Deliverable Phase 2 – Climate risk assessment

Sustainable Adaptation for Flood Emergencies in Hopa (SAFE-HOPA)

Türkiye, Hopa / Hopa

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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1. Summary of evaluation criteria for this deliverable

This deliverable report was prepared to present the climate risk assessment studies carried out in the second phase of the SAFE-HOPA project in an integrated structure. This structure is aligned with the CLIMAAX framework, technically traceable, and transferable to local decision-making processes. The main evaluation approach of the report is to explain what the project outputs mean for Hopa in terms of local disaster risk, urban development pattern, continuity of transportation, critical infrastructure, disaster coordination capacity, and vulnerable groups. For this reason, the report addresses the description of data and methods together with the interpretation of results. It also links the technical outputs to region-specific risk reduction and adaptation strategies.

The structure of the report was designed to allow the reader to understand Hopa's risk context in a gradual manner. The first sections explain the project objective, local context, project team, participation structure, risk ownership, and stakeholder process. The report then assesses the risks of river flooding, heavy rainfall, and rainfall-induced landslide in line with the steps of the CLIMAAX approach. The regionalized risk analysis section addresses both the outputs obtained from the standard CLIMAAX workflows and the additional analyses developed through local models, data, and expertise. In this way, the report presents a climate risk assessment that has been deepened through new and more detailed local analyses produced in Phase 2.

The methods, data, and models used in this phase are explained at a level that makes the assessment understandable for a reader who is not familiar with the region. The local data used in the report include elements that directly affect Hopa's disaster management capacity. These include the road network, building data, zoning blocks, infrastructure lines, healthcare facilities, temporary shelter areas, bridge crossings, coastline, soil classes, and critical institutional locations. This approach enables the findings of the report to serve as a basis for local planning and disaster management decisions.

The report includes local models and additional outputs beyond the standard workflows. Visual materials, maps, tables, and diagrams are used to support the technical narrative of the report. This visual structure enables the report to function as a decision-support document that can be used by decision-makers, technical units, and stakeholders. Instead of repeating the information from the previous phase, the report provides a more advanced level of assessment on Hopa's disaster resilience through new data, new analyses, and new planning decisions.

2. Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	This deliverable presents the Phase 2 climate risk assessment of the SAFE-HOPA project, focusing on flood, heavy rainfall and rainfall-triggered landslide risks in Hopa Municipality. It deepens the Phase 1 findings by integrating local datasets, GIS-based analyses, meteorological trend assessment, alternative route modelling, EOC site selection and disaster logistics planning. The report translates climate risk information into operational findings for emergency response, accessibility, critical infrastructure continuity, vulnerable groups and local adaptation planning.
Project name	Sustainable Adaptation for Flood Emergencies in Hopa (SAFE-HOPA)
Country	Türkiye
Region/Municipality	Hopa / Hopa Municipality
Leading Institution	Hopa Municipality
Author(s)	• Nilay KADAN (Hopa Municipality) • Prof. Dr. Halil AKINCI • Prof. Dr. Dilek BEYAZLI (Karadeniz Technical University) • Assistant Professor Seda ÖZLÜ (Karadeniz Technical University) • Assistant Professor Sinem DEDEOĞLU ÖZKAN (Karadeniz Technical University)
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Version	Date	Change editors	Changes
1.0	…	Hopa Municipality	Deliverable submitted
2.0	…	CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

3. Table of contents

4. List of figures

5. List of tables

6. Abbreviations and acronyms

Abbreviation / acronym	Description
AADYM	Disaster and Emergency Management Centers
AFAD	Disaster and Emergency Management Authority
AHP	Analytic Hierarchy Process
AUC	Area Under the Curve
CINEA	European Climate, Infrastructure and Environment Executive Agency
CI	Consistency Index
CLIMAAX	Climate risk and vulnerability assessment framework and toolbox
CRA	Climate Risk Assessment
CR	Consistency Ratio
DEMC	Disaster and Emergency Management Center
DSI / DSİ	General Directorate of State Hydraulic Works
DRM	Disaster Risk Management
EOC	Emergency Operations Center
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
GBM	Gradient Boosting Machine
GSM	Global System for Mobile Communications
GIS	Geographic Information Systems
ICS	Incident Command System
IFP	Individual Follow-up Plan
IMS	Incident Management System
İRAP	Artvin Provincial Disaster Risk Reduction Plan
JRC	Joint Research Centre
LightGBM	Light Gradient Boosting Machine
LPG	Liquefied Petroleum Gas
LUISA	Land Use-based Integrated Sustainability Assessment
MAKS	Spatial Address Registration System
MCV	Mobile Command Vehicle
MGM	Turkish State Meteorological Service
MTA	General Directorate of Mineral Research and Exploration
NDVI	Normalized Difference Vegetation Index
NFPA	National Fire Protection Association
NIMS	National Incident Management System

RCP	Representative Concentration Pathway
RF	Random Forest
RI	Random Index
SAFE-HOPA	Sustainable Adaptation for Flood Emergencies in Hopa
SPI	Stream Power Index
TAMP	Türkiye Disaster Response Plan
TPI	Topographic Position Index
TWI	topographic wetness index
UFC	Unified Facilities Criteria
ZB	Soil Class ZB
ZC	Soil Class ZC
ZD	Soil Class ZD
ZF	Soil Class ZF / Liquefiable alluvial soils in this analysis
XGBoost	eXtreme Gradient Boosting

7. Executive summary

This deliverable report presents the Phase 2 climate risk assessment of the SAFE-HOPA project, developed for Hopa Municipality within the CLIMAAX framework. The report responds to the need to deepen the risk findings obtained in Phase 1 through local data, local expertise, and GIS-based analyses.

The Phase 2 assessment builds on the outputs produced in the first phase regarding areas exposed to river flooding risk, temporary shelter areas, critical infrastructure, vulnerable groups, and Hopa's general multi-hazard context. In this phase, these findings were made more detailed through additional local analyses. River flooding and landslide susceptibility maps, meteorological trend analysis, building and road exposure data, alternative route modelling, Emergency Operations Center (EOC) site selection, equipment parking area planing, and heavy vehicle and disaster logistics area planning were integrated into a single risk assessment framework.

The main conclusion of this deliverable report is that climate risk in Hopa should be understood as an integrated urban resilience issue. River flooding, heavy rainfall, and landslides may create cascading impacts on roads, bridges, infrastructure, emergency services, vulnerable groups, and institutional coordination. For this reason, Phase 2 goes beyond hazard mapping and produces concrete decision-support outputs for safe access routes, the location of the EOC, disaster logistics, two-sided emergency response capacity, and local adaptation planning.

In the final phase of the project, these findings are intended to be translated into local adaptation strategies, disaster response planning, institutional capacity-building activities, community awareness actions, school-based disaster education, building inventory updates, planning recommendations, and policy outputs. In this way, the final phase will support Hopa Municipality's transition from risk assessment to implementation-oriented preparedness and long-term climate resilience.

1 Introduction

1.1 Background

Hopa is a district municipality located in northeastern Türkiye, within the borders of Artvin Province, on the Black Sea coast. The district shows high susceptibility to river flooding, flash flooding, and rainfall-induced landslide risks due to its narrow coastal plain, steep topography rising over short distances, river valleys, high annual precipitation, and intense settlement pressure. The contiguous area of Hopa Municipality covers 2,451.18 hectares. Elevation ranges from 0 to 626.72 m, while slope varies between 0° and 70.34°. The average slope of approximately 22° and the average annual precipitation reaching 2,370.78 mm increase the district's vulnerability to climate-related disasters.

Hopa receives an average annual precipitation of 2,370 mm, which is approximately four times the national average. This extreme precipitation regime increases the frequency and intensity of hydrometeorological events such as river flooding and inundation. It poses a threat to many sectors, from agricultural production to urban infrastructure.

Across Türkiye, landslides are most concentrated in the Black Sea Region. Approximately 30–40% of landslide events in the country are known to occur in this region. Artvin Province, and especially the surroundings of Hopa, are among the areas with high susceptibility within this distribution. In Hopa, many small- and medium-scale landslides have been recorded in previous years due to intense rainfall. These events have mostly affected settlement areas, transportation infrastructure, and areas close to riverbeds. Flash flooding and river flooding events that develop especially as a result of high amounts of precipitation within a short period cause riverbeds to overflow and slope stability to deteriorate, thereby increasing landslide risk.

On August 24, 2015, following intense rainfall, Hopa recorded 287.2 mm/m² of precipitation. This event resulted in the deaths of eight citizens, three people reported missing, and significant damage to infrastructure systems. This disaster is regarded as one of the most severe and destructive events in Hopa's recent history. It clearly demonstrated how extreme precipitation can trigger cascading impacts on human life, transportation, infrastructure, settlements, and local disaster response capacity.

1.2 Main objectives of the project

The main objective of the SAFE-HOPA project is to strengthen the municipality's disaster preparedness and climate adaptation capacity by assessing river flooding, heavy rainfall, and landslide risks in Hopa through local data, scientific analysis, and institutional decision-support processes. The project aims to make Hopa's current and future climate risks more visible, measurable, and manageable. It also seeks to identify the impacts of these risks on transportation, infrastructure, emergency response, temporary sheltering, vulnerable groups, and disaster coordination.

The use of the CLIMAAX Handbook provided a systematic and comparable risk assessment framework for the Phase 2 study. This framework enabled hazard, exposure, vulnerability, risk priority, stakeholder engagement, monitoring and evaluation, and next-phase planning to be addressed in a consistent manner. However, the specific conditions of Hopa, such as its narrow coastal strip, steep topography, high precipitation regime, and settlement structure extending across two banks, could not be fully explained through standard datasets. Therefore, the use of local data and models was critical in Phase 2. The inclusion of local data in the analysis ensured that the SAFE-HOPA outputs could be directly transferred to Hopa Municipality's decisions on disaster management, zoning, infrastructure, transportation, and local adaptation planning.

1.3 Project team

Dr. Utku CİHAN, Mayor of Hopa Municipality | Lead Coordinator

Dr. Utku Cihan is the Mayor of Hopa Municipality and holds a doctoral degree in Urban Planning. With an academic background combining theory and practice, he has developed expertise in sustainable urban development, spatial planning, and local governance. As the lead coordinator of the project, Dr. Cihan provides overall strategic direction and ensures that project activities are fully aligned with Hopa's development priorities and climate resilience goals. His role in this project is to secure institutional coordination, represent the municipality in international partnerships, and ensure the long-term integration of project outcomes into local policy.

Gökhan KARAİBRAHİMOĞLU, Deputy Mayor of Hopa Municipality | Technical Services

Gökhan Karaibrahimoğlu is a Geophysical Engineer with professional experience in disaster management and municipal technical services. He started his career at the Disaster and Emergency Management Authority (AFAD), where he served as an engineer and later as Acting Head of the Planning, Damage Reduction, and Recovery Department. His expertise strengthens the municipality's capacity to implement risk-informed strategies and enhance resilience against natural hazards.

Gökhan BAYAR, Director of Technical Services of Hopa Municipality | Infrastructure Analysis & Risk Assessment

Gökhan Bayar is a Civil Engineer with extensive experience in municipal infrastructure planning and management. His work has focused on analyzing past disaster events in Hopa, applying field-based insights to enhance infrastructure resilience and preparedness. His role involves coordinating the technical analysis of risk data and translating it into actionable infrastructure reinforcement strategies, ensuring that design and maintenance efforts are informed by real-world disaster scenarios.

Nilay KADAN, Project Coordinator of Hopa Municipality | Project Coordinator

Nilay Kadan serves as the Project Coordinator for Hopa Municipality, guiding the execution and strategic alignment of municipal projects. In her role, she ensures cohesive project implementation across departments, manages stakeholder communication, and coordinates technical meetings and inter-institutional collaboration. Her work contributes to translating strategic objectives into practical steps, fostering cooperation, and supporting the municipality's resilience efforts.

Prof. Dr. Halil AKINCI, GRIT Geographic Risk and Information Technology Services Ltd. | Academic Advisor

Prof. Dr. Halil AKINCI is a founding partner of GRIT Geographic Risk and Information Technology Services Industry and Trade Limited Company (GRIT), based at Samsun Technopark. As a Technopark company, GRIT draws on academic expertise to develop scientifically sound and innovative solutions for insurance and reinsurance companies. Prof. Dr. AKINCI has an extensive publication record in machine learning-based susceptibility mapping for landslides, floods, and wildfires. During Phase 2 of the project, he played a pivotal role and made significant contributions to landslide and flood susceptibility mapping, alternative route identification for disaster response, emergency operations centre (EOC) site selection, and meteorological trend analyses.

Prof. Dr. Dilek BEYAZLI | Academic Advisor

She serves in the Department of City and Regional Planning at Karadeniz Technical University (KTU). She has experience in urban design projects, architectural implementation projects, and master plans prepared for public institutions and organizations. She also serves as the KTU “Zero Waste Coordinator” and as the Director of the “Application and Research Center for Environment and Climate Change.” At the Research Center, which was included in the list of “Topic Centre Organisations” by the European Environment Agency (EEA) for the 2027–2030 period, she coordinates research and implementation activities on topics such as climate-adaptive spatial planning, water, and disaster risks. In Phase 2 of the project, she contributed to the analysis of alternative routes, the site selection and design of the Emergency Operations Center, and the planning of the heavy vehicle and disaster logistics area.

Assistant Professor Seda ÖZLÜ | Academic Advisor

She serves as an Assistant Professor in the Department of City and Regional Planning at Karadeniz Technical University (KTU). Her fields of study include urban planning, urban geography, participatory planning, and climate change adaptation. She is the Deputy Director of the KTU “Application and Research Center for Environment and Climate Change” and carries out studies on climate-adaptive spatial planning within the axes of “Climate Urbanism” and “Climate Governance.” In Phase 2 of the project, she contributed to the analysis of alternative routes, the site selection and design of the Emergency Operations Center, and the planning of the heavy vehicle and disaster logistics area.

Assistant Professor Sinem DEDEOĞLU ÖZKAN | Academic Advisor

She serves as an Assistant Professor in the Department of City and Regional Planning at Karadeniz Technical University (KTU) and conducts research in the fields of regional planning, sustainable urban development, climate change adaptation, and disaster management. She is a member of the “Climate Urbanism” working group within the KTU Application and Research Center for Environment and Climate Change. Her work focuses on spatial analyses for climate change adaptation and mitigation processes, risk-based planning tools, and the development of climate-sensitive design guidelines. In Phase 2 of the project, she contributed to the analysis of alternative routes, the site selection and design of the Emergency Operations Center, and the planning of the heavy vehicle and disaster logistics area.

Burak KAVAKLIOĞLU, M.Sc. | Senior GIS Software Analyst of EDANOVA Information Technologies JTC | Technical Advisor

Burak Kavaklıoğlu is a GIS Specialist with an M.Sc. in Geomatics and experience in spatial data management, geospatial analysis, and the development of digital mapping solutions. He provides technical guidance on the integration and processing of local geospatial datasets. In the SAFE-HOPA project, he supports the design and implementation of geospatial workflows to enhance regional climate risk assessments and resilience planning.

Umut CAN | Project Manager of EDANOVA Information Technologies JTC | Project Technical Coordinator

Umut Can serves as the Technical Coordinator, overseeing the overall execution and technical alignment of the SAFE-HOPA project activities. He ensures coordination between technical team and other stakeholders, monitors progress, and supports the integration of technical outputs into the broader project framework.

1.4 Outline of the document's structure

This report is structured to present the Phase 2 climate risk assessment of the SAFE-HOPA project in an integrated and traceable manner. The first section explains the local context of the project, its objectives, the project team, and the structure of the document. The second section addresses Hopa's climate risk assessment in line with the CLIMAAX framework. Within this scope, the report first explains scoping, participation and stakeholder engagement, the selection of main hazards, and the scenario approach. It then assesses river flooding, heavy rainfall, and landslide risks within a regionalized risk analysis supported by local data and models.

The following parts of the report link the additional studies developed in Phase 2, such as alternative route analysis, EOC site selection, equipment parking area assessment, and disaster logistics area planning, with the key risk findings, the monitoring and evaluation approach, and the Phase 3 work plan. The final section presents the main conclusions reached in Phase 2, the issues addressed and the topics that need to be further developed in the following phases, the progress evaluation of the project, supporting documentation, and references.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

The main objective of the Phase 2 climate risk assessment of the SAFE-HOPA project is to deepen the multi-hazard framework established in Phase 1 through local meteorological, hydrological, geotechnical, zoning, and infrastructure data. In this way, the project assesses river flooding, heavy rainfall, and landslide risks in Hopa in terms of access continuity, response capacity, critical infrastructure continuity, and decision-support mechanisms. In this respect, Phase 2 aims to test alternative transportation routes in terms of safety and feasibility. It also aims to relate the site selection and design logic of the emergency operations center and vehicle-equipment parking areas to risk reduction objectives. This approach is consistent with the expectations set for Phase 2 in the CLIMAAX template. These expectations include deepening the analysis through local data and models, explaining the relationship between methods, data, and models, and making the additional work carried out compared to Phase 1 visible.

The SAFE-HOPA project also draws attention to several issues included among the duties assigned to working groups in the Türkiye Disaster Response Plan (TAMP), which was prepared at the national level. These include identifying emergency areas and checking their suitability for use; determining, planning, and implementing evacuation priorities, evacuation routes, and areas to be evacuated before, during, and after disasters; providing fuel supply support for vehicles and equipment that will operate when needed; making the necessary arrangements to ensure transportation to and within the disaster area as soon as possible; and identifying alternative routes and priority routes to be used.

At the local level, the assessment is also aligned with the main aims and targets of the Artvin Provincial Disaster Risk Reduction Plan (İRAP). These include taking disaster risks into account in infrastructure investments under the aim of minimizing disaster hazards and risks (Objective 1, Target 3). They also include prioritizing the protection of critical and vulnerable groups in disasters under the aim of building disaster-resilient communities (Objective 3, Target 2).

This climate risk assessment was also carried out within certain boundaries. First, the local modelling developed in Phase 2 is largely based on river flooding and landslide susceptibility maps, Cost Path analyses, AHP-based site selection studies, zoning blocks, the road network, infrastructure, field information, and meeting inputs. Second, the currency of some zoning road data, the way unrealized zoning roads are reflected in the model, the differences between the actual location of buildings and planning decisions, and implementation issues such as expropriation were considered as limitations. These issues were not excluded from the analysis, but they require caution in the interpretation of the results.

Other main limitations of the study concern access to spatial and non-spatial data, the integration of social vulnerability information into operational analyses, and institutional data management. European-scale standard datasets do not always represent Hopa's narrow coastal strip, steep topography, local hydrometeorological conditions, and settlement structure extending across two banks in sufficient detail. For this reason, Phase 2 placed greater emphasis on the use of local data and local expertise. Social vulnerability data were identified in Phase 1. In Phase 2, these data were operationally considered through temporary shelter areas, access to healthcare facilities, buildings at risk, settlement exposure, and two-sided access continuity. However, the direct integration of demographic vulnerability variables, such as age, disability, socio-economic status, or special care needs, into route preference and accessibility analyses as data layers remains an area that needs further development. Another limitation is that the data management system has not yet been fully defined on the basis of institutional responsibilities.

2.1.2 Context

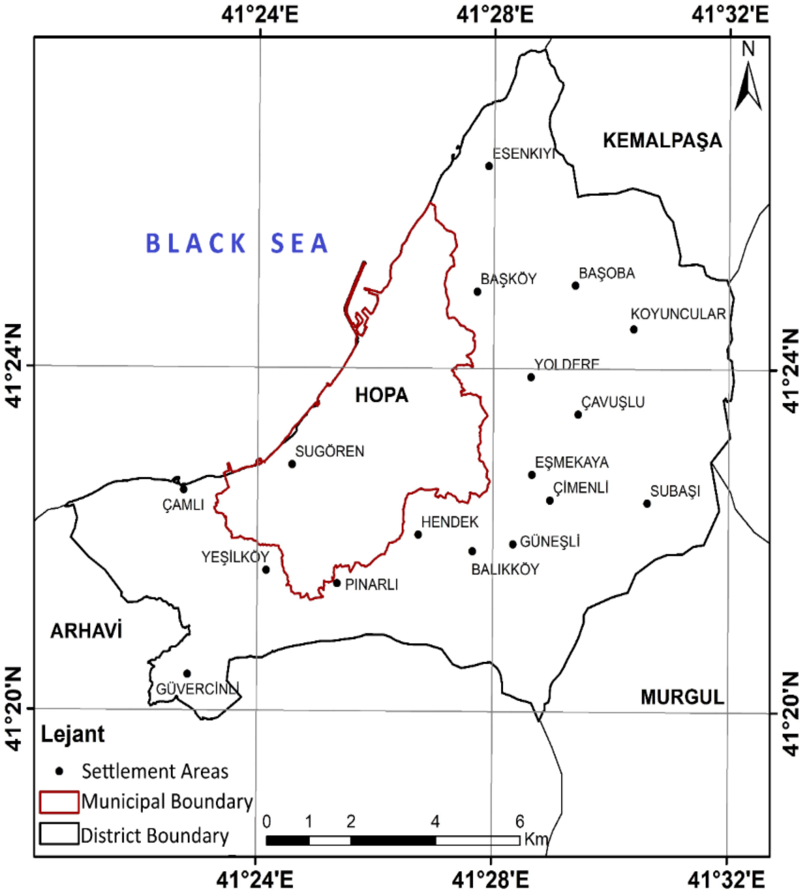

Figure 1 Study area (Hopa Municipality, 2024)

The contiguous area of Hopa Municipality covers 2,451.18 hectares. Elevation ranges from 0 to 626.72 metres, while slope varies between 0° and 70.34°. The average slope is approximately 22°, and around 55% of the area has slopes above this value. This makes Hopa a vulnerable settlement in terms of slope stability and access disruption.

The district has 9 neighbourhoods and 16 villages (Figure 1). Its total population is 27,844 people, of whom 23,580 people live within the municipal boundaries (Turkish Statistical Institute, 2026). The average annual precipitation of 2,370.78 mm and the very humid climate character show that the disaster problem in Hopa must be understood together with its high precipitation regime. Considering that Türkiye's average annual precipitation is approximately 650.9 mm, Hopa's annual precipitation corresponds to nearly four times the national average (Turkish State Meteorological Service, 2026, June 10). This explains why river flooding, flash flooding, and landslide risks are among the priority hazards for Hopa (Figure 3-4-5).

The most evident result of this physical context is the overlap between river flooding and landslide susceptibility and the urban fabric. In Hopa, river flooding and landslide susceptibility are mainly concentrated around Hopa Stream, which divides the city into two parts, and in Sundura Neighbourhood and its immediate surroundings. Sundura Neighbourhood, with a population of 8,547, is a settlement area that is spatially and topographically connected to the Hopa Stream valley and the low-elevation areas around it. This settlement pattern creates a spatial context that increases exposure to river flooding effects due to both topographic thresholds and proximity to the river corridor.

In addition, the coastal areas located west of Merkez Kuledibi Neighbourhood, the Hopa-Artvin Highway, and the Black Sea Coastal Road, which connects the city to other coastal cities of the Black

Sea, are among the urban areas where these risk zones become more evident. The risky areas identified especially around Sundura Neighbourhood constitute spatial focal points within the existing settlement pattern that show high vulnerability to disasters.

When the city's transportation infrastructure is examined, approximately 15% of the urban road network is located within areas at risk in terms of river flooding and landslides (Figure 4-5). Among these roads, the Hopa-Artvin Road stands out, as it forms the main transportation backbone of the city. This route is a fundamental and strategic transportation axis that connects the Black Sea Region to Eastern Anatolia and the inland regions and ensures regional transportation continuity in the north-south direction.

When the building stock within the boundaries of planned areas is examined, approximately 37% is found to be located in areas susceptible to river flooding and landslides (Figure 4-5). This indicates that even planned urban development processes have not taken place in full alignment with natural thresholds and hydrological and geomorphological risk areas. This development pattern, concentrated in the Hopa Stream valley and its immediate surroundings, especially in low-elevation areas, shows that urban growth has spatially expanded towards river corridors.

On the other hand, the expansion of the same development pattern towards valley slopes and inclined topographic units also creates a significant risk area in terms of landslide susceptibility. In this context, the orientation of urban development towards steep slope areas in the vertical dimension increases building density in areas that are vulnerable in terms of ground stability. Accordingly, residential areas, transportation links, and technical infrastructure systems show a higher level of vulnerability to river flooding and landslide processes.

The relationship between critical urban uses and risk areas shows that climate risk is directly related to the continuity of daily life and public services. In the impact areas around Hopa Stream, public and economic functions are located alongside residential and commercial areas. These include Artvin Çoruh University Hopa Faculty of Economics and Administrative Sciences, Hopa Vocational School, Hopa Bus Terminal, Hopa District Stadium, Hopa State Hospital, and the industrial site.

Similarly, the concentration of a significant share of technical infrastructure components around the Hopa Stream valley, such as energy transmission lines, transformer points, the sewerage network, and the water transmission line, places infrastructure continuity at the centre of the risk assessment. Therefore, the main problem addressed by SAFE-HOPA Phase 2 is the following question: "Which hazards turn which urban and institutional functions into an operational crisis, through which access thresholds and which infrastructure systems?"

When the spatial distribution of urban technical infrastructure components, such as energy transmission lines, transformer points, the sewerage network, and the water transmission line, is examined, these elements largely show a site selection pattern associated with urban development areas, main transportation axes, and natural thresholds. This indicates that technical infrastructure systems are spatially organized by taking both accessibility and settlement density into account.

A significant share of these infrastructure components is found to be concentrated around the Hopa Stream valley. In this context, Kars Street, located east of Hopa Stream, and Kilise Deresi and its immediate surroundings, located to the west, stand out as important concentration areas. Similarly, within the boundaries of Sundura Neighbourhood, infrastructure elements are also concentrated especially along Lise Street and Taşköprü Street. The overlap of these areas with zones of high river flooding susceptibility increases the exposure level of the relevant technical infrastructure lines to disaster risk. Therefore, this situation creates an important area of vulnerability in terms of the possible interruption of infrastructure service continuity during disasters.

In this context, the assessment was addressed within a cross-sectoral framework that includes municipal infrastructure, the transportation backbone, temporary shelter areas, access to healthcare, disaster coordination capacity, heavy vehicle and logistics mobility, and the safe evacuation of vulnerable groups.

The SAFE-HOPA project is aligned at the national scale with the framework of the Türkiye Disaster Response Plan regarding response organization, evacuation, emergency areas, transportation continuity, alternative routes, and equipment logistics. At the provincial scale, it is aligned with the objectives of the Artvin Provincial Disaster Risk Reduction Plan on reducing disaster risks, considering disaster risks in infrastructure investments, strengthening inter-institutional coordination, and prioritizing the protection of critical groups. In this respect, SAFE-HOPA is a local decision-support study that translates the national and provincial disaster management objectives defined in TAMP and İRAP into the local context of Hopa's topography, river flooding and landslide susceptibility, transportation network, temporary shelter areas, access to healthcare services, and vulnerable groups.

