COMPARATIVE ANALYSIS OF CLIMATE CHANGE ADAPTATION AND DISASTER RISK REDUCTION ARCHITECTURE AND RECOMMENDED ACTIONS

Road Map

2018

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Acronyms and Abbreviations

AAR	Adjara Autonomous Republic
ADB	Asian Development Bank
AF	Adaptation Fund
AHS	Automated Hydrological Station
ALCP	Alliances Lesser Caucasus Programme
ARCC	Agricultural Research and Consultation Centre
ASB	Arbeiter-Samariter-Bund
ASL	Above Sea Level
ASS	Georgian Samaritan Association
AWS	Automated Weather Station
BDD	Basic Data and Directions
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BS	Bachelor of Science
BSME-FFG	Black Sea and Middle East Flash Flood Guidance (BSMEFFG) System
BUR	Biennial Update Report
^{0}C	Celsius degree
CADRI	Capacity for Disaster Reduction Initiative
CBMHEWS	Community-based multi-hazard early warning system
CBMHRM	Community-based multi-hazard risk management
CC	Climate Change
CCA	Climate Change Adaptation
CCD	Climate Change Division
CCM	Climate Change Mitigation
CCNH	Centre for Control of Natural Hazards
CCTV	Closed-circuit television (also known as video surveillance)
CENN	Caucasus Environmental NGO Network
CEF	Climate Forum East
CIS	Commonwealth of Independent States
CLIDATA	archiving software for climatological data
CMF	Caucasus Mountain Forum
CMS	Composite of Multiple Signals
CNF	Caucasus Nature Fund
COP	Conference of Parties
CORS	Continuously Operating Reference Station
CRM	Climate Risk Management
CSA	Climate Smart Agriculture
CSO	Civil Society Organization
CZDA	Czech Development Agency
DELFT-FEWS	open data handling platform/software developed by Deltares as a hydrological forecasting and warning system
DEM	Digital Elevation Model
DIPECHO	EU Disaster Preparedness Programme
DMCT	UN Disaster Management Coordination Team
DoECC	Department of Environment and Climate Change
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction

EC	European Commission
ECCD	Environment and Climate Change Division
ECMWF	European Centre for Medium-Range Weather Forecasts
ED	Environment and Development, Georgian NGO
EEC	European Economic Community
EIA	Environmental Impact Assessment
EIB	European International Bank
EIEC	Environmental Information and Education Centre
EMA	Emergency Management Agency
EMS	Emergency Management Service
ENPARD	European neighbourhood programme for agriculture and rural development
ENPI	European Neighbourhood and Partnership Instrument
EU	European Union
EUAA	EU Georgia Association Agreement (full title: ASSOCIATION AGREEMENT between the European Union and the European Atomic Energy Community and their Member States, of the one part, and Georgia, of the other part)
EUD	EU Delegation to Georgia
EWS	Early Warning System
FAO	Food and Agriculture Organization
FD0	Number of frosty days (extreme weather index)
FCCC	Framework Convention on Climate Change
FEWS	Flood Early Warning System
FNC	Fourth National Communication
FTP	File Transfer Protocol
GCAA	Georgian Civic Aviation Agency
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEL	Georgian Lari
GEO	Georgia's Environmental Outlook, Georgian NGO
GEO	Group on Earth Observations
GEOSS	GEO System of Systems
GEO CORS	Georgian Continuously Operating Reference Station
G4G	Governance for Growth (USAID Economic Development Programme)
GFA	Gesellschaft für Agrarprojekte in Übersee (Society for agricultural projects, overseas)
GFS	Global Forecast System
GIS	Geographic Information System
GiZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GNSS	Global Navigation Satellite System
GoG	Government of Georgia
GPRS	General Packet Radio Service
GRF	The Governance Reform Fund
GRCS	Georgian Red Cross Society
GSHS	Georgian State Hydrographic Service
GSM	Global System for Mobile communications
GTU	Georgian Technical University
HEC-HMS	Hydrological modeling system of the Hydrological Engineering Centre
HCT	Humanitarian Coordination Team
HR	Human resources

HRM	Hydrological Research Model
HTTP	Hypertext Transfer Protocol
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICRC	International Committee of the Red Cross
ID0	Frosty days index
IDPs	Internally Displaced Persons
IFAD	International Fund for Agriculture Development
IHO	International Hydrographic Services
INDC	Intended Nationally Determined Contribution
INSPIRE	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community
IP	Internet Protocol
IR50	Tropical thunderstorm index (number of days with more than 50 mm precipitation)
JOC	Joint Operational Centre
KfW	Entwicklungsbank (German Development Bank)
km	Kilometre
km²	Square kilometre
LAM	Limited area model
LAN	Local Area Network
LEPL	Legal Entity of Public Law
LG	local government
LMD	Land Management Division
L-SLM	Landscape and Sustainable Land Management
Ltd	Limited liability
m	metre
mm	millimetre
m²	square metre
m³	cubic metre
MDF	Municipal Development Fund
MoEPA	Ministry of Environmental Protection and Agriculture
MoESCS	Ministry of Education, Science, Culture and Sports
MoESD	Ministry of Economy and Sustainable Development
MHEWS	Multi-hazard early warning system
MIA	Ministry of Internal Affairs
MIKE	Flood computer program that simulates inundation for rivers, flood plains and urban drainage systems.
MRDI	Ministry of Regional Development and Infrastructure
MS	Master of Science
MWS	Manual Weather Station
NALAG	National Association of Local Authorities of Georgia
NAP	National Adaptation Plan
NAPA	National Adaptation Program of Action
NAPR	National Agency for Public Registry
NC	National Communication
NCMC	National Crisis Management Centre
NDC	Nationally Determined Contribution
NEAP	National Environmental Action Programme
NEA	National Environmental Agency
NEMIS	National Emergency Management Information System

NFA	National Food Agency
NGO	Non-Governmental Organization
NVE	Norwegian Water Resources and Energy Directorate
OCMC	Operation Control/Management Centre
OPMET	Operational aeronautical meteorological data
QA/QC	Quality Assurance/Quality Control
PCPM	Polish Centre for International Aid
PDNA	Post-Disaster Need Assessment
PIF	Project Identification Form
PPRD	Prevention, Preparedness and Response to Natural and Man-made Disasters in the Eastern Partnership Countries
RC/HC	Resident Coordinator/Humanitarian Coordinator (of UNDP)
RDFG	Association Rural Development for Future Georgia
RECC	Regional Environmental Centre of Caucasus
RETIM 2000	part of World Meteorological Organization's Global Telecommunication System
RS	Remote Sensing
RTMC pro	Real-Time Monitor and Control Software, Professional Version
SDC	Swiss Development Cooperation Agency
SDG	Sustainable Development Goal
SIDA	Swedish International Development Agency
SISCO	Security Identification Systems Corporation
SNC-mt	Scientific Network for the Caucasus Mountain Region
SNC	Second National Communication
SOLAS	International Convention for the Safety of Life at Sea
SOP	Standard Operating Procedure
SSCMC	State Security and Crisis Management Council
SSH	Secure Shell (cryptographic network protocol for operating network services securely over an unsecured network)
SU25	Number of hot days index
TNC	Third National Communication
TSU	Tbilisi State University
TR20	Tropical nights index
TV	Television
UN	United Nations
UNECE	The United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
USA	United States of America
USAID	United States Agency for International Development
WAN	Wide Area Network
WB	World Bank
WG	Working Group
WinZPV	complex information system used by the Czech Hydrological Institute to record river water measurements
WMO	World Meteorological Organization
WMS	Web Map Service
WRF model	Weather Research and Forecasting Model

Executive Summary

Objective, scope and methodology of the study

The study "Assessment of hazard mapping system in Georgia and recommended actions (road map)" was developed under the inception phase of the Project "Strengthening the Climate Adaptation Capacities in Georgia", implemented by the UNDP Country Office in Georgia with financial support from the Swiss Agency for Development and Cooperation (SDC). The primary objective of the study is to assess the existing hazard mapping architecture in Georgia, including current capacities and gaps, and based on that, develop recommended actions (a "road map") for the country to fill the gaps and meet existing capacity needs in hazard mapping. It is composed of the following parts:

- A stakeholder analysis to identify relevant entities from national and local governments, international and local non-governmental organizations (NGOs), civil society organizations, and academia engaged in hazard mapping;
- An assessment of the institutional and legal set-up for hazard mapping in Georgia and progress achieved in implementation of international commitments, existing practices, gaps and technical (including financial) and human capacities for hazard mapping; and
- A series of recommendations (road map) for the period (2018-2023), with actions required to enhance hazard mapping capacities, as per identified gaps/weaknesses.

The assessment only addresses mandates and capacities of stakeholders engaged in mapping of climate-induced natural hazards such as: floods, flash floods, mudflows, rockfalls, avalanches, strong winds, hailstorms, droughts etc. The study covers the entire country as well as its regions, except for the Adjara Autonomous Republic (AAR), which is covered by another consultancy assignment commissioned by the UNDP Inception Phase of the project funded by SDC.

This report was developed by applying the following methodology:

- Desk review and analysis of:
    - previously prepared studies/reports, in particular the feasibility study of the UNDP/SDC/GCF project "Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia" (hereafter, the UNDP/SDC/GCF MHEWS project) and the study "Consolidation of the hazard mapping methodology and assessment of the legal framework for its application", carried out by the firm Geographic with SDC's assistance under

- the Civil Society Organizations (CSO) Disaster Risk Reduction ((DRR) project in Georgia.
- relevant current legal-regulatory and policy documents in the area of hazard mapping

- Interviews with public and non-public institutions engaged in hazard mapping;
- Capacity gap analysis against international commitments and national statutory requirements;
- Stakeholder consultations.

Existing legal-regulatory and legal frameworks and key stakeholders

International agreements. The major international agreements that set out Georgia's obligations in hazard assessment and mapping are the following:

- The Sendai Framework for Disaster Risk Reduction (2015-2030), the first priority of which is "**Understanding disaster risk**", including hazard assessment and mapping.
- The Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention), that obliges Georgia to provide a right for all citizens to receive environmental information that is held by public authorities ("access to environmental information"). This includes information on the state of the environment.
- The Association Agreement between the European Union and the European Atomic Energy Community and their Member States of the one part, and Georgia on the other part (EUAA) makes reference to the Aarhus Convention and obliges Georgia to set up a publicly available information management system. Furthermore, it requires the country to establish a flood assessment and management system in line with the EU's Flood Directive.
- the European Directive 2007/2/EC establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) aims to create an EU Spatial Data Infrastructure (SDI), enabling the better sharing of environmental spatial information and public access to spatial information across Europe. Geospatial information considered under the Directive is extensive and includes a great variety of themes, defined in its Annexes I, II III http://inspire.ec.europa.eu/data-specifications/2892. The INSPIRE geoportal prototype is available at http://inspire-geoportal.ec.europa.eu. Regardless of the fact that Georgia is not obliged to transpose INSPIRE into Georgia, the Government of Georgia (GoG) has already started this process.

National statutory documents. The following national laws and regulations are critical for hazard mapping:

- Law of Georgia on Structure, Powers and Operational Procedures of the GoG (2004), as amended in July 2018;
- Law of Georgia on Basic Principles of Spatial Arrangement and City Planning (2005), as amended in 2014;

- Local Self-Governance Code (2014);
- Law on Emergency Situations as amended in 2017;
- Law of Georgia on Civil Safety of 3 May 2018; Civil Safety
- Law of Georgia on the Procedure of Planning and Coordination of National Security (2015);
- Resolution #262 of the GoG, dated 9 October 2013 on Setting up the Governmental Commission for the Creation and Development of Spatial Data Infrastructure;
- Government resolution on a National Action Plan for the Implementation of **the Association Agenda** between Georgia and the EU (approved annually by a governmental decree);
- Resolution #508 of the GoG on Approval of Civil Security National Plan, of 24 September 2015;
- Order #2-255 of the Minister of Environmental Protection and Agriculture (MoEPA) of Georgia on Approval of the Regulations of the Legal Entity of Public Law - National Environmental Agency (NEA), dated 19 April 2018; and
- Government Resolution #4 on Approval of National DRR Strategy (2017-2020) and Action Plan.

Major policy documents. Major policy documents for hazard mapping are as follows:

- Basic Data and Directions (BDD; 2018-2021), a mid-term expenditure framework for Georgia including strategic directions and actions to be implemented by the GoG through state funding;
- Intended Nationally Determined Contribution (INDC) defining Georgia's plans until 2030 for climate change mitigation (CCM) and climate change adaptation (CCA), including hazard mapping;
- National Environmental Action Plan (NEAP 3) , a major environmental policy document covering the period 2017-2021 and containing long-term goals, immediate objectives and a number of actions for CCA/DRR;
- National Civil Safety Plan of Georgia (2015), a major policy document for the unified emergency management system, regulating activities of the state, regional and local authorities in the area of civil safety and, defining: i) protection measures for affected population and territories, their scale, implementation procedures and competent main and supportive authorities, including risk mapping; and ii) rules and procedures for prevention, preparedness, response, recovery and rehabilitation works;
- National DRR Strategy and Action Plan, containing national DRR goals, objectives, strategic priorities and a plan of action for 2017-2020. The goal of the DRR Strategy is to create a unified, flexible and efficient system, which will ensure reduction of natural and man-made disaster risks by joint efforts and coordinated activities of the agencies defined in the Georgian legislation. The National DRR Action Plan combines planned and ongoing projects, programmes and initiatives of different Governmental agencies and NGOs. Concerning hazard assessment and mapping and related activities, the action plan includes such actions as field studies for hydraulic and hydrological modeling, development of hydraulic and hydrological models for high risk areas of Tbilisi and other areas under high risk, monitoring of geodynamic processes, assessment and mapping of geological hazards, assessment and mapping of avalanche hazards in several highly susceptible areas, procurement of a regional radar for Kutaisi airport and mini-radars, and integration of existing radar data into the NEA's weather forecasting platform etc.;
- Spatial arrangement and city development plans: currently with the assistance of GIZ, work is ongoing to develop a National Spatial Arrangement Master Plan (NSAMP) and spatial and city plans for various municipalities and settlements.

Institutional setting. Following are the key public institutions engaged in hazard assessment and mapping:

- National Agency for Public Registry (NAPR) under the Ministry of Justice (MoJ), responsible for creating a unified geospatial information management system, through establishing a national geoportal and standards for geospatial information, as well as for a land cadastre;

- National Environmental Agency (NEA) under the Ministry of Environmental Protection and Agriculture (MoEPA), responsible for monitoring and forecasting of hydrometeorological and geological parameters and climate-induced hazards, assessing and mapping climate-induced hazards and establishing and operating user-friendly climate, geological and climate-induced hazard databases;
- Ministry of Regional Development and Infrastructure (MRDI) through its Spatial Planning and Construction Policy Department[1], responsible for development and coordination of implementation of a state policy on land use, land use zoning, urban development and spatial planning, including facilitation/coordination of development of masterplans for land use, land use zoning documents, urban development plans and spatial zoning documents, and development of technical methodologies for land use, spatial planning and urban development;
- Emergency Management Service (EMS) under the Prime Minister's Office, responsible for risk assessment and mapping and running an emergency risk database to be interlinked with hazard databases;
- Ministry of Economy and Sustainable Development (MoESD) through the Georgian State Hydrography Service (GSHS), responsible for hydrographic surveys, cartography and weather forecasting for the marine environment;
- Georgian Air Navigation (Sakaeronavigatsia)[2], a limited liability company fully owned by the GoG, through its Meteorological service, responsible for the provision of necessary meteorological information flights into and out of the city airports; and
- Architecture Service of Tbilisi City Hall, responsible for a multi-layer interactive map of the city. In the near future, it intends to integrate hazard and risk maps into its online map in cooperation with the NEA and other stakeholders.

According to the newly-adopted Law on Civil Safety, as well as national Strategies on Civil Safety and DRR, municipal authorities are responsible for developing emergency passports (assessment/inventory of emergency threats/disaster risks) and local threat assessment documents, which also implies hazard assessment and mapping.

Apart from public agencies, various NGOs are engaged in climate-induced hazard assessment, modeling, mapping, processing geospatial information and developing various geospatial meta-databases. The most active NGOs are the following:

- CENN, which in 2010-2014 was actively involved in hazard and risk mapping;
- Sustainable Caucasus, involved in designing and introducing undergraduate and graduate university courses for hazard mapping and DRR, based on a Swiss methodology;
- Geographic, a GIS and Remote Sensing and Consulting Centre, active since 1998 in the areas of GIS, spatial analysis and planning, development of thematic and web-based maps. It applies such methods as field topo-geodetic surveys, GIS, remote sensing (RS), photogrammetry, GPS-technologies, integrated geodatabases, web-based maps and spatial planning etc.;
- GeoLand, a GIS and spatial information management company, with some experience in hazard mapping;
- GisLab, a GIS and spatial information management NGO, with experience in sensitivity analysis of Georgian forests, slope stability assessment and assessment of erosion processes; and
- Environment and Development (ED), recently involved in: assessment of suitable flood mitigation measures in Tbilisi, with a major objective to improve the flood risk management in the Tsavkisiskhevi River basin.

1 *This function was recently transferred from the Ministry of Economy and Sustainable Development to the MRDI.*

2 *Source: http://airnav.ge/index.php?page=ms&fullstory=49*

Concerning academic and research institutions, there are geography and geology departments under the applied science faculty at Tbilisi State University (TSU) for undergraduate and graduate degree programmes. Among various mandatory courses is one on assessment of natural hazards. Furthermore, the Institute of Geophysics at TSU has experience in multi-hazard assessment, including assessment of earthquakes, landslides, snow avalanches, flash floods, mudflows, droughts, hurricanes, frost and hail.

Major donors active in Georgia in climate-induced multi-hazard mapping are the following:

- SDC, supporting capacity development for DRR and hazard mapping, including development of capacities of academic institution in DRR and hazard mapping;
- UNDP, supporting establishment of a near-real-time multi-hazard early warning system across the country through financial assistance from the Green Climate Fund (GCF) and SDC;
- the EU, supporting adoption of major provisions of its Flood Directive;
- Sida, supporting establishment of information/data management systems in line with EU standards;
- FAO, supporting development of agrometeorological monitoring and advisory services; and
- the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), through GIZ, supporting development of the National Spatial Arrangement Plan and Spatial Arrangement and City Plans for selected municipalities.

Capacity gaps

Based on the review and analysis of existing climate-induced hazard mapping architecture, gaps and capacity needs, the following conclusions can be drawn and relevant recommendations made:

- **Climate-induced hazard mapping methodologies.** There is no single regulation on a commonly-agreed, international, standards-based methodology for multi-hazard assessment and mapping in Georgia. Moreover, there is no EU-compliant flood assessment and mapping methodology as mandated by the EUAA.
- **Hazard databases/maps and data accessibility**:
  - There is a shortage of data and information on climate, geological and geographic parameters necessary for climate-induced natural hazards in Georgia.
  - The most comprehensive, renewable, open-source database on natural hazards (the Web-Portal on Natural Hazards and Risks) hosted by the CENN is outdated. Relevant stakeholders do not actually use or maintain it. Moreover, maps contained in the Portal are of very small-scale.
  - Currently, generally available climate-induced hazard maps within the NEA are for floods and geological hazards (landslides, mudflows, rockfalls etc.). For other climate-induced hazards, including flash floods, droughts, strong winds and hailstorms, haz-

ard maps are lacking. Most maps are of small scale (1:100,000 and more) and there is a significant shortage of small-scale maps, which require hydrometeorological and geological parameters that the NEA also lacks.

- A major portion of climate and geological data and information necessary for hazard mapping is archived at the NEA mostly in paper format, and these data are not available for free to non-public sector representatives.
- Existing hazard, climate and geological databases and GIS maps are not fully compatible with the requirements and standards of the INSPIRE Directive and are not linked with the Geospatial Portal, created within the NAPR under the Sida-supported project which aims at building a unified geospatial information system in Georgia, having a single geoportal and relevant meta-databases in line with the INSPIRE Directive.

Climate-induced hazard assessment and mapping practices

- Floods and flash floods: The NEA lacks large-scale maps on high-probability floods, flash floods, flood depth, flow velocity and direction. These are lacking due to: i) a shortage of hydrometeorological (rainfall, peak discharges, water elevation/level), geodetic and geological data on river channel and floodplains as a result of limited hydrometeor-ological and geological monitoring and field surveys; ii) limited weather modeling capacities; iii) limited hydrological modeling capacities (a lack of models for major river basins, except for the Rioni River basin and the left tributaries of Alazani River basin), stemming from a lack of hydrographs for smaller watersheds due to the lack of data on watershed physical features/parameters and a lack of high-resolution (5-m and higher resolution) DEMs; iv) limited hydrodynamic/hydraulic modeling capacities without e.g. the **1D-2D/MIKE** Basin-based hydraulic models for river basins other than the Rioni River basin and catchments of the left tributaries of the Alazani River basin, also attributable to a shortage of data on channel-floodplain hydrodynamic and topographic data and lack of a high-resolution DEM; v) limited use of ground radar, and satellite imagery data and their integration into forecasting and modelling platforms.

