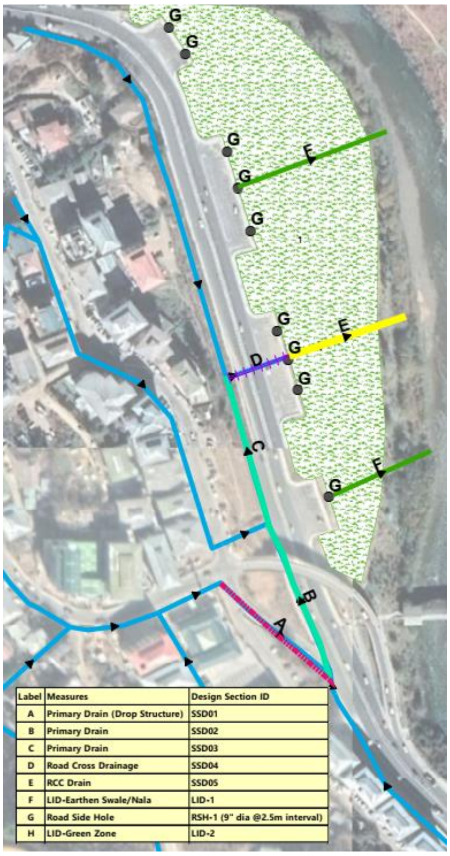


Figure 5.31: Possible Solution for low lying flat areas near flyover

Near Bangladesh Embassy

Embassy of Bangladesh in Bhutan has plan to construct the new embassy building as per plot allocated by the Royal Government of Bhutan. However, due to lack of proper drainage structures, huge volume of water discharges through open outlet from a hume pipe just over the land of the Embassy of Bangladesh in Bhutan. Consequently, the land of the Embassy of Bangladesh and surrounding area have become marshy wetland. Another outlet has been found in the north of the embassy area which also discharges just over the land towards the river. In this regard, to have a proper sustainable solution for the internationally important diplomatic zone, this plan proposes following structural measures:

- Option 1: A: vegetative swale drain over marshy land
- Option 2: RCC drain instead of vegetative swale as swale drain needs huge space
- Option 3 and Option 4: RCC drain towards other directions which are longer in length

Figure 5.32: Possible Solution for area near Bangladesh Embassy

Finally study team recommended to construct RCC drain over marshy (option 2) land maintaining the site slope condition. To construct new drains, responsibilities of land acquisition can be done through proper channel, if required and Thimphu Thromde should facilitate the process.

Area Nearby to Chamlingthum Stadium

The area Nearby to Chamlingthum Stadium comprises the centenary park, a parking lot and some open areas. So, in order to reduce stormwater load, LID measures are proposed for this area (As presented in figure 5.31). This include, conversion of paved areas in the centenary park to LID measures like permeable pavements, converting the parking area to permeable parking and introducing rain garden in the small open area down the stadium.

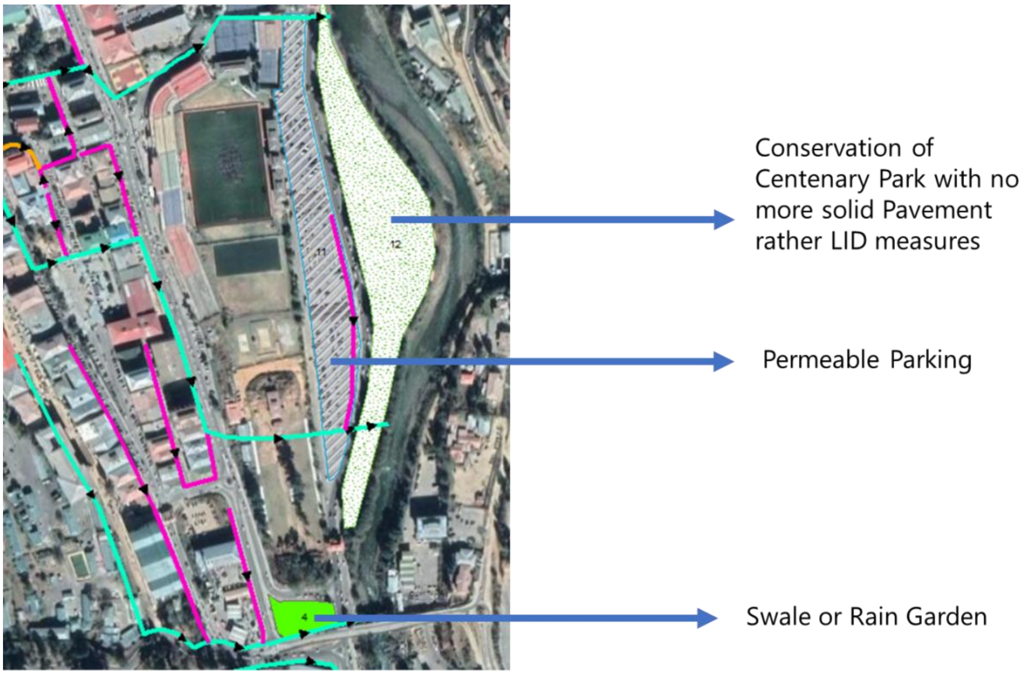


Figure 5.33: Possible Solution for area Nearby to Chamlingthum Stadium

Stormwater Quality Prevention Near Govt. Staff Quarter

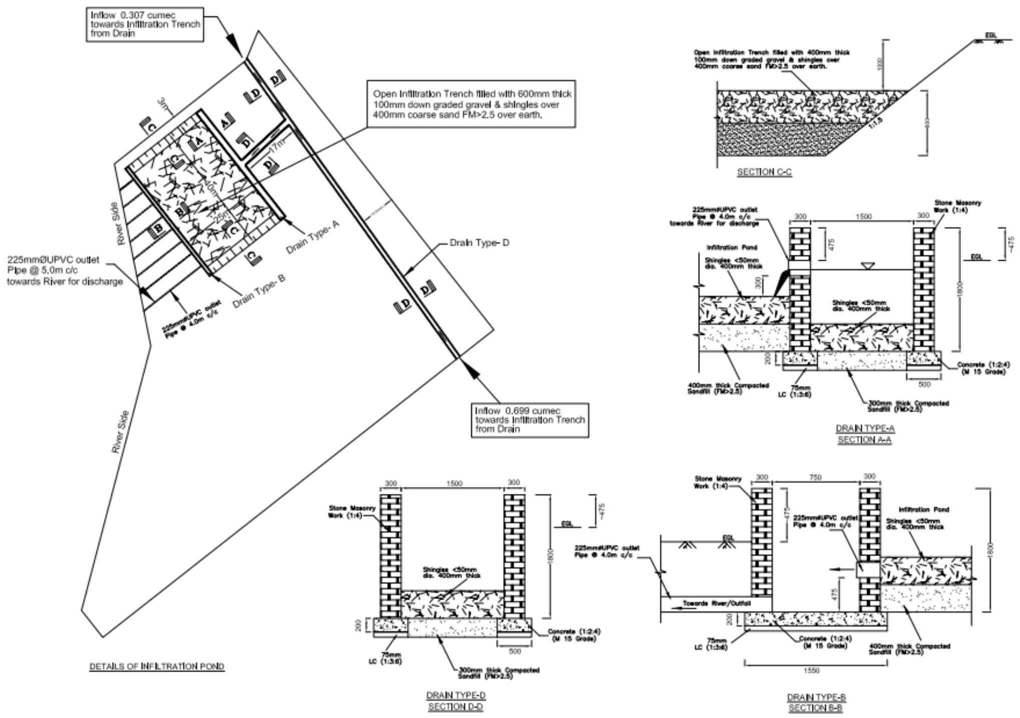


Figure 5.34: Typical design of infiltration trench for stormwater quality prevention

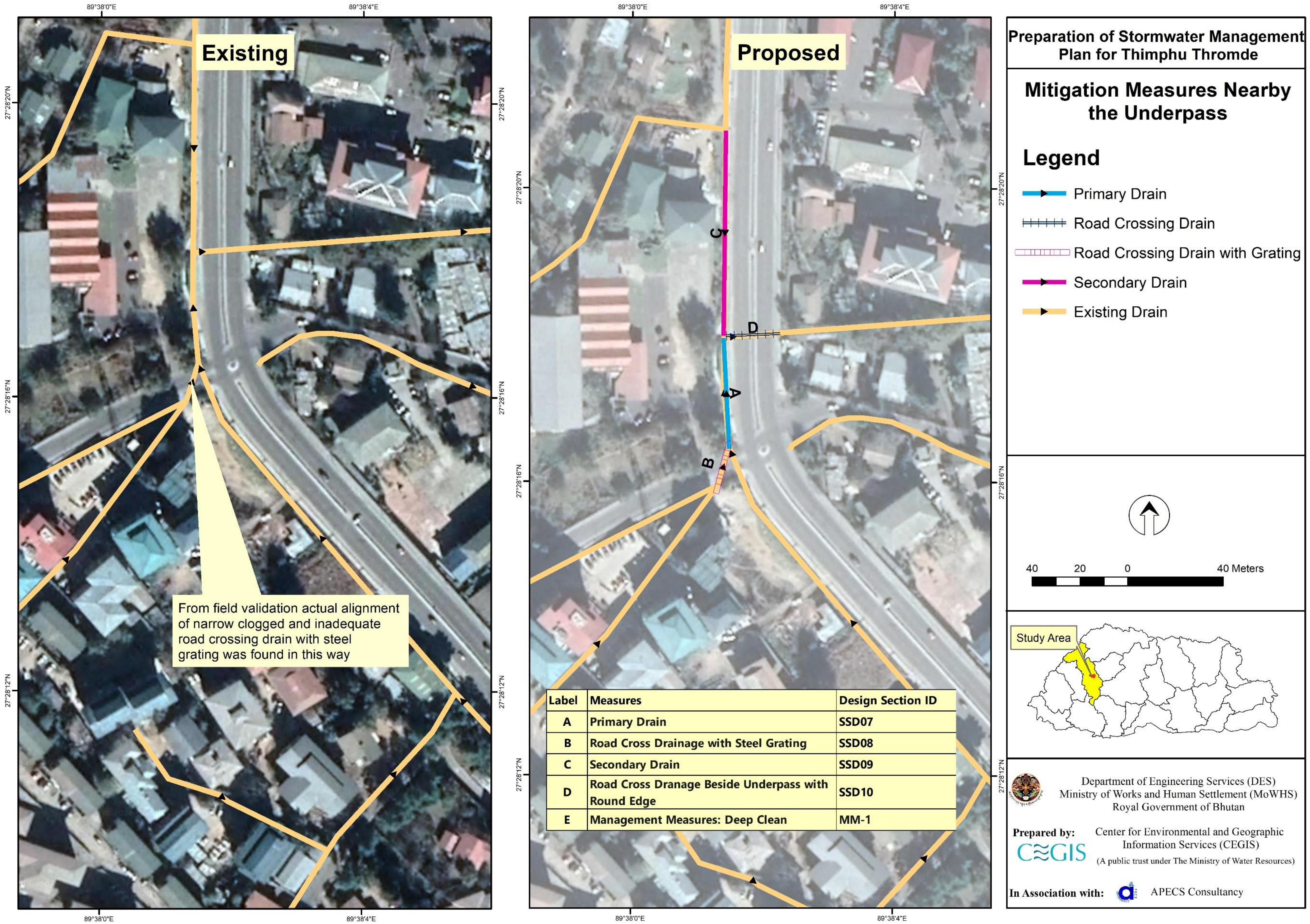
5.5 Formulation of Non-structural Measures

The identified non-structural measures that can be implemented are as following:

- Institutional Reform: Setting 'Emergency Response Unit'
- Development and implementation of standard operational procedure for emergency response Recovery
- Procurement of Machineries and Equipment for Emergency Response
- Integration of Explicit 'Regulatory Framework for Stormwater Management' into the Existing Standard Operational Procedure
- Enhancement of Inter and Intra Institutional Coordination
- Establishment of Financing Mechanism for Stormwater Management and Mainstream into Existing Budgeting System
- Establishment of Functional Monitoring Mechanism for Stormwater Management
- Monitoring, Review and Update of Stormwater Management Plan
- Development of Stormwater Drain Design and Management Guideline
- Capacity Building and Skill Development of Engineers and Planners
- Campaign for Citizen Behavior Change and Awareness Building
- Recruitment of skilled manpower for operation, maintenance, emergency response and recovery
- Popularization of LID measures or Best management practices at community level
- Update of Stormwater Drainage infrastructure geo Inventory
- Explicit Clause of SWM on Occupancy Certificates and other Inspection Form DCR
- Conservation and protection of natural streams or drains
- Explicit Clause of LID Measures i.e. rainwater harvest with low cost barrel-reuse-discharge into small trench-storm drain; disconnection of rooftop rain with smaller infiltration trench at household level, permeable parking in city regulations

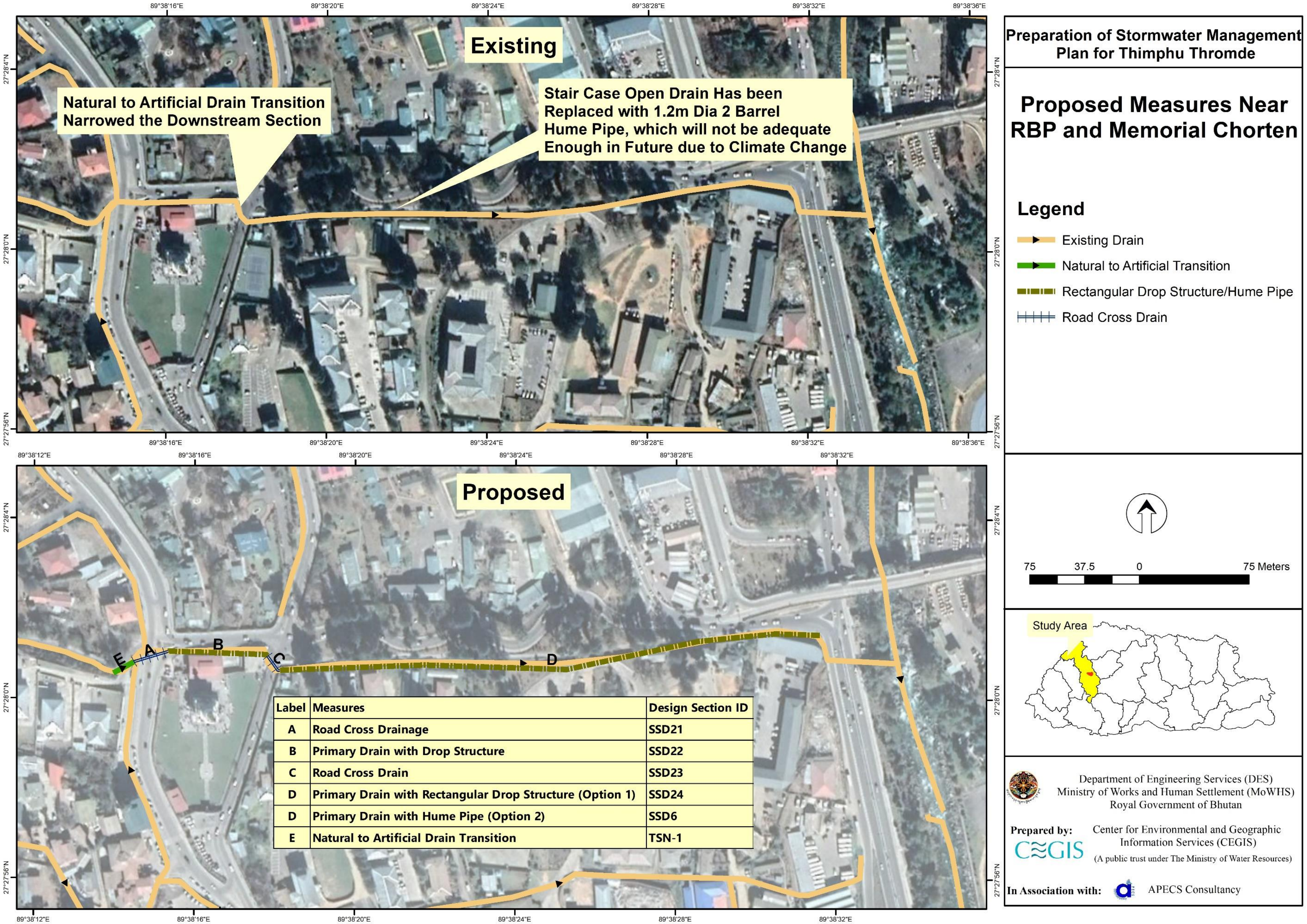
5.6 Mitigation Map

Mitigation map has been prepared for each of the site specific and generic measures described in the above segments which are shown in following figures. Detailed design, drawings and cost estimation of these site-specific problems are annexed in Appendix: Volume V along with typical sections which can be replicated in any other places with similar suitable condition. The considerations of selection of section size and type are outlined inside the preliminary design guideline on stormwater management of Thimphu Thromde, which is annexed as Appendix: Volume V.



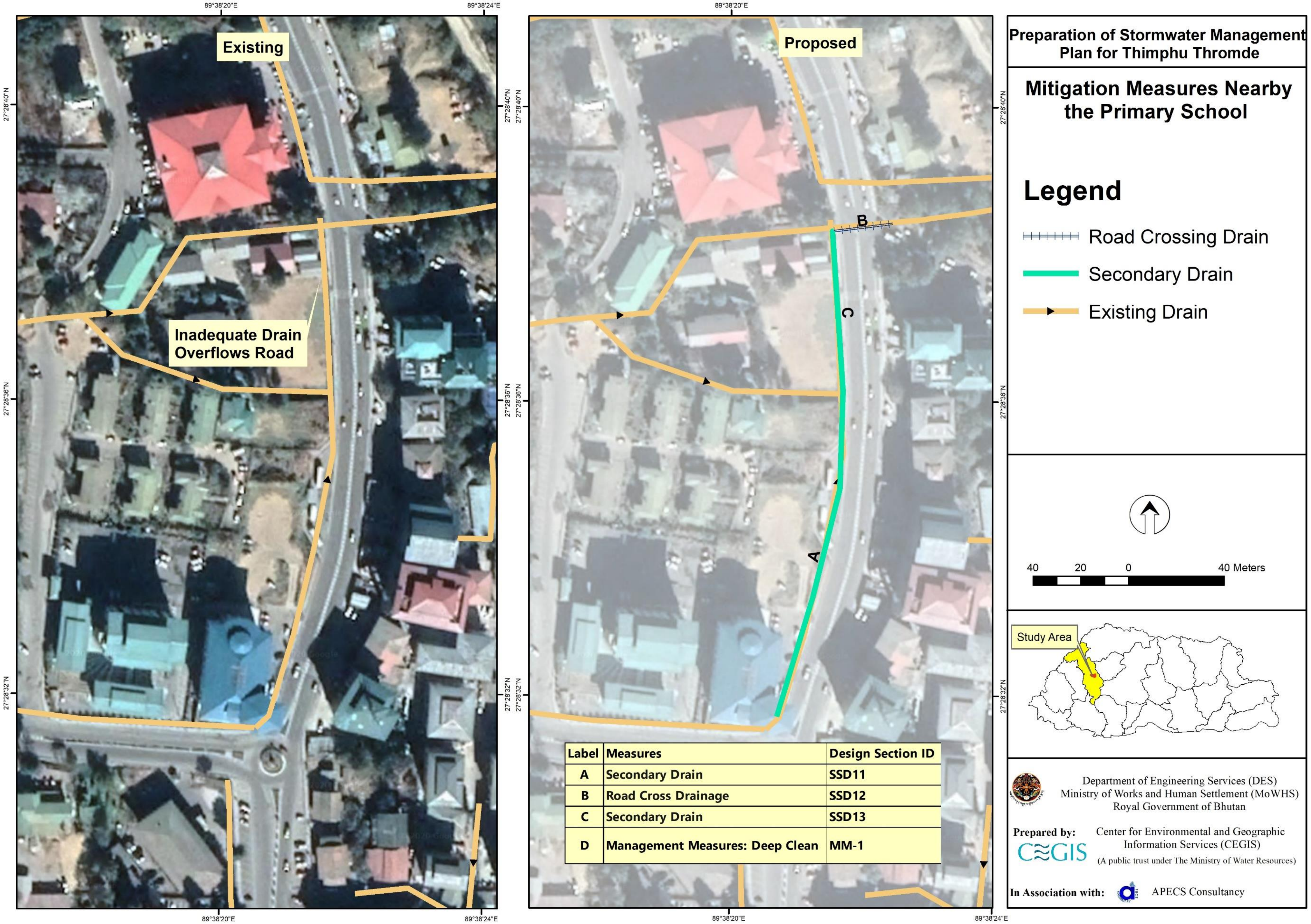
Label	Measures	Design Section ID
A	Primary Drain	SSD07
B	Road Cross Drainage with Steel Grating	SSD08
C	Secondary Drain	SSD09
D	Road Cross Dranage Beside Underpass with Round Edge	SSD10
E	Management Measures: Deep Clean	MM-1

Figure 5.35: Mitigation measures for area near the underpass



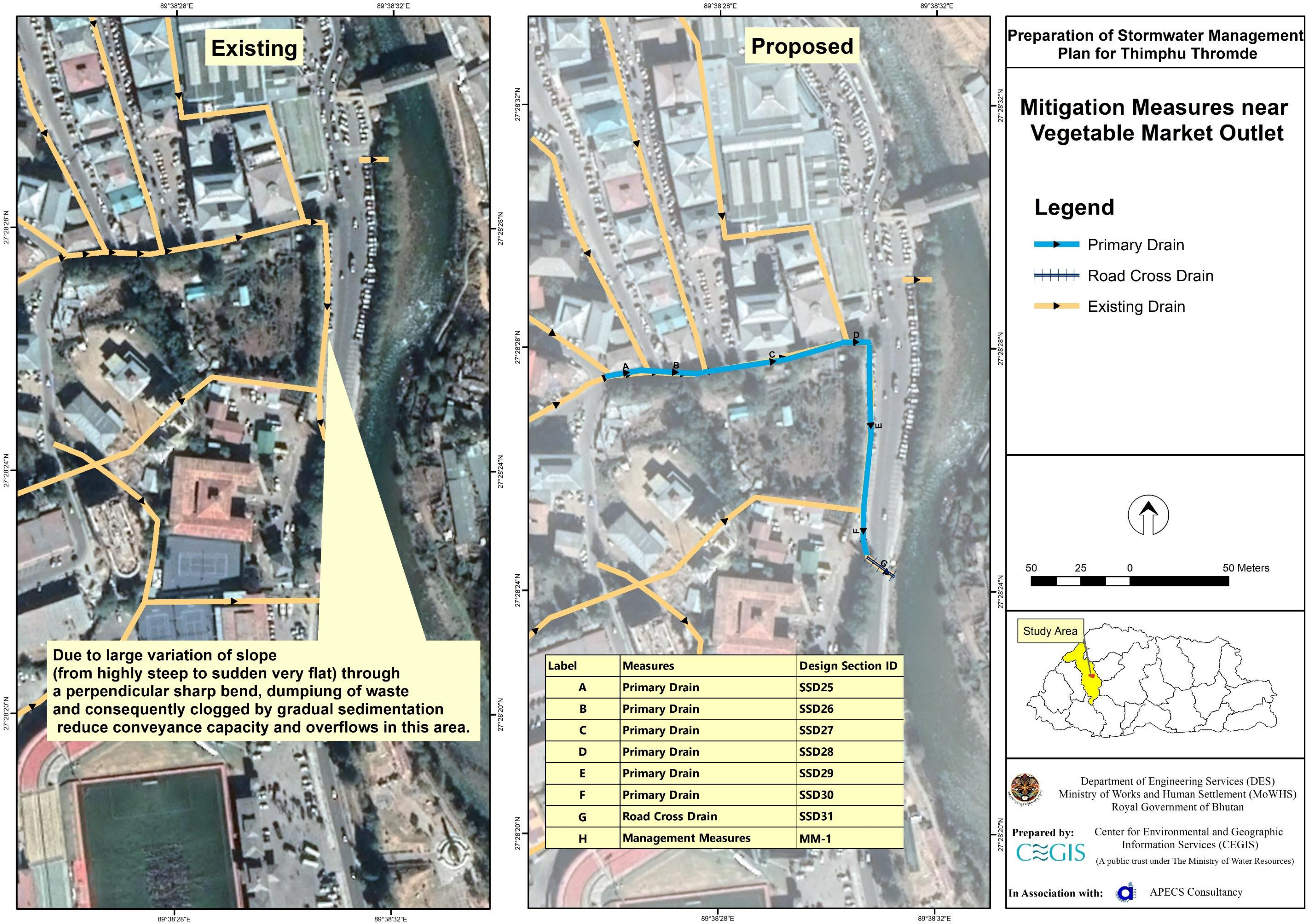
Label	Measures	Design Section ID
A	Road Cross Drainage	SSD21
B	Primary Drain with Drop Structure	SSD22
C	Road Cross Drain	SSD23
D	Primary Drain with Rectangular Drop Structure (Option 1)	SSD24
D	Primary Drain with Hume Pipe (Option 2)	SSD6
E	Natural to Artificial Drain Transition	TSN-1