The relationship between Hopa Municipality and AFAD within the project is established around disaster risk reduction, data sharing, local response capacity, and inter-institutional coordination. In SAFE-HOPA, disaster data provided by AFAD, the risk reduction approach, and the provincial disaster management framework are considered among the important inputs of local analyses. Hopa Municipality is positioned as the local implementing institution that can transfer these data and the maps, routes, EOC outputs, and equipment site selection outputs produced within the project into the municipality's disaster preparedness, local planning, evacuation, and response processes. This relationship aims to ensure that the SAFE-HOPA outputs are used in alignment with AFAD's provincial risk reduction and response planning processes.

2.1.3 Participation and risk ownership

The participation and risk ownership structure in Phase 2 was established around the role of Hopa Municipality as the local implementing and coordinating institution. Linking the project outputs with disaster management, transportation, infrastructure, zoning, and institutional planning processes was considered a primary responsibility of the municipality. The academic team produced the scientific and technical framework for the alternative route analyses, EOC site selection, meteorological assessment, and spatial data analyses. The technical team contributed to GIS, data processing, mapping, and reporting processes.

Participation operated at three levels. The first level consisted of project coordination and data compilation led by the municipality. The second level involved modelling and assessment carried out by the academic and technical teams. The third level included data, information-sharing, and decision-support relations established with the Governorship, District Governorship, AFAD, and the Turkish State Meteorological Service (Figure 2). This structure shows that risk ownership was coordinated by distinguishing between analytical responsibility and implementation responsibility.

In terms of priority groups, particular attention was given to neighbourhood headmen, the Hopa Association of People with Physical Disabilities, groups requiring uninterrupted access to healthcare services, and communities living in areas with high river flooding and landslide susceptibility. In the meeting held with the Hopa Association of People with Physical Disabilities, the need for safe evacuation, accessible temporary sheltering, access to emergency support services, and regular updating of vulnerability data was emphasized. For this reason, the dimensions of post-disaster access, evacuation, sheltering, and access to healthcare services were also made part of this structure.

Although a formal local threshold set for acceptable risk has not been defined in the documents, the direct exclusion of high-risk areas through a veto principle, especially in EOC site selection, shows that the local decision-making logic effectively adopts a low-tolerance and precautionary risk approach.

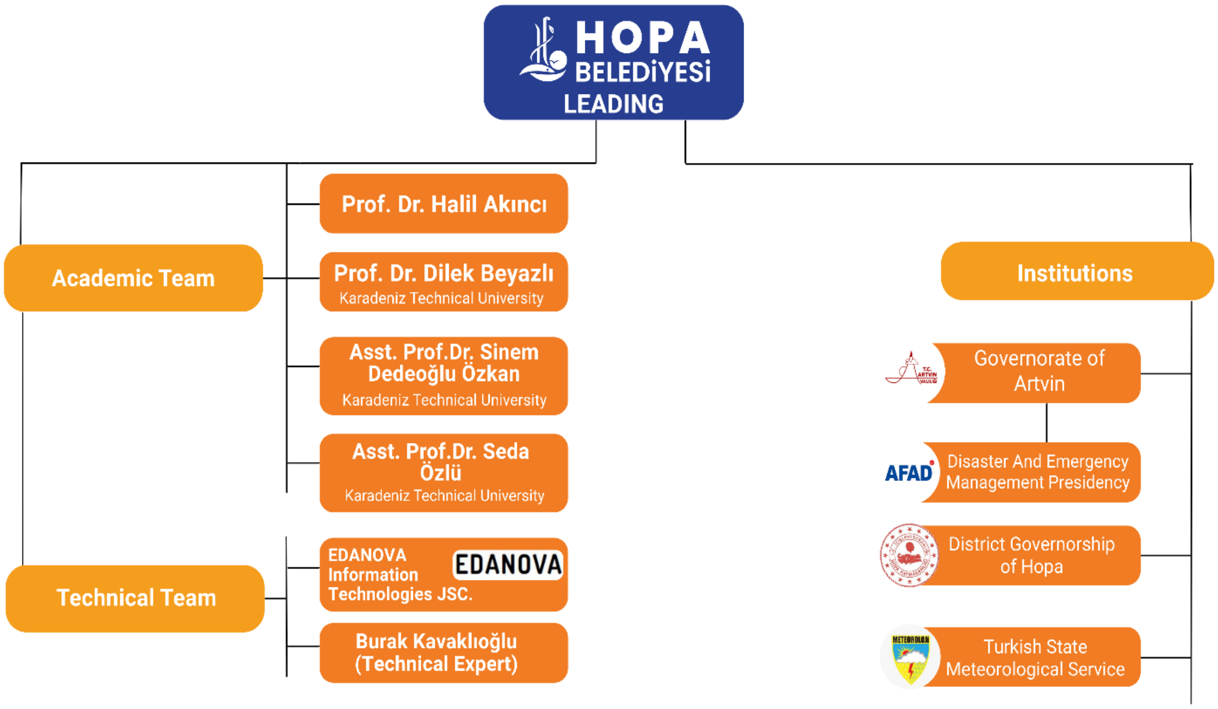

Figure 2 Organigram of SAFE-HOPA project

2.1.4 Application of principles

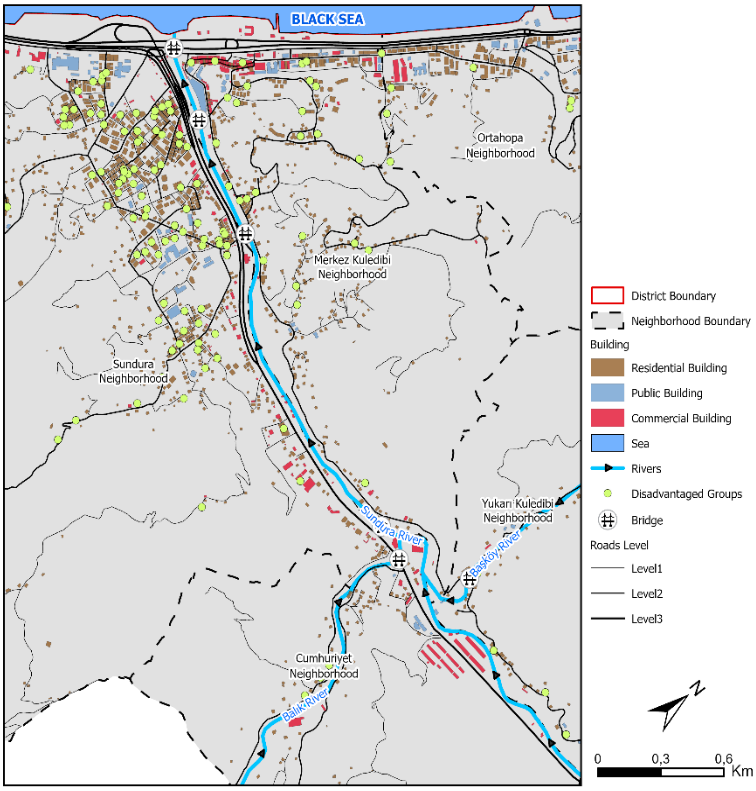

Figure 3 Phase 1 Disadvanteged Groups map

The principles of social justice, equity, and inclusiveness were concretized in Phase 2, particularly through safe access and rapid evacuation for vulnerable groups (Figure 3). In this context, the alternative routes were planned in terms of their location and cross-section to enable the rapid and safe evacuation of vulnerable groups living in Sundura neighbourhood, which is considered likely to be significantly affected by potential disasters. For this reason, alternative routes, temporary sheltering, access to healthcare services, and data updating requirements were assessed as matters of social justice.The principles of quality, scientific rigour, and transparency were ensured by reporting the datasets used and the decisions related to the models in a traceable manner. In the alternative route analysis, the existing road network, elevation, slope, river flooding and landslide susceptibility, building data, and zoning block data were clearly defined. The cost surface, cost distance, and final route generation steps of the Cost Path analysis were also detailed.

The algorithms used for landslide susceptibility, conditioning parameters, the 12 criteria used in EOC site selection, the AHP process involving 18 experts, the consistency ratio, and sub-criterion scores were presented systematically in the documents. The same approach was applied to the heavy vehicle and logistics area through the vehicle inventory, functional zoning, and technical safety distances. This transparency enables the output to meet the required level of detail, so that a reader can understand the assessment even without prior knowledge of the region or the datasets.

The precautionary approach was applied especially in site selection and route selection by excluding risks that could not be compensated for. The EOC site selection framework clearly argues that advantages such as high accessibility or low cost cannot make an area acceptable if it is exposed to river flooding, landslide, or secondary disaster risk. Accordingly, the vetoing of risky areas is made the first step. In this way, Phase 2 is based on consistently eliminating unsuitable areas.

2.1.5 Stakeholder engagement

In Phase 2, stakeholder engagement was carried out through technical meetings, institutional briefings, and consultations that linked local field knowledge with project outputs. The meeting held with the Deputy Governor of Artvin showed that SAFE-HOPA outputs could be used in decision-making processes at the provincial scale, especially in relation to the problematic areas around

Hopa State Hospital and discussions on possible additional building. The meeting held with the District Governor of Hopa emphasized the importance of alternative routes for access towards Artvin. It also showed that calculations of route length and estimated travel time would increase the decision-support value of the analysis.

Representatives of Sundura and Ortahopa neighbourhoods provided micro-level information on river flooding, drainage, road inundation, culvert maintenance, and landslides at the local scale. The Hopa Association of People with Physical Disabilities highlighted the need to keep vulnerable group data up to date and to ensure accessible evacuation. This feedback enabled the cross-checking of risk maps, route plans, and response priorities with field experience.

Technical meetings formed the more expertise-based dimension of stakeholder engagement. In the meeting held with the technical and academic teams on analysis models, the full integration of zoning plan data into the system, the consideration of zoning roads that are defined in the plan but not yet opened in practice, the prioritization of collector roads that function as the main backbone, and the inclusion of zoning blocks in Scenario 9 were discussed.

In the alternative route planning meeting, disaster-time speed assumptions, the slope limit, the Yanmış Köprü and Terzioğlu connection, the Health Center route, and the need to retain two different alternatives were discussed. In the site selection criteria meeting, the 12-criterion EOC analysis, raster scoring, nodata logic, geological veto areas, and the segmentation process were evaluated. In the site identification meeting, the 8-minute service areas of candidate sites, municipal ownership, scalability, proximity to the water tank, a second parking area for the Sundura side, and logistics requirements were clarified.

For this reason, stakeholder engagement became a decisive component of the Phase 2 process for defining models, screening alternatives, and producing implementable decisions.

2.2 Risk Exploration

2.2.2 Screen risks (selection of main hazards)

The main climate-related hazards screened in Phase 2 represent a continuation of the framework defined in Phase 1. In this phase, the local spatial, operational, and institutional impacts of the hazards were examined in much greater detail. The alternative route report shows that Hopa has high susceptibility to floods, river flooding, and landslides due to its high precipitation regime, mountainous and rugged topography, and geomorphological structure. It also shows that these events make disaster management operations more difficult by interrupting the main road providing access to Artvin and the connections between settlement areas.

In terms of the current situation, the concentration of areas with high river flooding and landslide susceptibility around Hopa Stream and Sundura Neighbourhood makes this area the most visible urban risk focus. The western coastal parts of the city, the Hopa–Artvin Highway, and the surroundings of the Black Sea Coastal Road are also among the areas where these risk zones become evident. The urban dimension of the problem becomes clearer through the overlap between critical land uses and risk areas. These uses include the university, hospital, stadium, bus terminal, industrial site, residential areas, and commercial areas. It is also evident in the concentration of technical infrastructure lines around the Hopa Stream valley. For this reason, the focus in Phase 2 is to screen hazards as urban system vulnerabilities that generate multiple risks.

Within this framework, the main risk clusters covered in the Phase 2 climate risk assessment were considered under five headings. The first cluster is the risk of river flooding and flash flooding developing along Hopa Stream and its tributaries. The second cluster is the landslide risk strengthened by steep topography, valley slopes, and the rainy climate. The third cluster is the risk of transportation disruption and weakening of the Artvin connection, which increases when these two hazards occur together. The fourth cluster is the risk that disaster coordination capacity may weaken during a disaster in the absence of a safe center and a reliable service area. The fifth cluster consists of indirect but critical risks related to the continuity of services for vulnerable groups, healthcare services, and technical infrastructure. This risk screening also placed the question “which functions fail first?” at the centre of Phase 2.

Tree-based ensemble learning algorithms, including Random Forest (RF), Gradient Boosting Machine (GBM), CatBoost, LightGBM, and XGBoost (eXtreme Gradient Boosting), were used to produce landslide susceptibility maps for the contiguous area. In the landslide susceptibility analyses, lithology, land cover, elevation, plan and profile curvature, topographic wetness index (TWI), NDVI, slope degree, aspect, distance to drainage networks, and distance to roads were considered as conditioning parameters.

The landslide inventory map produced by the Artvin Provincial Directorate of Disaster and Emergency Management was used to train susceptibility models. The landslide inventory map used in the analysis contains 227 landslide polygons. Of these landslides, 221 occurred on August 24, 2015, as a result of the triggering effect of extreme rainfall.

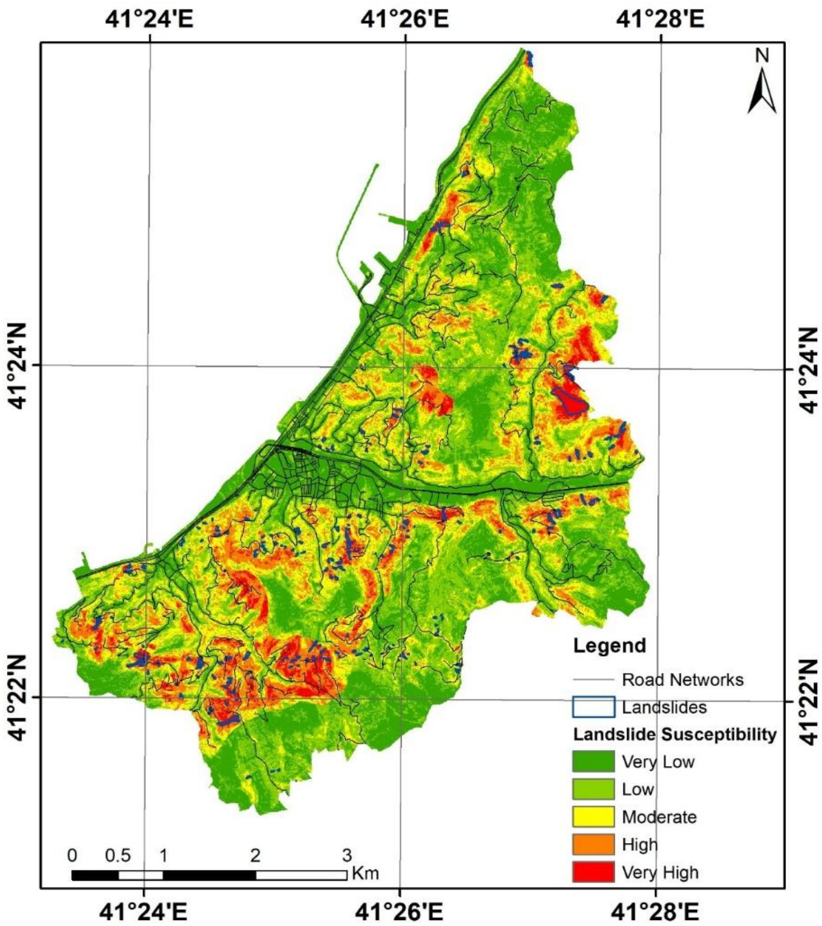

Figure 4 Landslide susceptibility map of the study area

The landslide susceptibility index map produced using the XGBoost algorithm, which showed the best performance with an AUC value of 0.957, was classified into five classes using the natural breaks classification method. These classes were very low, low, moderate, high, and very high. In this way, the landslide susceptibility map of the contiguous area was obtained (Figure 4). According to this map, **31.27%** of the contiguous area **has very low landslide susceptibility**, **31.82% has low susceptibility**, **19.66% has moderate susceptibility**, **13.17% has high susceptibility**, and **4.08% has very high susceptibility**.

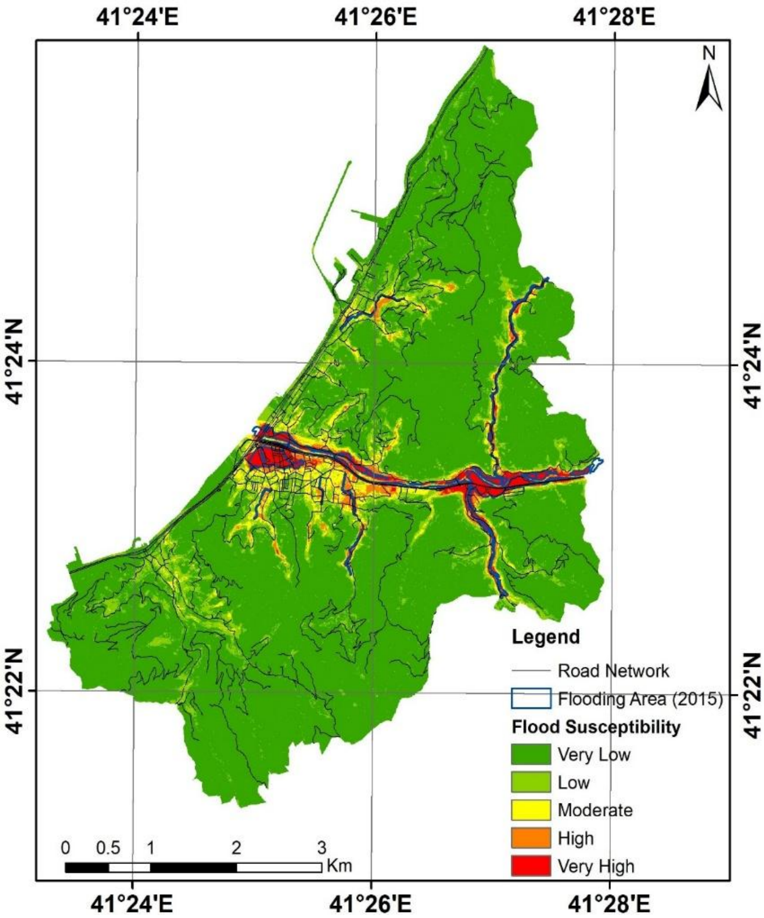

Figure 5 Flood susceptibility map of the study area

As with landslide susceptibility mapping, RF, GBM, CatBoost, LightGBM, and XGBoost algorithms were also used to produce river flooding susceptibility maps. In the river flooding susceptibility analyses, elevation, slope, aspect, plan and profile curvature, land cover, Normalized Difference Vegetation Index (NDVI), distance to rivers, drainage density, Stream Power Index (SPI), topographic wetness index (TWI), and Topographic Position Index (TPI) were used as factors.

The river flooding susceptibility index map produced using the XGBoost algorithm was classified into five classes using the natural breaks classification method. These classes were very low, low, moderate, high, and very high. In this way, the river flooding susceptibility map of the contiguous area was obtained (Figure 5). According to this map, **78.98%** of the contiguous area **has very low river flooding susceptibility**, **11.27% has low susceptibility**, **4.18% has moderate susceptibility**, **2.81% has high susceptibility**, and **2.76% has very high susceptibility**.

According to the Spatial Address Registration System (MAKS) data, there are **2,954 buildings** within the boundaries of the contiguous area. Of these, 360 buildings, corresponding to approximately **12% of the total building stock, are located in areas with high or very high landslide susceptibility**. Similarly, 827 of the existing buildings, corresponding to approximately **28%, are located in areas with high or very high river flooding susceptibility.**

The total length of the road network within the boundaries of the contiguous area is 165,142 m. Approximately 16 km of the road network is located in areas with high or very high landslide susceptibility. A 25.21 km section of the road network, corresponding to approximately 15% of the total road network, is located in areas with high or very high river flooding susceptibility.

The meteorological trend analysis carried out within the scope of Phase 2 (Figures 6-7-8-9) shows that hydrometeorological risks in Hopa are also supported by local climate trends. Monthly average temperature, monthly maximum temperature, monthly total precipitation, and monthly maximum precipitation variables were analysed using 36 years and 432 months of data from the MGM Hopa Meteorological Station for the 1990–2025 period.

Average Temperature: The Mann-Kendall test shows a statistically significant increasing trend in monthly average temperatures in Hopa ($p = 0.0086$). According to the Sen's slope estimator, average temperatures increase by approximately 0.074 °C per year (Figure 6). Over the 36-year period, this increase corresponds to approximately 2.65 °C cumulatively. This value is considerably higher than the global average temperature increase of approximately 1.1 °C and suggests that the region is more affected by climate change than the global average.

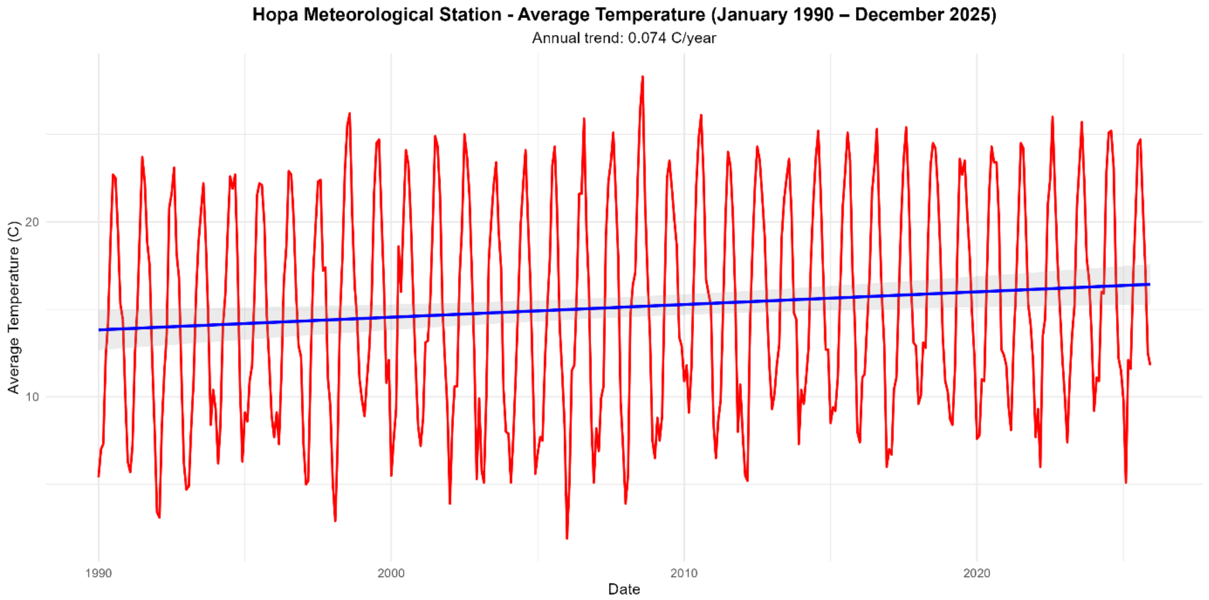

Figure 6 Hopa Meteorological Station – Average Temperature Time Series and Trend Line (1990–2025)

Maximum Temperature: No statistically significant trend was detected in the maximum temperature data (p = 0.9609). Maximum temperatures remained stable at around 27.66 °C on average during the 1990–2025 period, with no clear increase or decrease (Figure 7). This finding is consistent with the literature indicating that temperature increases are more concentrated in minimum and average temperatures, especially night-time and winter temperatures.

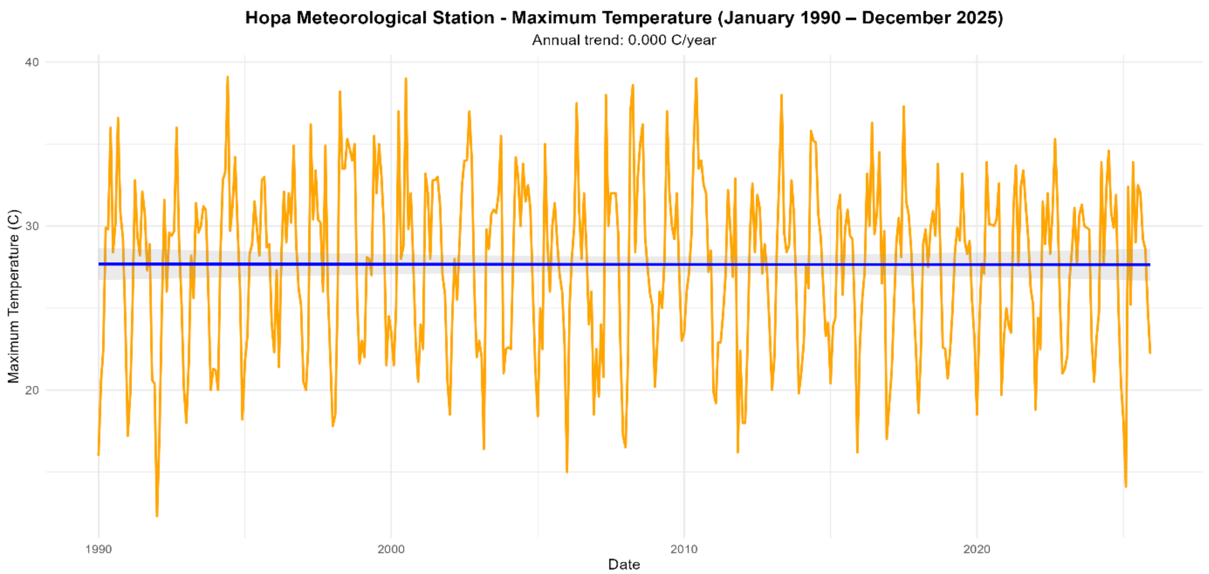

Figure 7 Hopa Meteorological Station – Maximum Temperature Time Series and Trend Line (1990–2025)

Monthly Total Precipitation: The Mann-Kendall test did not indicate a statistically significant trend in the monthly total precipitation data (p = 0.0572). However, the fact that the p-value is very close to the significance threshold (0.05) indicates the presence of a weak increasing trend. According to the Sen's slope estimator, there is an increase of approximately 0.89 mm/year in total annual precipitation (Figure 8). Over the 36-year period, this corresponds to a cumulative increase of approximately 32 mm.