  Concerning flash flood modeling, hazard maps on these are practically absent due to: i) a shortage of real-time rainfall monitoring data; and ii) a lack of data on soil moisture, slope and soil permeability/drainage.

- Glacier retreat: The NEA has limited experience in developing glacier hazards maps due to: i) the lack of data on complexity of terrain, weather variables, baseline data (volume, thickness), lack of the special hydrological models allowing glaciers' dynamic modeling, limited topographic and ice cover surveys/inventories and use of aerial photography and satellite imagery.
- Landslides: The NEA lacks up-to-date large-scale maps on landslide hazards due to: i) a shortage of data on meteorology (e.g. rainfall etc.) geology, topography, hydrology and vegetation cover, that can be attributed to limited hydrometeorological and geological monitoring and field surveys, and also to the limited use of software and knowledge of numerical models (e.g., the Swiss-based RAMMS).
- Mudflow and debris flow: The NEA lacks larger-scale (at least river basin level) mudflow hazard maps due to: i) a shortage/lack of data on runoff coefficient, design rainfall (intensity, duration and total amount of precipitation), peak discharges and amount of sediment available for transportation, attributable to limited hydrometeorological and geological monitoring, geological and geodetic surveys and use of aerial photography and satellite imagery; and ii) a lack of modeling tools, knowledge and capacities in application of numerical models.
- Avalanches: The NEA has limited experience in developing avalanche maps due to: i) the lack of data on complexity of terrain, weather variables, on-site weather (temperature, snowfall) and snowpack (snow depth), that can also be attributed to diminished hydrometeorological monitoring and forecasting, including snowfall and snowpack monitoring, limited topographic and snow cover surveys/inventories and use of aerial photography and satel-

lite imagery; and ii) a lack of numerical computer models (e.g. RAMMS) and capacities to run such models.

- Droughts: Only large-scale drought maps are available in the Hazard Web-Atlas, although even these are outdated. Up-to-date maps, both large- and small-scale ones are not currently produced due to: i) the lack of data on meteorological (e.g. rainfall, air temperature, relative humidity, wind velocity, solar radiation) and hydrological (e.g. discharge/streamflow) parameters, that can again be attributed to limited hydro-meteorological monitoring; ii) the lack of agrometeorological data (e.g. evapo-trans-piration, soil moisture, leaf wetness, phenology etc.), also attributable to extremely limited agrometeorological monitoring; and iii) a lack of knowledge and capacities for deriving various drought indices.
- Strong winds: Up-to-date strong wind hazard maps are not available, due to: i) the shortage of real-time meteorological data attributed to limited hydrometeorological monitoring; ii) limited weather forecasting/modeling (Numerical Weather Prediction Models) capacities; iii) limited use and integration of ground radar, lightening and satellite imagery data into existing forecasting/modelling platforms.
- Thunderstorms and hailstorms:up-to-date thunderstorm and hail hazard maps are not available, due to: i) the shortage of real-time meteorological data (e.g. rainstorms, thunderstorms, air temperature, etc.) attributed to limited hydrometeorological monitoring; ii) limited weather forecasting/modeling (NWP -Numerical Weather Prediction Models) capacities; iii) absent ground-based lightening networks and limited use and integration of ground radar and satellite imagery data into existing forecasting/modelling platforms.

- **Multi-hazard mapping.** The NEA does not practice multi-hazard mapping; however, there is some limited experience in this realm in the NGO sector.
- **Knowledge gaps and needs of local academic and research institutions, NGOs and private consulting companies in hazard mapping.** There is very limited experience of climate-induced hazard mapping in the NGO, academic and local private sectors, although many of these institutions, in particular those dealing with spatial information, GIS/RS, modeling and database management have both a solid technical background and the geospatial technologies to carry out hazard mapping (there are a few NGOs and universities that do have past and current experience in hazard mapping). The absolute majority of university courses on DRR provided by some of the leading academic institutions do not include climate-induced hazard assessment and mapping, including any on multi-hazard mapping.

Recommended actions

The recommended actions (road map) at the end of this document cover the period 2018-2023 to address gaps and meet needs in climate-induced hazard mapping. Each action is linked with relevant capacity gap(s)/need(s), international obligations, national statutory and policy requirements, responsible parties, potential source(s) of financing/donor(s), and approximate cost and timeframe.

According to cost criteria, actions are divided into low (up to 100,000 USD), medium (100,000-1,000,000 USD) and high (above 1,000,000 USD) cost categories. In terms of timeframe, actions are divided into short-term (up to one year), mid-term (up to three years) and longer-term (three to five years) categories.

The road map is a wide menu of non-structural measures that are grouped into the following three major categories: i) hazard assessment and mapping methodologies; ii) hazard databases/maps and data accessibility; and iii) hazard assessment and mapping practices.

The recommended actions focus on all of the following:

- Developing and adopting a regulation on EU-compliant flood assessment and mapping methodology;
- Developing and adopting a regulation on an international standards-based multi-hazard assessment and mapping methodology;
- Building knowledge and capacities of public authorities, primarily the NEA and local governments, as well as the non-public sector (e.g. research and academic community, NGOs and private consulting companies), representatives in application of international standards-based flood and multi-hazard assessment and mapping methodologies;
- Updating the electronic Hazards Atlas and inclusion of more detailed geospatial data and hazard maps therein;
- Building capacities of relevant state institutions, primarily the NEA, for developing climate-induced hazard maps for all types of climate-induced hazards relevant to Georgia, as well as for detailed hazard maps;
- Creating a user-friendly, electronic, climate-induced hazard database within the NEA, which various uses can readily access;
- Establishing national standards for geospatial data and maps, including hazard data and maps, aligning hazard data and maps with these standards and linking climate-induced hazard data and maps with a common Geospatial Portal;
- Expanding and upgrading existing hydrometeorological (including snowfall and snowpack/depth monitoring), agrometeorological and geological monitoring networks to cover all major river basins, as well as smaller watersheds with high climate-induced multi-hazard risks;
- Procuring additional radars (two radars for Western Georgia, in Kutaisi and Poti) as well as ground-level lightning (six detectors/antennas) detectors and integrating them into multi-hazard forecasting systems;
- Filling data gaps on watershed physical parameters, including land cover, channel-floodplain topography, geodesy, geology, hydrodynamics, soil moisture, slope, drainage, rainfall runoff coefficient, peak discharges and amounts of sediment available for transportation, and snow pack through:
    - conducting an inventory and processing historic hydrometeorological, agrometeor-ological and geological data;
    - intensifying field geological, geodetic, hydrological and snow cover surveys;
    - procuring/developing a high-resolution DEM; and
    - acquiring and effectively integrating radar, ground-based lightning detectors, aerial photography and satellite imagery data into multi-hazard forecasting and modeling platforms.
- Characterizing nearly all Georgian glaciers based on complex integrated use of high-quality satellite monitoring, along with rich historical data, current field data and expert knowledge; implementation of the quality assessment/quality control (QA/QC) procedures to obtain highly accurate and high-quality results;
- Carrying out research to determine current/recent regional climate change impacts on glaciers:

- Definition of large glaciers' retreat and changes of small glaciers' depth/volume;
- Determination of glaciers' degradation dynamics according to climate change scenarios based on hydrological modelling;
- Estimation of potentially existing fresh water resources contained in the glaciers; and
- Determination of glacial runoff share in the country's water balance and its evolution through time.

- Purchasing advanced numerical weather forecasting, hydrological, hydraulic, landslide, mudflow, avalanche and glacial melting models and training the NEA's staff in applying such models;
- Developing/calibrating hydrological, hydraulic (1D-2D/MIKE Basin), landslide, mudflow and avalanche models for all major river basins, as well as for sub-basins/smaller watersheds of river basins with high climate-induced multi-hazard risks; e.g., smaller watersheds of the Kura River Basin within the boundaries of the city of Tbilisi;
- Setting up near-real-time fully integrated flood/flash flood, landslide, mudflow/debris flow, avalanche, drought, strong wind, thunderstorm and hail forecast platforms for all major river basins, as well as for sub-basins/smaller watersheds of river basins with high multi-hazard risks, and integrating various-scale weather forecasting models and all available data into these, including monitoring, radar, ground-based lightning network and satellite data;
- Selecting and calculating proper drought indices and developing drought hazard maps: the NEA has lengthy historical data sets on daily (and sub-daily in some cases) precipitation and temperature from old stations, and a review of these data, particularly in the drought-prone regions should determine which indicator(s) should be used to calculate drought susceptibility. A drought indicator should be calculated for each grid cell within the model and for each month within the year, resulting in a drought hazard map by month and a drought susceptibility map. The results should be calibrated based on observed droughts, in particular the drought of 2000.
- Developing flood, flash flood, landslide, mudflow/debris flow, avalanche, drought, strong wind, thunderstorm and hail hazard maps, as well as climate-induced multi-hazard maps for all major basins, as well as for sub-basins/smaller watersheds with high multi-hazard risks;
- Building the NEA's and other stakeholders capacities in multi-hazard assessment and mapping, based on commonly-agreed, international standards-based methodology(-ies); and
- Developing university courses on international standards-based multi-hazard assessment and mapping.

1.0 Objective, scope and methodology of the study

This study "Assessment of Hazard Mapping System in Georgia and recommended actions (road map)" was developed under the inception phase of the Project "Strengthening the Climate Adaptation Capacities in Georgia", and implemented by the UNDP Country Office in Georgia with financial support from the Swiss Agency for Development and Cooperation (SDC).

The primary objective of the study is to assess the existing hazard mapping architecture in Georgia, including current capacities and gaps, and based on this develop a capacity building action plan (road map) for the country to fill the gaps and meet existing capacity needs in hazard mapping.

This report is composed of following parts:

- stakeholder analysis to identify relevant entities from national and local governments, international and local non-governmental organizations, civil society organizations and academia engaged in hazards mapping;
- assessment of the institutional and legal set-up for hazard mapping in Georgia and progress achieved in approximating EU standards, existing practices, gaps and technical (including financial) and human capacities for hazard mapping; and
- An action plan (Road Map) for the period covering 2018-2023, with required actions for enhancing hazard mapping capacities, in relation to the identified hazards.

The assessment only addresses mandates and capacities of stakeholders engaged in mapping of climate-induced natural hazards such as floods, flash floods, mudflows, rockfalls, avalanches, strong winds, hailstorms and, droughts etc. Furthermore, the study geographically focusses on the entire country, as well as regions except for the Adjara Autonomous Republic, which is covered by another consultancy assignment commissioned by the UNDP Inception Phase of the project and funded by the SDC.

This report was developed by applying the following methodology:

- Conducting of a desk review and analysis of previously prepared studies/reports and, in particular, the feasibility study of the UNDP/SDC/GCF project "Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia" (hereafter UNDP/SDC/GCF MHEWS project), and the study "Consolidation of the hazard mapping methodology and assessment of the legal framework for its application" carried out by Geographic with SDC's assistance under the CSO DRR project in Georgia;
- Conducting of a second desk review of the relevant current legal-regulatory, policy and institutional setting in the area of hazard mapping;
- Deriving information from interviews held with institutions engaged in hazard mapping;
- Preparation of a capacity gap analysis against international commitments and national statutory requirements; and
- Stakeholder consultations.

2.0 Legal-regulatory and policy framework for hazard mapping

2.1 International commitments

Sendai Framework. Georgia is a party to the Sendai Framework for Disaster Risk Reduction (2015-2030), adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, on 18 March 2015. The first priority under this Global DRR Platform is "**Understanding disaster risk**", which among other issues includes hazard assessment and mapping.

Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention). Georgian is a party to the Aarhus Convention, one of the major objectives of which is to provide the right to every person to receive environmental information that is held by public authorities ("access to environmental information"). This includes information on the state of the environment, but also on policies or measures taken, and on the state of human health and safety where this can be affected by the state of the environment.

Association Agreement between the European Union and the European Atomic Energy Community and their Member States of the one part, and Georgia (EUAA). Article 301 of EUAA states that "The Parties shall develop and strengthen their cooperation on environmental issues, thereby contributing to the long-term objective of sustainable development and greening the economy. It is expected that enhanced environment protection will bring benefits to citizens and businesses in Georgia and in the EU, including through improved public health, preserved natural resources, increased economic and environmental efficiency, as well as use of modern, cleaner technologies contributing to more sustainable production patterns. Cooperation shall be conducted considering the interests of the Parties on the basis of equality and mutual benefit, as well as taking into account the interdependence existing between the Parties in the field of environment protection, and multilateral agreements in the field."

Article 230 of the EUAA calls for implementation of the Aarhus Convention, including the provisions related to access to information.

According to Article 302 of the EUAA, "Cooperation shall aim at preserving, protecting, improving and rehabilitating the quality of the environment, protecting human health, sustainable utilization of natural resources and promoting measures at international level to deal with regional or global environmental problems, including in the areas of:

- (302.a) environmental governance and horizontal issues, including strategic planning, environmental impact assessment and strategic environmental assessment, education and training, monitoring and environmental information systems, inspection and enforcement, environmental liability, combating environmental crime, trans-boundary cooperation, public access to environmental information, decision-making processes and effective administrative and judicial review procedures;
- (302.c) water quality and resource management, including flood risk management, water scarcity and droughts as well as marine environment."

The EUAA's Annex XXVI sets concrete targets and timelines for the transposition/approximation of environmental laws, institutions and management systems to relevant EU directives in the realm of the environment.

Under this Annex, there are the following concrete targets for adoption and implementation of the EU Flood Directive:

"Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks

The following provisions of that Directive shall apply:

- adoption of national legislation and designation of competent authority(ies). Timetable: those provisions of that Directive shall be implemented within four years of the entry into force of this Agreement.
- undertaking preliminary flood assessment (Articles 4 and 5). Timetable: those provisions of that Directive shall be implemented within five years of the entry into force of this Agreement.
- preparation of flood hazards maps and flood risks maps (Article 6). Timetable: those provisions of that Directive shall be implemented within seven years of the entry into force of this Agreement.
- establishment of flood risk management plans (Article 7). Timetable: those provisions of that Directive shall be implemented within nine years of the entry into force of this Agreement."

The EU Directive on Flood Assessment and Management does not give a detailed methodology nor criteria for flood hazard assessment. Instead, it sets general criteria for hazard mapping to depict:

1. flood extent;

2. water depths or water level, as appropriate; and

3. where appropriate, the flow velocity or the relevant water flow.

It requires hazard assessments and mapping at the River Basin District level, which may or may not coincide with natural hydrological boundaries of river basins; e.g., several river basins can be combined for river basin planning and management purposes, as defined by the EU Water Framework Directive.

There is a guidance document on reporting under the Flood Directive, which includes specifications for preparing flood hazard maps[3]. More specifically, it allows for Member States to choose different scales of maps depending on the type of maps and floods although, in the EU's WISE (Water Information System for Europe) system, mostly 1:250,000 maps are accepted and readily available.

Flood hazard maps must show the geographical area that could be flooded under different scenarios. The flood maps must be prepared for the following flooding scenarios:

- floods with low probability, or extreme event scenarios;
- floods with a medium probability (likely return period ≥ 100 years); and
- floods with a high probability, where appropriate.

Member States have the flexibility to assign specific flood probabilities to these scenarios. For each scenario, Member States must prepare information on flood extents and water depth or levels. Where appropriate, Member States could also prepare information on flow velocities or the relevant water flow.

The maps may show other information that Member States consider useful, such as the indication of areas where floods with a high content of transported sediments and debris floods can occur, and information on other significant sources of pollution. For coastal flooding where there is an adequate level of protection in place, and for groundwater flooding, Member States can decide to limit the preparation of flood hazard maps to low probability or extreme events.

3 *Source: Guidance for Reporting under the Floods Directive (2007/60/EC). Guidance Document No. 29. A compilation of reporting sheets adopted by Water Directors Common Implementation Strategy for the Water Framework Directive (2000/60/EC). https://circabc.europa.eu/sd/a/acbcd98a-9540-480e-a876-420b7de64eba/Floods%20Reporting%20guidance%20-%20final_with%20revised%20paragraph%204.2.3.pdf*

Each Member State should also report through the WISE system the following:

1. Summary (< 10,000 characters) on methods used to identify, assess or calculate: flooding extent (including resolution of digital terrain models); flooding probabilities (including information as to why particular probabilities have been selected) or return periods; depths or water levels; velocities or flows (where appropriate); models used, data sets, uncertainties, if - and if so how - climate change has been taken into account in the mapping;

2. Where particular flood scenarios have been omitted, summary (<5000 characters) information on the exclusion of particular groundwater or coastal flooding scenarios, and a justification for these decisions, including information on the justification that an adequate level of protection is in place in coastal areas and where Articles 6.6 and 6.7 have been applied.

INSPIRE Directive. The INSPIRE is the European Directive 2007/2/EC establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). It entered into force on 15 May 2007 and is being implemented in various stages, with full implementation required by 2019.

The INSPIRE aims to create an EU Spatial Data Infrastructure (SDI), enabling the better sharing of environmental spatial information and public access to spatial information across Europe. INSPIRE is based on a number of common principles:

- Data should be collected only once and kept where they can be maintained most effectively.
- Seamlessly combine spatial information from different sources across Europe and share it with many users and applications.
- Information collected at one level/scale to be shared with all levels/scales.
- Geospatial data for good governance at all levels should be readily and transparently available.
- Easy to find what geospatial information is available, with conditions of acquisition and use.

Geospatial information considered under the Directive is extensive and includes a great variety of themes, defined in its Annexes I, II and III (http://inspire.ec.europa.eu/data-specifications/2892). The INSPIRE Geoportal prototype is available at http://inspire-geoportal.ec.europa.eu. Institutionally, the implementation of INSPIRE is coordinated by the following four European institutions:

- DG Environment acts as an overall legislative and policy co-ordinator for INSPIRE.
- The Joint Research Centre (JRC) acts as the overall technical co-ordinator of INSPIRE.
- The EEA is taking on tasks related to SEIS and EIONET in the overall INSPIRE context.
- In addition to the Coordination Team, EuroStat acts as the secretariat to INSPIRE Committee.

Regardless of the fact that Georgia does not have an obligation for transposing INSPIRE into Georgia, the Government of Georgia (GoG) has already started this process, which is explained in more detail in chapter 3 below.

2.2 National legislation

A number of laws and regulations create a legal basis for Disaster Risk Management, including hazard mapping. A detailed discussion of the legislative framework is given in another baseline report **Comparative Analysis of CCA/DRR Architecture and Norms in Georgia and relevant Action Plan (Road Map)** developed under this inception phase of the UNDP/SDC CCA project. The following national laws and regulations are critical for hazard mapping:

- Law of Georgia on Structure, Powers and Operational Procedure of the Government of Georgia (2004);
- Law of Georgia on Basic Principles of Spatial Arrangement and City Planning (2005) as amended in 2014;
- Local Self-Governance Code (2014);

- Law on Emergency Situations as amended in 2017;
- Law of Georgia on Civil Safety (2014) as amended in 2017;
- Law of Georgia on the Procedure of Planning and Coordination of National Security (2015);
- Resolution #262 of the GoG dated 9 October 2013 on Setting up the Governmental Commission for the Creation and Development of Spatial Data Infrastructure;
- Government resolution on National Action Plan for the Implementation of the Association Agenda between Georgia and the European Union (approved annually by a governmental decree);
- Resolution #508 of the GoG on Approval of Civil Security National Plan, dated 24 September 2015;
- Order #2-255 of the Minister of Environmental Protection and Agriculture (MoEPA) of Georgia on Approval of the Regulations of the Legal Entity of Public Law - National Environmental Agency, dated 19 April 2018; and
- Government Resolution # 4 on Approval of National DRR Strategy (2017-2020) and Action Plan.

According to the Law of Georgia on Structure, Powers and Operational Procedure of the Government of Georgia (2004), the following falls within the terms of reference of the Government: setting key tasks, duties and operational procedures for the executive authorities with a view to prevention of emergencies or reaction thereto (Article 20b). Among various measures response activities includes preparation of an emergency risk map, division of the territory of Georgia and cities into groups and organizations according to categories (Article 28.2b). This stipulation of the law means that the risk map is a set of interdisciplinary databases, which embodies all predictable risks (industrial risks, natural calamities, spread of epidemics etc.) that may lead to or cause an emergency situation. The map of natural disaster hazards is an integral part of the emergency risk map. Thus, the preparation of the emergency risk map is one of the decision-making instruments for prevention and response. Obligations related to preparation, maintenance and use of the risk map should be defined by the GoG in a related resolution.

Pursuant to the Law of Georgia on the Procedure of Planning and Coordinating National Security, one of the fields of national security policy is environmental and energy safety, which includes but is not limited to detection, identification, assessment and prediction of ecological and energy hazards, risks and challenges. According to the same Law, the nation-wide conceptual documents are:

a) National security concept;

b) Georgia's risk assessment paper; and

c) National strategies in security field.

According to the Laws of Georgia on Civil Safety, a National Civil Safety Plan should be developed. In an ideal case, a disaster risk assessment and related map including hazards should be an integral part of the given plan.