Figure 5.36: Mitigation measures for area near RBP and memorial chorten



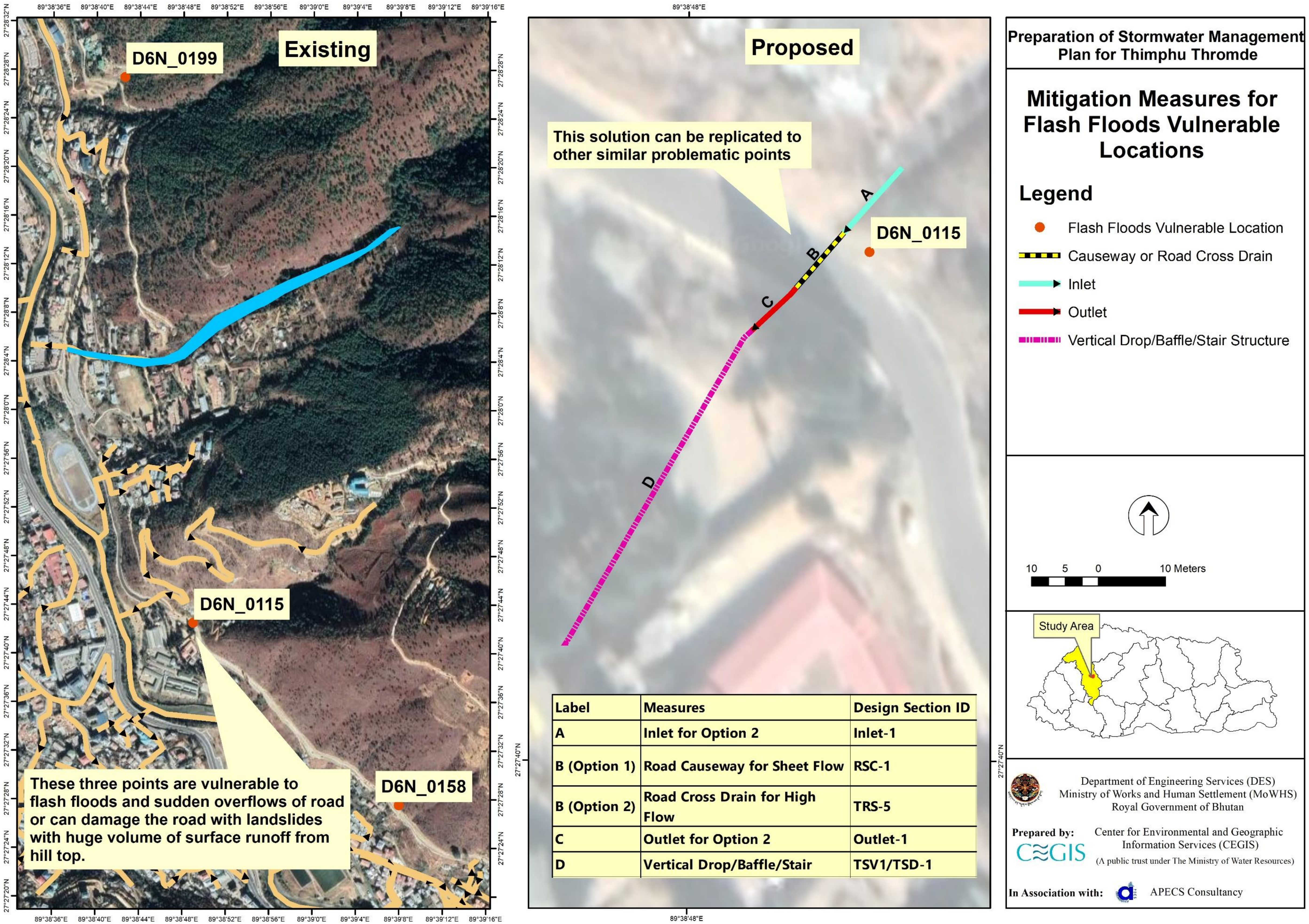
Label	Measures	Design Section ID
A	Secondary Drain	SSD11
B	Road Cross Drainage	SSD12
C	Secondary Drain	SSD13
D	Management Measures: Deep Clean	MM-1

Figure 5.37: Mitigation measures for the road near golden roots hotel and primary school



Label	Measures	Design Section ID
A	Primary Drain	SSD25
B	Primary Drain	SSD26
C	Primary Drain	SSD27
D	Primary Drain	SSD28
E	Primary Drain	SSD29
F	Primary Drain	SSD30
G	Road Cross Drain	SSD31
H	Management Measures	MM-1

Figure 5.38: Mitigation measures for vegetable market area



Label	Measures	Design Section ID
A	Inlet for Option 2	Inlet-1
B (Option 1)	Road Causeway for Sheet Flow	RSC-1
B (Option 2)	Road Cross Drain for High Flow	TRS-5
C	Outlet for Option 2	Outlet-1
D	Vertical Drop/Baffle/Stair	TSV1/TSD-1