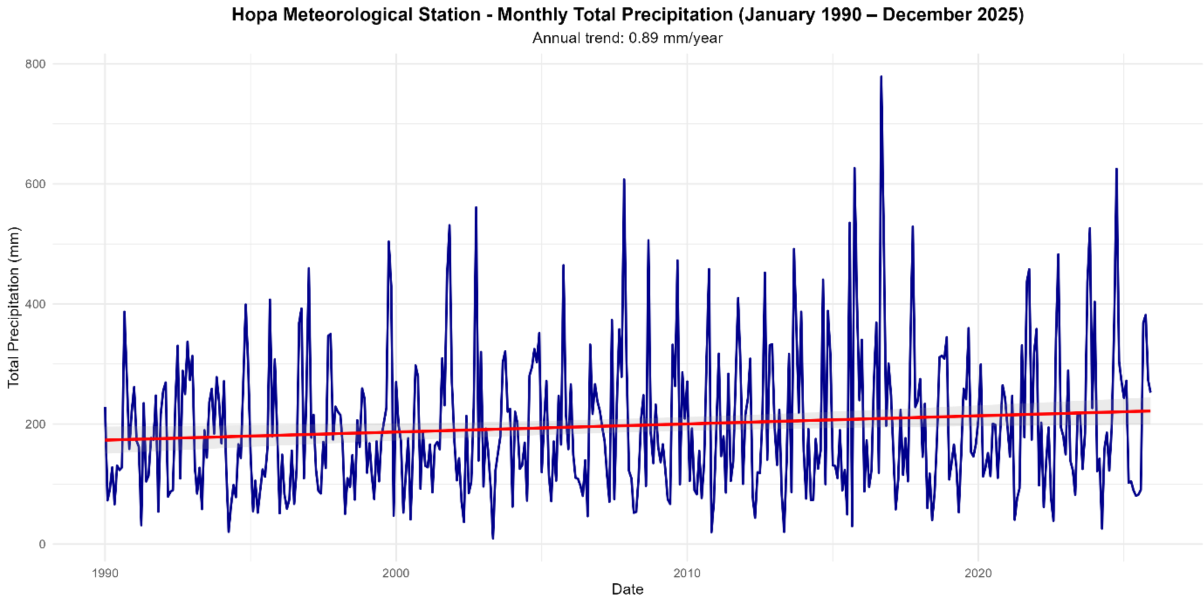

Figure 8 Hopa Meteorological Station – Monthly Total Precipitation Time Series and Trend Line (1990–2025)

Maximum Precipitation (Daily Maximum): A statistically significant increasing trend was detected in the maximum daily precipitation data (p = 0.0460). According to the Sen's slope estimator, monthly maximum precipitation values increase by approximately 0.24 mm per year (Figure 9). This finding is highly important because it indicates an increase over time in the intensity of extreme precipitation events. The fact that this variable, which is critical for floods and river flooding, shows a trend indicates that hydrometeorological disaster risks are increasing in the region.

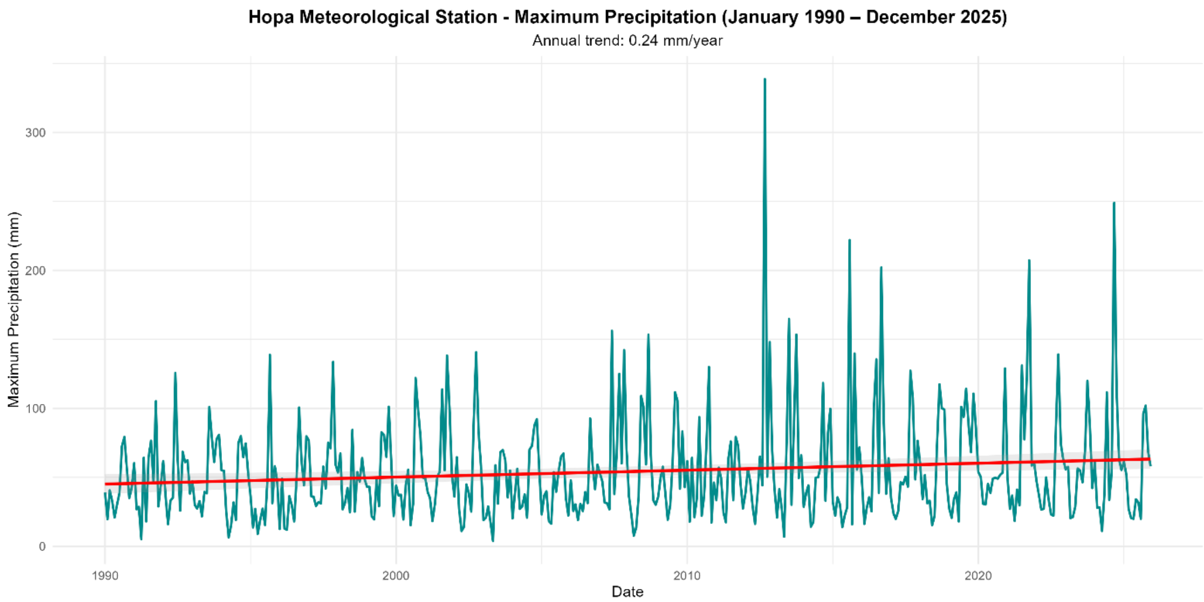

Figure 9 Hopa Meteorological Station – Maximum Precipitation Time Series and Trend Line (1990–2025)

In Phase 1, this disaster was assessed together with river flooding extent areas, disaster points, temporary shelter areas, critical infrastructure, and vulnerable groups. During the 2015 disaster, extreme rainfall occurring within a very short period caused deaths, missing people, damage to housing and infrastructure, economic losses, and transportation disruptions. This event shows that intense rainfall in Hopa represents a systemic risk that creates cascading impacts on river flooding, landslides, transportation disruption, shelter needs, access to healthcare services, and disaster response capacity.

Compared with Phase 1, the risk screening step in Phase 2 moved beyond the general identification of river flooding and heavy rainfall risks. It enabled a more local and multi-hazard-oriented interpretation of Hopa's climate risk profile. The additional analyses carried out in this phase show that the dominant climate-related risk in Hopa results from the interaction between heavy rainfall, river flooding susceptibility, landslide susceptibility, road accessibility constraints, and the operational continuity of emergency response systems.

The site selection criteria maps prepared within the scope of emergency operations center planning provide a spatial basis for this refined risk screening. **Figure 10a** shows that **river flooding susceptibility** is mainly concentrated in low-elevation valley corridors, urban interfaces associated with river systems, and areas around transportation axes. Although large areas within the municipal boundaries appear to have very low river flooding susceptibility, the overlap between areas of increasing river flooding susceptibility and settlement, infrastructure, and mobility corridors makes river flooding a high-priority risk for Hopa. This priority is also related to the fact that exposed elements include roads, bridges, public services, neighbourhood connections, and potential disaster logistics routes.

Figure 10b shows that **landslide susceptibility** has a more widespread and fragmented spatial distribution compared with river flooding susceptibility. Areas with high landslide susceptibility are concentrated especially in slope areas and topographically fragmented zones where steep topography intersects with settlement expansion, road cuts, and access routes. This result confirms that landslide risk should not be treated as a secondary or indirect consequence of heavy rainfall. In Hopa's local context, landslides are assessed as one of the main hazards because they can block road sections, isolate neighbourhoods, delay emergency response, damage infrastructure, and create cascading impacts during or immediately after extreme rainfall.

The distance-to-roads map in **Figure 10c** adds an **operational dimension to the risk screening**. This map shows that accessibility is both an element of exposure and a condition of resilience capacity. Areas close to the road network have strategic importance for emergency response, evacuation, logistics, and service delivery. However, in Hopa, these routes often follow narrow valley floors and topographically constrained corridors. This makes these roads vulnerable to river flooding and landslide processes. Therefore, road accessibility was assessed as a vulnerability line with the potential to generate cascading risks. This finding directly supports the need to reduce dependence on a limited number of transportation corridors and to strengthen alternative route planning under disaster conditions.

The geology/lithology map in **Figure 10d** was used to interpret ground conditions and site safety in relation to critical emergency infrastructure. The map distinguishes different soil classes and helps assess which areas are more or less suitable in geotechnical terms for emergency coordination functions. Within this screening, geology/lithology was used as a susceptibility and suitability criterion that affects the possible consequences of river flooding, landslides, and infrastructure disruptions. Safe ground conditions were considered a fundamental requirement, especially for facilities that must remain operational during and after disasters.

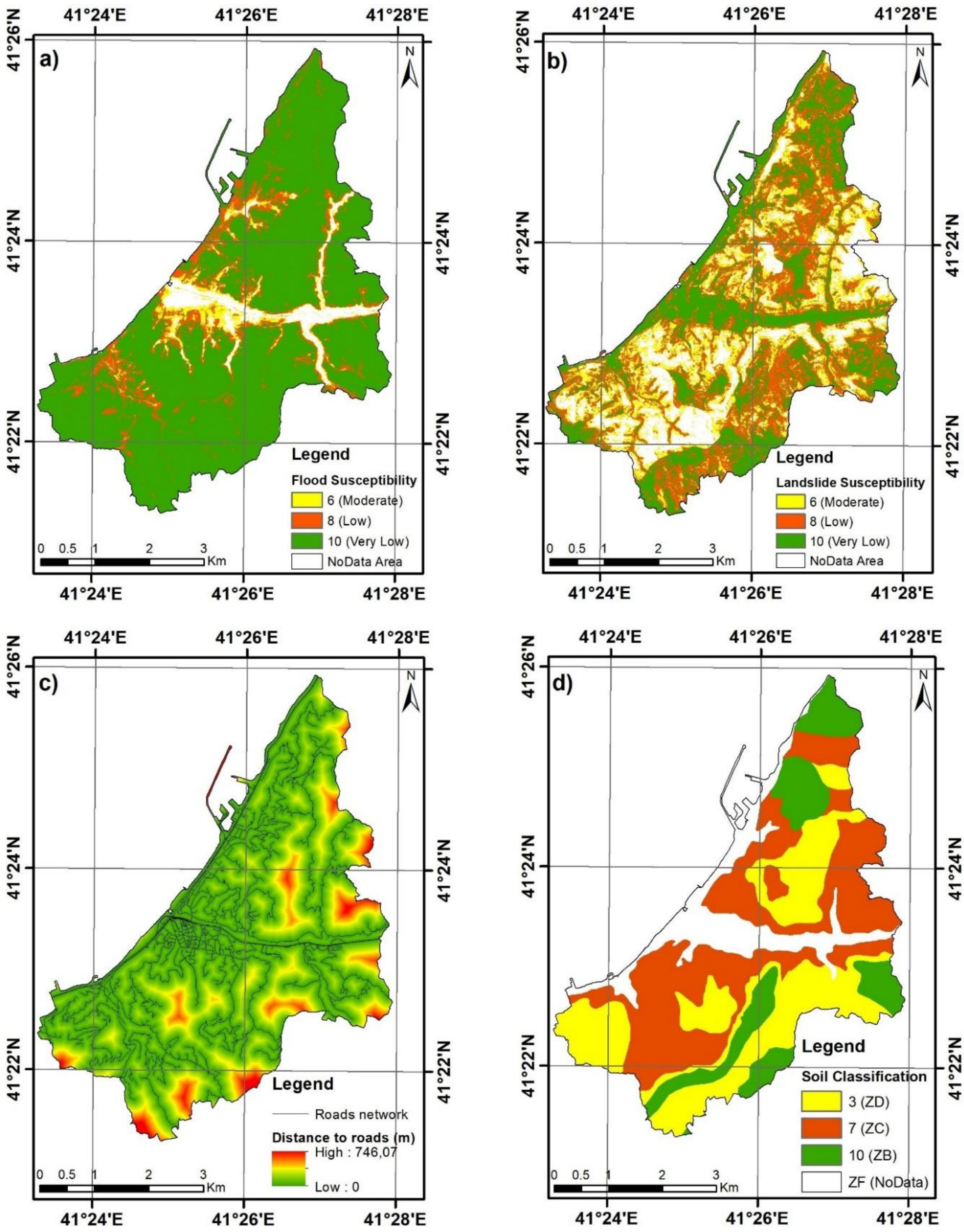

Figure 10 Site selection criteria maps: a) flood susceptibility, b) landslide susceptibility, c) distance to roads, d) geology/lithology (soil class)

The existing knowledge base on these hazards and risks was strengthened through the river flooding, heavy rainfall, and vulnerability layers developed in the previous phase, as well as the local modelling outputs produced by the academic and technical teams in Phase 2. The academic team produced a spatial risk assessment specific to the Hopa scale by jointly evaluating river flooding and landslide susceptibility, distance to roads, geology/lithology, the existing road network, building data, zoning blocks, bridge crossings, temporary shelter areas, and critical infrastructure information.

In this process, a GIS-based analysis infrastructure, Cost Path analyses in the ArcGIS environment, a multi-criteria decision-making approach, AHP assessment, meteorological time series analyses, and high-resolution thematic map production processes were used. In this way, the risk screening also made visible the impacts of these hazards on transportation continuity, disaster logistics, EOC site selection, and response capacity.

2.2.3 Choose Scenario

In the second phase of the SAFE-HOPA project, scenario selection was carried out by considering Hopa’s existing disaster experiences, local hazard conditions, urban exposure structure, and climate conditions expected to change in the future.

The main future climate conditions considered for Hopa aim to understand the future change in river flooding and heavy rainfall risks. In the river flood assessment used within the CLIMAAX approach, historical river flood depth maps provided by JRC and return periods of 10–500 years were taken into account. In addition, RCP4.5 and RCP8.5 scenarios obtained from the Aqueduct Floods dataset were evaluated for the 2030, 2050, and 2080 time horizons. While RCP4.5 represents a more moderate climate change condition, RCP8.5 was used to understand the risks that may occur under higher emissions and more severe climate pressure. Therefore, scenario selection in Hopa was based on the joint assessment of both existing climate risk and river flooding and extreme rainfall conditions that may become more severe in the future.

The disaster of 24 August 2015 was considered an important reference event in scenario selection. As one of the most destructive disaster experiences for Hopa, this event showed how extreme rainfall can create cascading impacts in a short time on river flooding, landslides, transportation disruption, infrastructure damage, loss of life, and response capacity. For this reason, the 2015 disaster was used as a learning scenario to understand the impacts of similar or more severe climate conditions that may recur in Hopa in the future on the urban system. In addition, the heavy rainfall events experienced in 2024 were also evaluated as recent indicators supporting the current importance of heavy rainfall and river flooding risk in Hopa.

In terms of future socio-economic developments, an independent and quantitative projection of population, economic growth, or food prices was not produced in this phase. Instead, Hopa’s existing socio-economic and spatial vulnerabilities were included in the scenario framework. In this context, the existing building stock, road network, temporary shelter areas, healthcare facilities, critical infrastructure lines, neighbourhood connections, vulnerable groups, rural livelihoods based on agriculture and livestock, and settlement pressure around Sundura Stream were taken into account. In this way, the socio-economic scenario was addressed as a local vulnerability framework showing how existing urban and social exposure may be affected under disaster conditions.

Climate conditions and socio-economic conditions were assessed together within the GIS-based risk assessment process. River flooding and landslide susceptibility maps were overlaid with the road network, building data, zoning blocks, bridge crossings, temporary shelter areas, healthcare facilities, infrastructure lines, and critical institutional locations. This method aimed to show which urban and operational consequences these hazards may cause during a disaster in Hopa. Therefore, scenario selection is based on an integrated approach that links hazard maps with decisions on transportation continuity, evacuation, aid dispatch, EOC accessibility, equipment parking areas, and disaster logistics.

Within this scope, two types of scenario logic were used together. The first is the assessment of future river flooding conditions based on RCP4.5 and RCP8.5 climate scenarios and the 2030, 2050, and 2080 time horizons within the CLIMAAX river flood workflow. The second consists of operational scenarios addressing Hopa's local disaster management needs. In the alternative route study, situations such as the interruption of the Artvin connection during a disaster, the inability to use bridge crossings, existing roads passing through risk areas, overlaps with buildings and zoning blocks, and insufficient road widths in terms of response capacity were tested through 10 different Cost Path scenarios. As a result of these scenarios, the aim was to identify safer, more applicable, and higher-capacity alternative routes that can be used during disasters.

As a result, the Choose Scenario step in SAFE-HOPA was structured to understand how different climate conditions and existing socio-spatial vulnerabilities are reflected in disaster management decisions. The selected scenario approach evaluates RCP4.5 and RCP8.5 climate scenarios and the 2030, 2050, and 2080 time horizons together with the 2015 disaster experience, existing urban exposure, vulnerable groups, transportation disruption, EOC site selection, alternative routes, and disaster logistics decisions. Therefore, this section shows that climate risk in Hopa is addressed as an integrated urban resilience issue that creates cascading impacts.

2.3 Regionalized Risk Analysis

In adherence to the methodologies outlined in the CLIMAAX Handbook, a comprehensive risk analysis was conducted to demonstrate the river flood risks in the Hopa district within a spatial dimension. In this process, hazard factors, exposure status of assets, and social vulnerability data were integrated and mapped using geographic information systems. All primary datasets utilized in the study were selected and processed to be fully compliant with the technical standards and framework specified in the CLIMAAX Handbook.

Risk assessment elements: The following core attributes were systematically analyzed:

Hazard Assessment:

River flood hazard was assessed using historical river flood depth maps from the Joint Research Centre (JRC), covering return periods of 10 to 500 years. Additionally, future climate-based flood projections from the Aqueduct Floods dataset (RCP4.5 and RCP8.5 scenarios for 2030, 2050, and 2080) were used to understand potential shifts in hazard severity.

Exposure Assessment:

The exposure layer included detailed land use data (residential, agricultural, industrial), with a specific focus on flood-prone infrastructure zones in Hopa such as the city hospital, coastal strip, and peri-urban agricultural lands. The economic value of different land use types was integrated using country-specific valuation tables.

Vulnerability Assessment:

Vulnerability was assessed through demographic and socio-economic indicators, focusing on vulnerable population groups such as the elderly, children, people with disabilities, and low-income households. Rural households dependent on agriculture and livestock, especially along Sundura

Stream, were also considered due to their increased exposure to economic disruption and land degradation

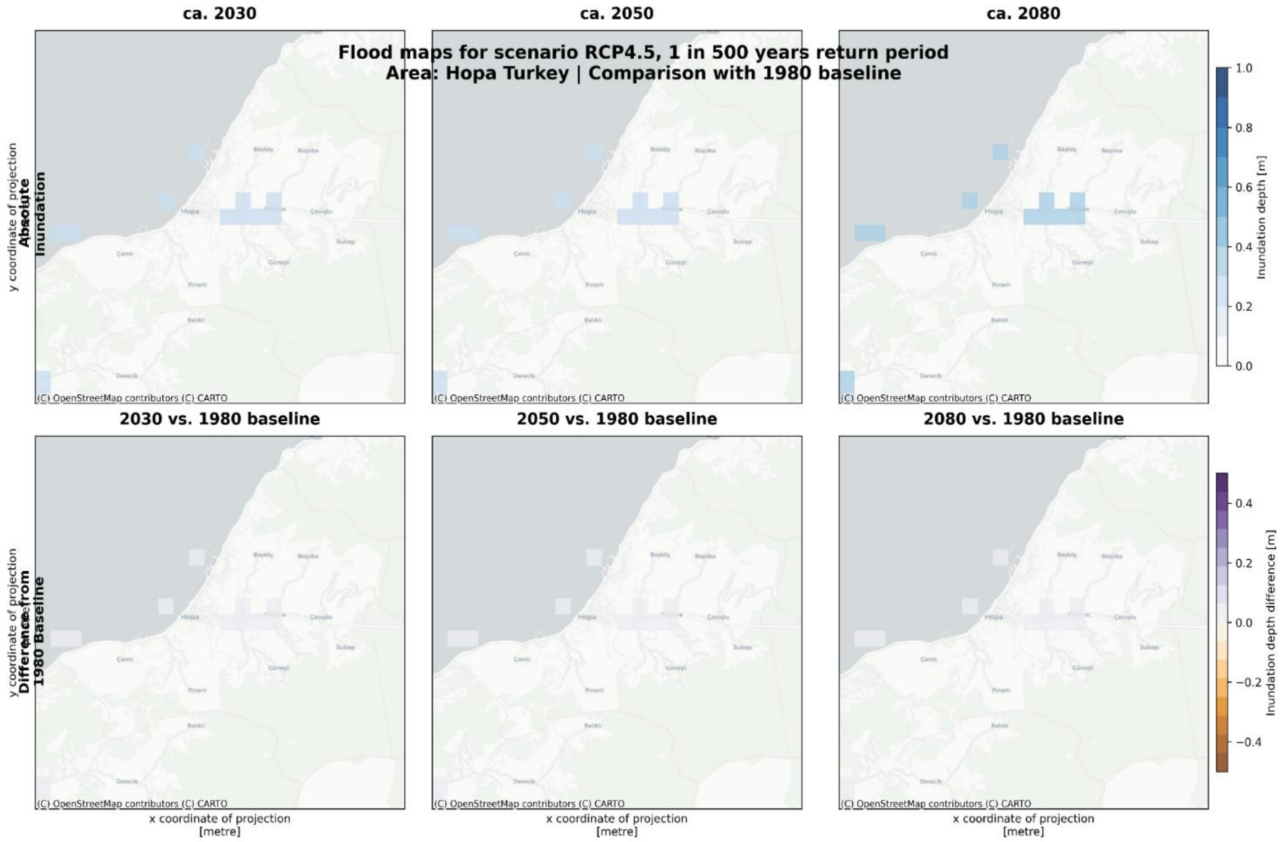

Figure 11 Flood maps for scenario RCP4.5, 1 in 500 years return period

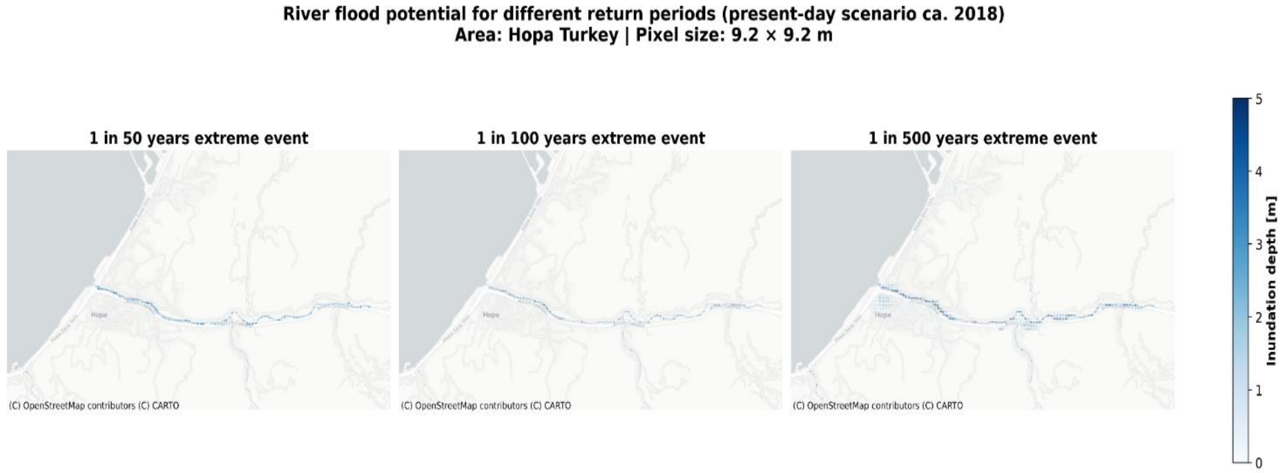

Figure 12 River flood potential for different return periods (Pixel size 9.2 x 9.2 m)

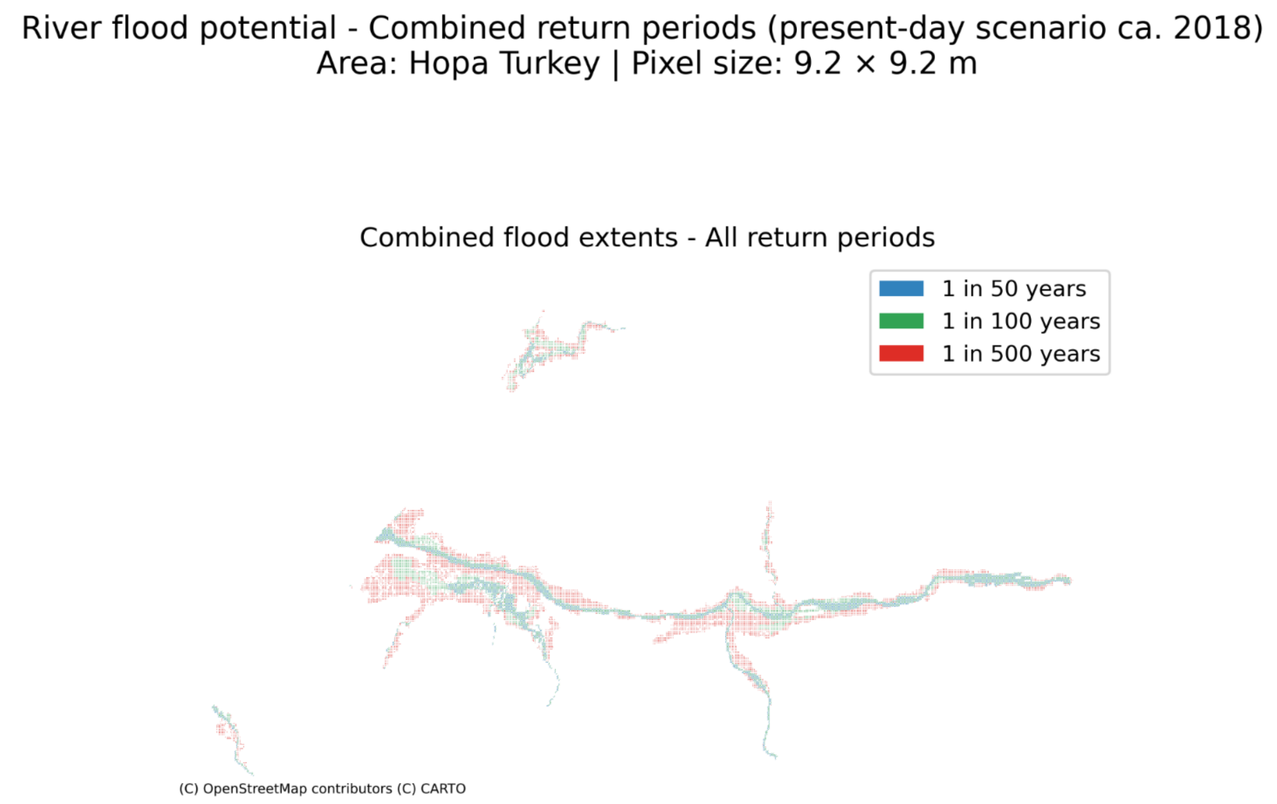

Figure 13 River flood potential - Combined return periods (Pixel size 9.2 x 9.2 m)