According to the Law of Georgia on Basic Principles of Spatial Arrangement and City Planning,, competent authorities are obliged to develop:

- National Master Plan on Spatial Arrangement;
- Master Plans of autonomous republics (e.g. Adjara and Abkhazia);
- Municipal Spatial Arrangement and Development Plans; and
- Urban/City Development Plans, composed of: i) a Land Use Master Plan (also including land use zoning maps); and ii) a Construction/Development Regulation Plan.

The above law allows for an exceptional (restricted) regime of regulation for certain territories with special spatial arrangement status, which is assigned to the territory based on various socio-economic and environmental criteria, including risks of natural disasters.

Order #2-255 of the MoEPA of Georgia on Approval of the Regulations of the Legal Entity of Public Law - the National Environmental Agency (NEA), dated 19 April 2018 charges the NEA with a number of functions, including: i) assessment and mapping of climate-induced (hydrometeorological and geological) hazards; ii) hydrometeorological and geological monitoring and forecasting; and iii) the setting up and operation of (a) hydrometeorological and geological database(s).

Under Resolution #262 of the GoG of 9 October 2013, a Governmental Commission was set up for establishing and development of a national Spatial Data Infrastructure (SDI) in Georgia. The Commission was set up to implement and/or oversee that the following duties and tasks be accomplished:

- Drafting of proposals and recommendations with a view to determination of common policy of the GoG in the field of establishing and development of infrastructure for national spatial data and improvement of the state system of management of related processes;
- Drafting of relevant proposals with regard to measures to be carried out in the field of establishing and development of infrastructure for national spatial data based on the European Parliament Directive №2007/2/EC (INSPIRE) of 14 March 2007 "Establishing an Infrastructure for Spatial Information in the European Community";
- Drafting of proposals for establishing infrastructure for national spatial data compatible with the European standards;
- Supervision over the elaboration of the concept of infrastructure for national spatial data and its compatibility with the European standards;
- Coordination of and supervision over the work/measures undertaken in the country with a view to establishing and development of infrastructure for national spatial data; drafting of national standards for collection, storage, updating and sharing of spatial data and meta-data; and also data format, digital information, identification of strategic goals, tasks and priorities for the national geo-informational policy of the country; and
- Identification of needs to be reflected in the infrastructure for national spatial data.

Based on the goals and duties found in the Regulations, it is clear that the Commission has a supervisory role in confirming the compatibility of the mentioned documents, as drafted by the authorized agencies or persons, in relation to the INSPIRE standards.

2.3 Policy framework

Basic Data and Directions (BDD) - BDD (2018-2021) is a mid-term expenditure framework for Georgia, including strategic directions and actions to be implemented by the GoG through state funding. In the area of DRR, the document contains the following actions to be funded from the state budget:

- Expansion of the hydrometeorological observation network and improvement of the relevant database;
- Improvement of weather and hydrological forecasting;
- Preparation and timely dissemination of effective early warning for hydrometeorological hazards;
- Spring-Autumn geological monitoring, assessment of geological processes under force-majeure situations and preparation of annual bulletins;
- Geological hazard mapping for Tbilisi; and
- Geological survey.

Intended Nationally Determined Contribution (INDC) – Georgia is a party to 2015 Paris Agreement and submitted its INDC to the UNFCCC Secretariat. The document covers the period to 2030 and contains a wide menu of actions for prevention, preparedness, response to climate-induced natural disasters and in particular, improvement of hazard and risk knowledge and upgrade of the hydrometric network.

National Environmental Action Plan (NEAP) 3 – The NEAP is a major environmental policy document that is developed periodically in Georgia. NEAP-3 covers the period 2017 through 2021 and contains long-term goals, immediate objectives and a number of actions for CCA/DRR. Concerning hazard assessment and mapping, it lists the following priority actions for implementation over the next five-year period:

- Renewal of hazard classification and risk assessment methodology for 2017-18;
- Development of a legal framework for managing flood and flash flood risks (in line with the EU Flood Directive) over the period 2017-19;
- Establishment of a system assessing and managing flood and flash flood risks (assessment of flood hazards and risks, hazard and risk mapping, and preparation of plans for reducing flood risks); implementation period 2017-21;
- Renewal of geological monitoring system for the city of Tbilisi (identification of hazards and hazard mapping); implementation period 2017-21;
- Preparation of large-scale GIS maps for geological hazards of Georgia; implementation period 2017-21;
- Establishment of GIS database on geological hazards; implementation period 2018-21;
- Development of GIS geological maps; implementation period 2018-21;
- Expansion of hydrometric network; implementation period 2017-20;
- Creation of an electronic hydrometorological database; implementation period 2017-20; and
- Establishment of short- to long-term drought forecasting and early warning system; implementation period 2019-2021.

Major sources of financing for the above action are given as: i) the state budget; ii) various donors (undefined); and iii) the EU Delegation to Georgia (EUD) for developing the flood risk assessment and legislative basis for management.

The National Civil Safety Plan of Georgia (2015) is a major policy document for the unified emergency management system, regulating activities of the state, regional and local authorities in the area of civil safety. It defines:

- protection measures for affected population and territories, their scale, implementation procedures and competent main and supportive authorities; and
- rules and procedures for prevention, preparedness, response, recovery and rehabilitation works.

It is based on the emergency and risk management plans of individual entities of the unified system.

One of the preventive measures listed in the Plan is the preparation of a national emergency risk map. The Ministry of Economy and Sustainable Development (MoESD) of Georgia and the Ministry of Justice (MoJ) of Georgia were assigned to participate in the preparation of risk maps.

The National DRR Strategy and Action Plan[4] includes national DRR goals, objectives, strategic priorities and a plan of actions for 2017-2020.

The goal of the DRR Strategy is to create a unified, flexible and efficient system, which will ensure reduction of natural and man-made disaster risks by joint efforts and coordinated activities of the agencies defined in Georgian legislation. To this end, the objective of this strategic document is to reduce natural and man-made disaster risks identified in the "National Threat Assessment Document 2015-2018" (floods, flash floods, landslides, mudflows, biological hazards, earthquakes, hailstorms, avalanches, strong winds, forest and valley fires, chemical threats, soil erosion by water, drought, hydrodynamic accidents etc.) and to mitigate the possible damage.

The National DRR Action Plan combines planned and ongoing projects, programmes and initiatives

4 Source: *https://matsne.gov.ge/ka/document/download/2993918/0/ge/pdf*

of different governmental agencies and non-governmental organizations. Concerning hazard assessment and mapping and related activities, the action plan includes such actions as field studies for hydraulic and hydrological modelling, development of hydraulic and hydrological models for high-risk areas of Tbilisi and other areas at high risk, monitoring of geodynamic processes, assessment and mapping of geological hazards, assessment and mapping of avalanche hazards in several highly susceptible areas (e.g. Bakhmaro and Kobi-Gudauri), procurement of a regional radar for Kutaisi Airport along with mini-radars, and integration of existing radar data into the NEA's weather forecasting platform etc.

Spatial arrangement and city development plans – Currently with assistance of GIZ the work is ongoing on the development of the National Spatial Arrangement Master Plan (NSAMP) and spatial and city plans for various municipalities and settlements.

3.0 Institutional setting for hazard mapping

3.1 State institutions

3.1.1 National Environmental Agency

The major state institution responsible for mapping of climate-induced natural hazards (e.g. severity, extent and probability) in Georgia is the National Environmental Agency (NEA), a Legal Entity of Public Law (LEPL) under the Ministry of Environmental Protection and Agriculture (MoEPA). Hydrometeorological hazards are dealt with by the Department of Hydrometeorology and geological hazards by the Department of Geology.

Functions, structure and staffing. The NEA's Hydrometeorological and Geological Departments are directly responsible for monitoring, forecasting and mapping of meteorological and geological hazards. More specifically, the Hydrometeorological Department according to the NEA's statutes performs the following functions in regard to climate-induced hazard assessment and mapping:

- Identification of causes and geographic distribution of climate-induced hydrometeorological hazards;
- Preparation of warnings for climate-induced natural hazards and dissemination to key decision-makers (including municipalities), organizations and the media according to a governmental list;
- Field hydrometeorological assessments/expeditions;
- Identification of physical parameters for snow cover in high mountainous regions;
- Conducting studies of glaciers;
- Marine observations and studies of the coastal zone;
- Hydrometeorological observations in river basins of Georgia;
- Hydrometeorological data processing, storage and QA/QC;
- Preparing hydrometeorological forecasts;
- Statistical anaysis of multi-year data, GIS mapping and creation and maintaining of databases;
- Preparation of climate yearbooks, hydrological cadastres, hydrometeorological bulletins and other information products; and

- Hydrometeorological hazard mapping and risk assessment.

Table 1 below provides information on the Hydrometeorology Department's structural sub-units and the number of staff employed under each of these units.

#	Structural unit	Number of staff employed
	1. Division for Hydrometeorological Forecasting	
1.1	Head of the division	1
1.2	Short-term weather forecasting unit	12
1.3	Long-term weather forecasting unit	4
1.4	Hydrological Forecasting unit	3
	Hydrometeorological modeling unit	4
Sub-total		**24**
	2. Division for Mitigation of Hydrometeorological Risks	
2.1	Head of the division	1
2.2	Coastal zone monitoring and hazard prevention unit	8
2.3	Hydrometeorological hazard early warning unit	7
Sub-total		**16**
	3. Division for Meteorology and Climatology	
3.1	Head of the division	1
3.2	Meteorology unit	8
3.3	Basic and applied climatology unit	4
3.4	Agrometeorology and agrometeorological modeling unit	3
Sub-total		**16**
	4. Telecommunications Division	
4.1	Head of the division	1
4.2	Staff	12
Sub-total		13
	5. Database Management Division	
5.1	Head of the division	1
5.2	Staff	9
Sub-total		**10**
	6. Measuring Equipment's Technical Maintenance and Metrology Division	
6.1	Head of the division	1
6.2	Staff	5
Sub-total		**6**
	7. Field Expeditions Division	
7.1	Head of the division	1
7.1	Staff	4
Sub-total		**5**
	8. Inland Hydrology Division	
8.1	Head of the division	1
8.2	Staff	5
Sub-total		**6**
	9. AAR Hydrometeorological Observatory	
9.1	Head	1
9.2	Staff of meteorological, hydrological and agrometeorological stations and posts	8
Sub-total		**9**

	10. Kolkheti Hydrometeorological Observatory	
10.1	Management, including head and professional staff	3
10.2	Staff of meteorological, hydrological and agrometeorological stations and posts	21
Sub-total		**24**
	11. Samtskhe-Javakheti Hydrometeorological Observatory	
11.1	Head	1
11.2	Staff of meteorological, hydrological and agrometeorological stations and posts	7
Sub-total		**8**
	11. Kartli and Kakheti Hydrometeorological Observatory	
12.1	Head	1
12.2	Staff of meteorological, hydrological and agrometeorological stations and posts	24
Sub-total		**25**
Total		**138**

Table 1. Structural division and number of staff of the Department of Hydrometeorology (NEA, 2018).

The functions of Geology Department are as follows:

- Management of geological hazards;
- Regular (Spring and Autumn) geological monitoring in settlements of Georgia;
- Response to geo-ecological risks;
- Under force majeure situations, risk and potential impact assessment in geological hazard-prone areas;
- Preparation of visual geological reports with recommendations for protection measures;
- Geological hazard mapping and monitoring within the boundaries of Tbilisi;
- Development and publication of an annual geological bulletin;
- Development/update of geological hazard maps, GIS and geological cadastres across the country;
- Geological surveys and preparation of state geological maps of various scales;
- Response to notifications/warnings received from the “Hotline”; and
- Fresh groundwater monitoring.

Table 2 below contains information on the structural division and number of staff for the Geology Department.

N	***Structural unit***	***Number of staff employed***
	1. Administration/management	
1.1	***Head of the department***	***1***
1.2	***Deputy head of the department***	***1***
	Sub-total	**2**
	2. Division for Geological Surveys	
2.1	***Head of the division***	***1***
2.2	***Professional Staff***	***5***
	Sub-total	**6**

3. Division for Disaster Processes, Engineering-Geology and Geoecology		
3.1	Head of the division	1
3.2	Disaster Processes and Engineering-Geology group	14 (nine permanent staff and five consultants)
3.3	Geoecological complication response group	9
Sub-total		24
Total		32 (27 permanent staff and five temporarily contracted employees)

Table 2. Structural division and number of staff of the Geology Department (NEA, 2018).

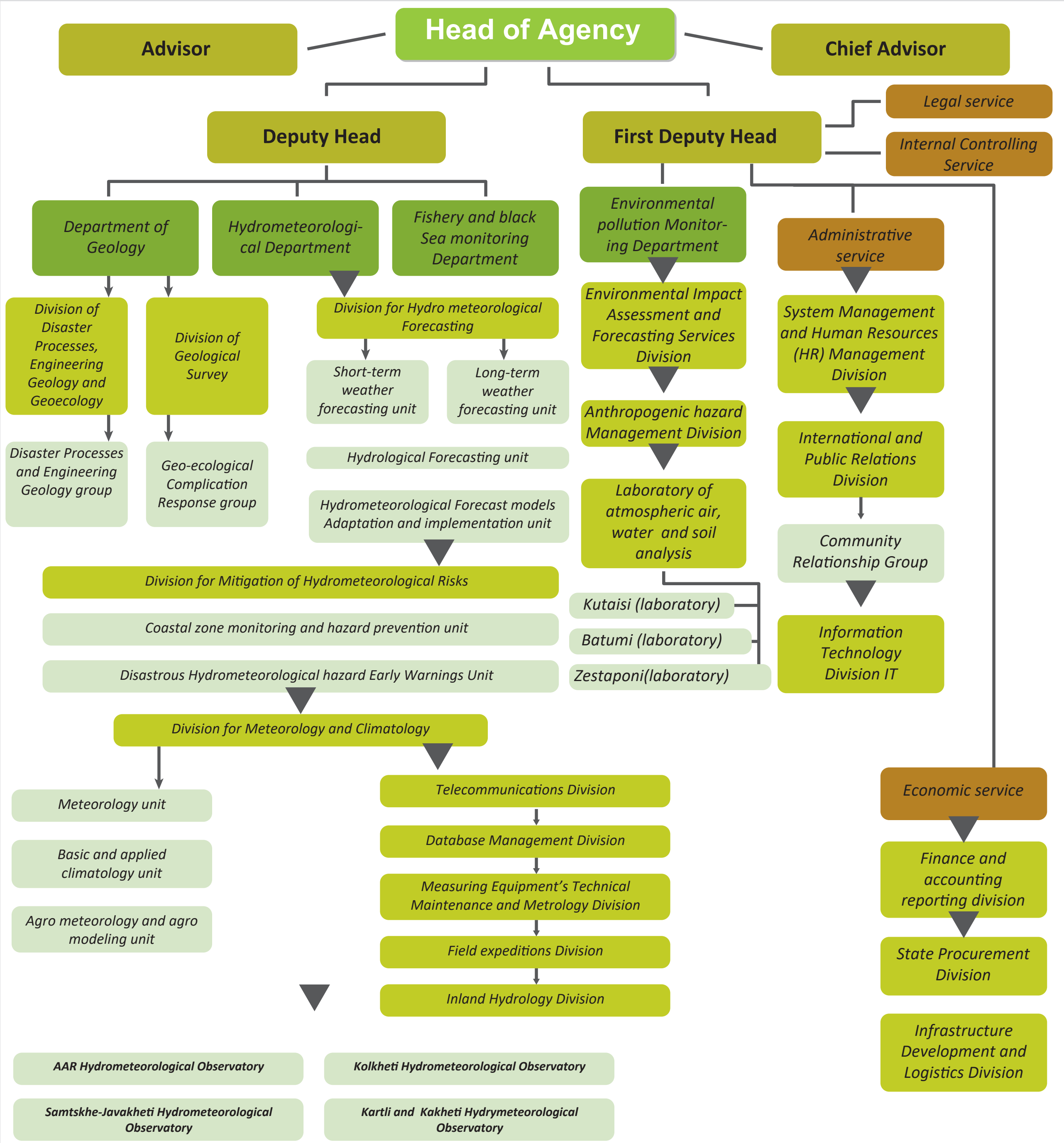


Figure 3. 2018 Organogram (NEA, 2018)

infrastructure. Georgia has a long history of hydrometeorological monitoring activities. In the 1980s, the Hydrometeorological Service of Georgia possessed a large network of hydrometeorological stations within Georgia. In that period, the meteorological observing network covered almost all residential areas and places with different microclimate conditions, including hilly and mountainous regions, while the hydrological observations covered almost all large- and medium-sized rivers. In addition, radar, aerological, actinometrical, ozonometric, agrometeorological and other types of specialized observations were conducted.

After Georgia became independent, the Hydrometeorological Service's funding was drastically reduced, which led to a significant decline in the observation network. At first, the number of standard hydro-meteorological parameters observation was reduced by three to five times, and then the above-listed specialized observations completely stopped. Since 2000, a number of projects aimed at strengthening the hydrometeorological service have been implemented and are still being carried out by the World Meteorological Organization (WMO), other international organizations and donor countries. Within the framework of these projects, dozens of meteorological and hydrological stations have been purchased and installed. The evolution of the number of hydrometeorological monitoring stations over time is shown in Figure 4 below.

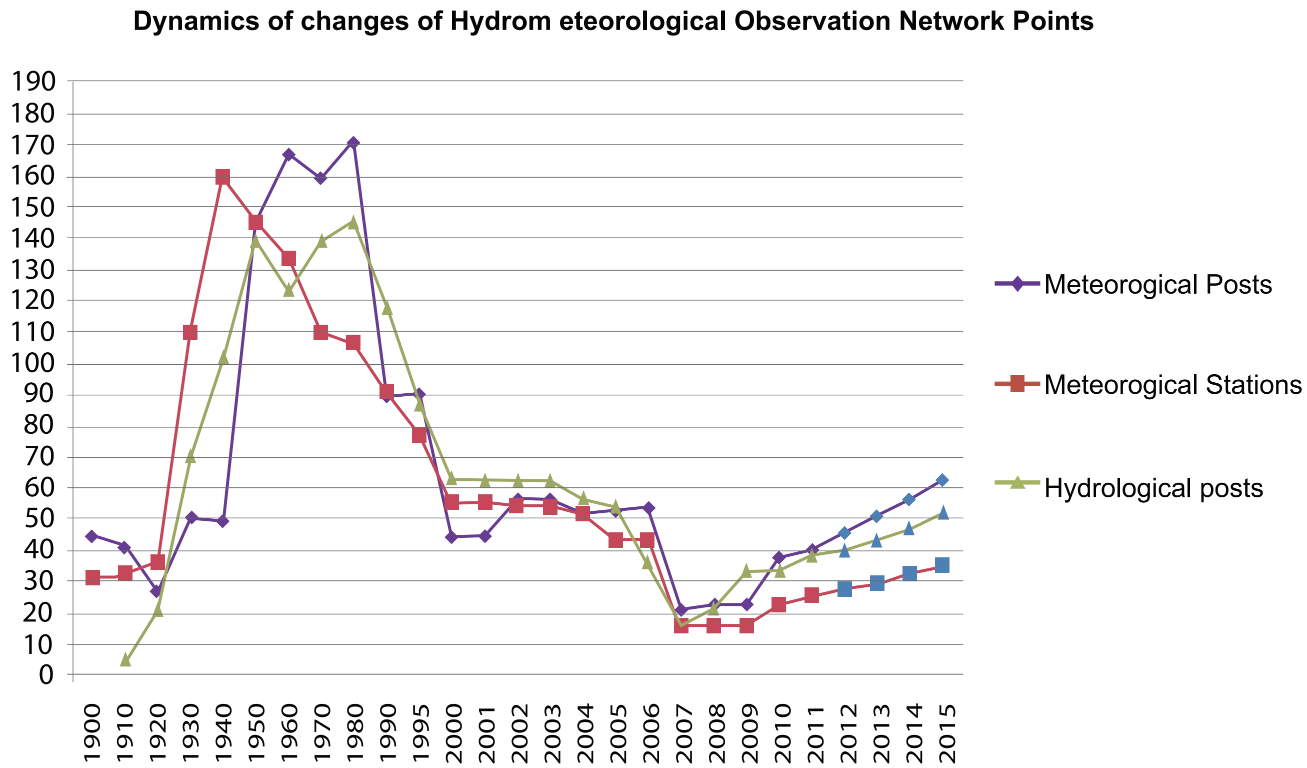


Figure 4. Dynamics of Hydrometeorological Network of Georgia (Feasibility study, UNDP/GCF project).

At present, hydrometeorological monitoring by the NEA is carried out at around 29 weather stations, including 24 automated weather stations and 58 meteorological posts, including 34 automated posts, 14 rain gauges (including six automated gauges) and 74 automated hydrological stations. The NEA has 10 automated agro-meteorological stations. Meteorological stations measure atmospheric temperature, humidity, pressure, precipitation, wind direction and speed; meteorological posts measure temperature, humidity and precipitation; and hydrological stations measure water level, water discharge and precipitation. Table 3 below gives a summary of the type, number and status of the stations, and Figure 5 below shows the geographic distribution of the network.