Figure 5.39: Mitigation measures for flash flood area

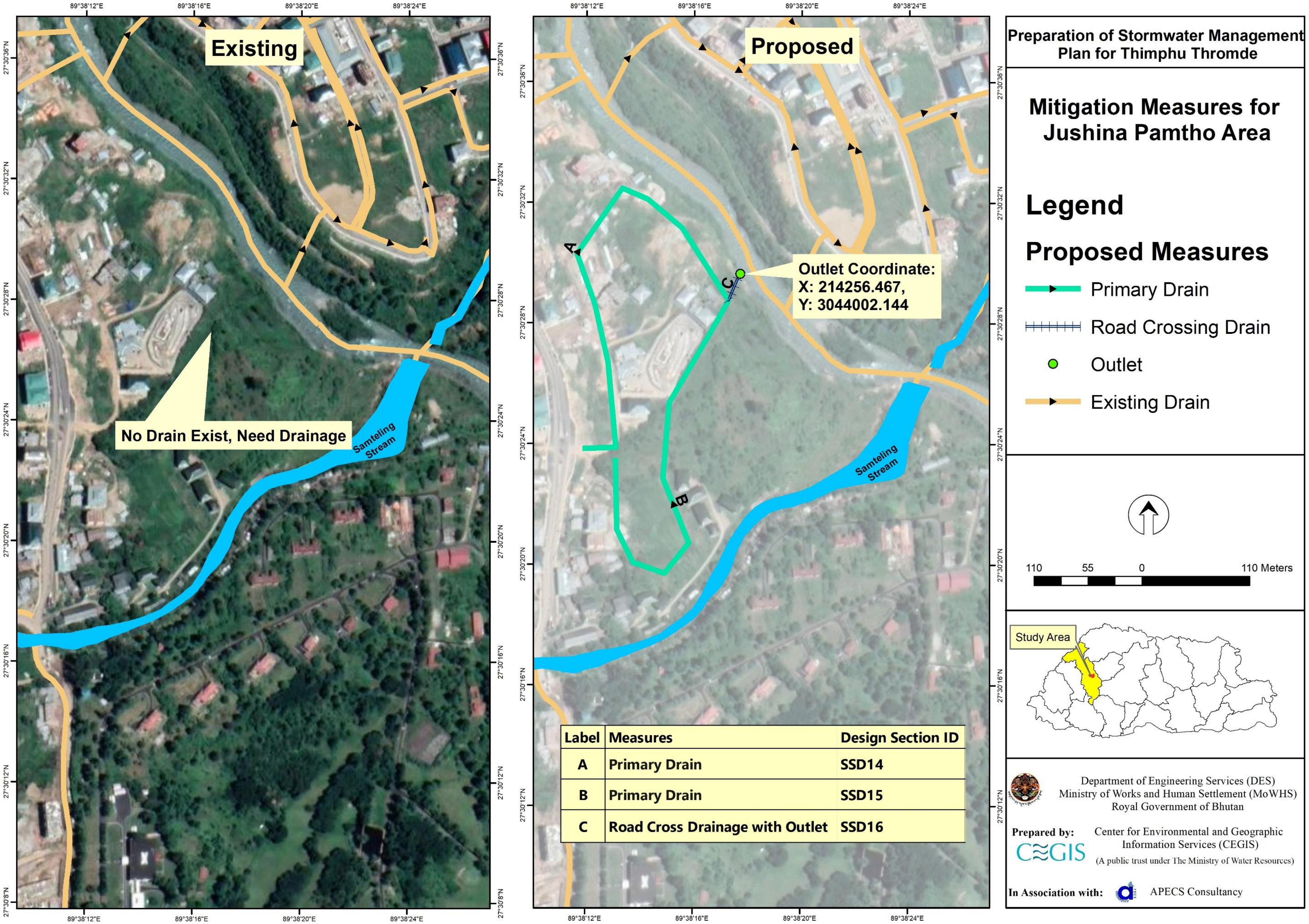


Figure 5.40: Mitigation measures for Jushina pamtho area

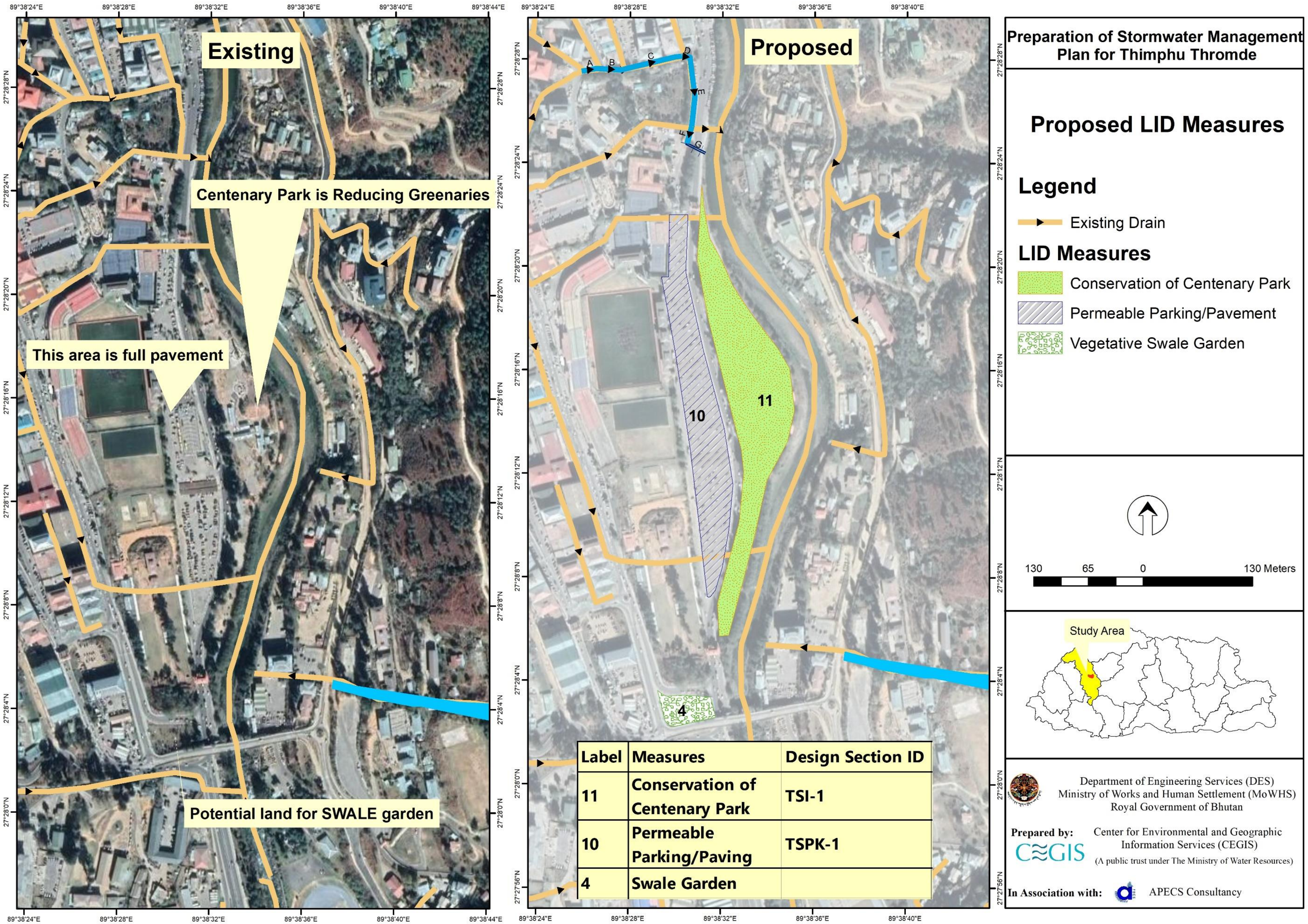


Figure 5.41: Mitigation measures for area near Chamlingthum stadium

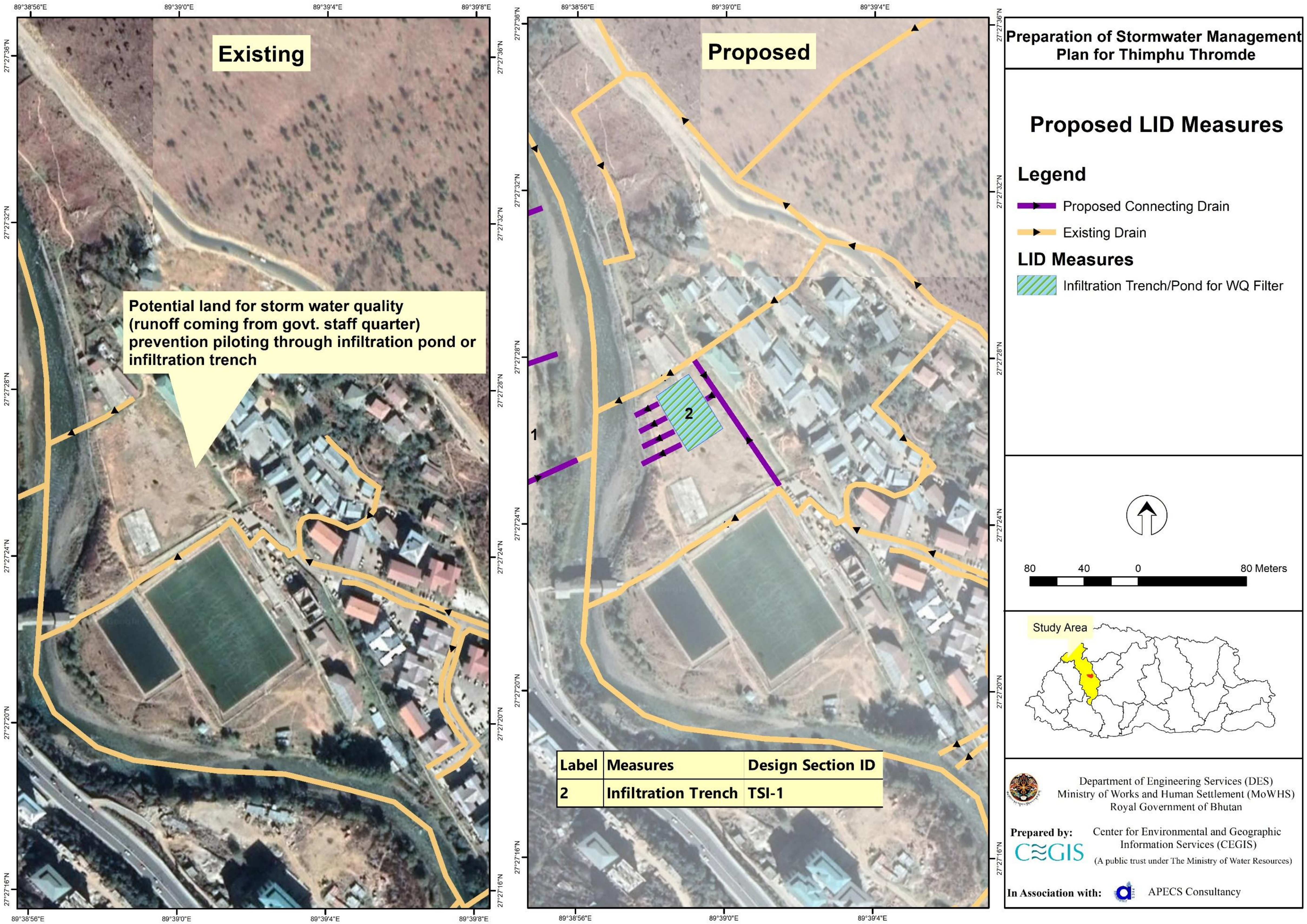


Figure 5.42: Proposed LID measure for stormwater quality control

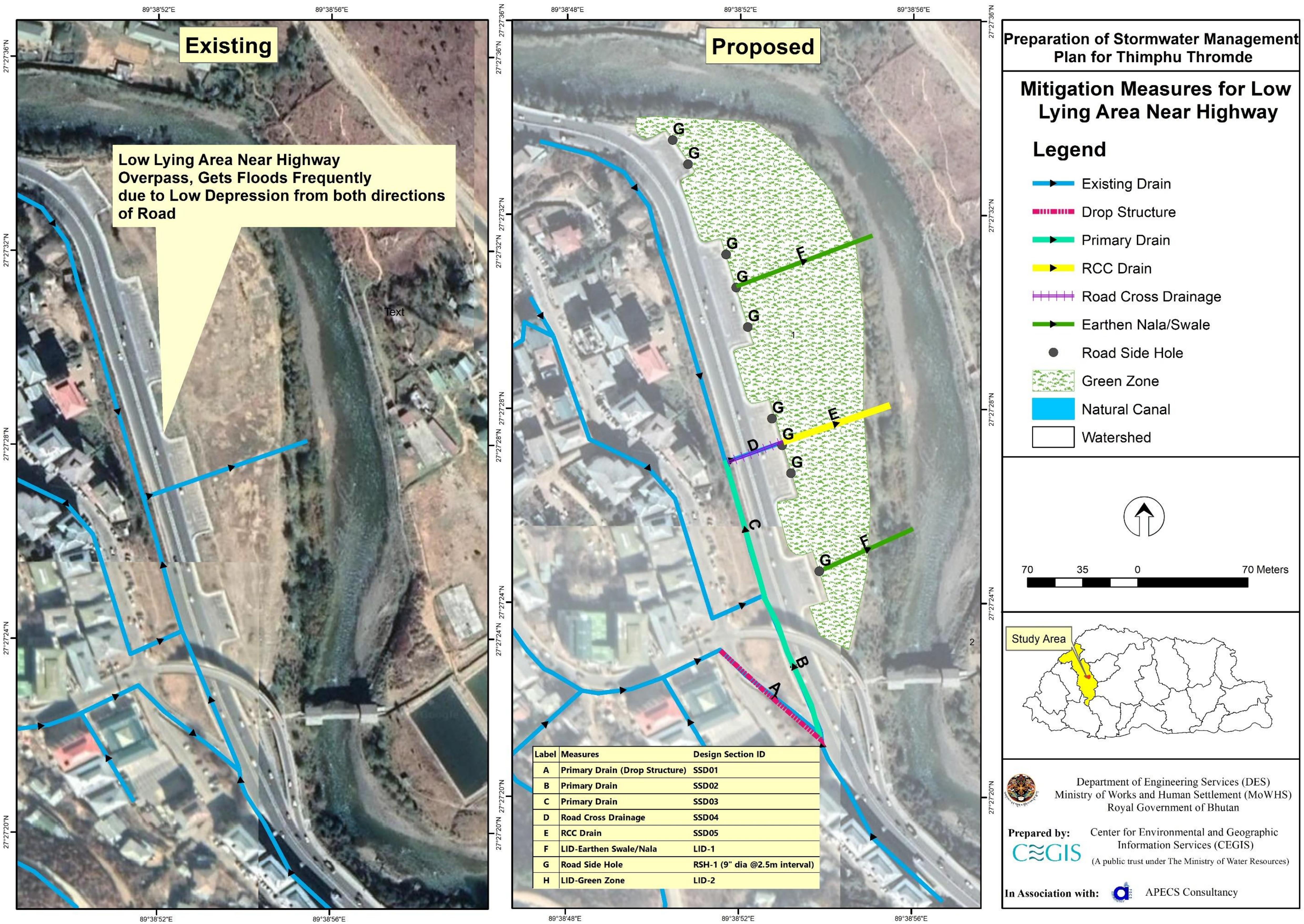


Figure 5.43: Mitigation measures for low lying area near highway

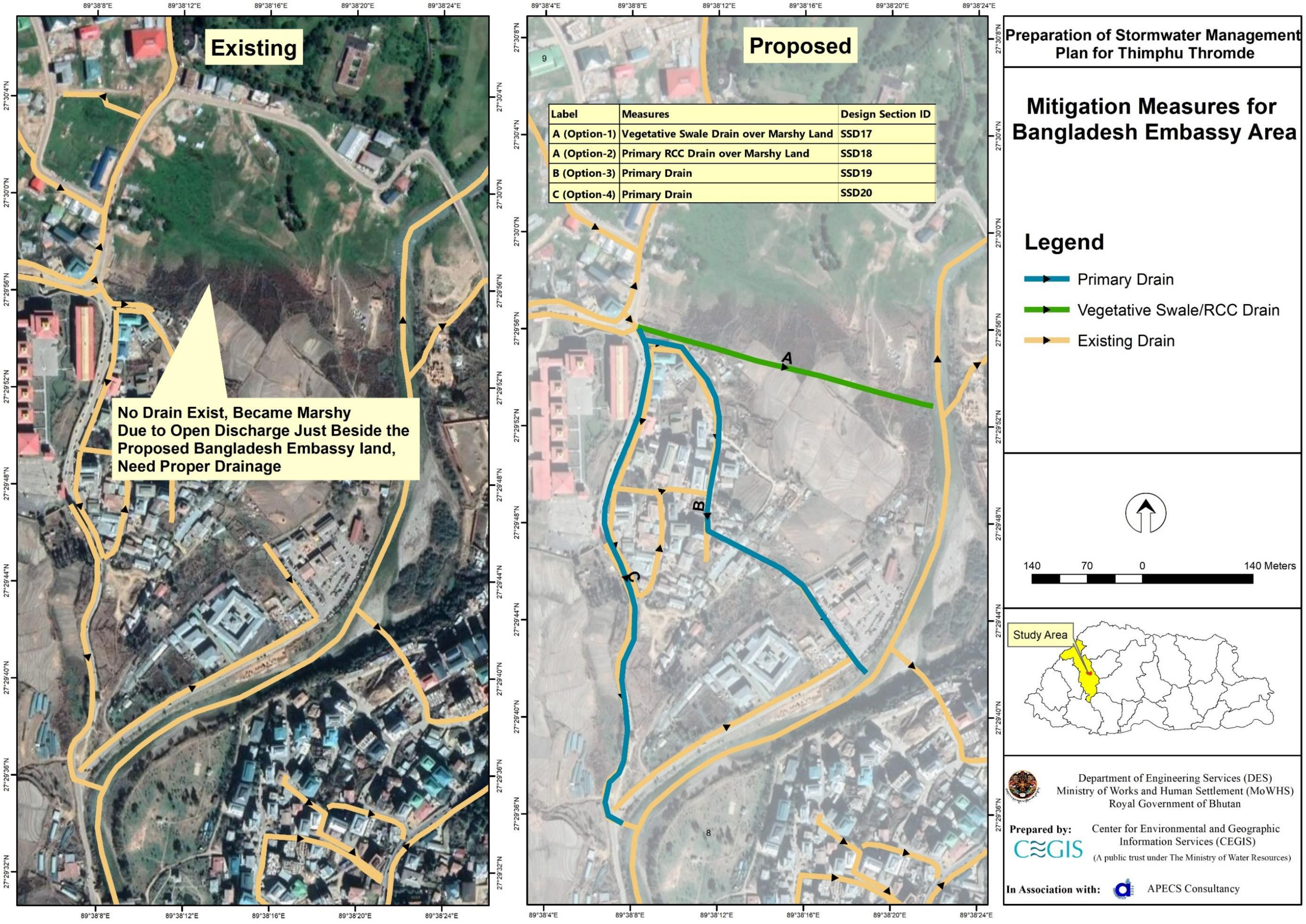


Figure 5.44: Mitigation Measures for Marshy Lands near New Plot of Bangladeshi Embassy