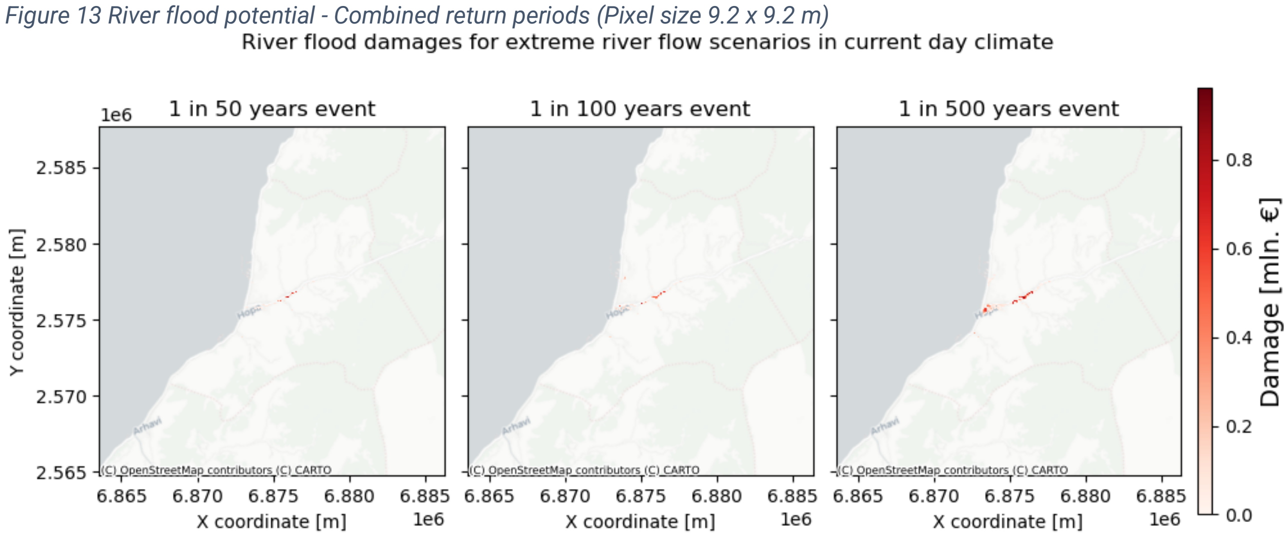

Figure 14 River flood damages for extreme river flow scenarios in current day climate

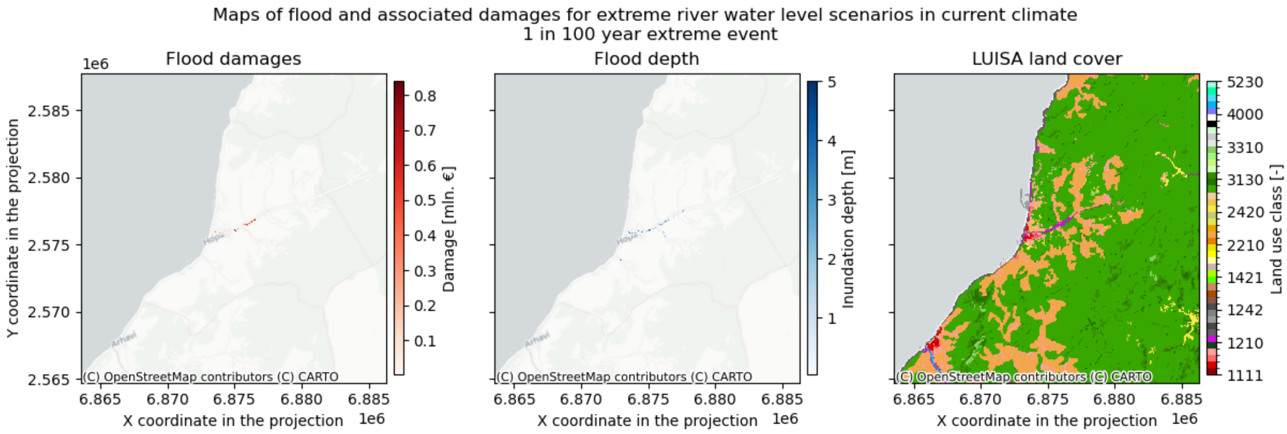

Figure 15 Maps of flood associated damages for extreme river water level scenarios in current climate

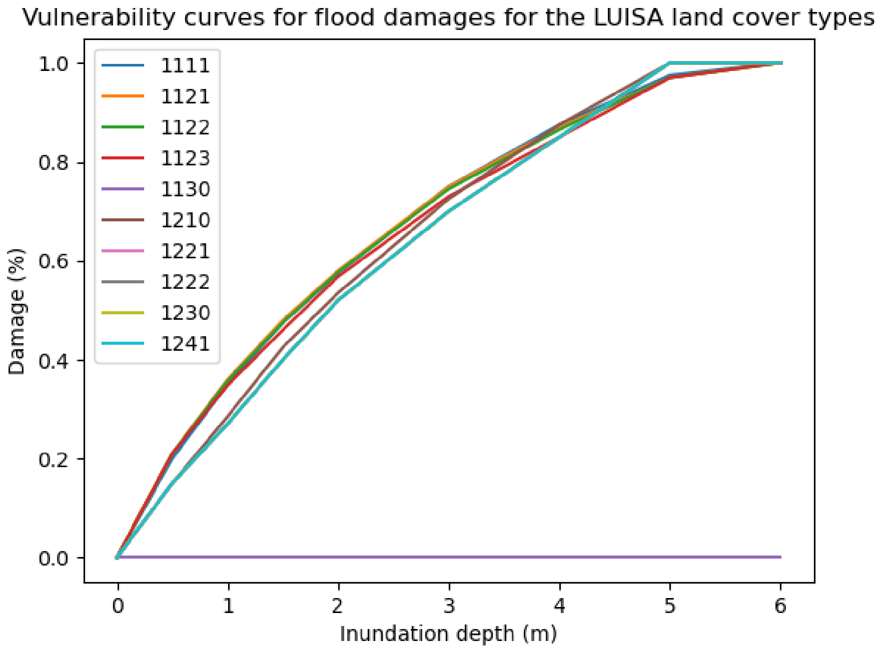

Figure 16 Vulnerability curves for flood damages for the LUISA land cover types

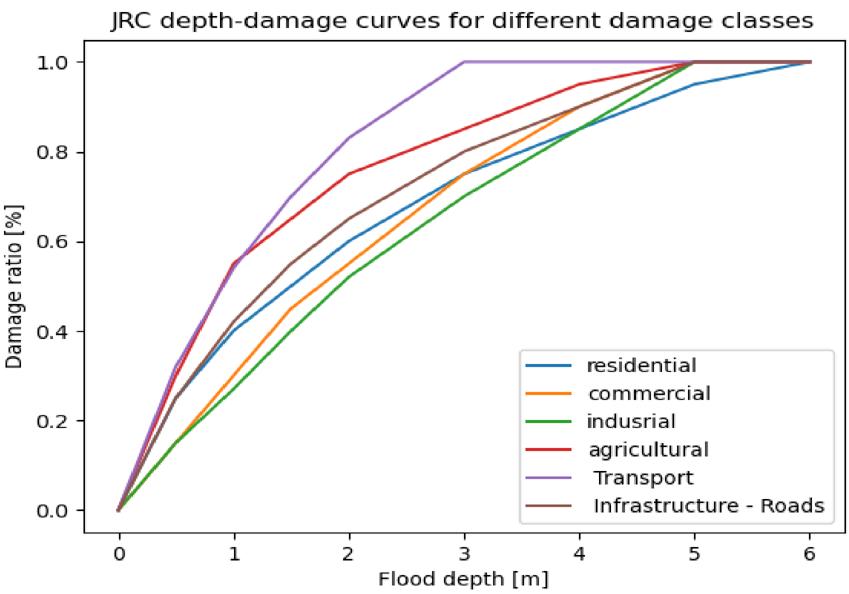

Figure 17 JRC depth - damage curves for different damage classes

2.3.1 Hazard #1 River Floods Risk Management

Centered on the Hopa district, this workflow evaluates riverine flood risks by specifically targeting zones highly exposed due to extreme rainfall events, unmanaged urban expansion, and infrastructural deficits. The region's acute vulnerability to flooding is historically underscored by catastrophic events, most notably the severe deluge of August 24, 2015. Key high-exposure corridors identified within this assessment encompass the Ortahopa and Sundura Streams, the urban center, the local industrial zone, the coastal settlements, and the immediate vicinity of Hopa City Hospital

Table 1 Data overview workflow #1 river floods

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Historical river flood maps (JRC; 10–500 yr return)	Flood depth-damage curves (JRC)	Land use (LUISA), Economic value of land use (country-specific)	Spatial economic flood damage estimates (€/km²) for various return periods
Future river flood maps (Aqueduct; RCP4.5 & RCP8.5)	…		Comparative analysis of flood risk change under climate scenarios (2030, 2050, 2080)

2.3.1.1 Hazard assessment

Key findings include:

- High-resolution flood maps indicate considerable flood exposure along the Sundura stream.
- Frequent inundation zones are concentrated in the Sundura and Ortahopa neighbourhoods, aligning with historical flood events.
- Flood depths increase substantially with higher return periods (≥100 years), especially in low-lying agricultural areas.
- The Aqueduct scenario-based projections suggest that under RCP8.5, flood depth and extent are likely to intensify by 2050 and 2080, particularly in the central parts of the region.
- Hazard maps do not account for existing flood protection infrastructure, requiring local interpretation.

2.3.1.2 Risk assessment

By integrating hazard, vulnerability, and exposure datasets, a comprehensive risk map for the Hopa district has been developed. The workflow identifies both spatial hotspots of economic damage and vulnerable populations disproportionately affected by floods.

Interpretation of Flood Risk Zones:

- **High-Risk Zones (Category 4–5):**
    - Include Sundura and Ortahopa neighbourhoods, the former municipal square, the hospital surroundings, industrial and old truck parking area.
    - These zones combine high flood exposure with vulnerable infrastructure, dense population, and low adaptive capacity.
- ***Moderate Risk (Category 3):***
    - *Found in peri-urban agricultural zones, especially along the Sundura Stream. These areas support livestock and small-scale tea farming vulnerable to crop loss and economic disruption.*
- ***Lower Risk (Categories 1–2):***
    - *Represent higher elevation residential areas with better-built structures and relatively reduced flood exposure*

2.3.2 Hazard #2: Heavy Rain Risk Management

Table 2 Data overview workflow #2 heavy rain

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
CHIRPS (Climate Hazards Center InfraRed Precipitation with Station data) Monthly Cumulative Precipitation 5 km resolution 1981 - 2026	…		
Rainfall intensities by duration and return period (e.g. 1h, 3h, 6h events)	…		

2.3.2.1 Hazard assessment

Key Technical Findings:

- A 46-year observational CHIRPS baseline (1981–2026) was statistically coupled with downscaled MOHC-HadGEM2-ES / CLMcom-CCLM4-8-17 regional climate model projections (2041–2070, RCP8.5) via the Delta Change Method, exhibiting a robust fit to a heavy-tailed Fréchet (GEV Type II) distribution.
- Transferring the model's climate change signal onto historical extremes reveals a thermodynamic intensification in monthly maximum precipitation depths, scaling from a

12.5% increase for 2-year return levels (425 mm → 478 mm) to a 28.5% increase for the 100-year design threshold (920 mm → 1180 mm).

- Spatial projection modeling indicates a spatially homogeneous 18% relative increase in 10-year return period rainfall across the basin, shifting historical all-time monthly anomalies (~589 mm) into decadal baseline flood drivers.
- Orographic forcing of Black Sea moisture masses against the Sundura basin's steep topography accelerates runoff concentration times, driven by Clausius-Clapeyron thermodynamic scaling of atmospheric water vapor holding capacity.
- Simulated hydro-climatic loads systematically surpass existing urban drainage capacities and riverbed conveyance limits, mandating the formal adoption of a 20% to 30% "Climate Change Safety Margin" in future civil engineering designs.

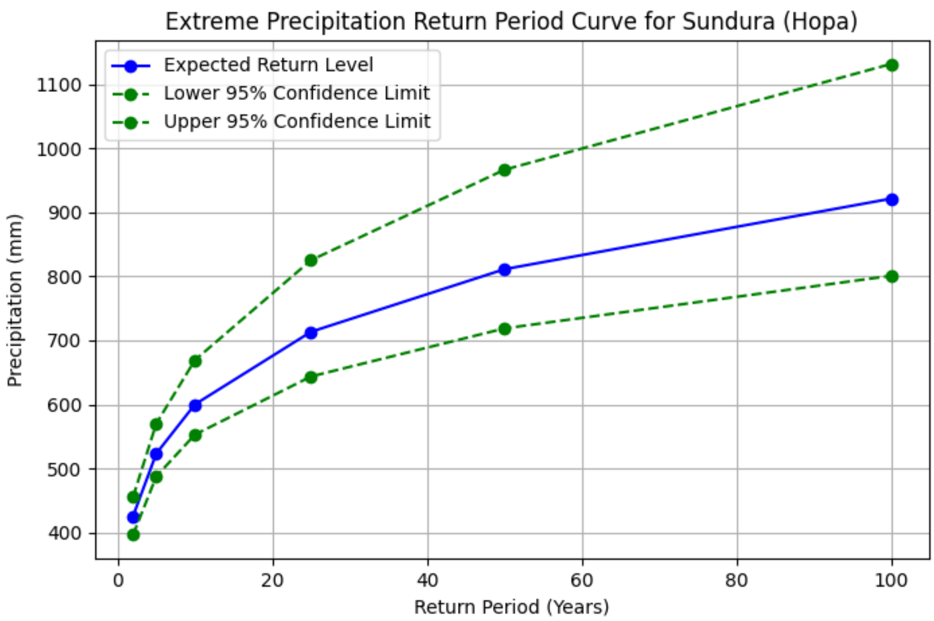

Figure 18 Extreme Precipitation Return Period Curve for Sundura (Hopa)

This analysis utilizes a 46-year historical dataset from the Hopa (Sundura) basin to determine the return periods of potential extreme monthly precipitation events and their associated uncertainty bounds via the Generalized Extreme Value (GEV) model. The fan-like widening of the green confidence intervals across extended return periods demonstrates that statistical uncertainty escalates substantially during extrapolation beyond the observational baseline, indicating that the expected 100-year extreme precipitation level of **920 mm** could reach up to **1130 mm** under a worst-case scenario. Furthermore, the fact that the maximum empirically recorded event—**777 mm** in October 2024—corresponds precisely to a 40-to-45-year return period confirms the high fidelity of the mathematical model with regional meteorological realities. Consequently, this figure serves as a critical engineering baseline, dictating that the design of flood mitigation structures for the Sundura Creek must be governed not merely by the expected mean, but by the upper confidence threshold (**1130 mm**) to safely buffer against disaster-scale risks.

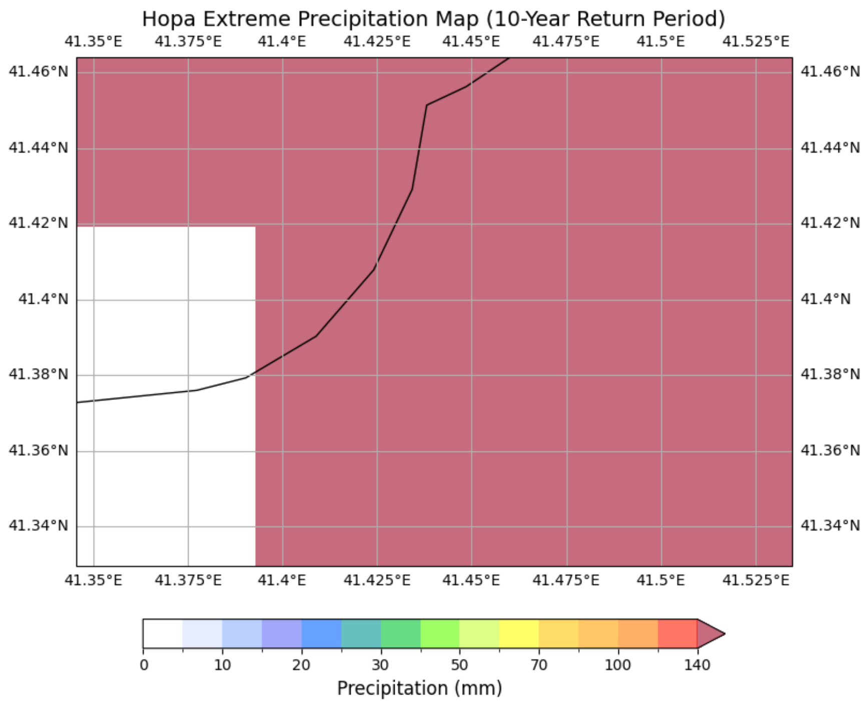

Figure 19 Hopa Extreme Precipitation Map (10-Year Return Period)

This figure delineates the spatial distribution of extreme monthly precipitation with a 10-year return period across the geographic coordinate domain of the Hopa basin (41.34°N–41.46°N and 41.35°E–41.52°E) using a pixel-based modeling approach. The exclusion of marine surfaces corresponding to the Black Sea (treated as NaN) to isolate the terrestrial topography confirms that the spatial interpolation has been effectively purged of statistical noise. Furthermore, the homogeneous distribution observed across the map—falling strictly within the **500–650 mm** band—indicates that, owing to its regional topographical structure, the entire basin possesses the potential to generate synchronized, high-magnitude flood events.

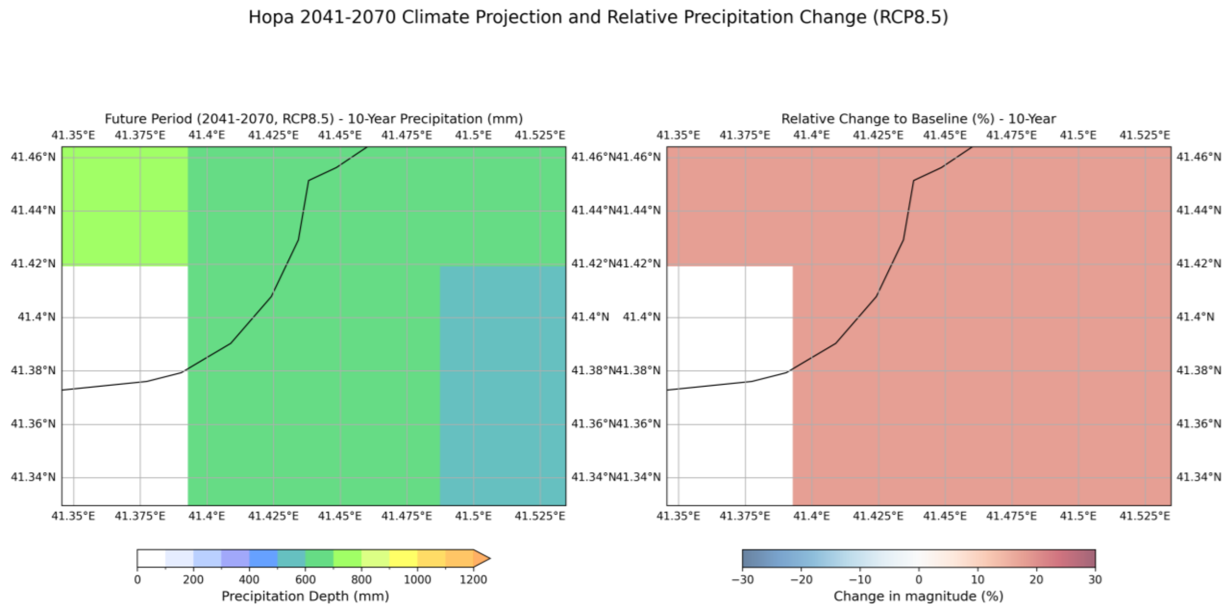

Figure 20 Hopa 2041-2070 Climate Projection and Relative Precipitation Change (RCP8.5)

As presented in Hopa 2041 – 2070 Climate Projection and Relative Precipitation Change (RCP8.5), this dual spatial analysis delineates the 2041–2070 projection (under the RCP8.5 scenario) of 10-year return period extreme monthly precipitation across the Hopa basin alongside its relative change dynamics compared to the historical baseline. The absolute precipitation depths clustering within the **600–750 mm** band in the left panel prove that historically rare, disaster-scale meteorological phenomena will shift into periodic occurrences in the future. In the right panel, the spatially homogeneous **18%** upward trend distributed across the entire catchment—represented by distinct red hues—points to a non-linear intensification of the regional flood regime when coupled with the local topography. Consequently, this map serves as a vital spatial decision-support baseline, dictating that urban drainage networks and river training projects can no longer rely on stationarity assumptions and must urgently incorporate these projected climatic increase coefficients into municipal zoning frameworks.

2.3.2.2 Risk assessment

Key Technical Findings:

The Extreme Precipitation Risk Assessment for Hopa reveals the following critical findings for the 2041–2070 projection horizon under the RCP8.5 scenario:

- **Frequency Amplification:** The critical **100 mm/24h** precipitation threshold is projected to occur significantly more frequently. At the Sundura reference location, the return period decreases from 5 years to 3 years. Across the district, the mean return period drops from ~40 years to ~16 years, representing a **2.5-fold** increase in event frequency.
- **Magnitude Intensification:** Under fixed historical recurrence intervals, precipitation depths are projected to increase by **+22% to +26%** (mean: **+24%**). Consequently, a historical "40-year event" generating **100 mm/day** is expected to yield approximately **124 mm/day** by mid-century.
- **High Spatial Resolution:** The utilization of the CHELSA W5E5 (**1 km**) dataset provides 425 grid cells across the Hopa district (151 valid terrestrial pixels), thereby enabling the identification of localized risk hotspots at a sub-municipal scale.
- **Policy Implications:** Existing flood defense infrastructure designed under historical precipitation baselines will become systematically inadequate. A minimum climate change safety factor of **+25%** must be formally integrated into all future civil infrastructure design specifications for the Hopa district

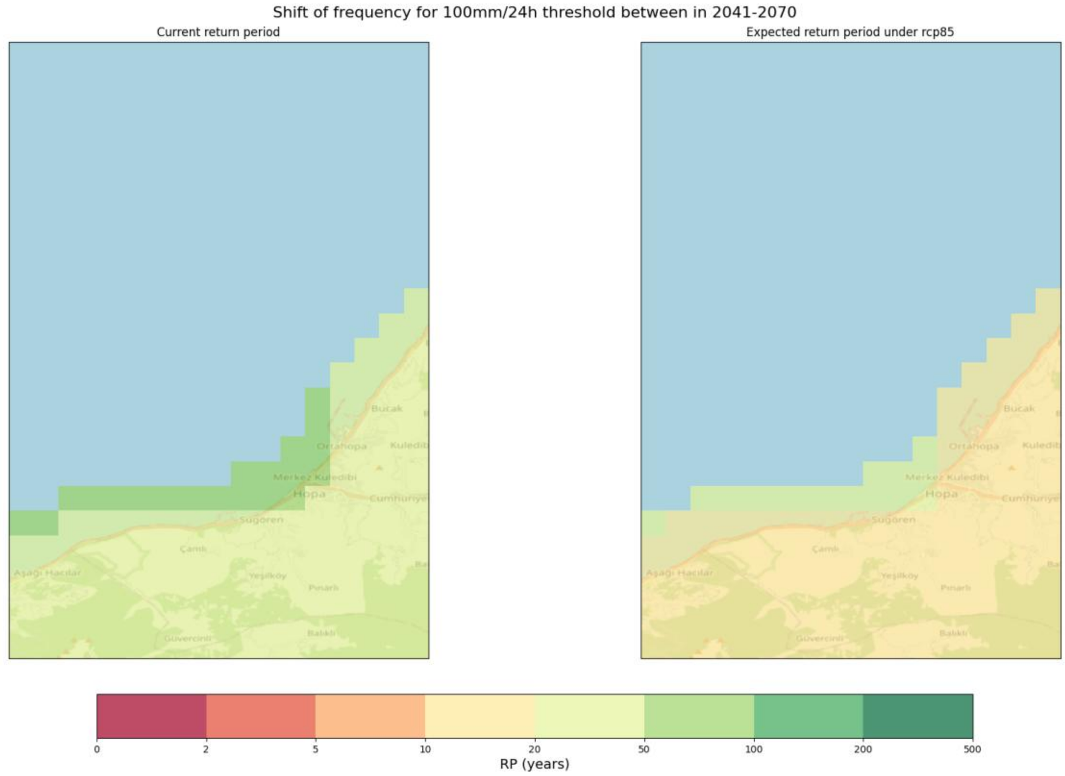

Figure 21 Shift of frequency for 100mm/24h threshold between in 2041-2070

As illustrated in Shift of frequency for 100mm/24h threshold between in 2041-2070, this frequency shift analysis investigates the spatial evolution of the return period for the critical **100 mm/24h** precipitation threshold across the Hopa basin over the 2041–2070 projection horizon under the RCP8.5 scenario. The transition from the historical recurrence intervals of **30–58 years** (left panel) to the yellow-orange spectrum indicating **12–22 years** (right panel) proves a dramatic **2.5-fold** increase in the frequency of extreme hydrometeorological events basin-wide. This indicates that urban drainage networks and floodwalls originally dimensioned for a 50-year protection standard under stationary climate conditions will effectively degrade into **20-year** structures by mid-century, systematically exceeding their designed hydraulic capacities. Consequently, these findings necessitate the immediate recalibration of early warning trigger thresholds and dictate the abandonment of stationary recurrence paradigms in civil infrastructure design in favor of dynamic frequency-shift coefficients.

Another evaluated aspect is the magnitude shift analysis, as illustrated in the figure titled *Shift of magnitude for 100mm/24h threshold with fixed frequency in 2041-2070*. This analysis delineates the projected intensification of the **100 mm/24h** precipitation threshold under a fixed recurrence interval across the Hopa basin over the 2041–2070 projection horizon (under the RCP8.5 scenario). The spatially uniform distribution of orange-red hues across the map proves that daily extreme precipitation magnitudes will increase by **22% to 26%** (averaging **24%**) district-wide. The slightly higher percentage increases observed along the coastal strip compared to the inland terrain perfectly reflect the Clausius-Clapeyron thermodynamic relationship, driven by enhanced moisture flux from the warming surface of the Black Sea. This spatial homogeneity demonstrates that the hazard is non-localized, highlighting the critical necessity for comprehensive, basin-wide urban adaptation planning against flood and landslide disasters.