Station type	Station N	Status
MWS (Manual weather/meteorological station)		
MS	29	Operational
MP	58	Operational
Rain gauge	14	Operational
AWS (Automated weather/meteorological station)		
AWS/MS	24	Operational
AWS/MP	34	Operational
AWS/rain	6	Operational
AWS/agro	10	Operational
AHS (automated hydrological station)		
AHS	74	Operational

Table 3. General characteristics of the current hydrometeorological network of Georgia (NEA, 2018)

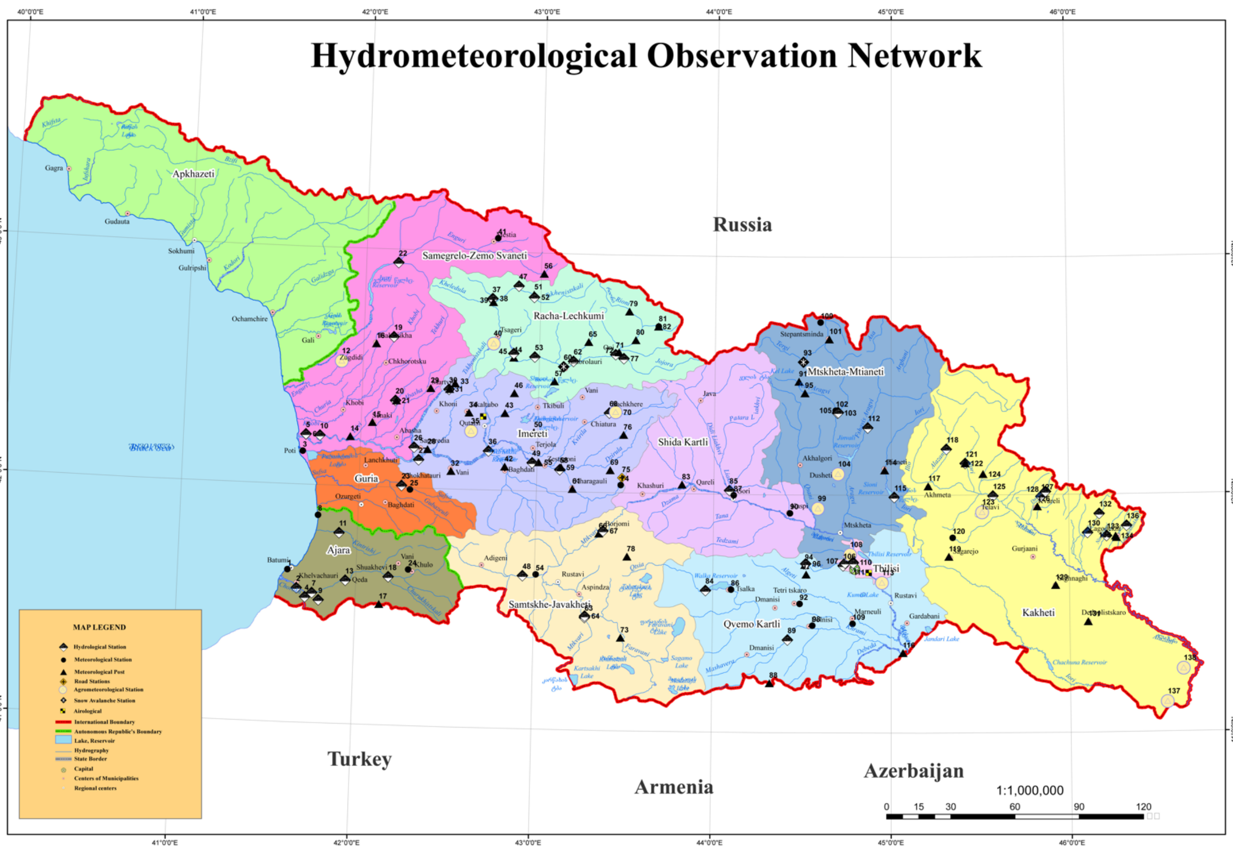


Figure 5. Geographical distribution of hydrometeorological network operated by NEA (NEA, 2018)

In Eastern Georgia, one radar installed in Kakheti is maintained by the Centre for Controlling Natural Hazards. The NEA purchased the license and has direct access to the data and operation of this radar. Another radar is installed at Tbilisi International Airport and is owned and operated by the National Aviation Service. The NEA is also licensed to operate this radar,and has direct access to the data. In Western Georgia, the NEA has access to two Turkish radars. One radar will soon be installed at Kutaisi International Airport with financial assistance from the U.S. government; this radar will also be operated by the NEA. A fourth radar is foreseen to be installed in Poti on the Black Sea coast by the National Aviation Service. The NEA will have the access to this radar's data as well. Last year, it was instrumental to access Tbilisi Radar data. The hydrometeorology department has also two drones. Two pilot sets of lightning monitoring elements already are functioning in Georgia and six more are needed. The radar data and the lightning monitoring data would be integrated into one system, allowing for the effective functioning of the DRR system.

Twice a year, the Department of Geology conducts monitoring of geologically hazardous processes including landslides, rockfalls and mudflows throughout Georgia (except Tbilisi municipality since 2000). A significant reduction of its staff and equipment has taken place over the years. There is a huge data archive available (geological maps), but the majority of the maps are in paper format. The lack of adequate equipment, human resources and finances are obstacles to the provision of reliable and timely warnings. The assessment of geological hazards is made based on the visual monitoring of the sites and the inventory performed in the 1970s and 1980s (geological maps). It should be noted that, in August 2015, the NEA initiated a project to digitize the geological information archived in paper format. The project is financed by the GoG and is being carried out by the Georgian National Archive . It is expected to be completed by the end of 2018. Under the UNDP Rioni Adaptation Fund (AF) project, several inclinometers were purchased and installed at locations in Ambrolauri, Tsageri and Tskaltubo municipalities. Modern monitoring equipment is installed in Dusheti municipality (three locations) through the project financed by the Czech CzDA, and instrumental monitoring is conducted in Tbilisi (for three landslide-prone areas). Moreover, a multi-hazard EWS is being implemented for the Devdorak-Amali gorge.

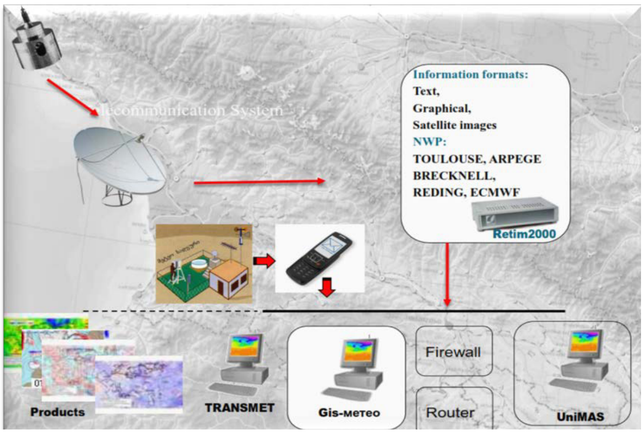
In general, the Geological Department conducts regular monitoring of landslide displacement at seven points across the country where landslide deformation, displacement and groundwater movement are measured by inclinometers, piezometers and rappers (GPS points). Two hydrological gauges measure water level and meteorological parameters at one station; these are also used for landslide monitoring and prediction. The Department has also one drone for topographic surveys and mapping.

The NEA also conducts surveys of snow cover during February-March of each year through field expeditions, and studies around 20 avalanche circumstances.

Georgian glaciers are an important climatic/economic resource, as they hold a significant amount of fresh water and make a major contribution to the status of the water regime and regional climatic conditions. The glacier zones are characterized by glacial and hydrological disasters that seriously affect the internal and trans-frontier roads of Georgia, having an impact on transportation safety and the life, health and socio-economic conditions of the population, leading ultimately to the emergence of eco-migrants. The Hydrometeorological Department conducts systematic annual monitoring of Georgian glaciers. In the Kazbegi region, an early warning system has been installed for the Devdoraki Glacier.

Thus, in terms of hydrometeorological and geological monitoring, it can be concluded that Georgia has a long history and extensive technical know-how. However, financial and human resources coupled with a severely reduced monitoring network limits its ability to monitor important variables and parameters at the appropriate spatial and temporal scales to provide adequate input to effective long-term management of hazards, or to support the development of a national multi-hazard EWS. This key barrier will need to be addressed in order to implement an effective multi-hazard EWS.

Concerning weather and hydrological forecasts and related early warnings, the NEA is responsible for preparing and distributing short (three-day advance) and medium-term (10-day advance) weather and hydrological forecasts daily. For the preparation of the short- and medium-term weather forecasts, the American and German models are commonly used.



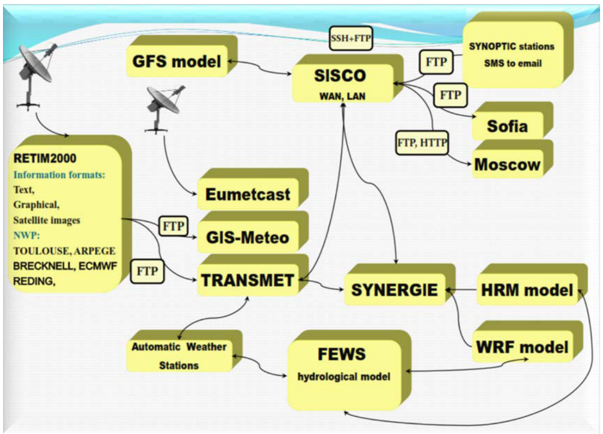


Figure 6. Telecommunication system of the NEA[5]

Figure 7. Hydrometeorological data circulation of the NEA[6]

Due to the lack of the high-resolution models, as well as radar and areological observation data, the spatial and temporal resolution of weather and hydrological forecasts is low. The short-term hydrological forecasts are 24 and 48 hours in advance and without indication of possible locations. This poor spatial resolution makes it difficult, in most cases impossible, for decision-makers to use these forecasts to avoid or mitigate the impacts of disasters. For example, on 12 June 2015, the day before the floods that affected Tbilisi, the NEA distributed a warning of the risk and potential disaster related to anticipated heavy rainfall, floods/flash floods and mudflow processes in Georgia, but this warning did not include information on the actual at-risk locations and expected time(s) the hazard might occur.

Concerning floods and flash floods, in the past the NEA did not use numerical hydrological and hydraulic models. Only the forecasting of Spring floods was based on snowmelt and temperature regime. Under the Rioni AF project, a hydrological model was developed and calibrated based on historic data. For this, the HEC-HMS computer model was applied for the rainfall-runoff component of the risk assessments and flood forecasts. For hydrodynamic modeling, the MIKE FLOOD (1D+2D) model, which is tailor-made for hydraulic modeling of surface water bodies modified by hydrotechnical structures, was applied for the risk assessment of flood water levels and flows. When integrated into the forecasting platform (Delft-FEWS), only the 1D element of the FLOOD model MIKE 11 was used. The Rioni FEWS provides forecasts of flooding in the Rioni River basin with up to 72 hours advance warning, and expected water level at key locations within the basin. In addition, the Rioni River flood hazard maps provide the expected flood extent of floods of various return periods; these can be used in combination with the forecasted flood levels to identify areas at risk from impending floods. This represents a step-change in the NEA's capability to forecast flooding in the Rioni River basin.

The NEA cooperates and exchanges information with the Georgian Civil Aviation Agency (GCAA), responsible for aviation meteorology, and with the Georgian State Hydrographic Service (GSHS). One of the objectives of the GSHS is marine navigation equipment monitoring and modernizing, in line with international hydrographic services and IHO and IALA standards, as well as according to the UN Convention SOLAS requirements. Its network consists of 48 ground-based and 34 sea units.

The NEA's Department of Geology provides an annual geo-hazards bulletin which is sent to municipalities, the EMA, the Ministry of Regional Development and Infrastructure (MRDI) of Georgia, and other interested parties along with an outlook for the year to come. Since 2000, the NEA has not conducted longer-term forecasts of geological hazards. Before, it was providing a 20-year prognosis.

In terms of data management, the NEA uses the WinZPV software, which hosts and stores hydrological data. Meteorological data are entered and stored in CLIDATA. For archiving purposes, the Oracle programme is used. It should be noted that there is no adequate information system for storing model and satellite images and data; these can only be stored for up to one year.

5 *Source: Feasibility study. Annex II. Funding Proposal to GCF*

6 *Source: Feasibility study. Annex II. Funding Proposal to GCF*

Under the Rioni AF project, the Delft-FEWS was established, which is a platform for integrating all sources of meteorological forecast data with observed data from automatic weather and hydrological stations, and managing the process of running hydrological and hydraulic models to produce water level forecasts at key locations. It is based on a GIS system and may generate alert and warning messages. Under the same project, two archives for meteorological and hydrological data have been merged and stored in the CLIDATA system.

Apart from the above, the NEA participates in the regional system of the Middle East and Black Sea Region countries for flash flood foreasting (BSME-FFG). This is the WMO-USAID developed global forecasting system applied for rough forecasts of flash floods in smaller watersheds. Turkey represents a regional hub for participating countries. The system includes a supercomputer and is operated by national meteorological service of Turkey. Georgia cannot use this tool presently since it does not have a sufficient number of rain gauges and weather radar data. Apart from this, the resolution of the model is not adequate for describing the country's topography. Therefore, for Georgia the model is verified annually based on seasonal forecasts.

In addition, a warning system was developed in the mountainous area (Devdorak-Amal gorge) in the northern part of Georgia. The area suffered from two major landslides/debris flows in 2014 (17 May and 20 August): the Dariali landslide/debris flow and a landslide from Mount Kazbegi (also known as Mkinvartsveri), which claimed the lives of ten people and caused damage to a transit gas pipeline for natural gas from Russia to Armenia through Georgia. The early warning system that is being developed by Swiss experts (GEOTEST) is based on monitoring devices and will provide advance warnings to local communities. It will allow the NEA to respond to such natural processes a few minutes in advance, not only giving time for people to evacuate the endangered area, but also ensuring safe travel along Georgia's Military Road, a major route through the Caucasus from Georgia to Russia.

Meteorological station and water level measures are installed in the Vere River basin, following the Tbilisi disaster of 13-14 June 2015, which caused 23 victims and destroyed extensive infrastructure.

Thus, it can be concluded that in terms of forecasting, the NEA has good experience in producing meteorological forecasts based on modern Limited Area Models (LAMs) and forecasts combined with sparse, locally-monitored data to produce hydrological forecasts of impending hazards. On a more strategic and seasonal basis, forecasting is well established as is evidenced by the daily and monthly bulletins that are produced. However, only recently with the development of the Rioni flood forecasting system under the UNDP/AF project, was the NEA provided with the capacity to undertake fully-integrated flood forecasting and early warning, by integrating all meteorological data from international and local sources with automatically monitored data in a flood forecasting model which predicted water level at key locations. This system and the capacity building that it included represented a step-change in the NEA's capacity in flood forecasting and early warning. Key barriers to comprehensive forecasting and early warning are the lack of: forecasting models for all basins; adequate real time automatic observations (due to inadequate hydrometric network); and human and financial resources to implement and maintain a national system for all relevant hydrometeorological hazards. In addition, while there great strides have been made in the institutional arrangements around issuing warnings, there is still a lack of clarity with respect to specific roles and responsibilities in this regard, as discussed below.

In case of necessity, the NEA prepares and delivers timely warnings of impending natural hydro-meteorological events to decision-makers (heavy precipitation, floods, hailstorms, snow avalanches, strong winds and droughts). The Spring flood and long-term weather forecasts (monthly and seasonal) are also regularly produced and delivered to the interested customers. More specifically, for floods, the NEA is responsible for the first stages of the dissemination of flood warnings. It publishes a water level bulletin on a daily basis detailing information from all of the operating stations. This bulletin is sent to the President's Administration, the State Security and Crisis Management Council (SSCMC) currently transformed into the EMS, Ministries (including the EMA of the Ministry of Interior), operators of hydropower plants and other users upon request. In the case of extreme events, this information is also sent to regional authorities. Information is also available through the NEA's website, where all the information from the different automated weather stations, hydrological stations and meteorological forecast information can be accessed by any interested user.

3.1.2 Emergency Management Service

The Emergency Management Service (EMS) by statutory requirements is mandated to develop risk maps and maintain a disaster database. Recently, the virtual data server for the DRR GIS-compatible computer programme Geonode-2.4-b22 was installed at the Operation Control/Management Centre (OC/MC) of the Emergency Management Agency (EMA) with technical assistance from the French Government under the EU Twinning programme. This geoinformation portal allows the user to create thematic maps by developing various GIS layers, and upload and download spatial data to/from the portal. It is further planned to integrate digital hazard maps developed by the NEA, GIS land inventory data contained at the Web Map Service (WMS) of the National Agency of Public Registry (NAPR) and other spatial data stored with various national agencies and institutions at the "Geonode2.4-b22". The Centre ensures receipt, processing and response to emergency signals transmitted through the "112 Service". All this information is logged in a common information and analysis system. The Centre receives and processes this information and immediately sends warnings to relevant authorities either through e-mail or SMS. During nation-wide disasters, the Centre sets up field operational centres. With a change of institutional structure, the operations of the geoportal needs to be adapted to the new situation. The Centre can also receive data from CCTV cameras operated by the Joint Operational Centre of the MIA. Following the merging of the EMA and SSCMC under the EMS, this information system will require fine-tuning to fit into the new institutional setting and requirements.

3.1.3 Ministry of Regional Development and Infrastructure (MRDI)

Under the latest institutional restructuring, the spatial planning function was transferred from the Ministry of Economy and Sustainable Development (MoESD) to MRDI. Thus, starting from June 2018, MRDI is responsible for development and coordination of implementation of a state policy on land use, land use zoning, urban development and spatial planning, including facilitation/coordination of development of masterplans for land use, land use zoning documents, urban development plans and spatial zoning documents, and development of technical methodologies for land use and spatial planning. The exact institutional set-up was not defined during the study preparation period but will be during the next six month as stipulated by the amendments to the Law on Structure, Authority and Rules of Operation of the GoG (5 July 2018). Consequently, a detailed assessment of the capacities of the MRDI in terms of hazard mapping data (responsibilities, holdings and use) was not conducted.

3.1.4 Ministry of Economy and Sustainable Development

The MoESD through its **Georgian State Hydrographic Service**[7] is a national coordinator for navigational warnings, consisting of navigational systems and equipment located on the coast of Georgia, signs placed in the open sea to provide safe navigation (48 ground-based and 34 sea from ground-based, 22 units in occupied territories). The Service is comprised of three main departments:

- **Navigational Marks/signs, Technical Services and Monitoring Department:** operates and maintains navigational signs and related infrastructure, keeps records of geographic coordinates, location of navigational signs, operates an emergency alarm system, includes an operational/control centre with an online monitoring system and electronic navigation map, maintains an online operational database and provides continuous data on navigation signs, and produces relevant reports.
- **Hydrographic Survey and Cartography Department:** conducts bathymetric surveys and observation of sea depths, conducts micro-bathymetry measurements, collects data from ports and anchorage regions, monitors changes in the coastline, maintains an inventory of navigational marks and lights, and prepares geodetic and bathymetric characterizations of ports and harbors/docks under construction. It also publishes "Notice to Mariners", notifying/providing warning to sailors and appropriate services to changes with regard to marine navigation as well as develops navigation maps, schemes, navigational route maps, etc.

7 *Source: http://gshs.gov.ge/en/*

- **Weather Forecast Department:** conducts regular monitoring of the weather, weather forecasts, storm warnings, meteorological events record keeping, and the establishment and operation of an electronic database.

3.1.5 Ministry of Defense

State Military Scientific-Technical Center Delta[8] is engaged in the defense industry and provides technical support for the Georgian armed forces in terms of ammunition, military vehicles, specialized buildings and fortifications, implementation/application of new weapons systems and their subsequent support, humanitarian demining and demilitarization works. It has recently elaborated, installed and tested an anti-hail system in the Kakheti region. It consists of a radar located on Mount Chotori, in the village of Nukriani, and an information and fire control centre as well as autonomous rocket systems.

Starting from 2018, the anti-hail system is operated by the Centre for Controlling Natural Hazards (CCNH), a limited liability company (100% government-owned), which will closely work with the Institutes of Geophysics and Hydrometeorology on research and development of technological and methodological innovations to be technically supported by Delta.

3.1.6 Georgian Air Navigation (Sakaeronavigatsia)[9]

Georgian Air Navigation is a limited liability company (100% government owned). It is in charge of managing air traffic within the Georgian airspace through monitoring and providing aviation services and flight safety in takeoff and landing zones at the international airports of Tbilisi, Kutaisi, Batumi and Mestia. More specifically, its major functions are:

- Management of air traffic movement;
- Provision of radio-wave, lightning and other communication systems;
- Meteorological Service; and
- Aeronautical information services.