5.7 Design, Drawing and Cost Estimation

5.7.1 *Design and Drawings*

Design, drawing and cost estimation has been performed to facilitate the preparation of Integrated Stormwater Management Program and Plan for the Thimphu Thromde. Design and drawings have been performed for following clustered structural measures:

- Replacement of existing inadequate drains
- New construction of proposed drains
- Site specific measures
- Generic measures which can be replicated in other similar problematic areas
- Low Impact Development (LID) measures

Design and Drawing Considerations

Detailed design and drawings have been performed for site specific measures where it is possible as unavailability of detailed longitudinal topography survey data of drains is the major drawback of this study to enable the study team to provide detailed design and drawings in every cases. Yet the provided detailed design and drawings are also subject to check the field or ground condition with detailed survey before implementation.

Therefore, typical sections have been provided with adequate guideline (Appendix: Volume II) to support local engineers on selection of those typical sections considering the site specific problems they might face in future considering the climate change scenario, urban growth and design parameters. All typical sections provided for primary, secondary and tertiary drains have been identified with a design section code, which can be useful to refer or identify the section very easily using the guideline and geo database.

The guideline provided for selection of design section type and opening size would enable local engineer to address solutions regarding replacement of existing inadequate drains or construction of new drains in any places facing similar problems. Any critical area which even now has been identified but facing either inadequacy problems or require new drain related problems, would follow the provided guideline to select best design type and section based on set criteria. Again the design section size would depend on the longitudinal slope which must be surveyed in detailed before implementation. The survey requirement has been stated inside the design guideline appendix (Volume II).

Detailed design and drawing has been given in Volume V and all design considerations and required guidelines have been spelled out inside the SWMP guideline (Volume II). All of those general design considerations should be followed and maintained strictly and applicable for all areas of Thimphu Thromde and can be replicated in any place of the city to solve similar kind of problems.

Design Life Expectancy

As all design and drawings provided considering the impacts of climate change at least 15-year life expectancy of all design and drawings have been expected with annual and periodic minimal maintenance.

All drawings have been done in the AutoCAD after necessary data processing, correction and formatting from ArcGIS.

5.7.2 Cost Estimation of Structural Measures

Cost estimation has been done performing rate analysis after identification of all relevant items from Bhutan Schedule of Rates (2020) and proposed solutions. Rational assumptions have been made from Bangladesh if any item or rate is missing the BSR, 2020.

The detailed rate analysis and problem specific cost estimation has been included inside the Volume V: Detailed Design, Drawing and Cost Estimation. III.

Following table shows the summary of the cost estimation as per identified structural measures:

Summary of Cost Estimation for Structural Measures

Sl. No.	Structural/LID Measures	Phase	Implementation Timeline	Quantity	Unit	Estimated Cost (Nu)	Estimated Cost (Million Nu)	Total Cost (Million Nu)
	General Measures							
1	Blockage and Clogging Removal	-	by 2021	44	No.	69060	0.07	0.07
2	Repair and Maintenance	-	by 2023	64	No.	5535764	5.54	5.54
3	Improvement of Existing Inadequate Drains	1	by 2023	15.4	Km	268169863	268.17	613.35
4		2	by 2028	21.2	Km	276867174	276.87	
5		3	by 2030	6.9	Km	68312526	68.31	
6	Construction of Proposed Drains	1	by 2023	22.2	Km	206793657	206.79	869.71
7		2	by 2028	38.23	Km	421521672	421.52	
8		3	by 2030	15.66	Km	241393386	241.39	
9	Household Level Infiltration Trench with Low Cost Rain Barrel			1	No.	28522	0.03	0.03
	Site Specific Measures							
10	Vegetable Market			255.66	Meter	9440619	9.44	70.28
11	Bangladesh Embassy			380	Meter	6179111	6.18	
12	Low Lying Area Near Highway			364.59	Meter	15010000	15.01	
13	Area Near Underpass			172.2	Meter	4329740	4.33	
14	Primary School			230.5	Meter	3408771	3.41	
15	Jushina Pamtho			985.5	Meter	10890701	10.89	
16	RBP and Memorial			500	Meter	18144993	18.14	
17	Infiltration Trench for Water Quality Prevention			1	No.	2877620	2.88	
18	Hume Pipe (Alternative of RCC Rectangular Drain in Specified Locations)- Domain 2			1.33	Km	9224676	9.22	53.71
19	Hume Pipe (Alternative of RCC Rectangular Drain in Specified Locations)- Domain 3			3.92	Km	41156644	41.16	
20	Hume Pipe (Alternative of RCC Rectangular Drain in Specified Locations)- Domain 5			0.52	Km	3330330	3.33	
21	Garbage Collection Sump- Domain 1			8	No.	5071012	5.07	36.66
22	Garbage Collection Sump- Domain 2			9	No.	5650617	5.65	
23	Garbage Collection Sump- Domain 3			15	No.	9128244	9.13	
24	Garbage Collection Sump- Domain 4			7	No.	4491407	4.49	
25	Garbage Collection Sump- Domain 5			4	No.	2752594	2.75	
26	Garbage Collection Sump- Domain 6			8	No.	5071012	5.07	
27	Garbage Collection Sump- Domain 7			7	No.	4491407	4.49	

Phasing of structural measures are determined analyzing the set targets to be achieved as per ISWMP. This estimated cost has been utilized to prepare investment plan. The detailed rate analysis and problem specific cost estimation has been annexed in this report in Appendix: Volume V.

6. Integrated Stormwater Management Program

6.1 Introduction

This chapter describes the investment plan comprising integrated stormwater management programs for Thimphu Thromde. Different projects or strategic actions under each of the programs have been described in detailed in program portfolio. Prioritization of projects have been presented to guide the decision makers or implementors to initiate short, medium- or longer-term projects. Further, phasing of investment has been outlined over the plan implemention period (2021-2030).

6.2 Program Summary

Total 4 programs have been considered for storm water management in Thimphu Thromde under which 25 separate activities or projects have been outlined. These 4 programs are:

1. **P1: Development of Sustainable and Climate Resilient Stormwater Infrastructures**
2. **P2: Emergency Response and Recovery**
3. **P3: Strengthening Institutions, Coordination and Monitoring**
4. **P4: Capacity Development**

Imeplementation of ISWMP with these 4 programs will cost around 2046 Million Nu in 10 years planning period, while Program P1 will require 89.5% of the total investment mostly depdendnet on different kinds of structural interventions for development of sustainable and climate resilient stormwater infrastructures. Following table shows the summary of the Investment Plan:

Table 6.1: Investment Plan for ISWMP, Thimphu Thromde (2021-2030)

Program Name	Tentative Cost (Million Nu)
Program 1 (P1): Development of Sustainable and Climate Resilient Stormwater Infrastructures	**1833.5**
Program 2 (P2): Emergency Response and Recovery	**106.5**
Program 3 (P3): Strengthening Institutions, Coordination and Monitoring	**42.5**
Program 4 (P4): Capacity Development	**63.5**
Total	**2046**

The activities or projects under each of these programs are outlined in below table:

Table 6.2: Proposed Programs and Projects for ISWMP, Thimphu Thromde (2021-2030)

SL. No.	Programs	Activity/Project
1	**Program 1 (P1): Development of Sustainable and Climate Resilient Stormwater Infrastructures**	**P1A1: Annual Deep Cleaning of Storm Water Drainage**
2		**P1A2: Repair and Maintenance (Annual and Periodic after 3 years)**

SL. No.	Programs	Activity/Project
3		P1A3: Detailed Topography Survey of Storm Drainage Network
4		P1A4: Replacement of Inadequate Drains and Cross Drainage Structures
5		P1A5: Construction of New Stormwater Drains and Infrastructures
6		P1A6: Applied Research, Piloting and Implementation of LID measures or Best Management Practices (BMP)
7		P1A7: IT based Monitoring Infrastructure Development for Highly Critical Area
8		P1A8: Relocation of Service Lines to Clear Blockage and Clogging
9		P1A9: Solving Site Specific Problems
10		P1A10: Stregthening Waste Management System in Thimphu Thromde
11	Program 2 (P2): Emergency Response and Recovery	P2A1: Institutional Reform: Setting 'Emergency Response Unit'
12		P2A2: Development and Implementation of Standard Operational Procedure for Emergency Response and Recovery
13		P2A3: Procurement of Machinaries and Equipment for Emergency Response
14	Program 3 (P3): Strengthening Institutions, Coordination and Monitoring	P3A1: Integration of Explicit 'Regulatory Framework for Stormwater Management' into the Existing Standard Operational Procedure
15		P3A2: Enhancement of Inter and Intra Institutional Coordination
16		P3A3: Establishment of Financing Mechanism for O&M in Stormwater Management and Mainstream into Existing Budgeting System
17		P3A4: Establishment of Functional Monitoring Mechanism for Stormwater Management
18		P3A5: Monitoring, Review and Update of Stormwater Management Plan
19	Program 4 (P4): Capacity Development	P4A1: Development of Stormwater Drainage Design and Management Guideline
20		P4A2: Development of GIS and SCADA based Operational Database
21		P4A3: Capacity Building and Skill Development of Engineers and Planners
22		P4A4: Campaign for Citizen Behavior Change and Awareness Building
23		P4A5: Recruitment of Skilled Manpower for Operation, Maintenance, Emergency Response and Recovery
24		P4A6: Popularization of Low Impact Development (LID) Measures or Best Management Practices (BMP) at Community Level
25		P4A7: Update of Stormwater Drainage Infrastructure Geo Inventory

6.3 Prioritization and Phasing of Investment

The storm water management plan for Thimphu Thromde have been planned for 10 (2021-2030) year time period. A total 25 activity/projects have been proposed under the 4 programs of the plan based on low, medium and high priority. Some milestone or targets have kept in mind while preparing these projects/activities which are following-

- Bhutan's 12th FYP will be completed in 2023 which lies in our planning period

- Bhutan's 13th FYP will start and end by end of 2028 which also lies in our planning period
- The last year 2030 of our planning period is the year for achieving SDGs which is considered as one of the significant international goals for each developing countries

Therefore keeping in mind the above milestones, the projects are designed in such a way that these projects might help Thimphu Thromde to achieve their 12th FYP, 13th FYP and SDGs by the ending of the implementation period 2030 of these storm water management plan. Basically the storm water management plan will help them fulfilling their national needs along with achieving international goals.