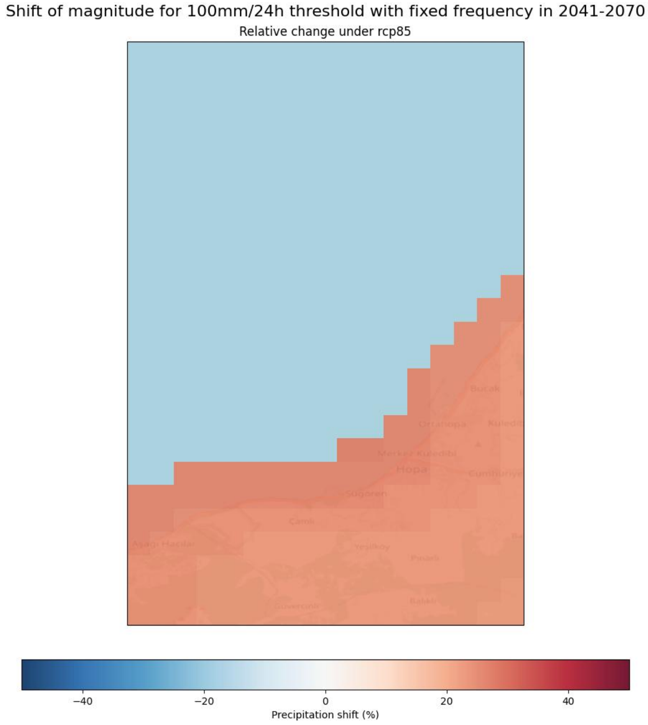

Figure 22 Shift of magnitude for 100mm/24h threshold with fixed frequency in 2041-2070

2.3.3 Additional assessments based on local models and data

2.3.3.1 Deternination of Alternative Routes

The alternative route study is a local modelling study that directly addresses the operational consequences of river flooding and landslide risks in Hopa during a disaster. These consequences include transportation disruption, evacuation delay, slower access to aid and materials, and disconnection between the two banks of Sundura Stream. In the study, Cost Path analysis was applied in the ArcGIS 10.8 environment. The existing road network, elevation, slope, landslide susceptibility, river flooding susceptibility, building data, zoning blocks, and stream-bridge constraints were integrated.

The least-cost path method was structured in three main steps: the creation of the cost surface, the calculation of cost distance and backlink rasters, and the conversion of the final route from raster to polyline in the final stage. The landslide and river flooding susceptibility maps used in the study area were produced during the preparation process of the Hopa Municipality Disaster Action Plan. In landslide modelling, tree-based algorithms such as RF, GBM, CatBoost, LightGBM, and XGBoost were used. The inventory containing 227 landslide polygons and the events of August 24, 2015 were evaluated as the main data sources. The best-performing landslide model was XGBoost, with an AUC value of 0.957. Multiple topographic and hydrological variables were also used in the river flooding susceptibility model. These data ensured that route planning was based on a cost surface weighted according to disaster safety, rather than only on road geometry.

After the source points were identified, the least-cost path analysis was applied to determine alternative routes providing access from four starting points to Artvin city centre. Ten different scenarios were run to identify the optimum routes.

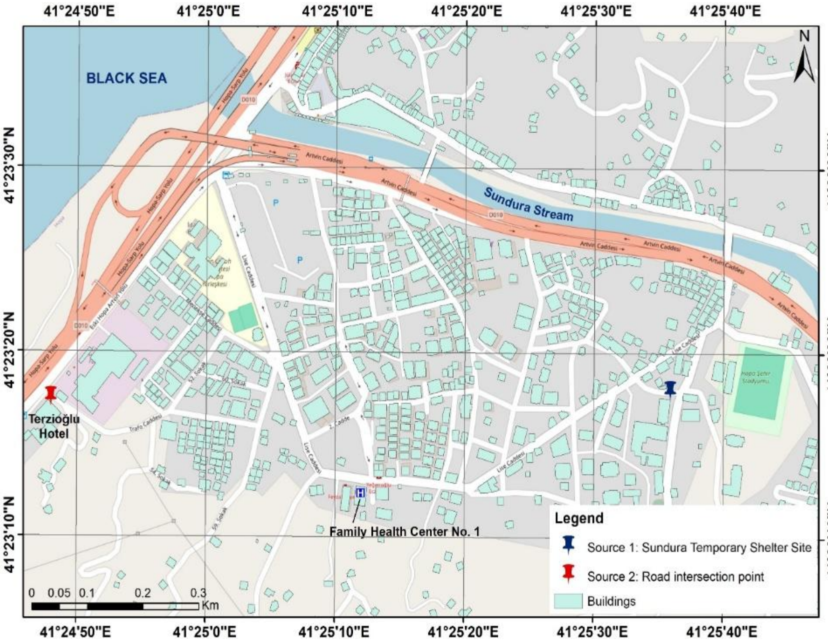

Figure 23 Source points in Sundura Neighborhood for cost path analysis

The source points of the model were also selected according to the logic of disaster planning. On the left side of Sundura Stream, in the southwestern section, Nuri Vatan Anatolian High School, which was identified as a temporary shelter area in SAFE-HOPA Phase 1, was defined as one of the source areas (Figure 18). Another source point was defined at the intersection of the old Hopa-Artvin highway and Terzioğlu Hotel. The selection of this second point was determined by both its relatively low river flooding and landslide risk and its strategic role as an entry point for aid arriving from the direction of Rize and Trabzon towards the Artvin connection.

On the right side of Sundura Stream, the gardens of Hopa Vocational and Technical Anatolian High School and Hüsnü Ciner Primary School were identified as source points. In addition, the location of No. 2 Family Health Center immediately next to Hopa Vocational and Technical Anatolian High School allowed this route to be assessed as a corridor providing access to healthcare services. At a later stage, the common area where the Hopa District Governor's Office and Hopa Municipality are located was included in the model as an additional source point, based on the need for communication and command continuity (Figure 22).

The methodological strength of the alternative route study lies in the fact that it was developed through 10 successive scenarios rather than a single model run. The scenarios represent a learning modelling process that was gradually reshaped through field-based planning knowledge, zoning hierarchy, road widths, bridge requirements, and implementation capacity. The model was also enriched through discussions held by the planning teams on road hierarchy, zoning blocks, incomplete zoning roads, the difference between slope and terracing, one-way traffic arrangements, and population. Therefore, the selection and elimination of scenarios were based on multidisciplinary expert interpretation.

Table 3 Summary of Alternative route modelling scenarios and revision rationale

Scenario	*Main Intervention*	*Result*	*Reason for Elimination or Revision*
Scenario 1	*The first cost surface was created using landslide, river flooding,*	*The route did not use existing roads in safe areas. It passed over*	*It was found insufficient in terms of operational*

Scenario	*Main Intervention*	*Result*	*Reason for Elimination or Revision*
	slope, elevation, road, and building layers.	*buildings near the source point and crossed slopes above 15°.*	*feasibility and engineering applicability.*
Scenario 2	*A 30 m buffer was added to the road layer to encourage the routes to use existing roads more frequently in safe areas.*	*Despite this, the route still did not use existing roads sufficiently. It passed over buildings and crossed slopes above 15°.*	*Although it increased road use, it did not resolve the structural and topographic problems.*
Scenario 3	*The stream + bridge criterion was added.*	*The route was able to move away from the streambed.*	*However, it did not use existing bridge crossings. Therefore, it was revised.*
Scenario 4	*A stronger cost difference in favour of bridges was tested in the stream-bridge layer.*	*The expected effect was not achieved.*	*Bridge use could not be ensured the total weight of the stream-bridge layer remained low.*
Scenario 5	*The stream + bridge layer was used as a constraint instead of a main cost layer.*	*The route began to use bridges.*	*However, in some sections, it continued to pass over buildings and slopes above 15°.*
Scenario 6	*Sub-criterion scores were reorganized to avoid risk, account for slope, use safe roads, avoid the stream, and use bridges.*	*The route used almost the entire existing road network.*	*It did not generate an alternative corridor and could not answer the question of backup access if the main road were closed.*
Scenario 7	*The model was designed to leave the existing road in risky areas and propose an alternative.*	*This time, the model also left the road in safe areas and generated a completely alternative route.*	*The advantage of the existing road was lost, and the result was unbalanced.*
Scenario 8	*A gradual cost system was established in the road layer according to risk thresholds.*	*It produced an acceptable result that used existing roads in safe areas, alternative corridors in risky areas, avoided buildings, and used bridges.*	*It produced a technically strong output. However, overlaps with zoning blocks were identified in some sections.*
Scenario 9	*Zoning blocks were added as a constraint layer, and zoning blocks*	*The routes used the existing road network in safe areas and did not*	*It was found acceptable. However, road widths were not sufficiently*

Scenario	*Main Intervention*	*Result*	*Reason for Elimination or Revision*
	were excluded with a cost value of 60	*pass over buildings or zoning blocks.*	*distinguished in terms of disaster-time capacity.*
Scenario 10	*Separate costs were defined for 15 m, 12 m, and narrower zoning roads.*	*A higher-capacity and relatively safer route was obtained, especially for the Terzioğlu Hotel source point.*	*This scenario was selected as the final option.*

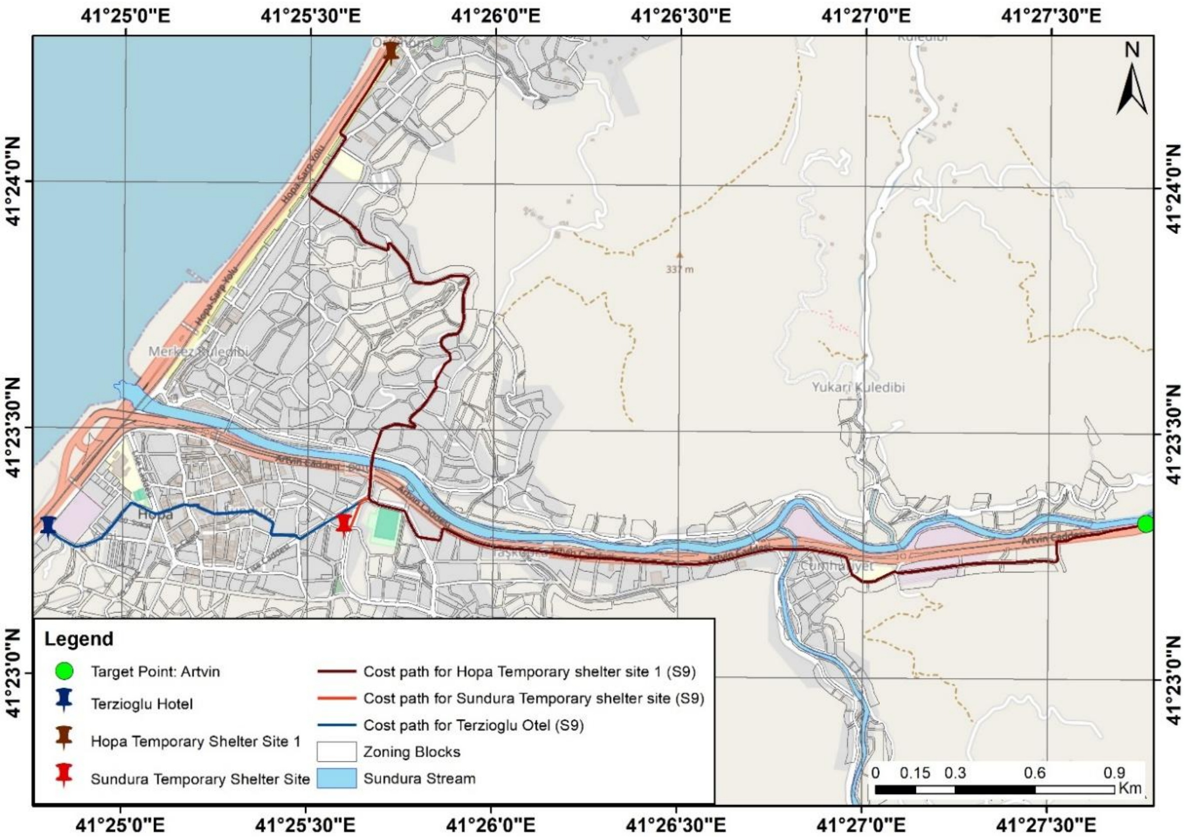

Figure 24 Cost paths for temporary shelter areas in Scenario 9

Checks carried out through the Cost Path analysis showed that the routes in Scenario 9 (Figure 19) used the existing road network in areas where risk was low and did not pass over buildings or zoning blocks. On the other hand, an examination of the zoning plan showed that road widths vary between 15 m, 12 m, 10 m, 7 m, and 5 m. Considering the traffic intensity that may occur after a disaster, one final scenario (Scenario 10) was run to ensure that the proposed alternative routes would pass especially through zoning roads with a width of 15 m.

In the zoning plan, roads with a width of 15 m were assigned a score of 1 (lowest cost), roads with a width of 12 m were assigned a score of 3, other roads were assigned a score of 5, and zoning blocks were assigned a score of 60 (highest cost). In this way, the cost scores of the zoning block layer were updated. The reclassified zoning block layer was evaluated as a constraint, and the cost surface for Scenario 10 was calculated. The final routes produced for the source points including Terzioğlu Hotel, Sundura, and the Hopa temporary shelter areas are shown in Figure 20.

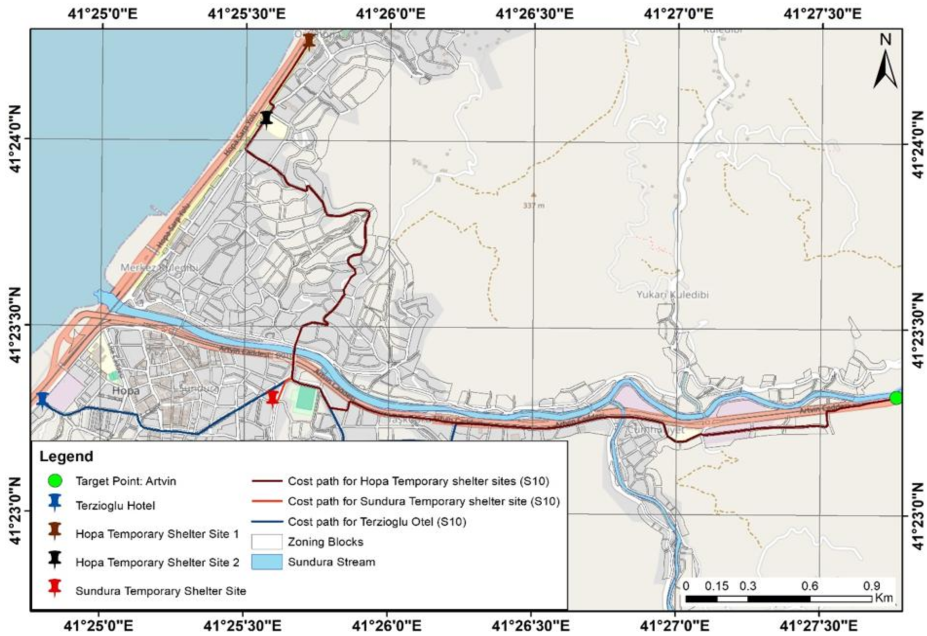

Figure 25 Cost paths generated in Scenario 10

It was determined that there was no change in the routes produced for the source points including the temporary shelter areas in Sundura and Hopa in Scenario 9 and Scenario 10. The routes passed through the same points. However, it was observed that the alternative routes providing the connection from the source point at the intersection where Terzioğlu Hotel is located towards Artvin were different.

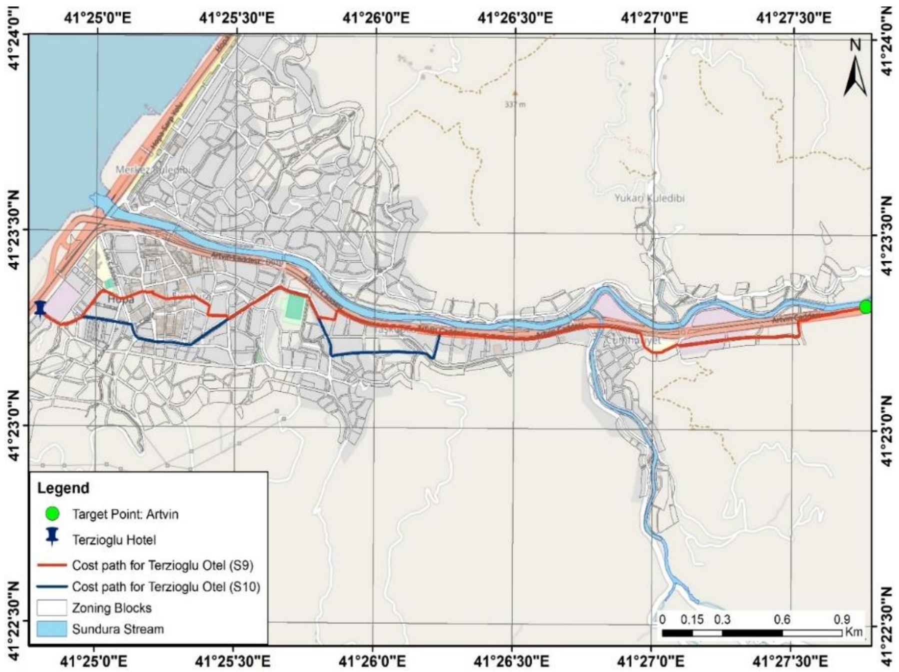

Figure 26 Alternative routes generated in Scenarios 9 and 10 for Terzioğlu Hotel

Based on the opinions of the academic team involved in the project, it was decided that both routes should be assessed in terms of length and disaster risk. The route produced under Scenario 9 has a length of 4,638.69 m, while the route produced under Scenario 10 has a length of 4,748.81 m. The difference in length between the two routes is only 110.12 m.

Although it is longer in terms of distance, the route produced in Scenario 10 was concluded to be more suitable because it uses zoning roads with a width of 15 m. It was also considered more appropriate because of the higher capacity of the transportation line and its relatively lower disaster risk compared with the route in Scenario 9.

When the studies produced under the 10 different scenarios were assessed holistically, it was observed that two separate routes were created for two separate source points in the part of the district located on the left side of Sundura Stream, namely Sundura Neighbourhood (Figure 21). However, in the part of the district located on the right side of Sundura Stream, namely Ortahopa Neighbourhood, although two separate source points, which are temporary shelter areas, were identified, only one alternative route was obtained (Figure 20).

The same route provides the connection with Artvin during a disaster for the temporary shelter areas that were decided to be established in the gardens of Hopa Vocational and Technical Anatolian High School and Hüsnü Ciner Primary School in the first phase of the project. For this reason, it was assessed that selecting one additional source point in Merkez Kuledibi Neighbourhood, on the right side of Sundura Stream, would be appropriate to ensure an uninterrupted access corridor.

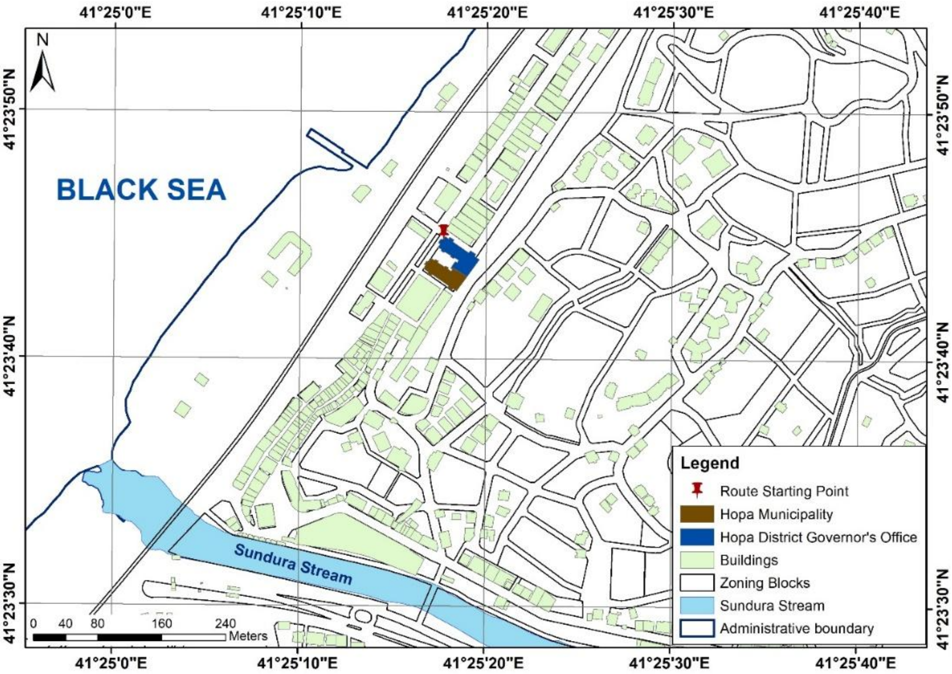

Figure 27 The source (route starting) point in Merkez Kuledibi Neighborhood

In Hopa District, the Hopa District Governor's Office and Hopa Municipality are located in adjacent buildings (Figure 22). Since communication networks may collapse during disasters, it is highly important that the district governor's office and municipal buildings are equipped with satellite communication systems, radio networks, and backup generators.

For this reason, the common area where these two institutions are located, in Merkez Kuledibi Neighbourhood, was selected as the starting point, namely the source point, of the alternative route in order to ensure continuous and reliable communication between Hopa and Artvin city centre after a disaster.

In addition, this source point is of vital importance for ensuring that disaster management can be carried out from a single centre, with uninterrupted communication, rapid logistics support, and clear lines of authority. For these reasons, it was decided that this common area would be defined as the source point in the Cost Path analysis.

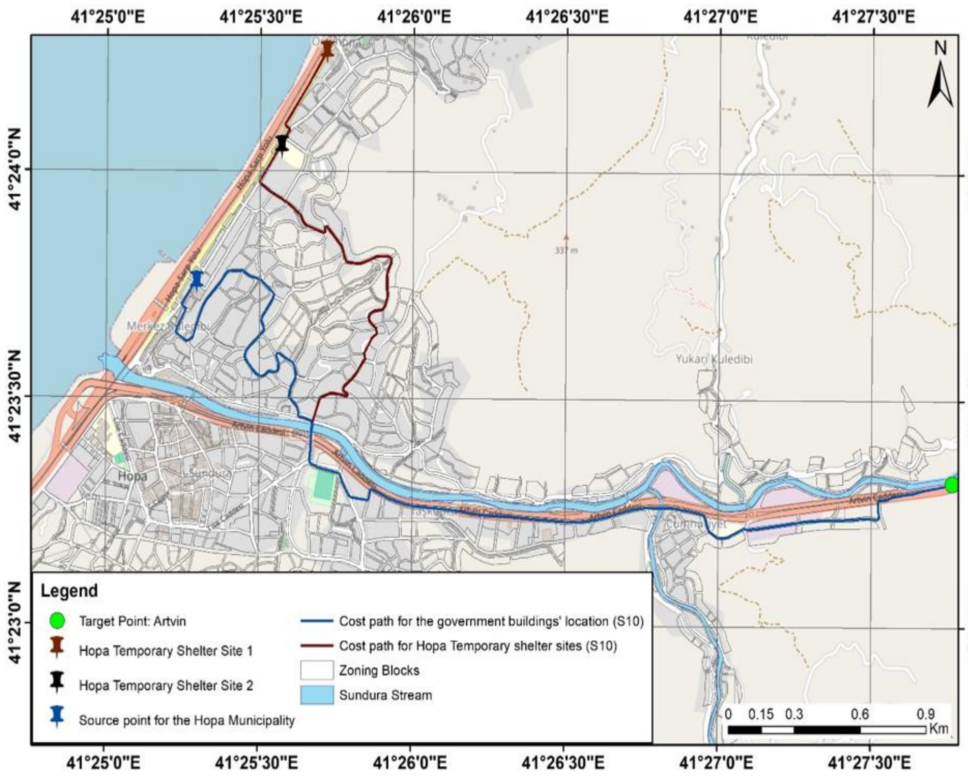

Figure 28 The alternative route for the point where the government buildings are located

The alternative route providing the connection with Artvin from the source point located in the common area of the Hopa District Governor's Office and Hopa Municipality is shown in Figure 23. The checks carried out showed that this route does not pass over buildings or zoning blocks, uses the existing road network in safe areas, and uses the existing bridge crossing to pass over Sundura Stream.

2.3.3.2 Emergency Operations Center Site Selection

The Emergency Operations Center site selection study defines the disaster management center as a critical disaster management facility where teams and materials are dispatched and managed during disasters, inter-institutional communication is established, appropriate risk management procedures are implemented, media relations are conducted, and decision flows are managed. Therefore, the required facility is a command-and-control focal point that is protected from river flooding, landslides, and secondary hazards; accessible from more than one direction; supported by existing infrastructure; capable of expansion when needed; and advantageous in terms of response time. This definition also explains why the EOC was addressed as an additional assessment in Phase 2. It translates hazard information into the spatial safety and accessibility problem of the institutional core that must remain operational during a disaster.

In the study, three main criteria and several sub-criteria were defined for site selection by considering FEMA's rapid reference guide (FEMA, 2021), international articles, national standards, and feasibility reports.

Disaster Hazard Criteria

1. The EOC should be located in an area that will not be affected by natural disasters. In particular, it should be located at a sufficient distance from streambeds, areas at risk of river flooding, and active landslide areas. It should also be positioned in areas where ground surveys have been conducted (FEMA, 2021; AFAD, 2025).
2. It should be built on geologically stable ground with no liquefaction risk, especially outside alluvial soils (FEMA, 2022).

3. It should be located away from places that may create secondary disaster hazards, such as fuel stations, LPG storage facilities, chemical or radioactive facilities, and waste disposal areas.

Access and Accessibility Criteria

1. The EOC facility should be located away from protected areas (Neal, 2003; Alidadi et al., 2025).
2. It should be located close to government offices such as the governorship, district governor's office, and municipality (Neal, 2003).
3. The EOC should be close to main transportation networks to support both personnel and logistics dispatch and the rapid movement of response teams, such as search and rescue and health teams, to the disaster or emergency area (FEMA, 2022).
4. It should be accessible from at least two different routes (FEMA, 2022).
5. To facilitate control and coordination, it should be located outside settlement areas, but at a sufficient distance from them.
6. Proximity to a helicopter landing area, if available, for example for an air ambulance, or to a hospital would also be an advantage.

Technical and Infrastructure Criteria

1. During a disaster, GSM networks, terrestrial lines, and the urban electricity grid may fail. The center should operate strategically without being affected by these interruptions (AFAD, 2025).
2. It should be supported by a generator against the risk of interruption during a disaster, including a generator system and water tank capable of operating continuously for at least 72 hours, as well as multiple communication channels such as radio, satellite, and wireless systems.
3. It should be designed to allow future expansion. It should have sufficient space for additional buildings, adequate vehicle parking areas, team management areas, meeting rooms, media areas, and logistics support units (FEMA, 2022).
4. It should be located in a physically secure area and should be protectable against potential security problems after a disaster.