The Meteorological Service is part of “Sakaeronavigatsia”. The Service consists of Tbilisi, Batumi and Kutaisi meteorological offices, which are responsible to provide meteorological information for flights to/from these city airports. The Tbilisi meteorological office provides meteorological flight information for Mestia airport according to a contract with the NEA. The Meteorological Service conducts permanent observations of meteorological conditions (weather elements) for each operating airport region, produces day/night aviation forecasts, forecasts for take-off and landing, and also provides aviation customers including the World Operative Meteorological Data (OPMET) bank with this information. Meteorological observations at these airports are done using new automatic sensors produced by well-known manufacturers: Vaisala (Finland), Thies Clima (Germany), Eliasson (Sweden), Biral (England), Setra (England), L-3 Communication Avionics Systems (USA) and Rotnic (Germany). The Service has one radar installed at Tbilisi International Airport. There is a plan for purchasing and installing a second radar at Kutaisi International Airport.

3.1.7 The Architecture Service of Tbilisi City Hall

The Architecture Service of Tbilisi City Hall maintains a multi-layer interactive map of the city. In the near future, it intends to integrate hazard and risk maps into its online map in cooperation with the NEA and other stakeholders.

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8 Source: http://www.delta.gov.ge

9 Source: http://airnav.ge/index.php?page=ms&fullstory=49

3.1.8 Ministry of Justice

The Ministry of Justice (MoJ) through its National Agency for Public Registry (NAPR)[10] is responsible for geodetic and cartographic works, including land registration, cadastre and the setting up and operation of a GIS. More specifically, the Department for Geodesy and Cartography is in charge of developing state policy, the legal-regulatory and methodological basis for geodesy, cartography and GISes, as well as for coordinating/carrying out geodetic/cartographic activities/projects, including topographic, gravimetric and aerial photographic ones, and satellite data generation and processing, setting up and operating the GNSS stationary reference stations (GEO-CORS), registering real property cadastre data and developing, standardizing and operating GISes, including the creation and operation of the central geospatial database.

NAPR's land cadastre contains information on land plots per region and ownership type. However, there is no information on types of soil, elevation and exposed hazards. At the same time, the MoJ with Sida's assistance actively works on the development of the National Spatial Data Infrastructure (NSDI) under the EUAA. The initiative will be completed in 2018. The INSPIRE Directive calls for harmonization of the geo-information system, legislative base and administrative matters with European Standards. The NSDI provides an opportunity for effective usage and sharing of geospatial information and will provide the basis for data on physical and socio-economic assets at risk from natural disasters. It will also provide a platform for the sharing and dissemination of single-source, definitive spatial data and information and will contribute to a more effective regulation of the activities that impact disaster management. Further details on developments and processes can be found at the website http://nsdi.gov.gehttp://nsdi.gov.ge/en/Maps operated by the NAPR, including information about the State Commission on NSDI's Establishment and Development (chaired and co-chaired respectively by MoJ and MoEPA Deputy Ministers), formed per Resolution No. 262 of the GoG on 9 October 2013. Based on this legal act, the NAPR coordinates the NSDI's development, formed the Secretariat to NSDI State Commission, established and also coordinates thematic working groups (currently six: legislation, PR, business model, GIS, IT and education).

It is important to note that Article 3 of the same Resolution is almost entirely devoted to mandating the NSDI of Georgia to become INSPIRE-compliant. It is important to note that for an INSPIRE-compliant NSDI, all spatial data infrastructure instruments, including hazard mapping ones, are considered as key components, and every development in the field of hazard mapping data collection and sharing, including meta-data, should take into account the NSDI development's direction and processes. Intense cooperation and coordination with NSDI stakeholders is strongly recommended in any decision-making. The NEA is part of the NSDI process, which makes it possible for the NEA to comply with EU standards and at the same time, integrate the NEA's hazard data into the NSDI portal.

3.1.9 NGOs and Private Sector

CENN. In the recent past (2010-2014), CENN was very active in hazard and risk mapping. As was mentioned above, under the Matra project in cooperation with the NEA and Twente University (NL) it developed a web-based disaster risk atlas, the portal for which is not active anymore. It is planned to update this portal in the near future. CENN was also engaged in a participatory climate-induced multi-hazard disaster risk and vulnerability assessment for communities of seven municipalities within the Alazani and Rioni River basins, using field studies, compilations of existing data, GIS and community-based information.

Sustainable Caucasus currently implements the SDC supported project "Strengthening the Climate Adaptation Capacities in the South Caucasus" with financial support from the SDC Caucasus office, whose 1st component aims at designing and introducing undergraduate and graduate university courses for hazard mapping and DRR. The courses will be based on Swiss methodology.

10 Source: https://napr.gov.ge

GIS and Remote Sensing and Consulting Centre (Geographic). Geographic has been active since 1998 in the areas of GIS, spatial analysis and planning, and the development of thematic and web-based maps. It applies such tools as field topo-geodetic surveys, GIS, remote sensing (RS), photogrammetry, GPS-technologies, integrated geodatabases, WEB-based maps etc. Currently it is involved in the following:

- Spatial planning for municipalities;
- Land use cadastre and planning;
- Urban development;
- Settlement and resettlement planning for separate areas; and
- Historical and cultural area settlement planning.

Every year, the Centre organizes international conference of users of RS and GIS technologies on new products and methodologies in these areas.

In recent years the Center developed an urban development plan for Khertvisi-Vardzia-Oloda Cultural Landscale within Aspindza and Akhalkalaki municipalities. Similar plans are being implemented for Ambrolauri, Akhmeta and Mestia municipalities. These plans also incorporate hazards data, which are taken from the NEA and processed using modern methodologies. In case data are absent, the Centre conducts hazard assessment and mapping using ArcMap, Erdas, RAMMS (rapid mass movement simulation; see below) and other software.

The Centre is an official representative of ESRI in Georgia and sells ESRI products.

A relatively new software that is used by Geographics is the Swiss-based RAMMS numerical rapid mass movement simulation model which may be used to conduct avalanche, flood and mudflow modeling. This technology is well suited to mountainous and forested landscapes. It can provide expanded 3D visualization, digital-elevation models (DEMs), aerial photos, topographic maps, modeling results and other georeferenced products, calculation and modeling of velocity of various mass flows, and export these to Google Earth, ArcGIS and other programmes. RAMMS can be applied for the following:

- Hazard mapping and zoning;
- Modeling of natural hazards;
- Risk assessment for building and road infrastructure;
- Planning and assessment of protection measures; and
- Study of avalanche and mudflow dynamics.

GeoLand is a GIS and spatial information management company with some experience in hazard mapping. During the period 2011-12 it participated in developing The DRR Atlas of Georgia under the leadership of the CENN. More specifically, the organization was involved only in cartographic work (the hazards themselves were assessed by CENN experts). Currently, GeoLand is not engaged in any hazard mapping activities. However, the staff has the relevant expertise and Geoland the technologies to solve any of cartographic and spatial analysis problem as well as conduct modeling.

GeoLand currently uses QGIS, PostgreSQL and PostGIS. Postgres is a database management system which is accessed via PostGIS. In essence, the latter is the geographic component of the PostGres, while the cartography is performed via QGIS. These platforms enabled the company to process vast masses of complex data in comparison with ESRI products.

GisLab is a GIS and spatial information management NGO, which has experience in sensitivity analysis of Georgian forests, slope stability assessment and assessment of erosion processes. It is not directly engaged in hazard and risk mapping, but has all the technical means and expertise to solve any spatial analysis or cartographic assignment. Moreover, it has very strong expertise in modeling. Similar to GeoLand, GisLab applies QGIS.

Environment and Development (ED). ED has recently been involved in an “Assessment of Suitable Flood Mitigation Measures in Tbilisi”. The main objective of this technical assistance project was to improve flood risk management in the Tsavkisiskhevi River basin. This was accomplished through the implementation of a modelling framework, inclusion of climate change impacts, preparation of flood maps and the designation of flood mitigation and adaptation measures.

3.1.10 Academic and research institutions

There are geography and geology departments under the natural sciences faculty within Tbilisi State University (TSU) for undergraduate and graduate degree programmes. Among various mandatory courses, there is a course on assessment of natural hazards. Furthermore, the Institute of Geophysics at TSU has experience in multi-hazard assessment, including assessment of earthquakes, landslides, snow avalanches, flash floods, mudflows, droughts, hurricanes, frost and hailstorms. Such multi-hazard assessment was conducted in 2006-2009, but data were made available only in 2013. The ongoing SDC-supported project implemented by Sustainable Caucasus and referred to above will focus on introducing modern methodologies and techniques for hazard mapping in Georgian academic institutions.

3.1.11 Donors

Major donors active in Georgia in climate-induced multi-hazard mapping are :

- SDC (Switzerland), supporting capacity development for DRR and hazard mapping, including development of capacities of academic institution in DRR and hazard mapping;
- UNDP, supporting establishment of a near-real-time multi-hazard early warning system across the country through the financial assistance from GCF and SDC;
- EU, supporting adoption of major provisions of Flood Directive;
- Sida, supporting establishment of information/data management systems in line with EU standards;
- FAO, supporting development of agrometeorological monitoring and advisory services; and
- German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through GIZ, supporting development of National Spatial Arrangement Plan and Spatial Arrangement and City Plans for selected municipalities.

4.1 Existing climate-induced hazard data and maps

The greatest experience in climate-induced hazard mapping in Georgia exists in assessment and mapping of floods and geodynamic processes, mostly for landslides. For other hazards, including flash floods, avalanches, droughts, strong winds, thunderstorms and hailstorms, the experience is limited.

The largest compilation of hazard, exposure and risk maps of the country is contained in the open-source renewable Geoportal of Natural Hazards and Risks of Georgia created by the CENN and available at http://drm.cenn.org/index.php/en/. However, these maps date back to 2012 and are small-scale. In the meantime, the majority of hazard maps kept by the NEA are of 1:100,000 and smaller scale, while 1:5,000 and 1:10,000 scale maps are lacking.

Hydrometeorological and geological hazard maps (flood/flash flood, mudflow, landslides), developed by the NEA are kept in catalogues of climate-induced natural hazards. The latter are stored as hard copies and contain data on natural hazards from the early 1840s when the first field observations began, and continue up until now. These are data on the dates, locations, intensity, human losses and damaged areas related to each recorded hazard.

The NEA on an annual basis issues geological bulletins on new and older geological hazards and their causes. Maps at scales of 1:500,000, 1:200,000, 1:50,000 and 1:25,000 showing landslide and mudflow hazard zones (susceptibility) are available at the NEA in electronic and hard-copy format. Recently, over 1000 landslide and mudflow processes and bodies were inventoried by the Agency. Under the UNDP Rioni AF project, a geological survey of all municipalities of the Racha-Lechkhumi and Kvemo Svaneti region, along with Samtredia and Tskaltubo municipalities was carried out, and a 1:100,000 map of geological hazards was developed. In general, 1:10,000 and smaller-scale geological hazard maps exist for over 50% of the country's territory, while 1:2,000 maps are available for over 100 specific areas. Hydrometeorological hazard maps at 1:50,000 scale are available for Upper and Lower Svaneti, Mtskheta-Mtianeti and the part of the Adjara region.

4.2 Applied methodologies

Flood hazard mapping. At present, the NEA uses a GIS along with statistical analysis of hydrometeorological observations and hydraulic equations for developing smaller-scale hazard (so-called flood extent/susceptibility) maps for floods with different recurrence intervals. More specifically, the freely accessible ASTER Global Digital Elevation Model v2 (GDEMv2) is processed and adapted to the Georgian situation (100 m resolution), deriving a national Digital Terrain Model (DTM). Based on the latter and a specially elaborated script, river locations are defined. The height of the water is then calculated for each target point/node and specific values are assigned to catchments. The maximum height of water is determined using statistical analysis of hydrological data. For each station, water level/height for 10, 50 and 100-year floods are identified, based on an Inverse Distance Weighting (IDW) interpolation method. Water height data retrieved from the DTM and calculated for various probability floods are compared with each other, and flood extent maps are derived for each probability flood. Flood hazard maps for different recurrence floods are a result of a combination of flood extent (inundation) maps. At the final stage, maps are corrected based on experts' judgment and local information received from communities. Based on these corrections, flood extent was reduced in Eastern Georgia's Udabno territory and was increased in the Kolkheti lowland. This indicates that the method is not fully applicable to all regions of Georgia and the DTM generates significant errors. Flood levels are put on flood extent maps using hydraulic equations and the width of the river is calculated for 10, 50 and 100-year floods. The related error is less than 1 pixel. For more precision, it is necessary to have 1D and 2D flood modeling, requiring water level and floodplain height data, which the NEA does not have for the majority of rivers.

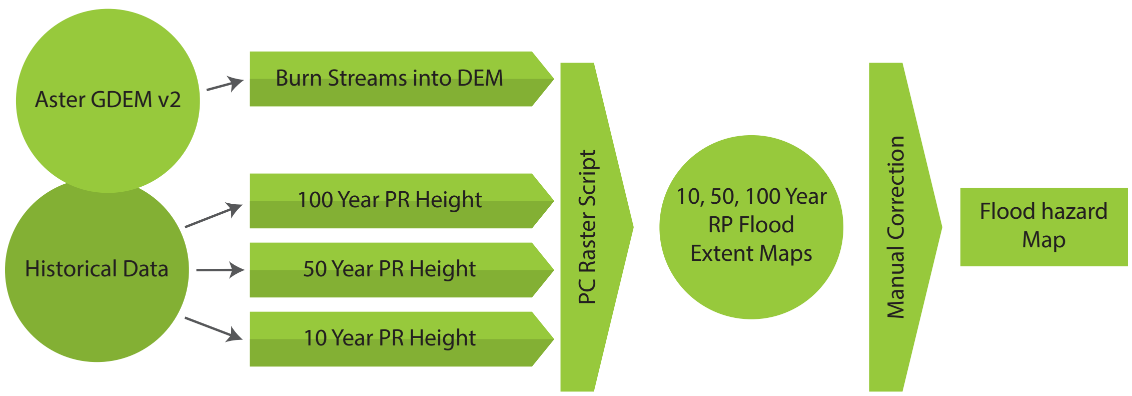


Figure 8. Schematic diagramme of the methodology used for developing larger-scale flood hazard maps by the NEA.

To summarize, for flood hazard mapping, the NEA traditionally has been using a method of statistical analysis of historic hydrometeorological data (discharge and precipitation to derive runoff coefficient and ultimately the discharge value, in case discharge data are absent) and, calculating peak discharge values with various recurrence intervals and water level, based on rating curves. This makes it possible to develop general background (small-scale) hydrometeorological hazard (e.g. flood susceptibility/extent) maps. Discharge can be calculated using spatial hydrological models, analysed data sets (e.g. the ECMWF ERA data sets) or climate models (e.g. the Hadley and ECHAM models). Spatial hydrological models determine water balance for each geographical unit (e.g. grid-cell), and for each time step route the runoff downstream, yielding discharges throughout the entire catchment. Such models can additionally be used in scenario analysis; for example, in the assessment of the impact of changes in climate or land cover, by changing the input meteorological data or land cover scheme that has been done under the Second and Third National Communications.

Geological hazard mapping. Hazard mapping of geological processes is evaluated by different methods, both quantitative and qualitative. But of course there is a need for information/data to ensure that the risk of hazard is correctly measured. Hazard assessment is carried out step-by-step as follows:

- Collection of historical data using baseline (archived) materials ;
- Analysis of the current topographical maps and aerial photographs;
- Field Geological Survey;
- Desk study of information received from field geological survey;
- Compilation of Geological Hazard Catalogue - Cadastre and filling of the Database;
- Preparation of information and maps about geological hazard triggering factors; and
- Preparation of Geological Hazard zoning maps using current methodologies .

Data Collection

GROUP	TECHNICS
Photo interpretation	*High resolution satellite images*
	Lidar aero imagery
	Stereo-Pairs
	Radar Images
Automated classification: Spectral	*Aero-Photo-Imagery (medium resolution)*
	Multi-spectral imagery
	Optic and Radar image combination
Automated classification	*Insar images*
	Lidar
	Aster
	Photogrammetry
Filed survey	*Filed mapping*
	Interview
Analyzubf archive material	*Reports, newspaper archives*
	Road information

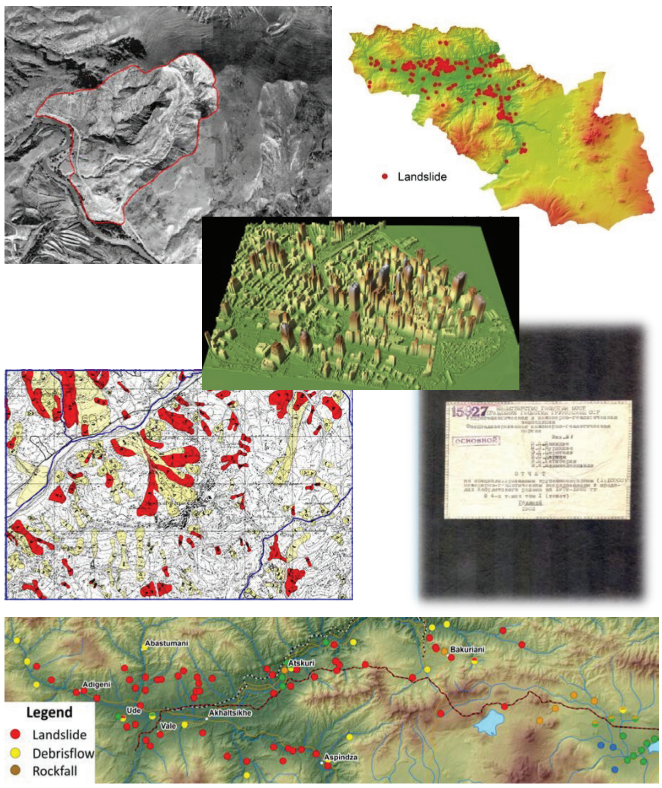


Figure 9. Data collection methodology

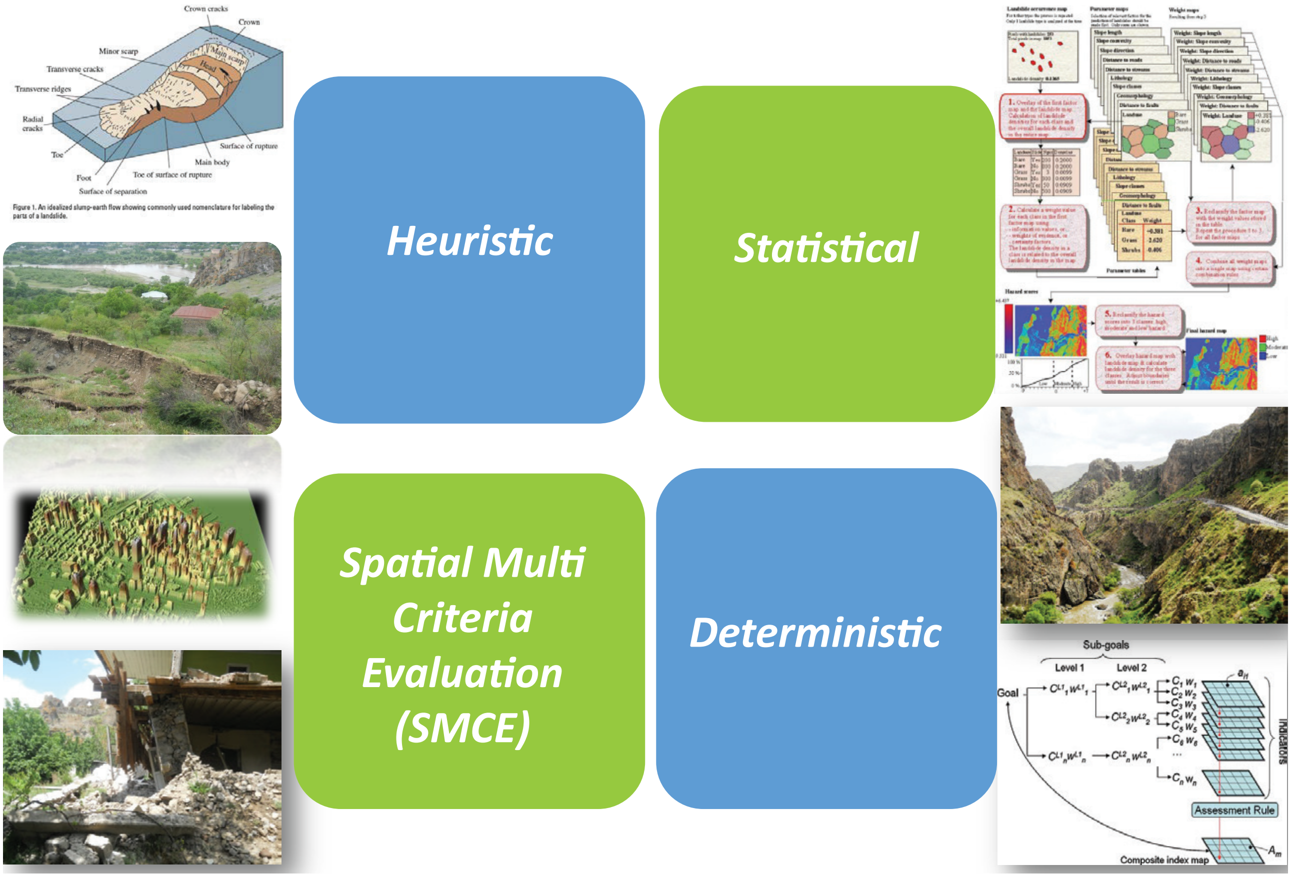
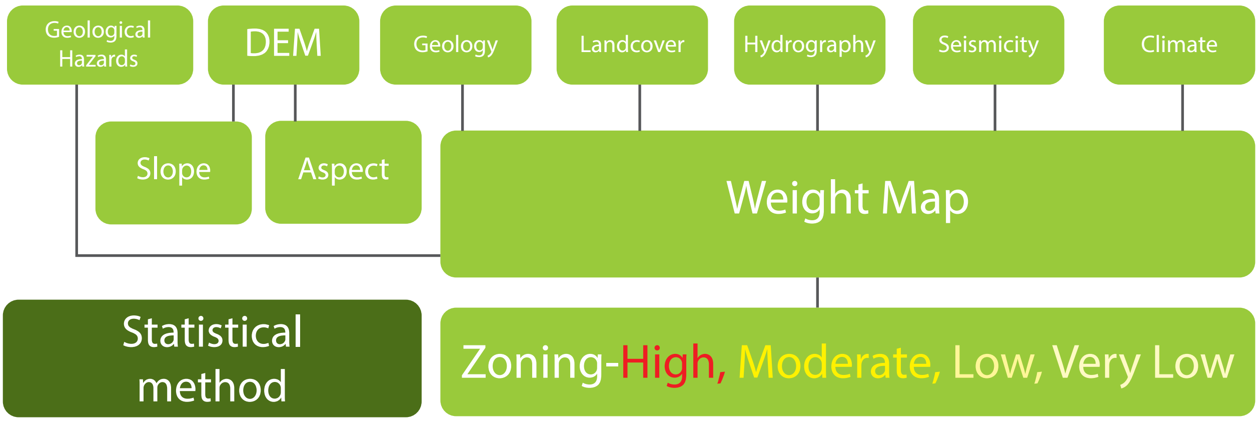