The investment phasing of these have also been prepared to achieve the targets of SDGs and their 12th FYP, 13th FYP particularly focusing on storm water management, storm water drainage, urban resilience. Prioritization of the projects have also been prepared based on their immediate need and the availability of their capacity and budget.

Generally Thimphu Thromde have no separate budget for storm water management, they basically use their Thromde's fund according the Budget report published by their Finance Ministry in 2020. The plan proposed to strengthen their financing mechanism at first and then gradually the investment will increase. The phasing has also done keeping in mind that, because of COVID-19 pandemic time should be given to the country to reach in a optimize and stable condition as according to Budget 2020-21 the GDP growth rate have been affected immensely due to COVID-19 and thus the investment have kept lower to manage the funding in the 1st planning year 2021.

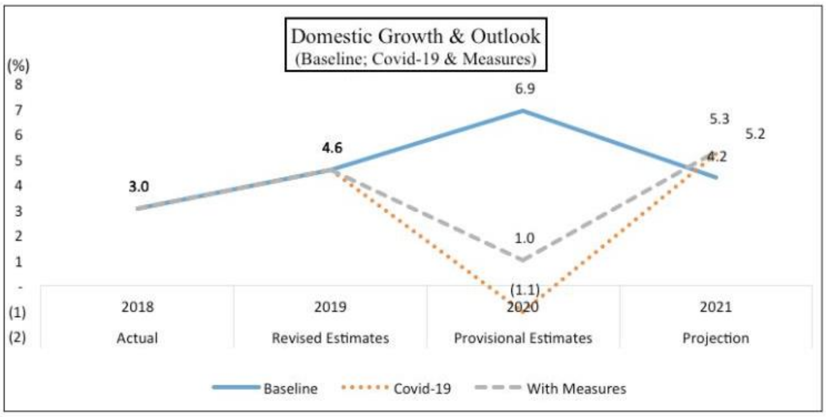


Figure 6.1: Impacts of COVID19 Pandemic on GDP of RgoB Projected in the 2019-2020 Budget

Table below thus represents the prioritization of activities under each of the program to be implemented throughout the planning horizon of ISWMP, Thimhpu Thromde:

Table 6.3: Prioritizartion of Major Projects of ISWMP, Thimphu Thromde (2021-2030)

SL. No.	Programs	Activity/Project	Priority	Project Duration
1	Program 1 (P1): Development of Sustainable and Climate Resilient Stormwater Infrastructures	P1A1: Annual Deep Cleaning of Storm Water Drainage	High	Long (5 years and beyond)
2		P1A2: Repair and Maintenance (Annual and Periodic after 3 years)	High	Long (5 years and beyond)
3		P1A3: Detailed Topography Survey of Storm Drainage Network	High	Short (less than 3 years)
4		P1A4: Replacement of Inadequate Drains and Cross Drainage Structures	High	Long (5 years and beyond)
5		P1A5: Construction of New Stormwater Drains and Infrastructures	Medium	Long (5 years and beyond)
6		P1A6: Applied Research, Piloting and Implementation of LID measures or Best Management Practices (BMP)	Medium	Long (5 years and beyond)

SL. No.	Programs	Activity/Project	Priority	Project Duration
7		P1A7: IT based Monitoring Infrastructure Development for Highly Critical Area	High	Short (less than 3 years)
8		P1A8: Relocation of Service Lines to Clear Blockage and Clogging	Medium	Medium (3 to 4 years)
9		P1A9: Solving Site Specific Problems	High	Long (5 years and beyond)
10		P1A10: Stregthening Waste Management System in Thimphu Thromde	Low	Medium (3 to 4 years)
11	Program 2 (P2): Emergency Response and Recovery	P2A1: Institutional Reform: Setting 'Emergency Response Unit'	High	Medium (3 to 4 years)
12		P2A2: Development and Implementation of Standard Operational Procedure for Emergency Response and Recovery	High	Long (5 years and beyond)
13		P2A3: Procurement of Machinaries and Equipment for Emergency Response	High	Medium (3 to 4 years)
14	Program 3 (P3): Strengthening Institutions, Coordination and Monitoring	P3A1: Integration of Explicit 'Regulatory Framework for Stormwater Management' into the Existing Standard Operational Procedure	Medium	Short (less than 3 years)
15		P3A2: Enhancement of Inter and Intra Institutional Coordination	High	Medium (3 to 4 years)
16		P3A3: Establishment of Financing Mechanism for O&M in Stormwater Management and Mainstream into Existing Budgeting System	High	Medium (3 to 4 years)
17		P3A4: Establishment of Functional Monitoring Mechanism for Stormwater Management	High	Short (less than 3 years)
18		P3A5: Monitoring, Review and Update of Stormwater Management Plan	Low	Short (less than 3 years)
19	Program 4 (P4): Capacity Development	P4A1: Development of Stormwater Drainage Design and Management Guideline	High	Short (less than 3 years)
20		P4A2: Development of GIS and SCADA based Operational Database	Low	Short (less than 3 years)
21		P4A3: Capacity Building and Skill Development of Engineers and Planners	High	Long (5 years and beyond)
22		P4A4: Campaign for Citizen Behavior Change and Awareness Building	High	Long (5 years and beyond)
23		P4A5: Recruitment of Skilled Manpower for Operation, Maintenance, Emergency Response and Recovery	High	Short (less than 3 years)
24		P4A6: Popularization of Low Impact Development (LID) Measures or Best Management Practices (BMP) at Community Level	Medium	Long (5 years and beyond)
25		P4A7: Update of Stormwater Drainage Infrastructure Geo Inventory	Low	Short (less than 3 years)

A total investment of 2046 million Nu is proposed to be required to implement the plan throughout 10 years. It is significant from the investment phasing that the peak investment lies in FY24-25 which is 328.2 million Nu and after that the phasing has decreased drastically. FY25-26 lies almost in the middle of planning period and the consideration behind these phasing is to achieve their milestone by the end of their 13th FYP 2028 and in the remaining two years (2028-2030) they will focus on aligning with SDGs and fill the gaps if they find any through monitoring and evaluation.

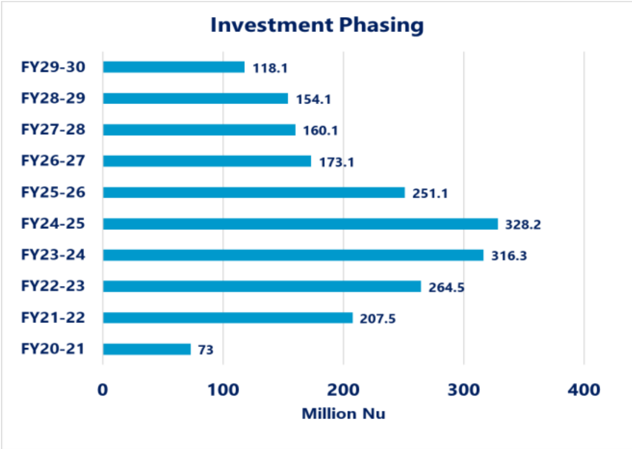


Figure 6.2: Investment phasing of ISWMP, Thimphu Thromde (2021-2030)

The detailed costing against each activities are illustrated in below table:

Table 6.4: Detailed investment plan for all major projects/activity under 4 programs of ISWMP

SL. No.	Programs	Activity/Project	Priority	Project Duration	FY20-21	FY21-22	FY22-23	FY23-24	FY24-25	FY25-26	FY26-27	FY27-28	FY28-29	FY29-30	Tentative Budget (MillionNu)
1	Program 1 (P1): Development of Sustainable and Climate Resilient Stormwater Infrastructures	P1A1	High	Long (5 years and beyond)	5	5	5	5	5	5	5	5	5	5	50
2		P1A2	High	Long (5 years and beyond)	2	2	2	1	1	2	1	1	2	1	15
3		P1A3	High	Short (less than 3 years)		10	7.5								17.5
4		P1A4	High	Long (5 years and beyond)	30	80	100	120	100	60	40	40	40	40	650
5		P1A5	Medium	Long (5 years and beyond)	30	80	100	100	120	150	120	100	90	60	950
6		P1A6	Medium	Long (5 years and beyond)			2	10	10	5	3				30
7		P1A7	High	Short (less than 3 years)		5									5
8		P1A8	Medium	Medium (3 to 4 years)						2	2	2			6
9		P1A9	High	Long (5 years and beyond)		10	20	25	30	10					95
10		P1A10	Low	Medium (3 to 4 years)				5	5	5					15
11	Program 2 (P2): Emergency Response and Recovery	P2A1	High	Medium (3 to 4 years)		5	3	2							10
12		P2A2	High	Long (5 years and beyond)			0.5	0.3	0.2	0.1	0.1	0.1	0.1	0.1	1.5
13		P2A3	High	Medium (3 to 4 years)		5	10	30	50						95
14	Program 3 (P3): Strengthening Institutions, Coordination and Monitoring	P3A1	Medium	Short (less than 3 years)					5	5					10
15		P3A2	High	Medium (3 to 4 years)	2	1	1	1							5
16		P3A3	High	Medium (3 to 4 years)	2	0.5	0.5								3
17		P3A4	High	Short (less than 3 years)		2	2								4
18		P3A5	Low	Short (less than 3 years)			0.5			5			5	10	20.5
19	Program 4 (P4): Capacity Development	P4A1	High	Short (less than 3 years)			5	10							15
20		P4A2	Low	Short (less than 3 years)								10	5		15
21		P4A3	High	Long (5 years and beyond)		1		1		1		1		1	5
22		P4A4	High	Long (5 years and beyond)		1		1		1		1		1	5
23		P4A5	High	Short (less than 3 years)	2		5								7
24		P4A6	Medium	Long (5 years and beyond)			0.5		2		2		2		6.5
25		P4A7	Low	Short (less than 3 years)				5					5		10

6.4 Program Portfolio

Program 1 (P1): Development of Sustainable and Climate Resilient Stormwater Infrastructure

Objective

To develop a sustainabe and climate resilient stormwater infrastructure system of Thimphu Thromde which will be adequate to meet the future demand during the planning period 2021-2030.

Rationale

Thimphu Thromde being the capital city of Bhutan is recognized as an economic hub of the country. Due to expanding at a high rate compared to other parts of the country, the population of Thimphu Thromde is estimated to grow further 162,327 by the year 2027. Therefore, the rapid urbanization is increasing manifold problems and storm water management is the significant one among those problems.

The existing storm water drains in Thimphu Thromde is constructed on an ad hoc basis and thus the city faces heavy storm water drainage problem. In addition due to lack of coverage of network, loss of connectivity, inadequate capacity of existing urban drainage infrastructures, poor quality workmanship, lack of operation and maintenance work, poor planning with no outlet, lack of awareness of waste management etc. also supplements storm water drainage problems.

The RGoB has already taken noteworthy initiatives on urban resilience enhancement. As the city is facing now stormwater drainage problems frequently even being 68% well performing by existing drainage network and having almost 64% coverage of drainage network. Unplanned and ad hoc construction of drainage network without considering hydrological considerations or proper technical study fueled much in this case along with irregular repair, maintenance and cleaning work. Therefore, a well planned stormwater management infrstructure system should be developed considering the future uncertainties of climate change and urban development scenario.