Determination of Site Selection Criteria and Calculation of Weights

When the main criteria were examined, it was assessed that the technical and infrastructure criteria were related more to the facility's hardware and equipment characteristics than to EOC site selection itself. Therefore, considering the availability of spatial data, Hopa's disaster-prone character, and the topographic, meteorological, geological, and environmental characteristics of the area, it was decided that the following 12 criteria would be appropriate for EOC site selection:

1. River flooding susceptibility,
2. Landslide susceptibility,
3. Geology/lithology, including ground structure and liquefaction,
4. Proximity to hazardous facilities, such as fuel stations and LPG filling facilities,
5. Proximity to the coastline,
6. Proximity to government offices, such as the District Governor's Office and Municipality,
7. Proximity to main transportation networks, namely roads,

8. Proximity to settlement areas,
9. Proximity to infrastructure facilities, including electricity, water, sewerage, and communication,
10. Proximity to healthcare facilities,
11. Proximity to police station locations,
12. Proximity to the fire station.

A pairwise comparison matrix was created by considering the opinions of 18 experts on the subject, including local administrators, academics, AFAD officials, and search and rescue teams. The weights of the main criteria were then calculated (Table 4).

Table 4 The weights of the main criteria

Criteria	RFS	LS	PY	GL	PIF	PHF	PSA	PC	PPSL	PHazF	PFS	PGO	W
RFS	1	1	2	3	3	4	4	5	6	7	8	9	0.204
LS	1	1	2	3	3	4	4	5	6	7	8	9	0.204
PY	1/2	1/2	1	2	2	3	3	4	5	6	7	8	0.141
GL	1/3	1/3	1/2	1	2	3	3	4	4	5	6	7	0.114
PIF	1/3	1/3	1/2	1/2	1	2	2	3	3	4	5	6	0.085
PHF	1/4	1/4	1/3	1/3	1/2	1	2	3	3	4	4	5	0.069
PSA	1/4	1/4	1/3	1/3	1/2	1/2	1	2	2	3	3	4	0.052
PC	1/5	1/5	1/4	1/4	1/3	1/3	1/2	1	2	2	3	4	0.040
PPSL	1/6	1/6	1/5	1/4	1/3	1/3	1/2	1/2	1	2	3	4	0.034
PHazF	1/7	1/7	1/6	1/5	1/4	1/4	1/3	1/2	1/2	1	2	3	0.025
PFS	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/3	1/3	1/2	1	2	0.018
PGO	1/9	1/9	1/8	1/7	1/6	1/5	1/4	1/4	1/4	1/3	1/2	1	0.014

***RFS**: River flooding susceptibility, **LS**: Landslide susceptibility, **PY**: Proximity to roads, **GL**: Geology Lithology, **PIF**: Proximity to infrastructure facilities, **PHF**: Proximity to healthcare facilities, **PSA**: Proximity to settlement areas, **PC**: Proximity to the coastline, **PPSL**: Proximity to police station locations, **PHazF**: Proximity to hazardous facilities, **PFS**: Proximity to the fire station, **PGO**: Proximity to government offices.*

λ_max = 12.754, CI = 0.0685, RI = 1.54 (n = 12 için), CR = 0.0445

The consistency ratio (CR) of the pairwise comparison matrix was calculated as 0.0445. The fact that the CR value is below 0.10 showed that the judgments in the matrix were consistent and that the calculated weights could be used. When Table 1 is examined, it is seen that 66.3% of the total weight belongs to the first four criteria: river flooding susceptibility, landslide susceptibility, proximity to roads, and geology/lithology. This emphasizes that the selected land should primarily be located on safe ground without disaster hazards and should be accessible, namely close to roads. After the requirements related to disaster safety and access are met, the criteria of proximity to infrastructure facilities, proximity to healthcare facilities, proximity to settlement areas, and proximity to the coastline come into play in site selection, with a combined weight of 24.6%.

The scores for the sub-criteria were determined by the project team with reference to national and international literature and the technical documents of the relevant institutions.

The safest areas for the EOC were accepted as the areas with the lowest susceptibility. The scoring for the other susceptibility classes was carried out as follows: areas with very low susceptibility were assigned 10 points, areas with low susceptibility were assigned 8 points, and areas with moderate susceptibility were assigned 6 points.

In the EOC site selection analysis, the four main criterion maps presented in Figure 10 were produced to ensure that the facility can remain safe, accessible, and functional during a disaster. **The river flooding susceptibility map in Figure 10a** was prepared because the EOC must be located away from streambeds, river flooding extent areas, and areas with high river flooding risk. Areas with high and very high river flooding susceptibility were not considered suitable for site selection and were excluded from the analysis**. The landslide susceptibility map in Figure 10b** was used to ensure that the EOC is planned in safe areas that will not be affected by active or potential landslide areas, due to Hopa's steep topography and landslide risk. Areas with high and very high landslide susceptibility were likewise excluded from the suitability analysis. **The distance-to-roads map in Figure 10c** was produced based on the assumption that the EOC should be close to main transportation networks so that personnel, vehicles, equipment, search and rescue teams, and health teams can rapidly reach the incident site during disasters and emergencies. The road network obtained from the MAKS database was analysed in ArcGIS 10.8 using the Euclidean Distance method and classified at 150 m intervals. **The geology/lithology map in Figure 10d** was prepared to locate the EOC in areas with more stable ground conditions rather than on alluvial soils with liquefaction risk. The 1/100,000-scale geology data obtained from MTA were classified into soil classes according to the Türkiye Building Earthquake Code, and ZF-class liquefiable soils were excluded from the analysis.

These four maps enabled the joint assessment of river flooding susceptibility, landslide susceptibility, proximity to roads, and geology/lithology criteria. They formed the basis of disaster safety, ground suitability, and accessibility in EOC site selection. Together with the other eight site selection criteria, they were included in the weighted overlay analysis as raster layers with a spatial resolution of 5 m and provided the basis for producing the final site selection criteria maps.

The EOC facility must be able to continue its strategic activities without interruption during a disaster. In the EOC site selection analysis, the four criterion maps presented in Figure 24 were produced to ensure that the facility is planned in a location that can access critical services during a disaster, remain operationally sustainable, and be protected from environmental risks.

The distance-to-infrastructure facilities map in Figure 24a was prepared based on the assumption that the EOC must have safe access to basic infrastructure systems such as electricity, water, sewerage, and communication in order to continue its strategic activities without interruption during a disaster. The water transmission and sewerage lines obtained from Hopa Municipality and the electricity transmission lines obtained from AKSA Çoruh Electricity Retail Sales Inc., Artvin Provincial Directorate, were analysed in ArcGIS 10.8 using the Euclidean Distance method and classified at 150 m intervals.

The distance-to-healthcare facilities map in Figure 24b was prepared to reduce the first response time in disaster management, strengthen coordination with health teams, and increase operational sustainability. Based on one fully equipped State Hospital and two Family Health Centers in Hopa, areas closer to healthcare facilities were classified with higher suitability values.

The distance-to-settlement areas map in Figure 24c was produced in line with the planning principle that the EOC should not be located so far from the city that it becomes inaccessible, but should also not be located within dense built-up areas where the center itself may become dysfunctional during a disaster. Using building data obtained from the MAKS database, areas located at the edges of settlements and offering wider land opportunities were considered more suitable than the very centre of dense settlements.

The distance-to-coastline map in Figure 24d was prepared because Hopa is a coastal district. It aimed to keep the EOC away from possible coastal risks such as storm surge, coastal flooding, inundation areas, and coastal infrastructure failure. Based on the coastline digitized from current Google Earth imagery, the first 50 m from the coastline was not considered suitable, and the suitability score increased with distance from the coast.

These four maps formed spatial suitability layers that support the post-disaster operability of the EOC by jointly assessing access to infrastructure, relation with healthcare services, balanced distance to the settlement pattern, and distance from coastal risks. Together with the other site selection criteria, they were included in the weighted overlay analysis as raster datasets with a spatial resolution of 5 m and contributed to the production of the final EOC site selection suitability map.

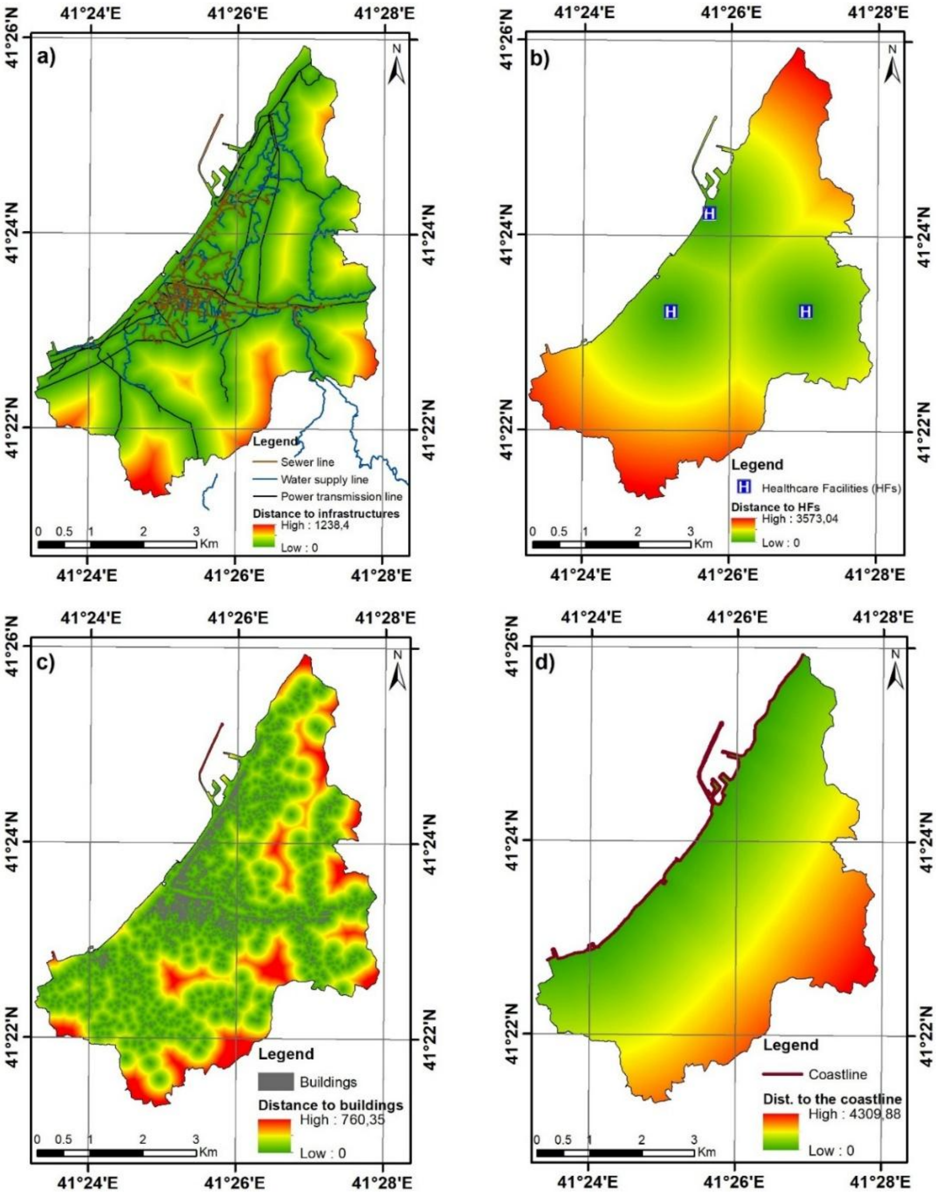

Figure 29 Site selection criteria maps: a) distance to infrastructure facilities, b) distance to healthcare facilities, c) distance to residential areas, d) distance to the coastline

After disasters, social chaos, looting attempts, or panic may occur. Since the EOC serves as the city's command and coordination center, the security of this facility is of vital importance. In the EOC site selection analysis, the four criterion maps presented in Figure 25 were produced to assess the center's capacity for post-disaster security, response speed, protection from secondary hazards, and access to decision-making institutions.

The distance-to-police station locations map in Figure 25a was prepared to ensure the security of the EOC in situations such as social panic, security risks, looting attempts, or uncontrolled movement after a disaster. Police and gendarmerie locations within the boundaries of Hopa Municipality were digitized using the base map and Google Maps, analysed in ArcGIS 10.8 using the Euclidean Distance method, and areas closer to police station locations were classified with higher suitability values.

The distance-to-fuel stations map in Figure 25b was prepared to avoid facilities that may create secondary disaster risks after a disaster, such as explosions, fires, leaks, or hazards related to dangerous materials. Based on the four fuel stations located within the boundaries of Hopa Municipality, areas close to these stations were assigned lower suitability values, while areas farther from these facilities were assigned higher suitability values.

The distance-to-fire station map in Figure 25c was produced to ensure that the EOC can establish rapid and direct coordination with the fire service, since the fire brigade is the most dynamic field force in disaster management for fire response, inundation, search and rescue, and hazardous material response. Proximity classes were defined based on the existing fire station within the boundaries of Hopa Municipality.

The distance-to-government offices map in Figure 25d was prepared to ensure that the administrators of the Hopa District Governor's Office and Hopa Municipality, who are decision-makers in dispatch and administration processes during disasters, can reach the EOC in a short time. Based on the adjacent District Governor's Office and Municipality buildings, areas close to these administrative centres were assigned higher suitability scores.

These four maps made visible the criteria of access to security support, distance from secondary disaster sources, proximity to fire and emergency response capacity, and access to administrative decision-making centres. Together with the other eight site selection criteria, they were included in the weighted overlay analysis as raster layers with a spatial resolution of 5 m and contributed to the production of the final EOC site selection suitability map.

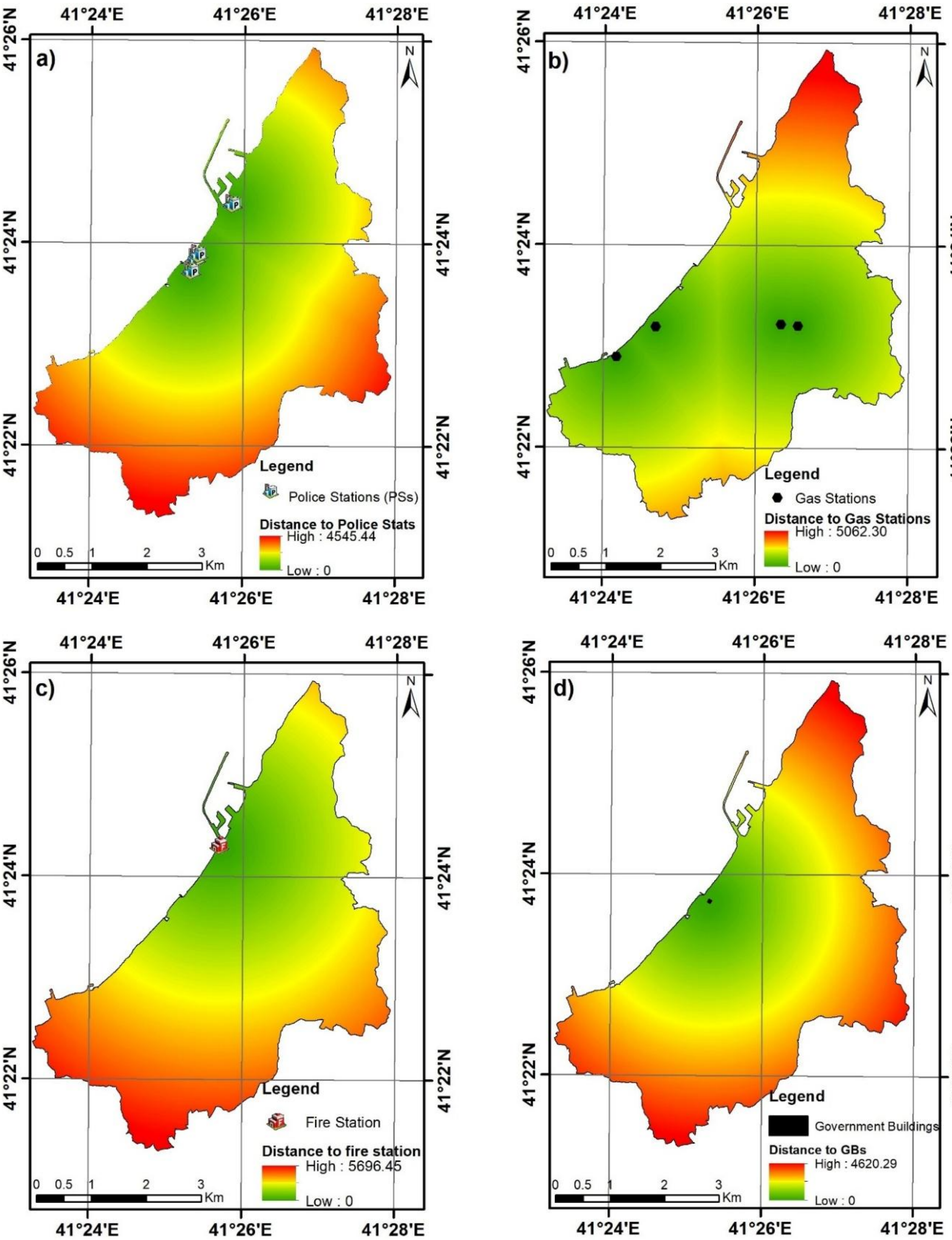

Figure 30 Site selection criteria maps: a) distance to police stations, b) distance to gas stations, c) distance to fire station, d) distance to government buildings (Hopa Municipality and District Governor's Office)

EOC sites should be expandable to accommodate different scenarios (FEMA, 2021). In Hopa, an area of 4,500–5,000 m² is envisaged as a rational solution for a sustainable and safe EOC campus that can meet both daily operational needs and increased capacity requirements during disasters. This planning includes a 300–400 m² administrative building to serve a core team of 30 people, an emergency response parking area for 8 vehicles, including 2 ambulances, 2 fire trucks, 2 search and rescue vehicles, and 2 construction machines, and a 1,500–2,000 m² helicopter landing area, namely a helipad, which is of vital importance against transportation risks in the region. Due to disaster risks such as floods and landslides, which may interrupt road transportation, air-supported response and safe manoeuvring areas are among the most critical components of this project. Considering the dynamic structure of the EOC, logistics needs, and inter-institutional coordination requirements, it is a technical necessity under engineering standards to leave a flexibility margin of 30–50% in addition to the existing area.

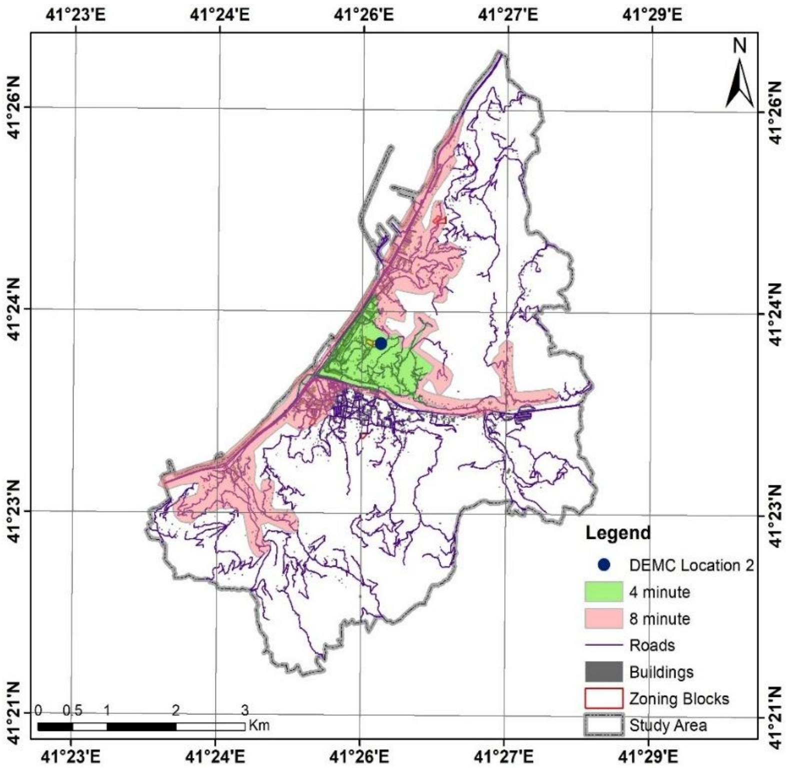

Figure 31 Service areas for DEMC Location 2

According to the standards published by the National Fire Protection Association (NFPA 1710), the response time of professional first responders to reach the incident site is evaluated as the sum of call processing time, turnout time, and travel time. The target time for the first response unit is generally approximately 4 minutes, while the time required to achieve full response capacity is around 8 minutes (National Fire Protection Association, 2020).

Taking these access times into account, a service area analysis was carried out for the two identified zoning blocks (Figure 26). This analysis defines the geographical area that a facility or service unit can reach, affect, or serve within a specific period of time (ESRI, 2026). It was decided that the EOC facility shown in Figure 26 is the most suitable location because it has a wider area of influence within 8 minutes, is located immediately near the water tank, is close to the existing sewerage network, and is very close to the identified alternative route in case existing roads are closed during a disaster. The zoning block of 6,250.29 m² located at Location No. 2 is approximately 25% larger than the 4,500–5,000 m² base area requirement explained above. This additional area provides an ideal buffer zone for the need for "surging capability" in times of crisis, as also emphasized by FEMA (2021).

After the placement of the EOC building, the parking area for 8 vehicles, and the helipad, the remaining area can be used for temporary logistics storage, including the storage of containers and tent city equipment. On the other hand, although the 18° slope will increase construction costs compared to flat land, considering Hopa's narrow coastal strip with high river flooding risk, its location on a "high and easily drained" point will provide a strategic advantage to the selected site.

2.3.3.3 Equipment Parking Area

Equipment and vehicle parking areas are parking areas or "logistics base" centres established for the storage and rapid dispatch of construction machinery, search and rescue equipment, containers, and tent city equipment during disasters.

As observed during the flood and river flooding disaster of 24 August 2015, large-scale disasters of this kind can completely disable transportation axes and bridge crossings between the two banks. If the existing equipment and vehicle park is located only on the right bank, in a scenario where physical access is interrupted due to river flooding, the left bank, including Sundura Neighbourhood, would be deprived of response capacity and would fall into operational isolation.

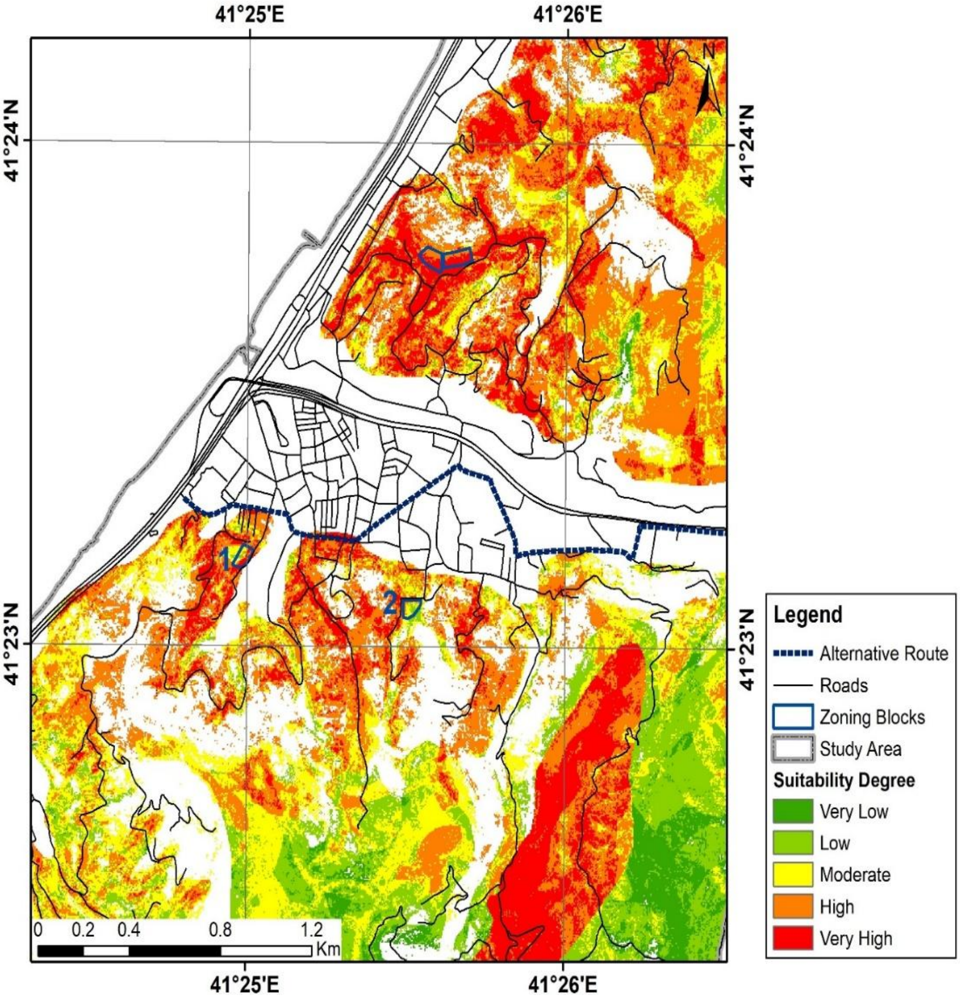

Figure 32 Suitable zoning blocks in the Sundura neighborhood

In order to eliminate this strategic risk and ensure operational continuity, it is a vital necessity to establish a second emergency response vehicle and equipment parking area on the left bank of Sundura Stream, directly within the boundaries of Sundura Neighbourhood. **This planning does the geographical redundancy of response capability.**

Therefore, this second area will secure the response capacity of the neighbourhoods on the left bank even in scenarios where the two banks of the stream are completely isolated from each other. Thus, if a similar river flooding event occurs again, disaster management will not remain dependent on a single location, and both banks will be able to respond without interruption with their own teams, vehicles, and equipment.

This approach, which is consistent with the principles of operational continuity and resource redundancy emphasized in NIMS (FEMA, 2017) and ICS (FEMA, 2018), is the most rational logistics solution for minimizing loss of life and property by enabling the achievement of **critical response time** targets during disasters.