Figure 10. Geological hazard mapping methodology

For mapping geological hazards, various quantitative and qualitative methods are used. Because of the difficulty of specifying a timeframe for the occurrence of a landslide or a mudflow, landslide and mudflow hazard maps are represented by susceptibility maps. Hence, similar to the concept of flood-prone areas, landslide/mudflow susceptibility only identifies potentially affected areas and does not imply a timeframe when they might occur. The data required to undertake landslide hazard mapping include geologic, topographic, hydrologic and vegetation maps, aerial photographs of the study area, a history of landslides and associated reports including photographic characterisation of previous landslides, and satellite imagery. Landslide hazard maps are produced based on the overlay, analysis and interpretation of the maps of the inventoried landslides and the permanent factors found to influence the occurrence of landslides. By overlaying the landslide inventory map on the maps of the type of bedrock, slope steepness and indirect hydrologic measures, the association of past landslides with the factors controlling landslide occurrence can be derived. The hazard map produced divides the catchment into sub-areas based on the degree of a potential hazard from landslides. Four levels of relative hazard are identified on a landslide hazard map: i) low; ii) moderate; ii) high; and iii) extreme hazard. The level of landslide hazard is measured on an ordinal scale with this method; it is a quantitative representation of differing hazard levels that shows only the order of relative hazard at a particular site and not the absolute hazard. Predicting absolute hazard is not possible with current capabilities. Figure 11 below shows the detailed representation of the statistical (so-called weight map) method which the NEA applies for landslide and mudflow mapping.



$$Fr_i = \frac{N_{pix(S_i)} / N_{pix(N_i)}}{\sum N_{pix(S_i)} / \sum N_{pix(N_i)}}$$

$$FR = \frac{\text{Area of landslides in class / Area of all Landslides}}{\text{Area of class / Entire map}}$$

Where,

$N_{pix(S_i)}$ - Landslide pixel number in class (i)

$N_{pix(N_i)}$ - total number of class pixels

$\sum N_{pix(S_i)}$ - total number of landslide pixels

$\sum N_{pix(N_i)}$ - total number pf pixels

Figure 11. Statistical method for landslide hazard mapping

The statistical method is based on merging of physical (parameter/factor: geology, slope, land cover, hydrography, seismicity, climate) maps with maps of geological processes/phenomena (landslide, mudflow, rockfall, etc.), after which it is possible to determine a landslide's relation with each parameter/factorial map; for instance, the number of landslides for concrete slopes or rockfalls per type of geological sediment. Such weighted maps are developed for each parameter/factorial map. Then each parameter/factorial map is assigned a weight. There are two types of statistical methods: multivariate and bi-variate. Both of these require maps of geological processes. Another method used by the NEA during research is the spatial multi-criteria evaluation method (SMCE).

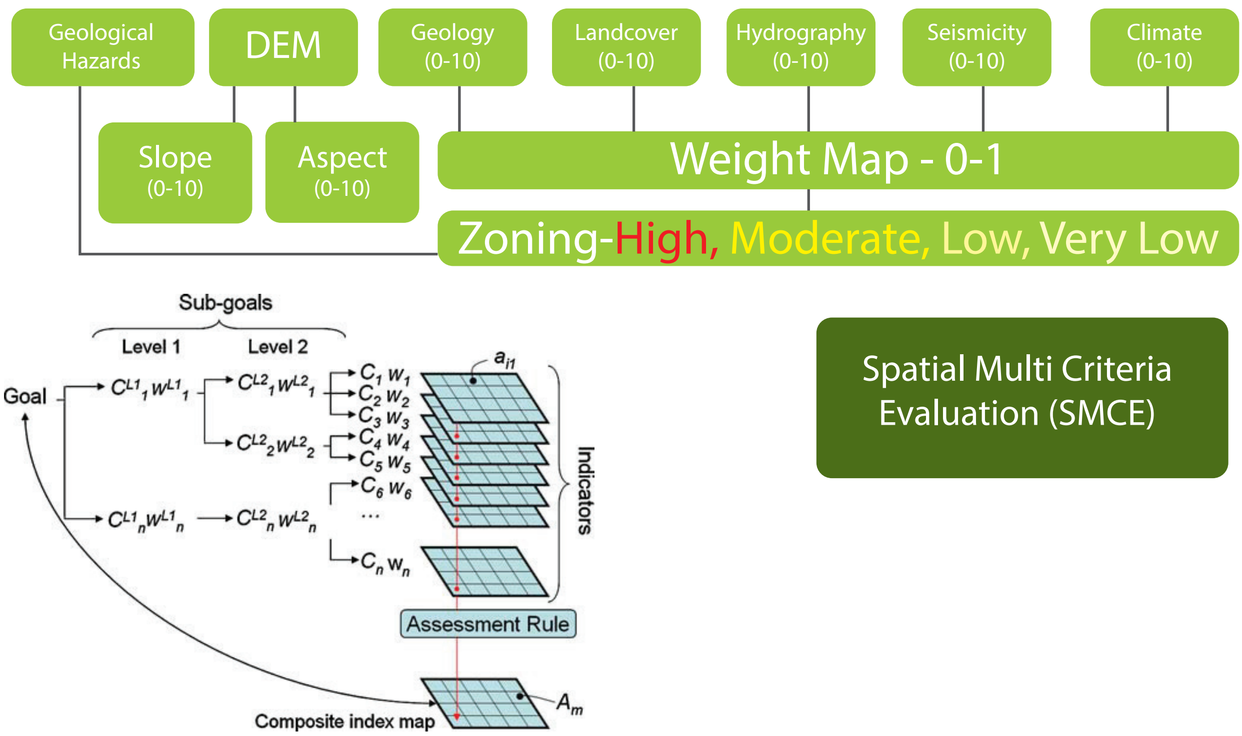


Figure 12. SMCE for geological hazard mapping

For landslide, mudflow and rockfall indices, maps of indicators are used which are acquired from various state entities. The initial step is to select these maps, structure the indicators and select a weighting method. It is necessary to standardize basic layers from their initial values to binary 0-1 values. Indicators have various measurement units (nominal, serial, relative, average) and they can be mapped differently. Stemming from this, the NEA used standardization methods embedded in the SMCE module. Standardization process may also vary depending on the type of indicators – measured values (intermediate, relative) versus categories/classes (nominal, serial). For standardization of variables' maps, various equations can be used in order to convert factual values of maps to binomial values. The next step is to decide which indicators are the most useful/applicable to achieve the desired end result.

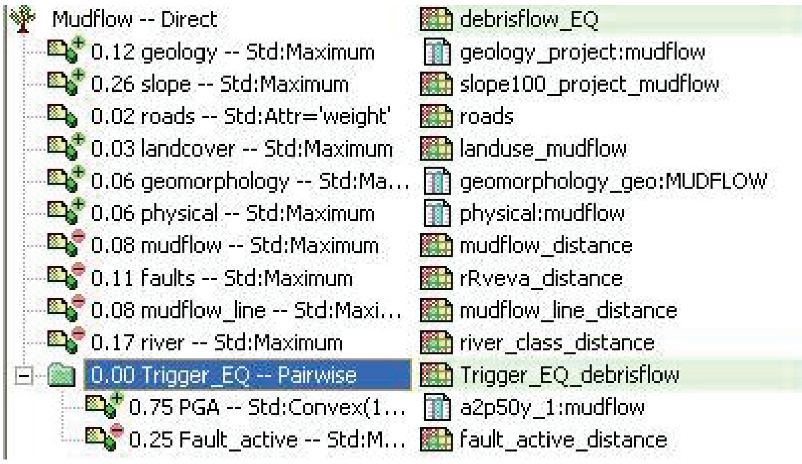


Figure 13. Grouping of indicators maps

The second important aspect is to set limits on the indicators. For weighting, there is possibility to use three major methods: direct, pairs comparison and ranking. The NEA has grouped hazard maps in three simplified categories: high, medium and low, which was based on a hydrogramme of the final weighted maps. These are dynamic maps given the change of indicators over time, and thus it is necessary to renew hazard maps from time to time.

Avalanche hazard mapping. Similar to landslides and mudflow hazard mapping, the NEA within the framework of developing the Web-Atlas has some experience in developing small-scale avalanche susceptibility maps, based on snow cover surveys, meteorological data, GIS and geospatial analysis. More specifically, for the given exercise, an ASTER-generated DEM, MODIS snow cover spatial and temporal data, topographic, cadastre and satellite data were used to derive seven factorial/parameter maps. Next, based on a multi-criteria analysis method, a weight map was produced and avalanche-prone areas were divided into four categories based on the level of hazard. Below, the diagramme of avalanche hazard mapping applied by the NEA is shown.

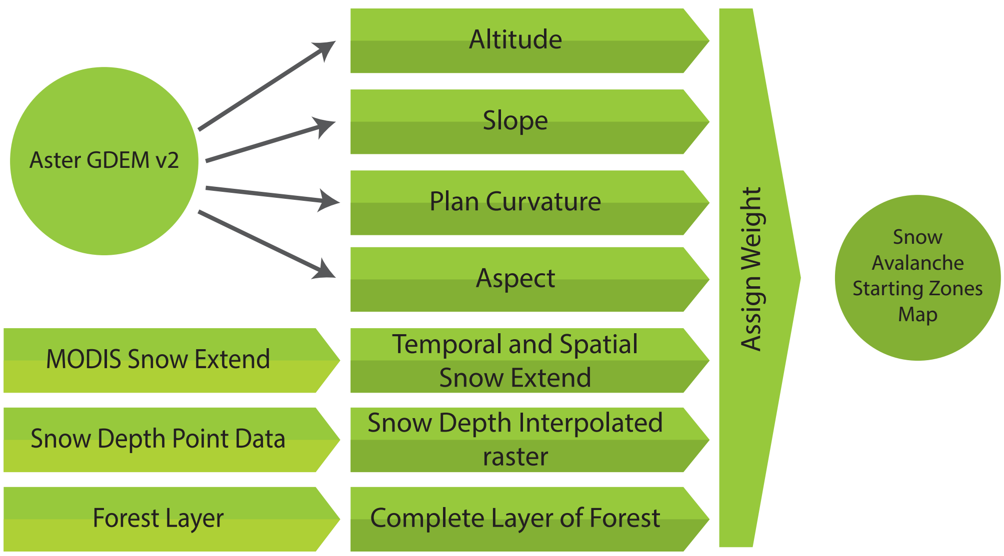


Figure 14. Diagramme of hazard mapping methodology used by the NEA.

Drought mapping. The NEA and the NFA operate agrometeorological stations; however, both have limited experience and capacities for drought hazard mapping. Usually, drought susceptibility maps are depicted by the NEA. Generally, the drought hazard is described by one or more drought indicators; for example, the Standard Precipitation Index (SPI). The SPI is a tool that was developed primarily for defining and monitoring drought. The SPI allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historic data. It can also be used to determine periods of anomalously wet events. Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring at a station.

Strong wind and hail mapping. The NEA has very limited past experience in mapping strong winds and hail within the frameworks of various donor-supported initiatives, the 2012 Web-Atlas development being the most recent project under which small-scale hazard maps were developed for all natural hazards, including strong winds and hailstorms. The approach is similar to other hazard mapping and is based on identification of areas prone/susceptible to given hazards. Usually, such maps are very small-scale and cover all of Georgia.

4.3 Existing experience gained from various projects

Since 2006, the NEA has been engaged in various projects with hazard mapping components using up-to-date hazard mapping methods and technologies applicable for both large-scale and small-scale hazard mapping; e.g., hydrological and hydraulic models. This experience largely covers flood and flash flood hazard assessment.

The most comprehensive and precise flood hazard assessment was carried out under the UNDP/AF Flood Project for the upper and lower Rioni River basin sections, in line with the EU Flood Directive and related standards. It included identification of vulnerable districts, hazard assessment, hydrological and hydraulic modeling, hazard and risk mapping. More specifically, under the Project, the NEA learned how to apply 1-D and 2-D hydrodynamic models. The first one is more applicable for upper watersheds with well-defined river channels/beds. For heavily modified water bodies/catchments or catchments with complex hydrodynamic processes, e.g. river confluences, the 2D model or combination of 1D and 2D models (1D for river channel modeling and 2D for floodplain modeling) is preferable. Furthermore, hydrodynamic models allow for the integration of additional flood parameters, such as flow velocity, propagation, duration and the rate at which the water rises. Some additional information is however required for 2-D hydrodynamic modeling, such as flood wave characteristics (duration and peak). Finally, the flooded area (and possibly flood depth) is determined by combining water levels with a DEM, thus creating a flood map showing flood extent or depth. A DEM is already included in 2-D hydrodynamic models, in which case this third step is already addressed. Through the application of the above methods, the following types of flood maps can be developed:

- **Flood extent maps** - These are maps displaying the inundated areas of a specific event. This can be an historical event, but also a hypothetical event with a specific recurrence interval (e.g. once every 100 years, often expressed as HQ100). The extent of a single flood event or of multiple events can be depicted, and the extent of historical floods can also be shown. As flood extents are easy to depict, they can be supplemented with point information on other flood parameters (e.g. depth or velocity at some points) and important exposed assets (e.g. hospitals, power stations). The NEA mostly possesses flood extent maps.
- **Flood depth maps** - Having flood extent maps for various recurrent floods, flood depths can also be calculated and flood depth maps developed. A different type of water depth map is created in areas where flooding is not the result of overflow but rather of failing structures. In such cases it is not possible to calculate general flood extents and depth for a specific return period, as the flooded area is determined by the location of a breach which is not known beforehand, and scenarios are often used. In order to generate a general picture of the flood hazard. The results of these scenarios can be combined into a single map showing the maximum (or average) flood depth per pixel.

- **Maps displaying other flood parameters** - Flood extents and depths are usually considered the most important flood parameters, especially when it comes to mapping flood hazards. However, some other parameters, such as velocity, duration, propagation and the rate of water's rising can also be very important depending on the situation and the purpose of the map. Maps showing such parameters always relate to a single return period, as it is practically impossible to depict, for instance, velocities of several return periods on a single map.
- **Flood hazard (threat) maps** - Flood maps usually only show one out of several flood parameters, though in some cases flood depth information of a specific recurrence interval is added to a flood extent map. In order to get an impression of the overall flood hazard, parameters can instead be aggregated into qualitative classes, resulting in so-called flood hazard maps. This is commonly done using matrices or formulas to relate different flood parameters into a single measure for the "hazard". In such matrices, two axes are used to relate flood parameters (e.g. depth, velocity, return period), or sometimes a grouped parameter is used. An example of the use of a formula to calculate a measure for the flood hazard can be found in the UK, where the hazard rating is defined as: depth × (velocity + 0.5) + debris factor.

Details of concrete activities related to flood and landslide hazard mapping implemented under the UNDP/AF Rioni Flood Project are as follows:

- The NEA has elaborated 1:5,000 flood hazard and risk maps for the upper watershed of the Rioni River, as well as 1:10,000 floodplain inundation maps using hydrological and hydraulic modeling. For this, hydrometeorological time series data for 1936-2000 were digitized. Based on detailed topographic, soil, land use, geology and 75 years of hydrometric data (rainfall, flow and temperature data for 28 stations digitized by the project) a detailed rainfall-runoff model was developed using Hec-HMS for 92 sub-catchments of the Rioni basin. The Hec-HMS model was linked to a 1D-2D hydraulic model of the main Rioni River and major tributaries which was developed in Mike FLOOD software (acquired by the project) using channel survey (more than 300 cross-sections) and floodplain topographic data (undertaken and acquired by the project). The resulting linked hydrological-hydraulic model formed the basis of all flood mapping for the basin, and was used to generate flood depth and hazard maps for a number of flood events of different recurrence interval (two-year to 1,000-year floods) and for modeling the effects of climate change.

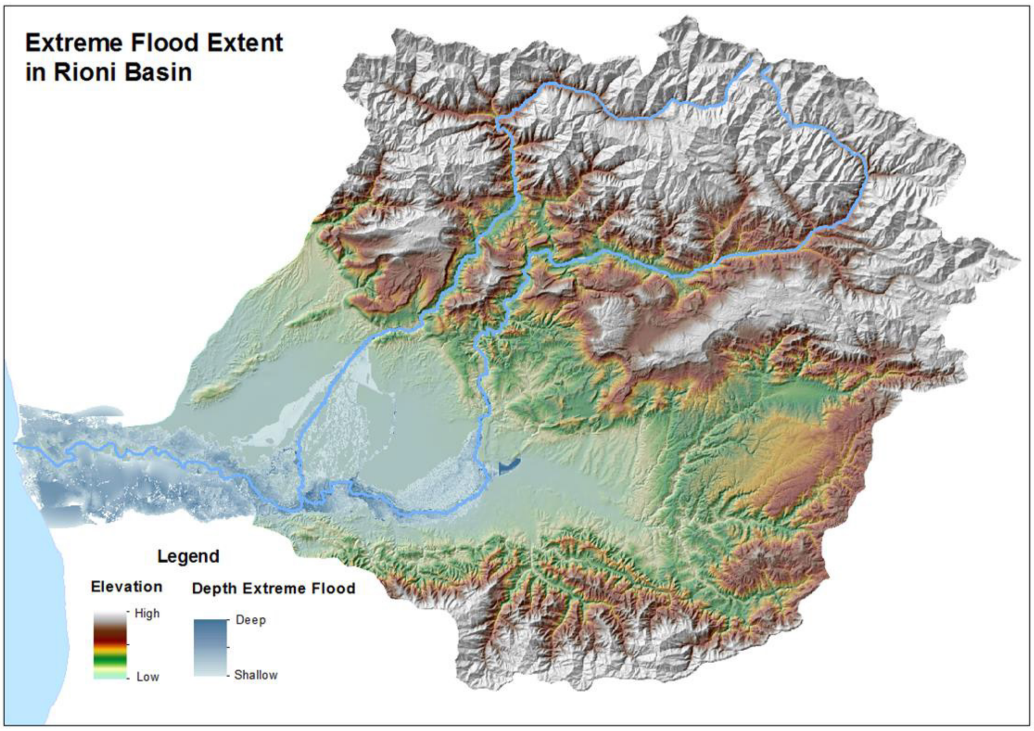


Figure 15. Rioni River basin flood extent and depth map.

- The NEA has produced geological hazard zoning maps based on detailed fieldwork over one year. With the project funds, NEA geologists undertook their most comprehensive geotechnical assessment of the Rioni basin by characterizing previous landslides, and identifying potential future landslides, while creating zones of high, medium and low hazard areas prone to landslides. The project mapped and categorised 492 historical landslides; collected, reviewed and catalogued reports of landslides from the National Library (149 information items) and catalogued by admininstrative boundaries the name of natural hazards, their location, time of occurrence and incurred damage, to produce landslide hazard maps. In addition, the study identified areas where landslides will potentially develop in the future and the communities at risk from these potential landslides.