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
1	Program 1 (P1)	P1A1: Annual Deep Cleaning of Storm Water Drainage	High	• Installation of Garbage Collection Sump (58 nos throughout next 5 years) • Annual Deep Cleaning Before Monsoon (for fist year-44 nos, for next year monitoring team will identify) • Procurement of cleaning machinaries like 2 hydro jet, 1 water tanker, 1 excavator, 1 drump truck, 1 pay loader • Hire skilled labor
2		P1A2: Repair and Maintenance (Annual and Periodic after 3 years)	High	• Repair and maintenance work in 64 locations by 2023
3		P1A3: Detailed Topography Survey of Storm Drainage Network	High	• Detailed topography and longitudinal survey (see design guideline: Volume II for survey considerations)
4		P1A4: Replacement of Inadequate Drains and Cross Drainage Structures	High	• Improvement of existing inadequate drainage infrastructures in 3 phases (15.4km by 2023, 21.2km by 2028, 6.9 km by 2030)
5		P1A5: Construction of New Stormwater Drains and Infrastructures	Medium	• Cnstruction of existing inadequate drainage infrastructures in 3 phases (22.3 km by 2023, 38.23 km by 2028, 15.66 km by 2030)
6		P1A6: Applied Research, Piloting and Implementation of LID measures or Best	Medium	• Conservation and protection of natural streams or drainage • Piloting of stormwater quality infiltration pond of domain 6

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
		Management Practices (BMP)		• Piloting of permeable pavement in front of centenary park • Piloting of green zone in other areas • Research on vegetative swale for peak runoff reduction potential for Thimphu Soil • Implementation of household level trench with low cost rain barrel
7		P1A7: IT based Monitoring Infrastructure Development for Highly Critical Area	High	• Procurement of 10-15 IP Camera • Installation IP camera in roadside pole • Installation survielence computer monitor in monitoring cell
8		P1A8: Relocation of Service Lines to Clear Blockage and Clogging	Medium	• Identification of service line relocation potential location • Relocation of service lines with coordinating relevant authority
9		P1A9: Solving Site Specific Problems	High	• Solving vegetable market, BD Embassy, low lying area, Jushina Pamtho, under highway flyover by 2023 as per prescribed solutions • Solving RBP and memorial chorten, primary school, flash floods location, underpass problems by 2025 as per prescribed solutions
10		P1A10: Stregthening Waste Management System in Thimphu Thromde	Low	• Awareness raising program • Cooperation cleaning program • Implement 4R

Tentative Cost: 1833.5 million Nu

Responsible Agencies: Thimphu Thromde, DES, NCHM, DHS, DoR, DDM

Program 2 (P2) : Emergency Response and Recovery

Objective

To enhance the services need to be provided after a sudden downpour causing waterlogging in Thimphu Thromde.

Rationale

As a climate vulnerable country Bhutan is aware of the future climate change projections for the country. National Center for Hydrology and Meteorology (NCHM) conducted a study to analyze the historical climate and future climate change projections for Bhutan and in relation with storm water management the rainfall projection under RCP4.5 scenarios shows that Bhutan is likely to experience an increasing trend in rainfall during 2021-2050 and will also experience a marginal decrease in rainfall at the end of the century (2070-2099). On the other hand a marginal increase in rainfall trend is indicated under the RCP8.5

Considering the above scenarios it is quite clear that Thimphu is going to face an increasing trend in rainfall and this will further impact on storm water related management. Uncertainties in climate change associated with increase in rainfall will demand emergency response services to overcome storm water management issue. So, a guiding principle reflecting the activities need to be taken on an emergency basis during storm water drainage problems.

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
11	Program 2 (P2)	P2A1: Institutional Reform: Setting 'Emergency Response Unit'	High	• Instituional Reform Committee Form • Review of Scopes of ERU • Stakeholder Consultation • Review Paper Preparation

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
				• Develop organogram and set mandate • Assign responsibilities from different division of the Thromde • Institutional Reform pass by 2024
12		P2A2: Development and Implementation of Standard Operational Procedure for Emergency Response and Recovery	High	• Developed SOP for ERU operation • Make SOP Operational • Integrate with e-service portal of RGoB or Thromde • Track progress through Annual Performance Agreement wth suitable indicators like service provided or consumer satisfaction
13		P2A3: Procurement of Machinaries and Equipment for Emergency Response	High	• Procurement of 1 pay loadr, 1 drum truck, 1 water tank, 1 water jet or hydro jet, 2 excavators • Purchase computer and other software for supporting monitoring activities

Tentative Cost: 106.5 million Nu

Responsible Agencies: Thimphu Thromde, DES, NCHM, DHS, DoR, DDM

Program 3 (P3): Strengthening Institutions, Coordination, and Monitoring

Objective

To ensure the smooth implementation of actions through building coordination among institutions and enhance monitoring process

Rationale

The whole process of storm water management is done by four divisions of Thimphu Thromde e.g. infrastructure division, environment division, urban planning division and development control regulatory division.

The planning is done by the urban planning division upon getting application from peoples or assessments of needs. The infrastructure division of Thromde does the design, drawing, and construction. The environment division handles the issues related to waste management and the Development control division give the permission of constructing any development work changing land covers.

Strengthening coordination among this divisions and the relevant institutions is a prerequisite for proper functioning of ISWMP. A multi-dsciplinary teambuilding effort can check and balance all progress, achivement and failures and so plan work smoothly. Monitoring in proper way can guide zone engineers and decision makers for further initiatives they need to do learning past lessons.

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
14	Program 3 (P3)	P3A1: Integration of Explicit 'Regulatory Framework for Stormwater Management' into the Existing Standard Operational Procedure	Medium	• Integration of explicit farework for stormwater management into existing 'SOP' • Explicit recommendations to be included are provided under the implementation plsn
15		P3A2: Enhancement of Inter and Intra Institutional Coordination	High	• Organisation regular meeting among divisions and agencies • Track progress of decisions taken in the meeting
16		P3A3: Establishment of Financing Mechanism for O&M in Stormwater Management and Mainstream into Existing Budgeting System	High	• Establish dedicated financing mechanism establishing partnership with development partners and private sectors along with RGoB
17		P3A4: Establishment of Functional Monitoring Mechanism for Stormwater Management	High	• Establish monitoring cell • Establish monitoring protocol and keep tracking • Install IP based monitoring mechanism
18		P3A5: Monitoring, Review and Update of Stormwater Management Plan	Low	• Data collection in certain interval for monitoring of progress of ISWMP • Review and evaluate ISWMP progress • Conduct further comprehensive technical study and update the plan by 2030

Tentative Cost: 42.5 million Nu

Responsible Agencies: Thimphu Thromde, DES, NCHM, DHS, DoR, DDM

Program 4 (P4): Capacity Development

Objective

Development of capacity among vertical and hosrizontal level of stakeholders and the stormwater management system itself

Rationale

Lack of proper and regular maintenance of storm water drains has been found in most of the areas of Thimphu Thromde. Many drains have been found clogged due to dumping of solid wastes, ad hoc construction of slab for vehicle moving, thus connectivity of drains have been lost badly in a few places. Lack of awareness of people is also responsible for clogging of drains as they dump waste into the drain and other mismanagement associated with storm water management.

Through capacity building these issues like dumping of wastes in drains, irregularities in construction can be sorted to some extent. It is important to make the people of Thimphu Thromde understand that along with government it is also their responsibilities to maintain drainage condition by following some rules. It is also seen that the drain connection comprising household liquid wastes is connected to storm drain which result deterioration of storm water quality along with overflow of drains during a storm event.

Therefore, capacity need to be developed among both Thimphu Thromde local people and government focusing on the issues that requires most capacity like increasing awareness, construction of separate drain for household wastes and storm water, increasing the drain capacity etc.

SL. No.	Programs	Activity/Project	Priority	Major Sub-Activities
19	Program 4 (P4):	P4A1: Development of Stormwater Drainage Design and Management Guideline	High	• Development of Stormwater Drainage Design and Management Guideline
20		P4A2: Development of GIS and SCADA based Operational Database	Low	• Development of GIS and SCADA based Operational Database
21		P4A3: Capacity Building and Skill Development of Engineers and Planners	High	• Capacity Building and Skill Development of Engineers and Planners
22		P4A4: Campaign for Citizen Behavior Change and Awareness Building	High	• Campaign for Citizen Behavior Change and Awareness Building
23		P4A5: Recruitment of Skilled Manpower for Operation, Maintenance, Emergency Response and Recovery	High	• Recruitment of Skilled Manpower for Operation, Maintenance, Emergency Response and Recovery
24		P4A6: Popularization of Low Impact Development (LID) Measures or Best Management Practices (BMP) at Community Level	Medium	• Popularization of Low Impact Development (LID) Measures or Best Management Practices
25		P4A7: Update of Stormwater Drainage Infrastructure Geo Inventory	Low	• Update of Stormwater Drainage Infrastructure Geo Inventory

Tentative Cost: 63.5 million Nu

Implementing Agency: Thimphu Thromde, DES, NCHM, DHS, DoR, DDM

7. Implementation Plan of Thimphu Thromde ISWMP

7.1 Institutional Reform: Emergency Response Unit (ERU)

The SWOT analysis of the main implementing agency of stormwater management programs reveal there are dire need of an Emergency Response Unit (ERU) under the Infrastructure division to act promptly to an emergency problematic area and response smartly to get quick recovery from the situation. Urban Policy Note: Urban Resilience (2018) accorded same that Bhutan is frequently facing disasters with increasing recurrent cost, but there is lack of emergency response activities. The stakeholder analysis also depicts similar urge that ERU can be good solution to the ad hoc repair and maintenance work and suggested to make responsible the Infrastructure Division of the Thimphu Thromde to take care of ERU.

This plan thus proposes institutional reform setting up an Emergency Response Unit (ERU) under the Infrastructure Division of the Thimphu Thromde with all required infrastructures. ERU division should take one representative from other divisions of the Thimphu Thromde to maintain better coordination during emergency response, especially when it comes to waste dumping and clogging issues.

ERU should recruit adequate skill manpower and procure heavy machineries like hydro jet, vacuum pump, pay loader to act promptly during an emergency. ERU can have a central monitoring room functional in monsoon season with low cost IP camera and surveillance system setup in the road side pole of the identified highly critical area, staff can monitor and take actions if required. ERU should have a separate allocation of budget as per their requirement for annual emergency response and recovery.

7.2 Institutional Arrangement and Coordination Mechanism

Inter and intra institutional coordination is very important in case of stormwater management as multi-stakeholder are engaged. DoR, DES, DHS, DDM are somewhat linked with the activities of stormwater management. Engineers and planners from multiple disciplines like civil engineers, hydrologist, urban planners, road engineers etc. should be on board to sought their expert input and opinion before going for detailed design and drawing. On the other hand, each of the division inside the Thromde like Environment Division, Infrastructure Division, Urban Planning Division and Development Control Division are inter-dependent to each other. Therefore, institutional arrangement should be strengthened enough to make all relevant stakeholders well informed and coordinated. To enhance the institutional coordination, an Institutional coordination committee should be formed involving all potential agencies. The committee should sit in monthly or more frequent meetings as per requirement. The committee should have a chair and members from all relevant agencies and Thromde divisions.