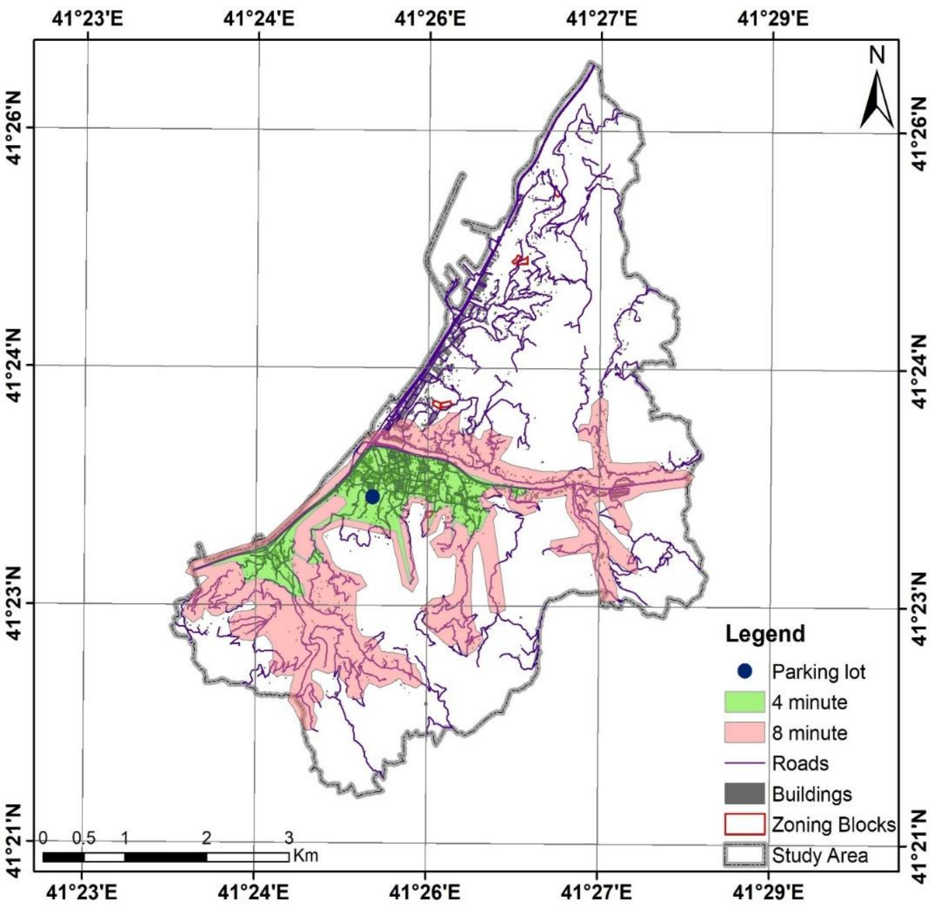

Figure 33 The 4- and 8-minute service areas of the park in Zoning Block No. 1

The results of the service area analysis carried out for Zoning Block No. 1 are shown in Figure 28. It is observed that the 8-minute service area of the equipment parking area in this location can reach almost all areas in the left section of Hopa. Therefore, it was concluded that this zoning block in Sundura Neighbourhood would be suitable for allocation as a parking area for the equipment and vehicles of search and rescue teams.

2.3.3.3.1 Hopa EOC – Emergency Operations Center Design Criteria

EOCs are potentially highly effective structures, with suitable roads, helicopter areas, large storage areas, parking areas, and similar facilities (FEMA, 2022). Emergency Operations Centers (EOCs) carry out the functions of information management, training, monitoring, infrastructure, coordination, and operations (Bertazzo et al., 2025).

The Hopa Emergency Operations Center will operate as the main center where crisis coordination, communication, logistics management, search and rescue coordination, and field operations are managed within the first 72 hours after a disaster. Within the center:

- In the first 0–24 hours, emergency response, data collection, and field security will be prioritized.
- Between 24–48 hours, logistics distribution, temporary shelter coordination, and health support organization will be carried out.
- Between 48–72 hours, sustainable operations, critical infrastructure repairs, and regional coordination activities will continue.

The structural platform of the Hopa Emergency Operations Center, developed for Hopa District, which is one of the most critical logistics nodes of the Eastern Black Sea Region but is exposed to multiple disaster risks such as landslides and river flooding due to its topography, should be resolved through a stepped terracing system, taking into account the coastal topography of the Black Sea.

On the sloping terrain, rainwater control, drainage ditches, controlled slope systems, retaining elements around the structural platform, and permeable landscape strips should be planned. Within the scope of the project, a surface water drainage network was designed by considering Hopa's high precipitation regime. The controlled removal of water is targeted through open drainage channels, rain gardens, and underground discharge lines. In areas with landslide risk, landscape and drainage measures that reduce surface load are recommended.

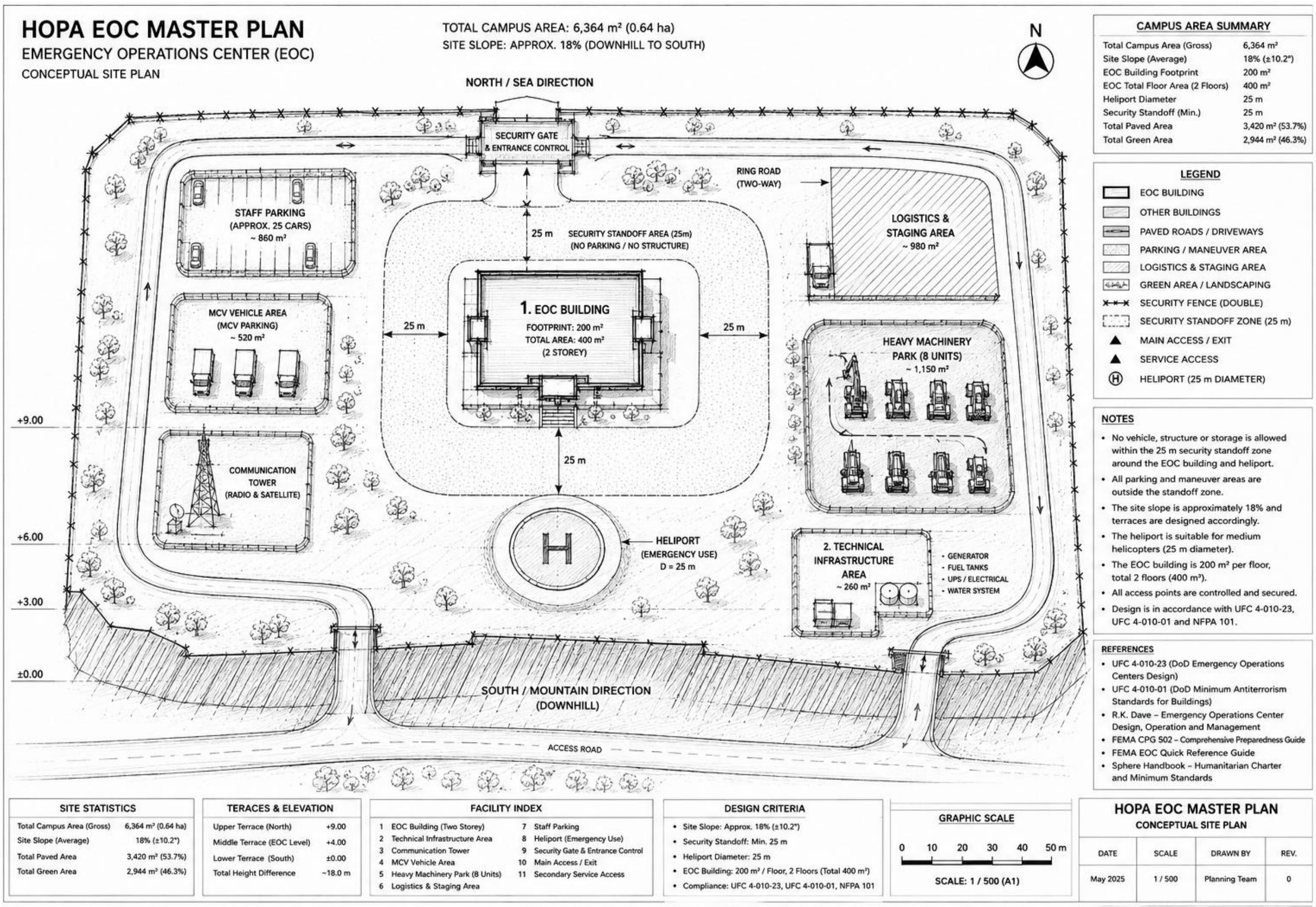

Figure 34 Emergency Operations Center and Immediate Surroundings Design

The design was developed to create a district-level disaster management campus model that can **provide uninterrupted service for at least 72 hours without any external assistance**, in response to Hopa's risk of geographical isolation. It is designed so that internal circulation never becomes blocked and maximum geometric protection is provided against external threats.

In the EOC site design, vehicle circulation was separated into civilian access, emergency response vehicle flows, and logistics service flows. Construction machinery parking areas were planned both within the EOC campus area and separately on the other side of the city. Turning and manoeuvring areas were provided for bulldozers, excavators, graders, and trucks. For the operational continuity of the EOC, a heliport area was positioned at a safe distance from the main structure. Dedicated energy and data connection points were proposed for mobile command vehicles.

Central EOC Building and Security Standoff Area: The EOC building was placed in the geometrically most protected core of the campus. Thanks to the circular ring road around it, the building can be served from both axes, namely the logistics and administrative axes, within equal time. In accordance with the Department of Defense (2008), a 25 m "Security Standoff Area" was defined around the building. No secondary structure or vehicle parking will be allowed within this area. The aim is to prevent shock waves caused by a potential explosion, fire, or vehicle accident on the outer perimeter from reaching the main management base, namely the EOC, and to preserve the survivability capacity of the structure (Figure 29).

Positioning of Technical Infrastructure and Support Units: Technical units carrying a high risk of fire or explosion, such as the generator room, transformer, and 5-day backup fuel tanks, were completely separated from the main building. Since they are located at the end of the logistics axis, tankers that will provide fuel supply during a disaster will be able to reach this area directly without disrupting campus traffic. Mobile Command Vehicles (MCVs) and the satellite-radio communication tower were placed on the western façade, close to the administrative section but isolated from the buildings, so that infrastructure frequencies are not affected by the electromagnetic pollution that may be created by logistics vehicles (Figure 29).

2.3.3.3.2 Hopa EOC Heavy Vehicle and Disaster Logistics Area

Ensuring operational continuity in disaster management depends on structuring decision-making mechanisms and the logistics forces that will operate in the field as an integrated system during a crisis. In this respect, it is a technical necessity to consider the planned facility as an operational base.

In accordance with the logistics approaches of FEMA (2022) and Dave (2015), emergency areas are not merely spaces where heavy vehicles are passively parked. They are strategic centers where vehicles are dispatched, routine maintenance is carried out, fuel supply processes are managed, and resources are reorganized according to dynamic disaster scenarios.

Table 5 Hopa Municipality Emergency Response Vehicle Inventory

Vehicle Type	*Number*	*Vehicle Type*	*Number*
Bulldozer	1	Fire Truck	2
Excavator	1	Fire Tanker	1
Grader	1	Platform Truck	1
Loader	1	Lowbed Trailer	1
Backhoe Loader	3	Road Sweeper	1
Backhoe Loader with Breaker	1	Infrastructure Vehicles	3
Roller	1	Generator Vehicle	1
Dump Truck	7	Pick-up and 4x4 Vehicles	2
Water Tanker	1	**Total**	**29**

Macro Site Planning: In the proposed layout model, an open area of approximately 140 m × 90 m, with a total size of 12,600 m², namely approximately 1.2–1.5 hectares, should be planned for emergency response and heavy equipment management. Producing such an area at the scale of a single parcel is quite difficult in a steep and challenging geography such as Hopa. Similarly, in a city divided by Hopa Stream and consisting of two different morphological structures, a one-sided solution would not be operationally effective. For this reason, the required area size was planned as two separate areas capable of accommodating, during the most intense phase of a disaster, 50–60 heavy-duty vehicles, 10–15 construction machines, maintenance, fuel supply, container storage, and logistics loading activities without operational conflict.

Functional Zoning: In order to prevent on-site vehicle traffic from becoming blocked and to maximize activation speed, the site was divided into four main working zones:

- **ZONE A – Construction Machinery Park:** This area, located in the section of the site with the highest static load-bearing capacity, will accommodate a total of 15 tracked and heavy-wheeled construction machines, including bulldozers, excavators, loaders, backhoe loaders, backhoe loaders with breakers, graders, and rollers. The parking bay size for each vehicle was determined as 5.0 m × 12.0 m, and the manoeuvring road width was planned as 12 m by considering the turning movements of construction machinery and their loading onto trailers.
- **ZONE B – Heavy Truck Park:** This is an area with a capacity of 20 vehicles, including dump trucks, lowbeds carrying construction machinery, trailers, water tankers, and fire water supply tankers. Due to the chassis lengths of these vehicles and their reverse manoeuvring limitations, each parking bay was schematized as 4.5 m × 15.0 m, and the manoeuvring corridor width was set at 15 m to ensure safe turning.
- **ZONE C – Emergency Response Vehicles Area:** This zone is reserved for a priority fleet of 10 vehicles that operate under time-critical conditions, such as fire trucks, AFAD search and rescue vehicles, Emergency Medical Team ambulances, and Mobile Command Vehicles. This zone was positioned at the closest point to the main Emergency Operations Center building to facilitate radio/data integration and was supported by an uninterrupted “rapid exit” lane providing direct access to the main road.
- **ZONE D – Temporary Support Vehicles Area, or Empty Reserve Area:** An additional fleet area may be allocated for reinforcement vehicles arriving from external institutions after a disaster, including DSI, Highways, the General Directorate of Forestry, the Gendarmerie, and neighbouring municipalities. Under normal conditions, this area is kept completely empty to reduce the daily operating costs of the facility and to be used as a drill area. During a crisis, it can accommodate sudden increases in capacity.

Operational Support and Technical Infrastructure Areas: The following logistics units were integrated into the campus to ensure that the site can remain self-sufficient and unaffected by failures in external infrastructure:

- **Fuel Supply Point:** This station, which is critical for operational continuity, was isolated from the main buildings and vehicle parking areas with a minimum safety distance of 30 m in accordance with NFPA 30, the Flammable and Combustible Liquids Code, and UFC 3-460-01, Petroleum Fuel Facilities, due to flash fire and explosion risks.

- **Maintenance Workshop:** A workshop was designed to enable immediate intervention for vehicles that may break down on site. It includes critical spare parts storage areas, tyre replacement units, and storage areas for lubricants and hydraulic equipment.
- **Open Logistics Storage Area:** An area was allocated for the storage of humanitarian aid materials, emergency containers, field tents, and mobile generators. In the planning of this area, the Sphere Handbook, namely the Humanitarian Charter and Minimum Standards in Humanitarian Response, and the FEMA Logistics Planning Guide were used as references, with consideration given to protecting materials from moisture and ensuring suitability for forklift traffic.

Specific Design Decisions for Hopa's Microclimate and Geography

Due to Hopa District's high annual average precipitation, landslide and mass movement risks associated with steep topography, the logistics constraints of its narrow coastal plain, and its international strategic position arising from its proximity to the border gate, the following structural measures must be taken on site:

- **Ground Structure:** Measures should be taken to eliminate the risk of liquefaction and settlement under excessive rainfall and the high point loads that heavy-duty vehicles and tracked machinery will exert on the ground. A minimum uninterrupted slope of 2% should be provided across the site to ensure the rapid removal of surface water.
- **Advanced Drainage System:** To prevent ponding on the site during sudden extreme rainfall events, the campus should be surrounded by open drainage ditches and grated stormwater collection channels.
- **Slope and Hillside Safety:** Against the landslide risk created by the topography, the slopes behind the site should be reinforced, stepped retaining walls should be constructed where required, and vertical drainage drains should be planned to divert surface water from the rear slopes away from the site.

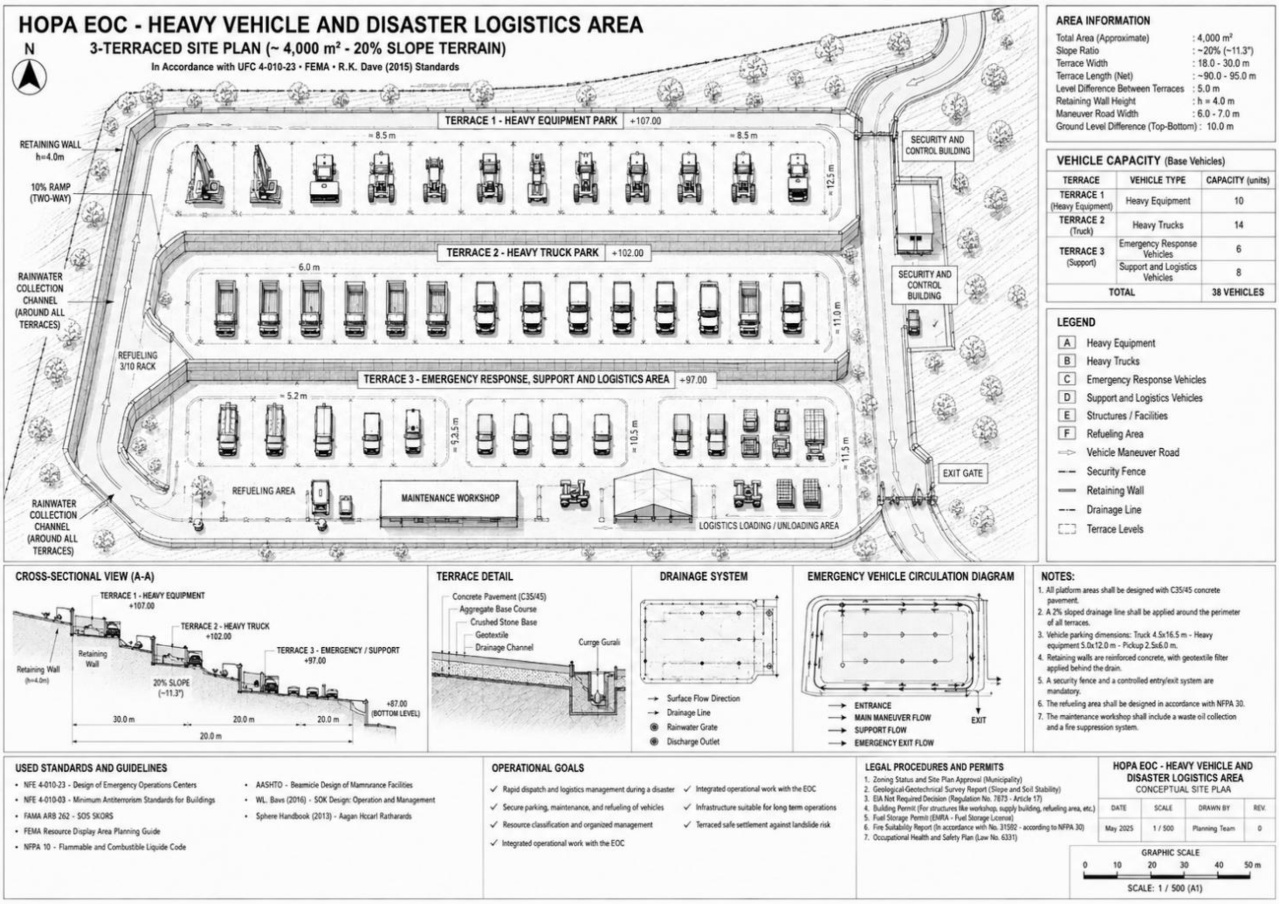

Figure 35 Hopa EOC Heavy Vehicle and Disaster Logistics Area Design

In conclusion, the proposed Hopa EOC Heavy Vehicle and Disaster Logistics Area was developed by taking into account the district's existing vehicle fleet and potential disaster scenarios. The layout, covering approximately 4,000 m², was resolved through a three-terrace system on topography with a 20% slope. Construction machinery, heavy trucks, emergency response vehicles, and logistics support vehicles were separated according to their functions (Figure 30).

Despite the limited size of the area, it is assessed that it is capable of meeting the principles of operational continuity, safety, accessibility, and logistics efficiency during a disaster. However, it is recommended that an additional logistics storage area be allocated for future capacity increases.

The proposed layout model is based on the integrated operational capacity approach, which is one of the most fundamental principles of modern emergency management. The proposed design presents an implementable planning solution under Hopa's geographical constraints by combining architectural safety criteria with the practical needs of disaster management, including vehicle manoeuvring areas, logistics flexibility, and the continuity of maintenance and supply.

2.3.3.1 Hazard assessment

In the additional assessments based on local models and datasets, the hazard analysis aimed to interpret the spatial distribution of river flooding, heavy rainfall, and landslide processes in Hopa in greater detail and in operational terms. In this context, local data layers related to river flooding susceptibility, landslide susceptibility, slope, elevation, geology/lithology, streambeds, bridge crossings, the existing road network, zoning roads, building pattern, and the coastline were assessed together. In this way, hazard was addressed as a spatial threshold associated with Hopa's narrow valley floors, steep topography, stream crossings, hillside settlements, and transportation corridors.

The Cost Path analysis used in the alternative route study was applied to identify safe access corridors with low river flooding and landslide susceptibility, more feasible slope conditions, use of existing bridges at stream crossings, and no overlap with buildings or zoning blocks. In the EOC site selection study, areas with high river flooding and landslide susceptibility, liquefiable soils, and zones close to facilities that may create secondary hazards were not considered suitable for a critical disaster management facility.

This approach shows that, in Hopa, local hazard information was used as the spatial basis for safe site selection, route determination, disaster logistics, and emergency response capacity. Therefore, the additional hazard assessment carried out in Phase 2 went beyond standard hazard identification and revealed which areas are safe or vulnerable during a disaster within Hopa's local topography, hydrological structure, and urban development pattern.

2.3.3.2 Risk assessment

In the additional assessments based on local models and datasets, the risk analysis evaluated the urban and operational consequences that river flooding, heavy rainfall, and landslide hazards may cause in Hopa. In this section, risk was addressed through cascading impacts such as road closures during a disaster, disruption of access between the two banks, delays in evacuation and aid processes, weakened access to healthcare services, disruption of vehicle and equipment dispatch, interruption of the coordination capacity of decision-making institutions, and the inability to sustain critical infrastructure services.

Within this framework, the alternative route analyses were evaluated as a risk reduction tool aimed at reducing dependence on the existing main transportation axes in Hopa and creating access corridors that can remain operational under disaster conditions. The comparison of Scenario 9 and Scenario 10 showed that the shortest distance alone is not sufficient for risk reduction. Criteria such as road width, disaster susceptibility, avoidance of overlap with built-up areas, and emergency response capacity should be assessed together.

Similarly, EOC site selection was addressed as a decision-support process aimed at preventing the disaster management center itself from becoming dysfunctional during a disaster. The service area, infrastructure connection, proximity to the alternative route, and expansion capacity of the area identified in Merkez Kuledibi Neighbourhood made this location strategic in terms of disaster coordination.

The assessments of the equipment and vehicle parking area and the heavy vehicle–disaster logistics area made the response capacity dimension of risk visible. The fact that Sundura Stream divides Hopa into two banks shows that a single-center response structure may be insufficient, as bridge and road connections may be interrupted during major river flooding events. Therefore, the second vehicle and equipment parking area mean the geographical redundancy of response capability.

As a result, the additional risk assessment carried out in Phase 2 transformed local hazard layers into concrete disaster management decisions. Safe routes, a safe coordination center, equipment deployment on both banks, and logistics continuity were defined as the main risk reduction outputs of SAFE-HOPA.

2.4 Key Risk Assessment Findings

The Key Risk Assessment step was used to translate the outputs of the Phase 2 climate risk assessment into a structured risk prioritisation framework. In this step, the main risks identified for Hopa were evaluated by considering three dimensions: severity, urgency, and resilience capacity. The evaluation focused on three interrelated climate-related risks: river flooding, heavy rainfall, and landslides. These risks were not assessed as isolated hazards. Instead, they were considered as interacting processes that may generate cascading impacts on transportation continuity, emergency response, critical infrastructure, access to healthcare services, temporary sheltering, vulnerable groups, and institutional coordination.

The assessment shows that river flooding and heavy rainfall represent very high-priority risks for Hopa. Landslides were assessed as a high-priority risk because of their strong relationship with heavy rainfall, steep topography, road cuts, and access disruption. The overall key risk finding is that the main climate risk for Hopa is the possibility of integrated urban infrastructure and access failure during extreme rainfall events.

2.4.1 Mode of engagement for participation

The risk evaluation process was informed by the participation and stakeholder engagement structure described in Section 2.1.5. The engagement process was coordinated by Hopa Municipality and involved the academic team, the technical GIS team, public institutions, neighbourhood representatives, and local actors representing vulnerable groups.

Institutional engagement included Artvin Governorship, Hopa District Governor's Office, AFAD, the Turkish State Meteorological Service, and relevant municipal units. These institutions contributed to the interpretation of local disaster risk, data needs, emergency response priorities, and institutional coordination requirements. The academic and technical teams contributed to the interpretation of GIS-based models, susceptibility maps, Cost Path scenarios, EOC site selection criteria, service area analyses, and disaster logistics planning.

The feedback received from stakeholders directly shaped the risk evaluation. The Artvin Deputy Governor drew attention to the relationship between the development dynamics around Hopa State Hospital and river flooding susceptibility. This feedback strengthened the interpretation of flood risk as a public service continuity issue. The Hopa District Governor emphasized the strategic importance of evacuation and access routes towards Artvin and requested that route distance and estimated travel time be considered in the modelling process. This feedback increased the operational relevance of the alternative route analysis.

Neighbourhood headmen, particularly from Sundura and Ortahopa, provided micro-scale field information on road sections affected by inundation, drainage problems, culvert blockages, and local landslide points. This field knowledge helped compare model outputs with observed local conditions. The Hopa Association of People with Physical Disabilities emphasized safe evacuation, accessible temporary sheltering, access to healthcare services, and the regular updating of vulnerable group data. As a result, risk evaluation was not limited to physical hazard exposure, but also included access, social vulnerability, and emergency service continuity.

Therefore, the Key Risk Assessment was not carried out only as a desk-based technical exercise. It was developed as a joint interpretation process in which local knowledge, institutional priorities, expert judgement, and the needs of vulnerable groups were brought together.

2.4.2 Gather output from Risk Analysis step

The risk evaluation used both the outputs of the standard CLIMAAX workflows and the additional local analyses produced in Phase 2. These outputs were brought together to assess how river flooding, heavy rainfall, and landslides may affect Hopa's urban system and disaster management capacity.

For river flooding, the evaluation used historical river flood depth maps provided by JRC for 10–500 year return periods, future river flood maps from Aqueduct under RCP4.5 and RCP8.5 scenarios, and comparative flood risk outputs for 2030, 2050, and 2080. These datasets were used to understand both current flood exposure and possible future changes in flood depth and extent.

For heavy rainfall, the evaluation used a 46-year CHIRPS baseline, downscaled MOHC-HadGEM2-ES climate projections for the 2041–2070 period under RCP8.5, and GEV-based extreme precipitation return period analyses. These outputs were used to assess changes in the frequency and magnitude of extreme rainfall thresholds, particularly the 100 mm/24h threshold.

For landslides and local susceptibility, the evaluation used machine learning-based susceptibility maps produced for the Hopa contiguous area. The landslide susceptibility model was trained using the AFAD landslide inventory, which included 227 landslide polygons, most of which were associated with the 24 August 2015 disaster. The XGBoost model, which had the best performance with an AUC value of 0.957, was used as a key input. River flooding susceptibility maps produced with the same modelling logic were also used.