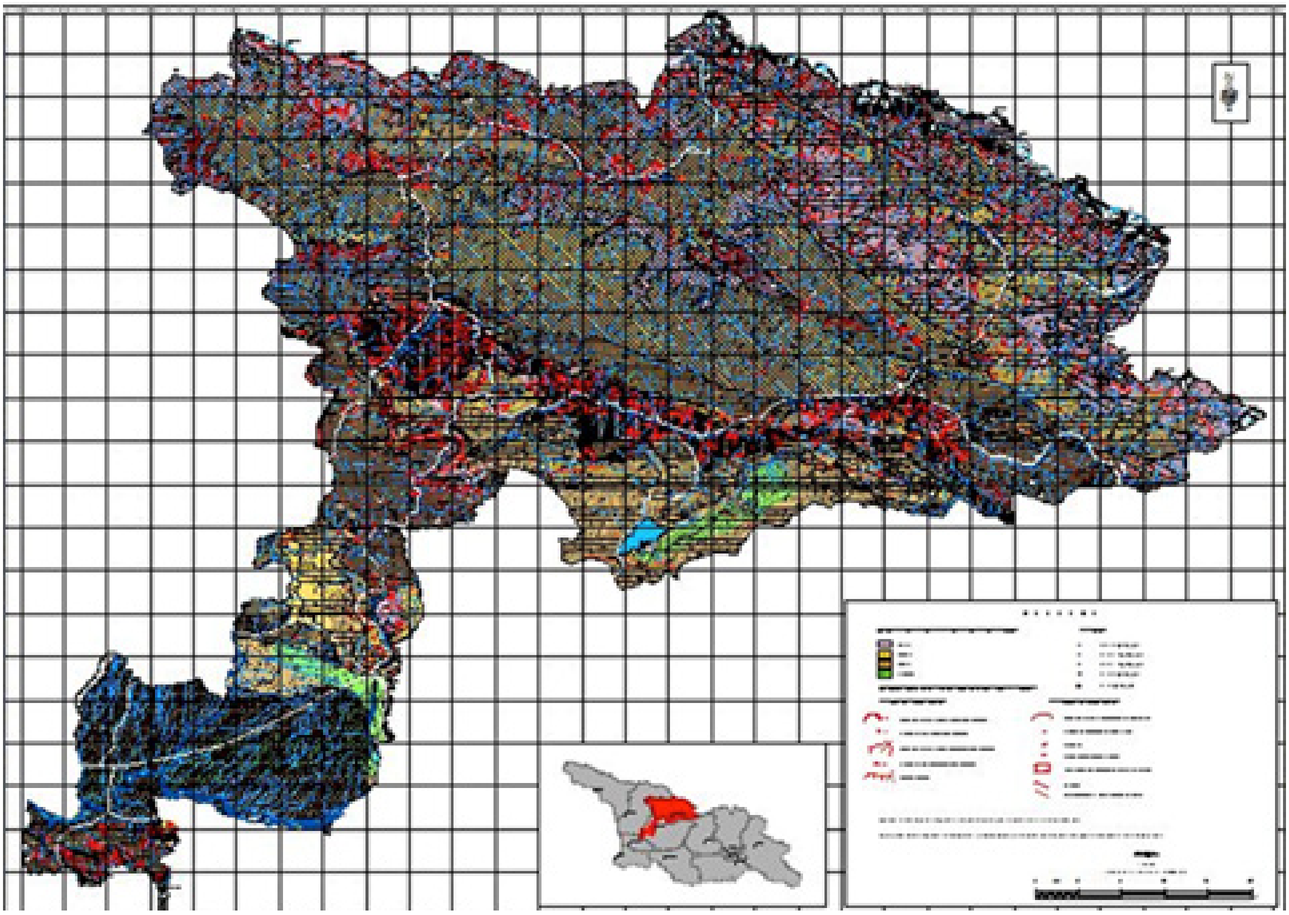


Figure 16: Geological hazard zoning map for the Rioni River basin.

In 2012, the NEA was engaged in the development of national-level hazard maps (Atlas of Natural Hazards and Disaster Risks of Georgia) as part of the MATRA project **Institutional building for natural disaster risk reduction in Georgia** implemented by the Faculty of Geo-Information Science and Earth Observation, the University of Twente (ITC) and the CENN, NEA, EMA and Ilia University (IliaUni). The Risk Atlas provides information on nine types of hazards and various elements at risk (i.e. population, buildings, GDP etc.) at different levels (regional, district, community) (van Westen, 2012) and is available online on the Web-based Risk Atlas (Portal). Through the Portal, users can combine different types of information, and display this information in a variety of ways, for example different types of hazard maps, information on elements at risk, exposure maps, vulnerability maps and maps of individual, specific risk types. The Portal also allows the public/users to report disaster events and thus update the historical disaster record. However, it has to be noted that assessments given in the Risk Atlas were hardly used for decision-making. Possible reasons include that the Risk Atlas was not available through the NEA's webpage; non-acceptance of these broad-brush national scale maps as insufficiently detailed; lack of consensus on the technical robustness of the methods used to produce the maps; and their not being updated since development in 2012. Recently, it has been decided to update the Atlas.

Under the above-mentioned MATRA project, the NEA in cooperation with the CENN and ITC developed flood hazard maps based on an ASTER DEM using predicted flood recurrence value (water discharge with various return period), which is a statistical method for predicting floods. In order to analyse river discharge, data from 108 hydrological gauges were used. For each station, maximum level and discharge was identified. The relationship between volume and discharge was determined based on a mathematical formula deriving the relation between peak flow frequency and magnitude, using the single example of Supsa station. Based on this, floods (maximum volume and discharge) with five, 10, 20, 50 and 100-year recurrent intervals were predicted. All stations were entered and georeferenced in a GIS system.

In 2014-2015, the NEA with SDC's assistance conducted hazard mapping for six territorial-administrative units of Mestia Municipality, using a Swiss methodology[11]. It was comprised of following steps:

- Collection of baseline data;
- Identification of hazards;
- Classification of hazards through identifying frequency and magnitude/intensity;
- Development of landslide, mudflow and gravitational processes spatial distribution maps;
- Identification of hazard level/rank and zoning of targeted territories.

Flood hazard mapping was conducted for Mestiachala, Mulkhuri, Nakra, Nenskra and Dolri and, based on this exercise, flood inundation/extent maps with 1:5,000 scale were developed. For this, long profiles of river beds/channels and floodplains were developed, peak discharges were calculated based on the relevant technical guidance document for Caucasus rivers, and maximum water levels were calculated based on channel cross-sections (lateral profiles) and hydraulic parameters. Also, average velocity of the flow (also known as open channel flow) was calculated based on the Manning formula; 10%, 3% and 1% peak discharges were assigned relevant water levels; and floodplains were zoned in three (I -10% flood, II -3% flood and III – 1% flood) categories. Figure 17 below is an illustrative flood extent map for the Mulkhuri River, and Figure 18 shows a floodplain zoning map for the Dolra River.

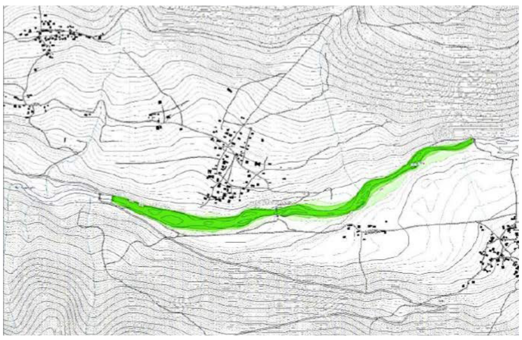


Figure 17. Flood inundation map for the Mulkhuri River (NEA).

Figure 18. Floodplain zoning map for the Dolra River (NEA).

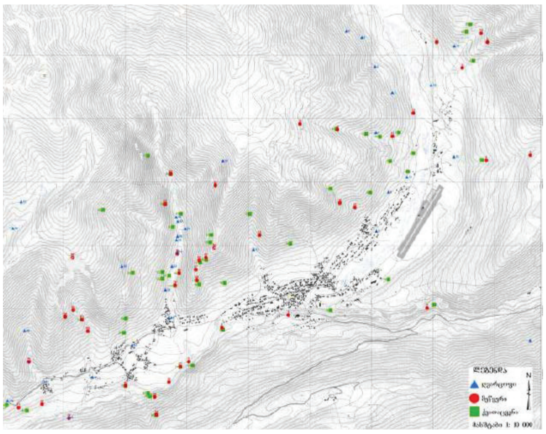
For landslide, mudflow and rockfall hazard mapping similar to other climate-induced hazard mapping conducted under this Project, another method was applied to develop a susceptibility map. The process included: an inventory of geological processes/collection of existing data; identification of hazardous processes; identification of the frequency and intensity of the process; and identification of hazard-prone areas. Based on this method, the map of geological hazard sources and zoning of territories into three hazard classes was developed.

For landslide hazard, the following criteria were used: slope, geology, risk factors, anthropogenic pressures and landslide type. For mudflows, relief/morphological location, sediment genesis and

11 *Source: Mapping of natural hazards for Mestia Municipality. SDC: Disaster Risk Reduction, Prevention and Preparedness Programme. NEA. February 2016. http://nea.gov.ge/uploads/slides/589485d40bccd.pdf*

type of mudflow were used as criteria; for rockfalls, slope, granulometry and intensity class were used.

For avalanche hazards, avalanche-prone areas/sources and susceptibility maps were developed. The exercise was conducted using an ASTER DEM and the ARC GIS software. Initially, various geomorphological and dynamic parameters were used, including absolute and relative height, area, average slope/inclination, velocity and energy, and parameter/factorial maps were developed. Using fieldwork data and factorial maps, geomorphological and dynamic parameters (relative and absolute elevation, area, average slope, velocity, intensity etc.) were calculated and the map of avalanche-prone areas/sources was derived. The territory was then divided into three hazard categories. Figure 23 below shows the avalanche hazard zoning maps.



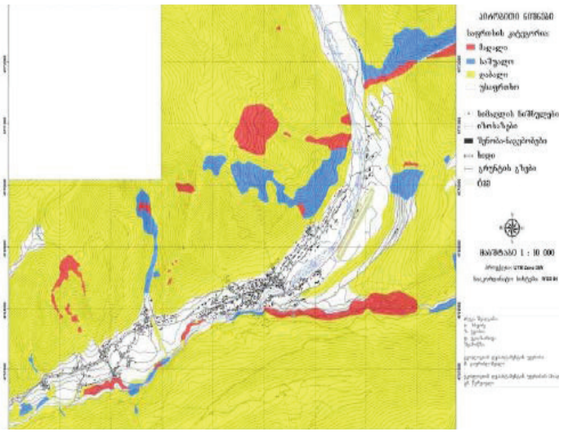
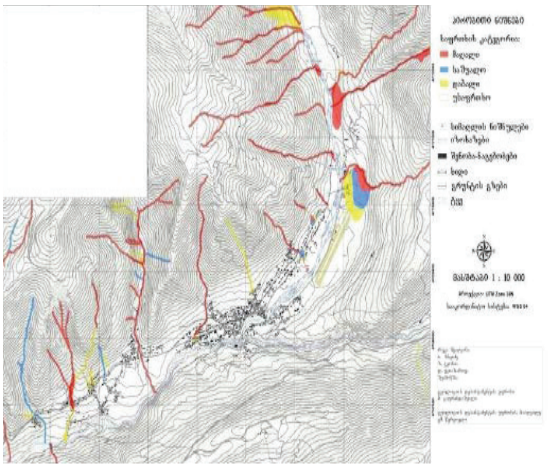


Figure 19. Map of the geological hazard sources of the Mestia-Lendgeri area

Figure 20. Landslide hazard zoning map for the Mestia-Lendgeri area



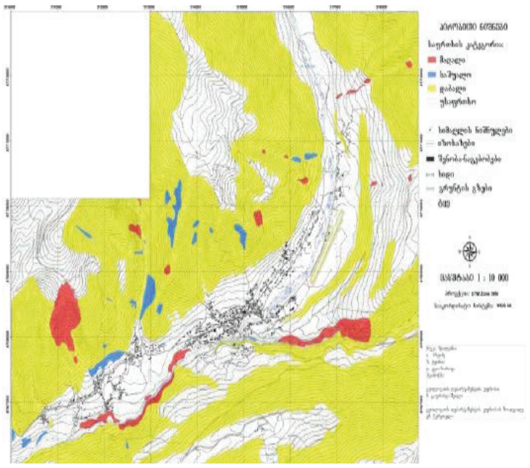


Figure 21. Mudflow hazard zoning map for the Mestia-Lendgeri area

Figure 22. Mudflow hazard zoning map for the Mestia-Lendgeri area

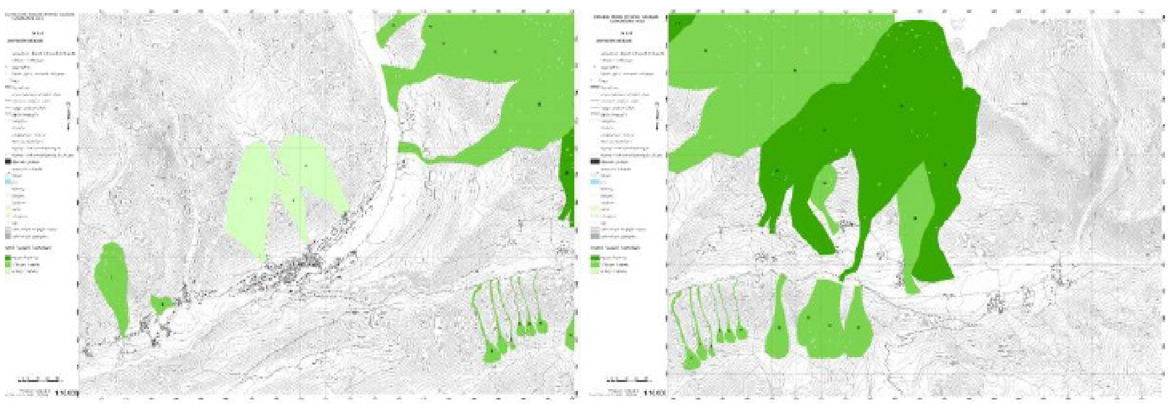


Figure 23. Avalanche zoning map for the Mestia-Lendjeri area.

In 2014-2015, the NEA through assistance of the Czech government conducted hydrological and hydraulic modeling of the left-side tributaries of the Alazani River (e.g. Duruji, Kabal, Ninoskhevi, Lagodekhiskhevi, Stori and Didkhevi Rivers), using the HEC-HMS and MIKE FLOOD models. Based on this modeling exercise, flood/flash flood hazard maps were developed. Figure 24 below shows the flood hazard map of the Duruji River for illustrative purposes[12].

Figure 24. Modeled Flood Hazard Map of the Duruji River (NEA, 2015).

In 2015-2016, the NEA Geology Department through the assistance of UNDP and the project "Strengthening Urban Risk Management of Tbilisi" executed geological surveys in the Gldanis Khevi River catchment basin. With this as background, a geological report was drafted and included specialized geological hazard zoning maps.

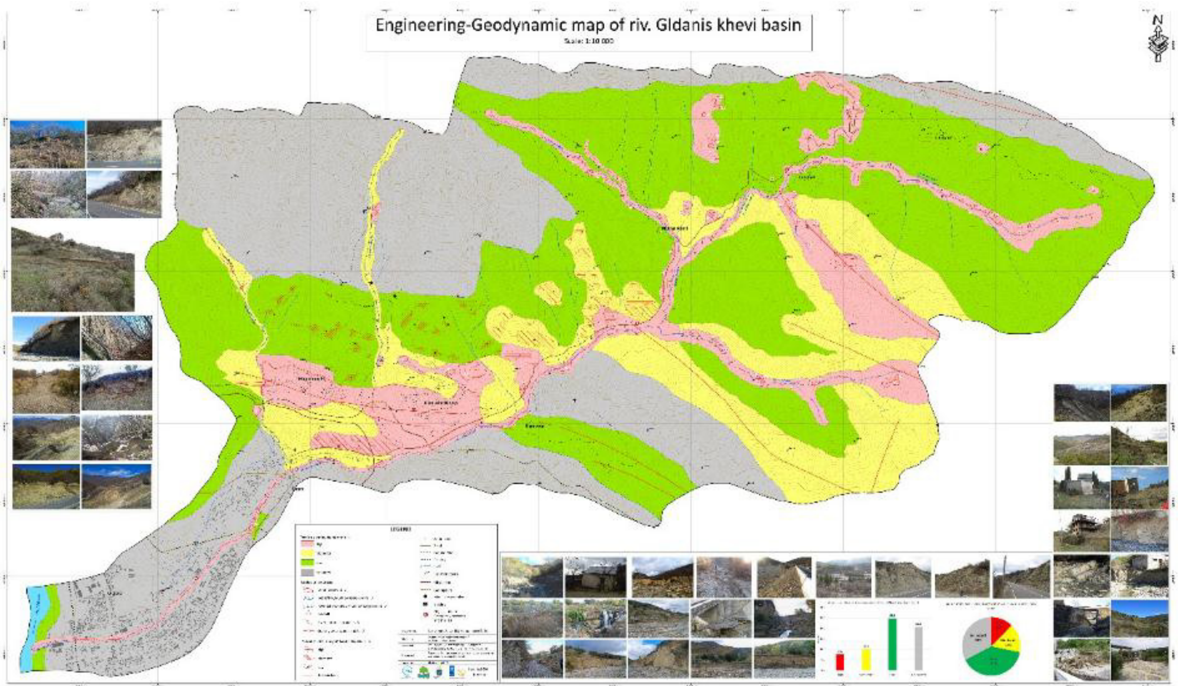


Figure 25. Geological Hazard (landslide, debris/mudflow etc.) hazard zoning map (Gldaniskhevi River basin)

12 Source: GIS technologies and Prevention of Natural Disasters (Ongoing and Planned Projects). NEA. 2015. http://nsdi.gov.ge/uploads/other/2015-12/National_Environment_Agency_Minister_of_Environment.pdf

A statistical (multivariate and bivariate) method was used by the Georgian and Czech geologists to produce a geological hazard zoning map for Dusheti municipality in the year 2017, as part of the project "Evaluation of landslide susceptibility in the mountainous parts of Georgia on the example of endangered settlements, international roads and energy conducts in Dusheti municipality", financed by the Czech Development Agency (CzDA).

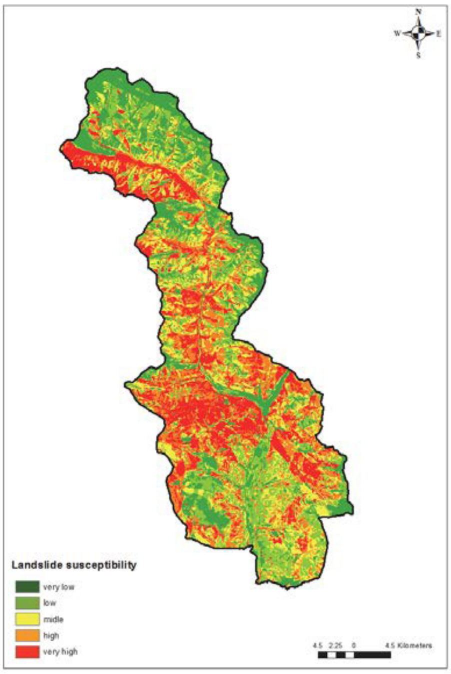


Figure 26. Geological Hazard (landslide, debris/mudflow, rockfall etc) susceptibility map.

5.0

Gap and needs analysis of existing hazard mapping norms, practices and capacities in relation to international commitments and national statutory and policy requirements

5.1 Gaps in climate-induced hazard mapping methodologies

As prescribed by the UNFCCC/INDC, the Sendai Framework and a number of national statutory and policy documents, including the Law on Civil Safety, National Civil Safety Plan, BDD, NEAP-3 and National DRR Strategy and Action Plan, Georgia should work towards the improvement of risk knowledge including knowledge of hazards that along with the routine monitoring of climate parameters, implies assessment of climate-induced natural hazards and mapping.

In Georgia, there is no single regulation defining requirements and EU standard-based methodologies for climate-induced hazard mapping, including procedures, criteria, data needs, formats, hazard scale and technical approach etc. Moreover, for hazard zoning, it is necessary to define levels of natural hazards and related colours. Based on the best international practice, it is recommended to have three or four colours for three or four standardized categories. After establishing the above standards, similar categories and colours will be used in the early warning systems, where certain regions and municipalities will be depicted with these same colours for predicting the hazards.

In general, in Georgia the largest experience exists in flood and geological (landslide, mudflow and rockfall) hazard mapping. Mostly, small-scale susceptibility maps are derived without proper or sufficient detail. Experience and capacities for other climate-induced hazards is weak. Thus, there is a need to develop and adopt an international standards-based multi-hazard assessment and mapping methodology.

5.2 Gaps in managing hazard databases

The UNFCCC/INDC, Sendai Framework and a number of national statutory and policy documents mentioned above, together with the EUAA, oblige Georgia to set and operate a dynamic standardized user-friendly database on natural hazards. Moreover, the Aarhus Convention, which Georgia is a party Georgia to, obliges the country to ensure access to environmental information.

Currently, the most comprehensive renewable user-friendly database is the Web-Portal on Natural Hazards and Risks hosted by the CENN, which any user can access. However, maps included in the Portal date back to 2012 and are of very small scale. Thus, there is a need for renewal/updating of the Portal, including the possible inclusion of larger-scale maps; the GoG has plans to update the Portal. The rest of the hazard-related information, including hydrometeorological, geological monitoring and hazard data, are stored at the NEA, mostly in paper formats, and are only available for free to government entities. For individual citizens (e.g. students, researchers, etc.), NGOs, development projects, educational and scientific/research and academic institutions, these data are not available for free. Thus, there is a need for creation of a user-friendly readily available electronic database on natural hazards within the NEA. The latter has been working on the revision of its service provision policy to allow for free access to data and information in the case of research and education projects.