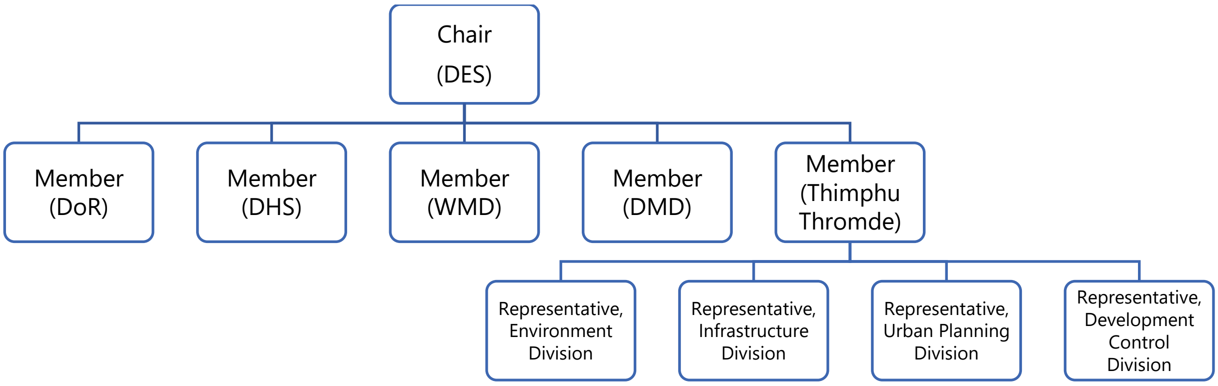


Table 7.1: Proposed Institutional coordination committee

7.3 Integration of Explicit Stormwater Management Clauses into the Existing Regulatory Framework

This plan strongly proposes to integrate a few explicit stormwater management and low impact development measures related clauses to address the stormwater management challenges with more emphasis and stringent enforcement, which are as following:

- Make household level small infiltration trench mandatory for new building construction approval to use for domestic water discharge avoiding directly into the storm drain, disconnection of roof top rain water through rain gutter to the trench. Update required clauses relevant to this proposal in the Development Control Regulation, Building Code and mainstream it into the Standard Operating Procedure (SOP).
- Make mandatory 3 low cost 80 gallons barrel in each of the household to harvest roof top rainwater, reuse for domestic water use and discharge into the small infiltration trench. Update required clauses relevant to this proposal in the Development Control Regulation, Building Code and mainstream it into the Standard Operating Procedure (SOP).
- Make permeable pavement or parking mandatory at both household, and institutional level. Traditional Dolep pathways with locally available stone slate can be highly promoted for permeable footpath. Update required clauses relevant to this proposal in the Development Control Regulation, Road Design Guideline and mainstream it into the Standard Operating Procedure (SOP).
- Provide tax rebate or introduce insurance mechanism to promote implementing different Low Impact Development (LID) measures like vegetative swale, swale garden, infiltration trench, rainwater harvesting, permeable pavement, or parking etc.
- Introduce, integrate, and make operational explicit or separate stormwater management related clauses rather than keeping it implicit or hidden under water and sanitation in different regulatory tools like site inspection form, building approval form and most importantly occupancy certificate form or other relevant forms. For instances, keeping provision and maintaining storm water drains, small infiltration trench and disconnection of runoff, rainwater harvesting in every household level and institutional level, keeping adequate opening of storm drain or road side L-drain while constructing approach slab for vehicle movement over that, prohibit waste dumping into open drain and management of spoil or waste as part of Civil

Society Responsibility (CSR) etc. should be integrated separately under the stormwater management clauses.

- Inclusion or mainstreaming of Bhutan Green Building Guideline 2013 into the Development Control Regulations

7.4 Financing Mechanism

Financial mechanism of storm water management plan proposed that about 15% of total investment will come from Royal Government of Bhutan fund and 84% of total investment will come from Development partners or climate funds. A project is also included to enhance the financial mechanism through mainstreaming the investment in their budget. Administrative and Finance Division of Thimphu Thromde is mainly responsible for establishing financial mechanism. Capital Budget for Thromde's including CMI allocation for FY 2020-21 shows that Grand total 1,915.999 Nu in million is allocated for Thimphu Thromde.

The Asian Development Bank (ADB) has been supporting Bhutan since 1982, mostly concentrating its efforts on programs and projects in energy, transport, finance, and urban development. Bhutan is eligible for concessionary OCR lending. The country can also additional Asian Development Fund grant and concessionary OCR lending from ADB's disaster risk reduction mechanism to supplement project. Similar to Asian Development Bank, **World Bank** can be another option to access funds for enhancing urban resilience.

The Green Climate Fund announced a USD 43 million partnership to permanently preserve Bhutan's protected areas, which comprise 51 percent of the country's territory. The Bhutan Trust Fund for Environmental Conservation (BTFEC) has gained accreditation as Bhutan's first National Implementing Entity (NIE) of the Green Climate Fund (GCF). UNCDF assisted BTFEC through the application process, with the support of the EU's Global Climate Change Alliance Plus Initiative and the Swedish International Development Cooperation Agency (SIDA). GCF accreditation will allow BTFEC to propose projects for GCF funding with support from Gross National Happiness Commission (GNHC), the National Designated Agency for GCF in Bhutan. BTFEC can propose projects of project up to US$ 10 million value for GCF assistance, with project implemented directly by BTFEC or by nominated implementing entities. All projects must meet GCF requirements for financing. The name of some donors are also found from reviewing the budget like UNICEF, GoI, WHO, EU, ADHOC, SCF/USA, ICIMOD/ICIMD, UNDP, BF, FF, WWF, GEF-UNDP, AUSTRAIN, and others. A list of total funding Bhutan received from some of the international donors (https://www.thegef.org/country/bhutan)are following-

Trust Fund	Project Type	Number of Projects	Total Financing	Total Co-Financing
GEF	National	18	$32,167,457	$39,951,460
	Regional/Global	9	$124,055,452	$107,565,623
LDCF	National	3	$15,135,250	$58,576,053
	Regional/Global	1	$6,000,000	$88,190,417
	Regional/Global	1	$4,500,000	$15,963,559
NPIF	National	1	$1,000,000	$3,003,668
	Regional/Global	0	$0	$0
	National	1	$13,967,124	$42,630,300
	Regional/Global	1	$99,207,741	$591,501,798

According to **Bhutan Urban Policy Note**, current grants are allocated to Thromde's annually through negotiation between the MoF and the respective during budget preparation. The ceilings to the Thromdes are decided by the DNB. While approving the allocation, DNB takes into consideration the following key factors-

- Trends in past recurrent expenditure
- Disallowing any wasteful expenditure
- Incentivizing Thromdes to generate own revenues through better management and reforms in tax administration

Besides some private sectors like Banks of Bhutan can be engaged for providing funding for Storm water management plan. The Royal Government of Bhutan recognizing the important role of the private sector in implementing PPP projects has approved a PPP policy during the 98th session of the Lhengye Zhungtshog in March 2016. The PPP policy provides an excellent platform for the private sector to partake in development of viable and feasible projects that offer reasonable returns to the private sector, better service delivery options for the citizens of Bhutan while assuming the associated risks.

According to the 12th FYP of Bhutan, to reduce financial pressure on government, PPP will be promoted as an alternative source of financing for major infrastructure projects. For example, assessment of Integrated Bus Terminal in Thimphu as PPP model is already being initiated. Their potential projects include affordable housing, construction of offices etc. The sectors that are reliable for implementation of PPP projects in Bhutan are roads and highways, urban transport, airports, tourism, industrial estates / parks, healthcare, education, water supply and sanitation, power and energy. Some PPP projects in Bhutan under their 11th FYP were Dagachhu Hydro Power Corporation, Integrated MSWM for Thimphu, Bhutan Education City. In this proposed storm water management plan, PPP can be introduced in those projects which requires large investment like Construction of New Stormwater Drains and Infrastructures, IT based Monitoring Infrastructure Development for Highly Critical Area, Strengthening Waste Management System in Thimphu Thromde, Establishment of Functional Monitoring Mechanism for Stormwater Management, Establishment of Financing Mechanism for O&M in Stormwater Management and Mainstream into Existing Budgeting System.

However, reviewing the budget of Bhutan 2019-20, it is found that there were significant number of project regarding storm water management, waste management funded by RGoB along with ADB like

Construction of Water Treatment Plant Babesa, construction/ maintenance of storm water drainage, Thimphu Thromde. So, in order to mainstream the budget for storm water management Administrative and Finance division of Thimphu Thromde have to take the responsibility and create a channel to access the funds of their development partners like ADB, World Bank, etc. In this regard, Administrative and Finance division of Thimphu Thromde should build a dedicated storm water management financing mechanism. Before the Budget of 2019-20, all the drainage construction budget was allocated from road construction budget and for this reason they construct their drainage network in an ad hoc basis. For the first time, separate budget has been introduced for storm water drainage and this should continue in future along with integrating the budget in capital cost required for O&M in an integrated way.

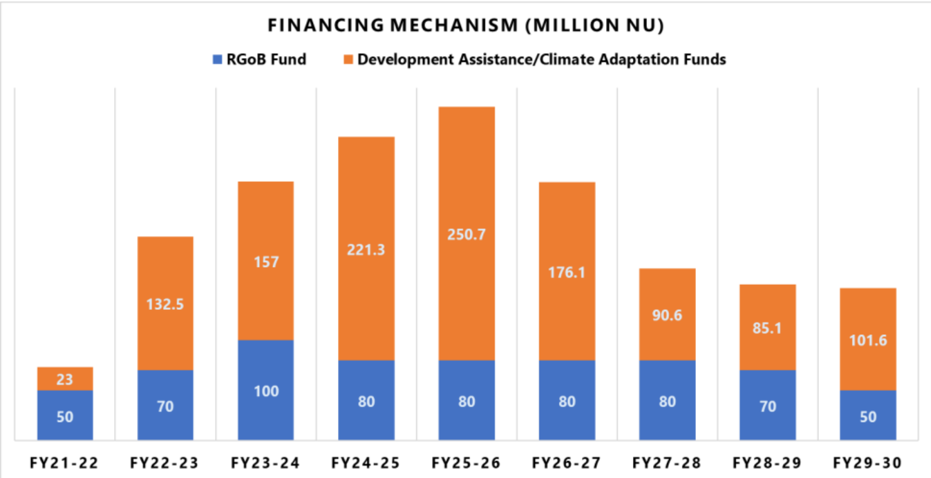


Figure 7.1: Potential financing mechanism of implementation of ISWMP, Thimphu Thromde

ISWMP proposes 35:65 ratio in case of investement for ISWMP for RGoB and development partners respectively. Above figure represent the possible investment requirement by the RGoB and additional financing access required from development partners like ADB and WB.

7.5 Capacity Building and Skill Development

Capacity building is an important activity for the successful implementation of the plan. This includes two major components;

Institutional capacity building and coordination enhancement

The institutional capacity development will include several activities including; Setting up 'Emergency Response Unit', developing SOP for it and procurement of machineries and equipment for it (e.g., heavy machines, jets to clean drains), recruitment of skilled manpower, enhancement of Inter and Intra Institutional Coordination, establishment and regular update of relevant information database of the stormwater drainage network and Development of automated and IT based Monitoring Infrastructure. This will ensure the institutions strengthened and effectively operating to achieve the planned targets.

Skill development of professionals working in the implementing agencies

The engineers, planners and emergency response unit staffs need to be trained for their skill development. These skill development activities should include; practice oriented trainings on drain design, hydrologic analysis, topographic survey and data QA/QC and management, LID and BMPs, planning aspects and its implementation process, technical knowledge needed for emergency response unit and related machineries etc. and also technical skill enhancement for plan preparation, monitoring, operational activities, cost estimation and procurement, tracking mechanism and data management to M&E etc.

7.6 Monitoring and Evaluation Framework

The M&E framework will follow outline of result based monitoring framework and will try to integrate already existing Annual Performance Indicators along with relevant new indicators. Based on thorough analysis of available data on previous annual plans and five year plans, a set of monitoring indicators have to be set. As Department of Engineering Services is preparing the plan and Thimphu Thromde will be the main custodian of this plan, monitoring should be thus performed with the lead of Department of Engineering Services (DES) making a steering committee headed by them and taking representatives from aligned department like Department of Roads, Department of Human Settlements, National Center for Hydrology and Meteorology, Watershed Management Division and Disaster Management Department. Figure aa shows a tentative layout of the committee. This steering committee should take care of the result based framework, identify indicators, collect data of monitoring indicators at certain interval and keep track of the related activities.

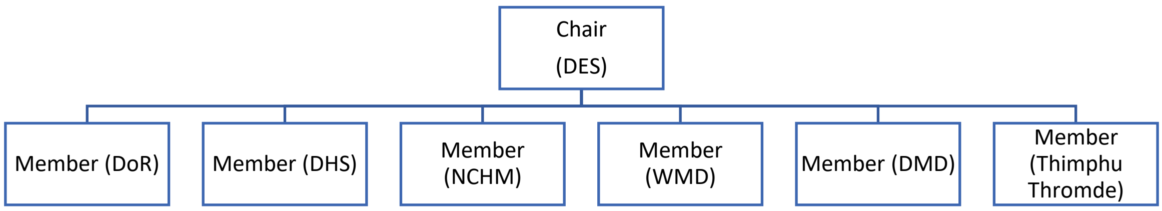


Figure 7.2: Proposed M&E steering committee

This result based monitoring framework basically will try to achieve and track progress on following set broad targets:

Figure 7.3: Targets of ISWMP, Thimphu

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