The urban exposure layer included MAKS-based building data, the road network, zoning blocks, infrastructure lines, healthcare facilities, temporary shelter areas, bridge crossings, stream corridors, coastline data, and critical institutional locations. The assessment also used the outputs of the alternative route modelling process, including the 10 Cost Path scenarios and the comparison between Scenario 9 and Scenario 10. In addition, EOC site selection outputs, AHP-based criteria weights, service area analyses, equipment parking area proposals, and the heavy vehicle and disaster logistics area design were integrated into the risk evaluation.

In this way, the risk evaluation was based on a combined set of hazard, exposure, vulnerability, accessibility, and operational capacity outputs.

2.4.3 Assess Severity

The severity assessment was carried out separately for current and future risk conditions, using the four categories defined in the Key Risk Assessment Protocol: limited, moderate, substantial, and critical.

River flooding was assessed as substantial under current conditions and critical under future conditions. The current severity is already substantial because Hopa has experienced destructive river flooding events in the recent past, most notably the disaster of 24 August 2015. This event caused loss of life, missing people, infrastructure damage, transport disruption, and damage to settlements. The spatial analysis also shows that 827 buildings, corresponding to approximately 28% of the existing building stock within the contiguous area, are located in areas with high or very high river flooding susceptibility. In addition, 25.21 km of the road network, corresponding to approximately 15% of the total road network, is located in high or very high river flooding susceptibility zones.

Future severity was assessed as critical because projections indicate that flood depth, flood extent, and extreme rainfall conditions may intensify under climate change scenarios, particularly under RCP8.5. Flooding in Hopa does not only affect individual buildings or isolated land parcels. It may disrupt roads, bridges, healthcare access, temporary shelter access, critical infrastructure services, and the connection between the two banks of the city. Therefore, river flooding has the potential to create cascading impacts on the entire local disaster management system.

Heavy rainfall was assessed as substantial under current conditions and critical under future conditions. The current severity is substantial because heavy rainfall is the primary driver of river flooding, flash flooding, surface runoff, drainage overload, slope instability, and landslide processes in Hopa. The local meteorological trend analysis shows an increasing trend in maximum precipitation, which is particularly important for flood and river flooding risk. The 2015 disaster also showed that intense rainfall occurring within a short period can rapidly generate multiple impacts, including river flooding, landslides, infrastructure damage, and transport disruption.

Future severity was assessed as critical because the extreme precipitation analysis indicates a significant increase in both the frequency and magnitude of extreme rainfall events. Under the RCP8.5 mid-century projection, the 100 mm/24h precipitation threshold is expected to occur more frequently. This means that events that were historically rare may become more common. Heavy rainfall was therefore considered the main trigger of cascading failures in Hopa's urban and emergency response systems.

Landslides were assessed as moderate under current conditions and substantial under future conditions. The current severity is moderate because landslide susceptibility is spatially more fragmented than river flooding susceptibility, but it still affects critical road sections, slope settlements, and access corridors. According to the exposure analysis, 360 buildings, corresponding to approximately 12% of the building stock, are located in areas with high or very high landslide susceptibility. Approximately 16 km of the road network is also located in areas with high or very high landslide susceptibility.

Future severity was assessed as substantial because landslides are expected to become more critical under conditions of increasing extreme rainfall, soil saturation, and slope instability. Landslides may block evacuation routes, isolate neighbourhoods, damage roads and infrastructure, delay emergency response, and create secondary risks during or immediately after heavy rainfall events. For this reason, landslide risk was not treated as a secondary issue, but as a key component of Hopa's multi-hazard risk profile.

Stakeholder input strengthened the severity assessment. Local representatives highlighted road closures, culvert blockages, and landslide-prone points that are not always fully visible in standard datasets. The Hopa Association of People with Physical Disabilities added a social severity dimension by showing that road closures and shelter access problems may have disproportionate impacts on people with disabilities, elderly individuals, and people requiring continuous healthcare access. These perspectives confirmed that severity in Hopa should be assessed not only through hazard intensity, but also through the loss of access, service interruption, and the unequal impacts on vulnerable groups.

2.4.4 Assess Urgency

The urgency assessment was carried out using the categories defined in the Key Risk Assessment Protocol: no action needed, watching brief, more action needed, and immediate action needed.

River flooding was assessed as requiring immediate action. This score is based on both current exposure and projected future intensification. River flooding in Hopa is associated with sudden-onset events and can create major impacts within a short period of time. The risk is expected to worsen under future climate conditions, especially through the interaction of more intense precipitation, narrow valley floors, low-elevation urban areas, and constrained transportation corridors. Because roads, bridges, temporary shelter access, healthcare access, and institutional coordination may be affected at the same time, action needs to start immediately rather than being postponed to a later planning period.

Heavy rainfall was also assessed as requiring immediate action. The risk mechanism is sudden rather than slow-onset. Extreme rainfall can generate high surface runoff within minutes or hours, especially in Hopa's steep topography and narrow coastal plain. The mid-century RCP8.5 projections indicate that the frequency of the 100 mm/24h threshold may increase significantly, while precipitation magnitude may also intensify. This means that existing drainage, road, culvert, and flood protection assumptions based on historical rainfall conditions may become insufficient. Therefore, heavy rainfall requires urgent integration into infrastructure design, drainage capacity assessment, early warning systems, and emergency preparedness.

Landslides were assessed as requiring more action. Although landslide risk is closely linked to sudden rainfall events, many effective landslide risk reduction measures, such as slope stabilization, retaining structures, drainage improvements, and road cut reinforcement, require medium-term engineering planning and investment. The urgency is therefore high, but it is different from the immediate operational urgency of river flooding and heavy rainfall. Landslide risk needs more systematic action before future extreme rainfall conditions increase slope instability and road blockage risk.

Stakeholder perspectives increased the urgency scoring. The District Governor's emphasis on Artvin access routes, the neighbourhood headmen's feedback on road and culvert problems, and the feedback from vulnerable groups on evacuation needs all showed that delayed action would increase the probability of operational failure during a disaster. The urgency assessment therefore concluded that Hopa must prioritize immediate measures for river flooding and heavy rainfall, while initiating more structured and medium-term mitigation measures for landslides.

2.4.5 Understand Resilience Capacity

The resilience capacity assessment examined Hopa's ability to respond to each risk by considering existing physical, human, social, institutional, financial, and natural capacities. The categories used were low, medium, substantial, and high.

For river flooding, resilience capacity was assessed as low. Hopa has several existing capacities, including the municipal emergency response vehicle fleet, the fire brigade, temporary shelter areas identified in school gardens, healthcare facilities, and local institutional coordination experience. However, the city's two-bank settlement structure creates a major weakness. If bridge crossings or main road connections fail during a major river flooding event, the left bank, including Sundura Neighbourhood, may become physically isolated from the main emergency response network. This makes a single-centre response structure insufficient. The planned second equipment and vehicle parking area in Sundura is therefore a critical measure to strengthen geographical redundancy, but until this measure is fully implemented, resilience capacity remains low.

For heavy rainfall, resilience capacity was assessed as medium. Hopa has basic stormwater drainage infrastructure, municipal response capacity, meteorological data access, and institutional awareness of extreme rainfall risk. However, the analysis shows that future rainfall intensification may exceed the design assumptions of existing drainage and protection systems. The lack of a fully developed local early warning system, limited culvert and drainage capacity data, and the absence of a formal climate change safety margin in infrastructure design are important weak points. Therefore, the capacity is not low in all dimensions, but it is not yet sufficient to address the projected increase in extreme rainfall risk.

For landslides, resilience capacity was assessed as low. The municipality and AFAD have knowledge of landslide-prone areas, and the Phase 2 susceptibility mapping provides a strong technical basis for future action. However, systematic slope stabilization, road cut protection, event-based landslide monitoring, and drainage interventions are not yet sufficient across the entire risk area. Since landslides may block evacuation routes and isolate neighbourhoods, physical resilience capacity needs to be strengthened through engineering measures, road maintenance planning, and targeted investments.

Several planned interventions are expected to improve Hopa's resilience capacity. The proposed EOC in Merkez Kuledibi is designed to remain operational for at least 72 hours after a disaster, with backup energy, water storage, communication capacity, a helipad, security standoff distance, and logistics support functions. The EOC site selection process also excluded areas with high river flooding susceptibility, high landslide susceptibility, liquefiable ground, and proximity to secondary hazard sources.

Despite these planned improvements, **the current resilience capacity remains uneven.** Physical capacity is developing, but still vulnerable to road and bridge disruption. Human and institutional capacity is improving through the Phase 2 process and planned Phase 3 trainings. Social capacity has been strengthened by involving vulnerable groups, but more detailed demographic and accessibility data are still needed. Financial and implementation capacity will depend on transforming the planned routes, EOC area, equipment parking areas, and logistics facilities into funded implementation projects.

2.4.6 Decide on Risk Priority

Risk Workflow	Severity		Urgency	Capacity	Risk
	C	F		Resilience/ CRM	
River flooding	3	4	4	1	Very High
Heavy rainfall	3	4	4	2	Very High
Landslides	2	3	3	1	

Severity
- Critical
- Substantial
- Moderate
- Limited

Urgency
- Immediate action needed
- More action needed
- Watching brief
- No action needed

Resilience Capacity
- High
- Substantial
- Medium
- Low

Risk Ranking
- Very high
- High
- Moderate
- Low

Figure 36 The Evaluation Dashboard

Risk priority was assigned by combining the severity, urgency, and resilience capacity scores in the Key Risk Assessment dashboard. The process also considered stakeholder feedback, expert judgement, local exposure data, and the operational consequences identified in the Phase 2 analyses.

The first priority is the combined hydrometeorological risk created by heavy rainfall and river flooding. Heavy rainfall is the main trigger that can rapidly generate river flooding, drainage overload, surface runoff, slope instability, road disruption, and emergency access problems. River flooding is the main impact pathway through which this hazard affects settlements, roads, bridges, healthcare access, temporary shelter areas, infrastructure systems, and disaster logistics. For this reason, river flooding and heavy rainfall were both assigned a very high priority.

The second priority is landslide risk. Landslides were assigned a high priority because they can block evacuation corridors, interrupt the Hopa–Artvin road connection, damage infrastructure, and isolate neighbourhoods during or after heavy rainfall. Although current severity is assessed as moderate, future severity is expected to increase under more intense rainfall conditions. Low resilience capacity also raises the overall priority of this risk.

The overall priority decision is that Hopa's most critical risk is the possibility of integrated urban infrastructure and access disruption caused by the interaction of heavy rainfall, river flooding, and landslides. The highest spatial priorities are Sundura and Ortahopa Neighbourhoods, the former municipal square area, the surroundings of Hopa State Hospital, the industrial site, the old truck parking area, and access corridors linked to the Hopa–Artvin road. These areas combine physical exposure, critical infrastructure, dense or vulnerable population groups, and operational importance.

2.5 Monitoring and Evaluation

The second phase of the SAFE-HOPA project showed that climate risks in Hopa need to be assessed together with their impacts on the urban system, transportation continuity, disaster coordination, critical infrastructure, temporary shelter, access to healthcare services, and vulnerable groups. The most important learning from this phase is that river flooding, heavy rainfall, and landslide risks in Hopa should not be addressed as independent events, but as multi-risk processes that reinforce each other and directly affect disaster management capacity.

In particular, the fact that Sundura Stream divides the city into two banks, the strategic importance of the Hopa–Artvin connection, the exposure of buildings and roads in risk areas, the possibility that vehicle and equipment dispatch may be interrupted during a disaster, and the need to locate the EOC safely formed the main monitoring and learning themes of the Phase 2 assessment.

The main difficulty encountered in the second phase was the integration of datasets of different scales and characteristics within the same decision-support framework. River flooding and landslide susceptibility maps, meteorological trend analysis, road network data, building data, zoning blocks, bridge crossings, temporary shelter areas, infrastructure lines, healthcare facilities, service areas, and EOC site selection criteria consist of data produced through different institutions and technical processes. Some of these data directly represent the existing situation, while others are based on planning decisions, zoning roads, or design proposals.

For this reason, during the analysis process, model results were compared with field knowledge obtained from municipal units, the academic team, the technical team, and relevant stakeholders. In particular, the testing of 10 different scenarios in the alternative route study shows that the initial model outputs were not accepted directly. Instead, they were gradually improved together with local constraints such as buildings, zoning blocks, stream-bridge crossings, road width, and disaster susceptibility.

Stakeholders played the role of joint evaluators who defined the local meaning of risk and the applicable decisions within the monitoring and evaluation process. Contributions from the Governorship, District Governor's Office, AFAD, Meteorology, the academic team, the technical team, municipal units, neighbourhood representatives, and local actors representing vulnerable groups strengthened the different dimensions of the risk assessment.

The engagement established with the Hopa Association of People with Physical Disabilities also showed that risk should be assessed in terms of accessible evacuation, temporary shelter, and access to healthcare services. These feedback processes enabled the CRA outputs to become more inclusive and more responsive to local needs in terms of policy and implementation.

In Phase 2, new data and knowledge were produced on risks and the urban system. These include the relationship between river flooding and landslide susceptibility and urban uses and the road network, alternative route scenarios, the comparison of Scenario 9 and Scenario 10, EOC suitability analysis, service area analyses, equipment and vehicle parking area proposals, EOC campus design, and heavy vehicle–disaster logistics area design.

However, additional data are still needed to understand the risks better. The priority needs include event-based records of road closures and bridge damage, updated culvert and drainage capacity data, stream cross-sections and hydraulic modelling data, building-level information on vulnerable populations, an updated database on the disaster-time access needs of disabled and elderly individuals, real-time rainfall and stream level monitoring systems, critical infrastructure failure records, and a regular recording system for post-disaster response times.

In addition, further studies are needed on geotechnical surveys, ownership, expropriation, costs, and inter-institutional division of authority in order to transform the planned routes and facility areas into implementation projects.

The best-functioning process in this phase was the bringing together of academic and technical expertise with the municipality's local implementation knowledge within the same analytical framework. Cost Path analyses, AHP-based site selection, service area assessments, EOC campus design, and logistics area planning transformed Hopa's disaster risks from an abstract hazard assessment into concrete spatial and operational decisions.

On the other hand, data gaps and implementation uncertainties continue in some areas. In particular, the updating of social vulnerability data, the creation of event-based transportation interruption records, capacity analyses of drainage infrastructure, the feasibility of roads that are defined in the zoning plan but not yet opened on the ground, and the clarification of the proposed facility areas in terms of planning processes remain issues that need further work.

The impact of the SAFE-HOPA Phase 2 climate risk assessment is evaluated as a significant deepening of risk understanding in Hopa. The study made it possible to read river flooding and landslide risks not merely as hazard areas, but through the continuity of urban functions, emergency response capacity, two-bank access security, protection of vulnerable groups, continuity of infrastructure services, and disaster coordination.

In this respect, the CRA creates value in terms of public awareness, institutional capacity, technical planning, and investment prioritisation. The outputs obtained will enable Hopa Municipality to proceed with a stronger technical basis in the next phase for adaptation measures, implementation projects, training and drill activities, inter-institutional coordination, and financing searches.

2.6 Work plan Phase 3

Phase 3 will begin as the Local Adaptation Strategies stage covering the period from July 2026 to December 2026, as defined in the IFP.

The first area of work in this phase will be capacity-building activities for technical staff and stakeholders. Trainings will be organized for municipal staff, representatives of institutions related to disaster management, technical teams, and relevant stakeholders on climate risk assessment, the use of river flooding and landslide susceptibility maps, the integration of alternative routes into disaster response plans, and the implementation of the CLIMAAX approach at the local level. The aim of these activities is to transform the technical outputs produced in Phase 2 into a permanent decision-support capacity for the municipality and relevant institutions.

The second area of work will be the strengthening of disaster response planning. The alternative routes, EOC location, vehicle and equipment parking areas, and logistics area decisions identified in Phase 2 will be linked with disaster management plans. Within this scope, coordination meetings will be held with Hopa Municipality, AFAD, the District Governor’s Office, relevant public institutions, the academic team, and local stakeholders. Issues such as continuity of access during disasters, inter-institutional division of responsibilities, logistics dispatch, and access to vulnerable groups will be evaluated together.

The third area of work will be community awareness and training activities. In Phase 3, basic disaster awareness activities will be carried out for local residents, neighbourhood representatives, and groups at risk. These activities will focus on preparedness before heavy rainfall, safe behaviour during floods and landslides, evacuation, temporary shelter, access to healthcare services, and early warning communication strategies. In addition, disaster awareness and preparedness trainings will be conducted in 24 schools in Hopa. Students, teachers, and school administrations will be informed about the project outputs.

The fourth area of work will be data updating and planning integration. Updating the building inventory within municipal boundaries, reassessing the relationship between risk areas and the building stock, and reviewing zoning plans in light of geological and geotechnical data will be important components of Phase 3. This work is important for reflecting the river flooding and landslide susceptibility identified in Phase 2 in long-term urban planning decisions. In this way, risk maps will become a planning basis that can be used in zoning, infrastructure, and disaster management decisions.

The fifth area of work will be policy recommendations and dissemination of results. SAFE-HOPA outputs will be presented to decision-makers at municipal, district, and provincial levels, and policy recommendations will be prepared. Sharing the project results on national and international platforms and making them visible through media outputs and technical reports will also be part of this phase.

As a result, Phase 3 represents the transition stage of the SAFE-HOPA project from risk assessment to local adaptation strategy. During this period, the main risk priorities identified in Phase 2 will be followed up through training, awareness-raising, disaster response planning, data updating, zoning and planning assessment, policy recommendations, and dissemination activities. The final objective is to increase the institutional, social, and spatial resilience of Hopa Municipality against disasters caused by river flooding, heavy rainfall, and landslides, and to establish a strong basis for the adaptation strategies and improved risk management plans to be developed by the end of the project.

3 Conclusions Phase 2- Climate risk assessment

The second phase of the SAFE-HOPA project revealed that climate-related disaster risks in Hopa need to be assessed together with their cascading impacts on transportation continuity, continuity of urban services, emergency response capacity, logistics organization, critical infrastructure, and access to vulnerable groups. The main conclusion reached in this phase is that Hopa's disaster risk is an integrated urban resilience issue that must be interpreted together with the city's topography, high precipitation regime, two-bank settlement structure, narrow transportation corridors, development pressure around Hopa Stream, and limited operational redundancy capacity. For this reason, the Phase 2 studies advanced the risk framework defined in Phase 1 to a more applicable and decision-support-oriented level through local data, GIS-based analyses, disaster susceptibility maps, trend analysis, zoning data, alternative route modelling, and emergency operations center planning.

One of the most critical findings of Phase 2 is the overlap between the existing building stock and transportation network and risk areas. According to MAKS data, there are 2,954 buildings within the contiguous area. Of these, 360 buildings, corresponding to approximately 12%, are located in areas with high or very high landslide susceptibility, while 827 buildings, corresponding to approximately 28%, are located in areas with high or very high river flooding susceptibility. A similar vulnerability is observed in relation to the road network. Approximately 16 km of the 165,142 m road network is located in areas with high and very high landslide susceptibility, while 25.21 km is located in areas with high and very high river flooding susceptibility. This result shows that the core issue of disaster management in Hopa is to plan in advance which roads, crossings, neighbourhood connections, and service points may lose their function during a disaster.

The alternative route study was one of the most concrete local analytical responses to this problem. As a result of 10 different scenarios, alternative transportation routes that can maintain their functionality during disasters were identified. Ultimately, Scenario 10 was preferred, especially for the Terzioğlu Hotel source point, because it uses 15 m-wide zoning roads, is safer in terms of disaster risk, and increases transportation capacity.

The EOC site selection study constitutes the second main conclusion of Phase 2. This study showed that the disaster and emergency coordination center should be addressed as a critical disaster management facility where teams, materials, data, communication, media relations, and inter-institutional coordination are managed during disasters. In the analysis carried out using GIS and AHP methods, 12 criteria were used and weighted based on the opinions of 18 experts. The result showed that river flooding susceptibility, landslide susceptibility, proximity to roads, and geology/lithology accounted for 66.3% of the total weight. This clearly demonstrates that disaster safety, ground suitability, and accessibility should be the primary priorities in EOC site selection in Hopa.

The EOC design criteria transformed the site selection finding into an operational campus model. The Hopa EOC is planned to operate as the main center where crisis coordination, communication, logistics management, search and rescue coordination, and field operations are managed within the first 72 hours after a disaster. Emergency response, data collection, and field security were defined as the main functions in the first 0–24 hours. Logistics distribution, temporary shelter coordination, and health support organization were defined for the 24–48 hour period. Sustainable operations, critical infrastructure repairs, and regional coordination activities were defined for the 48–72 hour period.

The heavy vehicle and disaster logistics area study showed that the logistics capacity to be deployed in the field during disaster management also needs to be positioned in a safe, accessible, and redundant manner. Considering Hopa Municipality's existing fleet of 29 vehicles and the needs of reinforcement teams that may arrive during a disaster from AFAD, Highways, DSI, the Special Provincial Administration, and neighbouring municipalities, functional zoning was carried out for the EOC heavy vehicle and disaster logistics area by separating construction machinery, heavy trucks, emergency response vehicles, and temporary support vehicles. The fuel supply point, maintenance workshop, open logistics storage area, drainage system, slope safety measures, and manoeuvring areas formed the main components of this planning. The three-terrace logistics area design of approximately 4,000 m² was assessed as a solution capable of meeting the principles of operational continuity, safety, accessibility, and logistics efficiency despite limited land conditions. However, the need to plan additional logistics storage areas for future capacity increases also emerged as a clear conclusion.

As a result, Phase 2 transformed the climate risk assessment for Hopa from a general hazard identification study into an integrated analysis platform that directly informs local disaster management decisions. The main outputs of this phase are making visible the overlap between river flooding and landslide susceptibility and the urban structure, transportation, and infrastructure systems; identifying safe and applicable alternative routes that can be used during disasters; identifying a safe, accessible, and scalable EOC location in Merkez Kuledibi; spatially defining operational capacity for the heavy vehicle and disaster logistics area; clarifying the need for geographical redundancy on the two banks of Sundura Stream; and relating all these results to the objectives of the national TAMP and local IRAP. Therefore, Phase 2 was completed as a critical stage that strengthened Hopa Municipality's institutional capacity, spatial decision support, and response planning level against climate-related disasters.

The final conclusion of this study is clear: resilience in Hopa is possible by establishing safe access corridors, organizing disaster coordination at a high and secure location, distributing heavy vehicle and logistics capacity across the two banks, managing critical infrastructure together with risk information, and continuously feeding decision-making processes with up-to-date data. The analyses produced in Phase 2 created a strong technical basis for Hopa's future adaptation strategies and clearly identified the priorities through which the training, awareness-raising, plan updating, policy recommendation, and implementation preparation activities to be developed in Phase 3 should proceed. In this respect, SAFE-HOPA Phase 2 is a climate risk assessment stage establishes an applicable roadmap for reducing it.

4 Progress evaluation

Table 6 Overview key performance indicators

Key performance indicators	*Progress*
1 Multi-hazard risk assessment conducted using the CLIMAAX Toolbox	*Achieved*
2 risk maps using CLIMAAX's hazard assessment methodologies	*Achieved*
1 Subcontracting process completed and technical assessments initiated	*Achieved*
10 Stakeholder meetings organized to define responsibilities and collect data	*Achieved*
5 Infrastructure resilience studies conducted	*Achieved*
3 Refined local risk assessments completed with detailed local data	*Achieved*
3 Refined local risk assessments completed with detailed local data	*Phase 3*
30 technical staff and stakeholders trained in climate risk assessment	*Phase 3*
3 policy recommendations formulated for disaster resilience	*Phase 3*
27 Community awareness and education sessions held	*Phase 3*
5 Scientific publications, media mentions, or policy briefs prepared	*Phase 3*

Table 7 Overview milestones

Milestones	*Progress*
Project kickoff meeting held, and task distribution completed	*Achieved*
Stakeholders identified, and responsibilities defined	*Achieved*
Barcelona workshop attended	*Achieved*

Milestones	*Progress*
Multi-hazard risk assessment completed, and necessary data collected	*Achieved*
Temporary shelter areas identified, and priorities defined	*Achieved*
Infrastructure maps and alternative routes developed	*Achieved*
Necessary planning for the establishment of the Disaster Coordination Center and the data management system was completed	*Achieved*
Necessary measures planned for risk areas	*Achieved*
Obtained meteorological data and conducted temporal analysis	*Achieved*
All processes presented to policymakers	*Phase 3*
Communities and stakeholders were trained and actively included in the plan and finalized adaptation strategies and risk management plans.	*Phase 3*
Visits to all 24 schools in Hopa were completed, and students were engaged in awareness activities regarding the CLIMAAX Toolbox and project outputs	*Phase 3*
Sustainability ensured through continued monitoring	*Phase 3*
Brussels workshop attended.	*Phase 3*

5 Supporting documentation

Table 8 Scoring of the sub-criteria

Main Criterion	Sub-criteria	Score	Main Criterion	Sub-criteria	Score
River Flooding Susceptibility	1 (Very Low)	10	Proximity to the Coastline (m)	0 – 50	0
	2 (Low)	8		50 – 100	3
	3 (Moderate)	6		100 – 150	6
	4 (High)	NoData		150 – 300	8
	5 (Very High)	NoData		300 – 4309.88	10
Landslide Susceptibility	1 (Very Low)	10	Proximity to Police Station Locations (m)	0 – 1000	10
	2 (Low)	8		1000 – 2000	8
	3 (Moderate)	6		2000 – 3000	6
	4 (High)	NoData		3000 – 4000	4
	5 (Very High)	NoData		4000 – 4545.44	2
Proximity to Roads (m	0 – 150	10	Proximity to Hazardous Facilities (m)	0 – 100	0
	150 – 300	8		100 – 200	2
	300 – 450	6		200 – 300	6
	450 – 600	4		300 – 400	8
	600 – 746.07	2		400 – 5062.30	10
Altyapı Proximity to Infrastructure Facilities (m)	0 – 150	10	Proximity to the Fire Station (m)	0 – 1000	10
	150 – 300	8		1000 – 2000	8
	300 – 450	6		2000 – 3000	6
	450 – 600	4		3000 – 4000	4
	600 – 1238.40	2		4000 – 5696.45	2
Proximity to Healthcare Facilities (m)	0 – 500	10	Proximity to Government Offices (m)	0 – 500	10
	500 – 1000	8		500 – 1000	8
	1000 – 1500	6		1000 – 2000	6
	1500 – 2000	4		2000 – 3000	4
	2000 – 3573.04	2		3000 – 4620.29	2
Proximity to Settlement Areas (m)	0 – 150	0	Geology/Lithology (Soil Class)	2 (ZB)	10
	150 – 300	2		3 (ZC)	7
	300 – 450	4		4 (ZD)	3
	450 – 600	8		5 (ZF: Liquefiable alluvial soils)	NoData

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