The most widely available hazard maps are on floods and geological hazards (e.g. landslides, mudflows and rockfalls). For other climate-induced hazards including flash floods, avalanches, droughts, windstorms and hail storms, hazard maps are lacking. Most existing hazard maps are small-scale (e.g. 1:100,000, 1:200,000, 1:500,000 and 1:2,000,000) maps. There is a significant shortage of larger-scale maps, and thus a need to develop these.

Existing hazard, climate and geological databases and GIS maps are not fully compatible with the requirements and standards of the INSPIRE directive, and are also not linked with the Geospatial Portal, created within the NAPR under the Sida-supported project which aims at building a unified Geospatial information system in Georgia, with a single common Geoportal and relevant meta-databases in line with the INSPIRE directive.

Hence, there is a need for setting standards for geospatial data and maps, including hazard data and maps, aligning hazard data and maps with those standards and linking climate-induced hazard data and maps with a common, unique Geospatial Portal.

5.3 Gaps and needs in climate-induced hazard assessment and mapping

5.3.1 Capacity gaps

Floods and flash floods. The NEA is mostly experienced in developing smaller-scale flood (susceptibility) maps. For larger-scale and other types of hazard maps (higher probability of floods, flow levels, velocity and flow direction maps), detailed information on river channel and floodplain topography as well as on rainfall is necessary, all of which the NEA is significantly lacking. Apart from field observations and statistical methods, numerical hydraulic and hydrological models are applied for flood hazard mapping by the NEA, but at a limited scale.

Within the NEA, a fully-calibrated hydrological model and integrated near-real-time flood forecasting platform exist only for the Rioni River basin. The purpose of the hydrological analysis is to model the response of the catchment and sub-catchments to rainfall and derive flood hydrographs of different return periods (magnitudes). For this, rainfall as well as the catchment's physical data are needed, which the NEA is lacking. For catchment data, the ASPER DEM is used, but this has a low resolution (30 m.) that is not good enough for flood forecasting and modeling. Precipitation data apart from rain gauge data can also be acquired from regional radars. Currently, there is limited use of radar data and the integration of the same into weather and hydrological modeling and forecasting systems.

Concerning hydraulic (hydrodynamic) modeling applicable for floodplains, the NEA has such models (1-D, 2-D and MIKE) for the Rioni River basin, while other basins also need similar hydrodynamic models in order to develop flood hazard maps for floodplain areas. Furthermore, for hydraulic modeling, the channel and floodplain topography are required, which can be acquired though channel cross-section profile surveys and application of a high (5 m and higher) resolution DEM, which the NEA is lacking.

The hydraulic model will need to be calibrated and verified in tandem with the hydrological model by varying channel and floodplain frictional resistance and structure discharge coefficient values until good agreement is obtained between modeled and observed levels and flows at key gauging locations, or observed flood extent maps derived from historical flood surveys and satellite imagery. Calibration to historical events will need to be undertaken for the hydrological model, ensuring that the modeled runoff hydrographs fit the observed data as closely as possible. Depending on the availability of data, calibration of the hydraulic model should be done to fit observed flood levels and extents at key locations for which observations are available. This may include anecdotal information from the communities affected by flooding, which has to be collected as part of local surveys. Anecdotal information also needs to be collected using participatory GIS methods where possible. All data available for calibration should be reviewed and verified as much as possible. The calibrated and verified hydraulic model will be used to run design events of different annual probability (return period) of occurrences to produce flood maps.

Concerning flash flood hazard mapping, flash floods are defined as events, which cause flooding within six hours of the occurrence of the rainfall event. Flash floods essentially occur where precipitation cannot infiltrate either because the rainfall intensity is such that the rate of rainfall is faster than the rate of infiltration into the soil, or where slopes are so steep that water runs off at a faster rate than it can be absorbed. Also, flash flooding may occur where hard surfaces such as buildings, roads and other impervious surfaces cover large areas with insufficient drainage capacity in urban/built-up areas. Hence, flash flooding is a function of the intensity and duration of rainfall, antecedent soil moisture conditions, slope of the ground and presence of hard standing surfaces, with limited drainage. For flash flood hazard mapping, real-time rainfall data is required which the NEA totally lacks. Geomorphologic data are also pivotal for modeling flash-flood prone areas, and modeling of solid transport, which is not conducted by the NEA is particularly important, since it greatly affects the extent of the flood.

Thus, stemming from the above-mentioned gaps, relevant capacity development needs are as follows:

- expansion and upgrade of hydrometeorological (including rainfall) and geological monitoring networks;
- intensified seasonal hydrological and geological/geodetic field surveys;
- procuring/developing high resolution DEMs;
- conducting inventories of historical flood events and putting them into hydrological and hydraulic models for calibration purposes;
- extending the radar network and effectively using its data together with satellite data in forecasting and modelling platforms; and
- developing hydrological and hydraulic models for all major river basins as well as for smaller watersheds with high flood and flash flood risks.

Glacier retreat. The NEA has limited experience in developing glacier hazard maps, due to all of the following reasons: a lack of data on complexity of terrain, weather variables, initial data (volume, thickness), absence of special hydrological models allowing glaciers' dynamic modeling, limited topographic and ice cover surveys/inventories and use of aerial photography and satellite imagery.

Thus, stemming from the above-mentioned gaps, there are the following needs for:

- characterization of nearly all parameters of Georgian glaciers based on complex integrated use of high quality satellite monitoring, along with the rich historical data, current data of fieldworks and expert knowledge;
- implementation of the quality assessment and quality control (QA/QC) procedures and to obtain high accuracy and quality results;
- carrying out of research for indication of modern regional climate change impacts on glaciers:
    - definition of large glaciers' retreat and changes of small glaciers' extent/volume;
    - determination of glaciers' degradation dynamics according to climate change scenarios based on hydrological modelling;
    - estimation of potentially existing fresh water resources contained in the glaciers; and
    - determination of glacial runoff's share of the country's water balance and changes in this variable through time.

Landslides. The NEA traditionally develops small-scale landslide susceptibility maps. The data required to undertake landslide hazard mapping include geologic, topographic, hydrologic, vegetation maps, aerial photographs of the study area, history of landslides and associated reports including photographic description of previous landslides, and satellite imagery. The NEA lacks the finances and necessary equipment to carry out comprehensive geological and topographic surveys in order to conduct and depict landslide inventories (via e.g. isopleth maps. The use of aerial photography is also limited.

Mudflows and debris flows. Similar to landslide hazard mapping, a susceptibility mapping approach is applied by the NEA for mudflows and debris flow hazard mapping. For this exercise, it lacks the financial resources to carry out mudflow hazard mapping in all major river basins as well as in smaller basins with high mudflow susceptibility. It also lacks the necessary data to develop thematic (parameter/factorial) maps. Debris and mudflow hazards depend on the amount and velocity of the water and the amount of transportable soil material. High water discharge and unstable slopes near the bottom of the torrent can cause debris and mudflows. Hence, a detailed investigation of mudflows requires determination of runoff coefficients, rainfall (intensity, duration and total amount of precipitation), the peak discharge and the amount of solid material available to be transported. The NEA lacks the necessary data due to the inadequate monitoring network and the shortage of finances to upgrade it.

Avalanches. Similar to landslides and mudflows, the NEA has some experience in developing avalanche susceptibility maps, based on snow cover surveys, meteorological data, GIS and geospatial analyses. Inventories of avalanches exist, but are not based on extensively collected data at an appropriate spatial resolution. Hence, data for hazard modeling and mapping are limited. These gaps can be addressed by applying combined GIS tools, computational routines and statistical analyses in order to provide a “semi-automatic” definition of areas susceptible to avalanches (prone to avalanche release and motion). Zones of potential avalanche release should be defined based on the combined relations of slope, morphology, vegetation, snow cover and other climatological parameters (rainfall, wind, temperature). For each of the identified zones of potential release, the areas potentially affected by avalanche motion and run-out should be defined. The definition of avalanche impact areas should be implemented using a “flow-routing algorithm”, which allows for the determination of flow behavior in the track and in the run-out zone.

Droughts. Drought is a natural hazard known to be very difficult to quantify as its general characteristics, long lasting duration, large spatial extent and cross-boundary effects have hindered scientists and practitioners to precisely define the hazard. Therefore, drought susceptibility maps are most often developed at global or at least regional scale.

In Georgia, only large-scale drought susceptibility maps (nation-wide) are available, such as those included in the Hazard Web-Atlas of 2012. Up-to-date maps, both large and small-scale ones, are not currently produced due to: i) the lack of data on meteorological (e.g. rainfall, air temperature, relative humidity, wind velocity, solar radiation) and hydrological (e.g. discharge/streamflow) parameters attributed to limited hydrometeorological monitoring; ii) the lack of agrometeorological data (e.g. evapo-transpiration, soil moisture, leaf wetness, phenology, etc.) due to extremely limited agrometeorological monitoring; and iii) lack of knowledge and capacities for deriving various drought indices.

In fact, the total number of agrometeorological stations is 34, of which 24 are operated by the NFA and 10 by the NEA. The geographic distribution and density of these stations is not enough to detect and predict droughts across the country nor to conduct hazard mapping. Rain gauges that also could be used for some drought indicators are also lacking. Those stations operated by the NFA are more designed for predicting use of pesticides under various climate conditions. Thus, there is a need for expansion of the hydrometeorological (i.e. rain gauges) and agrometeorological monitoring network and generation of data necessary for drought forecasting and mapping.

Generally, drought hazard is described by one or a set of drought indicators. For example, the Standardized Precipitation Index (SPI) is a tool which was developed primarily for defining and monitoring drought. The SPI allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historic data. It can also be used to determine periods of anomalously wet events. Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring at a station. The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. The PDSI has been reasonably successful at quantifying long-term drought. For Europe, the standardized precipitation and evapotranspiration index (SPEI) has become popular for drought forecasting in recent years.

Strong winds, thunderstorms and hail. Up-to-date strong wind, thunderstorm and hailstorm hazard maps are not available, due to the following reasons:

- the shortage of real-time meteorological (wind speed and direction, rainfall, thunder/lightning, cloudiness, air temperature) data attributed to limited hydrometeorological monitoring;
- limited weather forecasting/modeling (Numerical Weather Prediction Models) capacities;
- under-developed regional radar and ground-based lightning monitoring network; and
- limited use and integration of radar, ground-level lightning monitoring network and satellite imagery data into existing weather forecasting/modeling platforms.

5.3.2 Capacity development needs

Based on the identified capacity gaps in climate-induced hazard assessment and mapping, following are the capacity development needs to be addressed:

- expanding and upgrading existing hydrometeorological (including snowfall and snowpack/depth monitoring), agrometeorological and geological monitoring networks to cover all major river basins, as well as smaller watersheds with high climate-induced multi-hazard risks;
- procuring additional radars (two radars for Western Georgia, Kutaisi and Poti) as well as ground-level lightning (four antennas) detectors and integrating these into multi-hazard forecasting systems;
- filling data gaps on watershed physical parameters, including land cover, channel-floodplain topography, geodesy, geology, hydrodynamics, soil moisture, slope, drainage, rainfall runoff coefficient, peak discharges and amount of sediment available for transportation, and snow pack depths/volumes through:
    - conducting inventories of and processing historic hydrometeorological, agrometeteorological and geological data;
    - intensifying field geological, geodetic, hydrological and snow cover surveys;
    - procuring/developing a high-resolution DEM;
    - acquiring and effectively integrating radar, ground-based lightning detectors, aerial photog-

raphy and satellite imagery data into multi-hazard forecasting and modeling platforms.

- characterization of nearly all Georgian glaciers based on complex integrated use of high-quality satellite monitoring, along with the rich historical data, current field data and expert knowledge; and implementation of QA/QC procedures to obtain highly accurate and high-quality results;
- carrying out of research to determine current regional climate change impacts on glaciers:
  - Definition of large glaciers' retreat and changes' of small glaciers depth/volume;
  - Determination of glaciers' degradation dynamics according to climate change scenarios based on hydrological modelling;
  - Estimation of potentially existing fresh water resources contained in the glaciers; and
  - Determination of the glacial runoff share in the country's water balance and its evolution through time.
  - purchasing advanced numerical weather forecasting, hydrological, hydraulic, landslide, mudflow, avalanche and glacial melting models and training the NEA's staff in applying such models;
  - developing/calibrating hydrological, hydraulic (1D-2D/MIKE Basin), landslide, mudflow and avalanche models for all major river basins, as well as for sub-basins/smaller watersheds of river basins with high climate-induced multi-hazard risks, e.g. smaller watersheds of the Kura River Basin within the boundaries of the city of Tbilisi;
  - setting up near-real-time, fully integrated flood/flash flood, landslide, mudflow/debris flow, avalanche, drought, strong wind, thunderstorm and hailstorm forecast platforms for all major river basins, as well as for sub-basins/smaller watersheds of river basins with high multi-hazard risks, and integrating various-scale weather forecasting models and all available data into them, including monitoring, radar, ground-based lightning network and satellite data;
  - selecting and calculating proper drought indices and developing drought hazard maps (the NEA has lengthy historical data sets on daily (and sub-daily in some cases) precipitation and temperature from old stations); a review of relevant data, particularly for drought-prone regions, should determine which indicator should be used to calculate drought susceptibility. A drought indicator should be calculated for each grid cell within the model and for each month within the year, resulting in a drought hazard map by month and a drought susceptibility map. The results should be calibrated based on past observed droughts, in particular the drought of 2000;
  - developing flood, flash flood, landslide, mudflow/debris flow, avalanche, drought, strong wind, thunderstorm and hailstorm hazard maps, as well as climate-induced multi-hazard maps for all major basins as well as for sub-basins/smaller watersheds with high multi-hazard risks; and
  - building the NEA's and other stakeholders' capacities in multi-hazard assessment and mapping, based on commonly-agreed, international, standards-based methodologies.

5.3.3 Multi-hazard mapping

Multi-hazard mapping is usually accomplished by combining various hazard maps in GIS systems. The NEA does not have experience in multi-hazard mapping, while there is some relevant experience in the NGO sector. For instance, under the USAID/GLOWS project Integrated Natural Resources Management in Georgia (INRMW) implemented in 2011-2014, the CENN (as a project partner) developed multi-hazard and risk maps for climate-induced natural hazards for the upper and lower Alazani and Rioni watershed areas covering seven municipalities. There is thus a need for building the NEA's capacities in multi-hazard assessment based on commonly-agreed, international, standards-based methodologies.

5.3.4 Knowledge gaps and needs of local academic and research institutions, NGOs and private consultancies in hazard mapping, including multi-hazard mapping

There is very limited experience of climate-induced hazard mapping in NGOs, academia and the local private sector, although many of these institutions, in particular those dealing with spatial information, GIS/RS, modeling and database management have a solid technical background and geospatial technologies to carry out hazard mapping. There are a couple of exceptions where there does exist past and current experience within NGOs and the academic sector in hazard mapping[13].

The absolute majority of university courses on DRR provided by some of the leading academic institutions do not include climate-induced hazard assessment and mapping, including multi-hazard mapping.

Stemming from the limited knowledge, experience and capacities of academic and research institutions, NGOs and the private sector in climate-induced hazard mapping, including multi-hazard assessment and mapping, there is a clear need for to increase such knowledge and capacities in all of these sectors.

6.0 Conclusions and Recommended Actions

6.1 Conclusions

Based on the review and analysis of existing climate-induced hazard mapping architecture, gaps and capacity needs, the following conclusions can be drawn and relevant recommendations suggested:

- **Climate-induced hazard mapping methodologies.** There is no single regulation for a commonly-agreed, international, standards-based methodology on multi-hazard assessment and mapping in Georgia. Moreover, there is no EU-compliant flood assessment and mapping methodology as mandated by the EUAA.
- **Hazard databases/maps and data accessibility:**
  - There is a shortage of data and information on climate, geological and geographic parameters necessary for climate-induced natural hazards in Georgia.
  - The most comprehensive, renewable, user-friendly open-source

13 *For instance, in 2012, CENN in cooperation with various local international organizations developed a Web-Alas on natural hazards. In addition, from 2011-2014 under the USAID/GLOWS INRMW project, it developed municipal-level multi-hazard maps for seven municipalities of Georgia. Another example is Geographic, which is engaged in spatial planning and integrates hazard assessment and mapping into spatial planning and city planning. It also applies the RAMMS numerical model for modeling of various natural hazards, including avalanches and mudflows. ED has been recently involved in assessment of climate-induced natural hazards for the Tsavkisiskhevi watershed in Tbilisi. The Institute of Earth Sciences and Seismic Monitoring Centre is one of the research institutes of the Ilia University (Iliauni), studying/managing seismic and related geological hazards and risks in Georgia. In 2017-2018 it conducted a multi-disciplinary hazard study of Nino Jvania Street and its adjacent area (Varaziskhevi district of Tbilisi). This geophysical and general geological study showed that the left slope of the upper portion of the Varaziskhevis River basin is not hazardous in terms of landslides (due to geological conditions), but just small-scale rockfalls can be expected; while the right slope is much more unstable and activation of landslide processes there can be expected. In case of heavy rainfall, a landslide may be triggered and there is a probability that the mudflow will block the river pipe. Most likely, afterwards water will overflow the barrier causing severe inundation. A landslide could be triggered by a strong earthquake as well. This study published in 2018 also includes recommendation on controlling construction and development in hazardous zones.*

database on natural hazards (Web-Portal on Natural Hazards and Risks) hosted by the CENN is outdated. Relevant stakeholders do not apply/renew it in practice. Moreover, maps contained in the Portal are of very small-scale.

- Currently, the more-or-less available climate-induced hazard maps within the NEA are for floods and geological hazards (landslides, mudflows, rockfalls etc.). For other climate-induced hazards, including flash floods, droughts, strong winds and hailstorms, hazard maps are lacking. The majority of maps are of small-scale (1:100,000 and more), and there is a significant shortage of large-scale maps that require hydrometeorological and geological parameters that the NEA lacks.
- A large portion of climate and geological data and information necessary for hazard mapping is archived at the NEA mostly in paper format, and is not available for free to non-public sector representatives.
- Existing hazard, climate and geological databases and GIS maps are not fully compatible with requirements and standards of the INSPIRE Directive and are not linked with the Geospatial Portal, created within the NAPR under the Sida-supported project which aims at building a unified geospatial information system in Georgia, having one common geoportal and relevant meta-databases in line with the INSPIRE Directive.

Climate-induced hazard assessment and mapping practices

- Floods and flash floods: The NEA lacks large-scale maps on high-probability floods, flash floods, flood depth and flow velocity or direction. These are lacking due to: i) the shortage of hydrometeorological (rainfall, peak discharges, water elevation/level), geodetic and geological data on river channel and floodplains and rainfall, as a result of limited hydrometeorological and geological monitoring and field surveys; ii) limited weather modeling capacities; iii) limited hydrological modeling capacities and lack of models for major river basins (except for the Rioni River basin and the left tributaries of the Alazani River basin), as a result of having few hydrographs for smaller watersheds attributed to a lack of data on watershed physical features/parameters and absent high-resolution (5-m and higher) DEMs; iv) limited hydrodynamic/hydraulic modeling capacities (lack of 1D-2D/MIKE Basin-based hydraulic models for river basins, again attributed to the shortage of data on channel-floodplain hydrodynamic and topographic data and the lack of a high resolution DEM; and v) limited use of ground radar and satellite imagery data and their integration into forecasting and modeling platforms.

Concerning flash flood modelling, hazard maps on these are practically absent due to: i) shortage of real-time rainfall monitoring data; and ii) a lack of data on soil moisture, slope and soil permeability/drainage.

- Glaciers' retreat: The NEA has limited experience in developing glacier hazards maps due to: i) the lack of data on complexity of terrain, weather variables, baseline data (volume, thickness), absence of the special hydrological models allowing glaciers' dynamic modeling, limited topographic and ice cover surveys/inventories along with limited use of aerial photography and satellite imagery.
- Landslides: The NEA lacks up-to-date large-scale maps on landslide hazards due to: i) a shortage of meteorological data (e.g. rainfall etc.), geology, topography, hydrology and vegetation cover, this being attributable to limited hydrometeorological and geological monitoring and field surveys and use of software and knowledge of numerical models (e.g., the Swiss-based RAMMS).
- Mudflow and debris flows: The NEA lacks larger-scale (at least river basin-level) mud-flow hazard maps due to: i) a shortage of data on runoff coefficient, design rainfall (intensity, duration and total amount of precipitation), peak discharges and amount of sediment available for transportation attributed to limited hydrometeorological and geological monitoring, geological and geodetic surveys and use of aerial photography and satellite imagery; and ii) lack of modeling tools, knowledge and capacities in application of numerical models.
- Avalanches: The NEA has limited experience in developing avalanche maps due to: i) the

lack of data on complexity of terrain, weather variables, on-site weather (temperature, snowfall) and snowpack (snow depth), this being attributable to diminished hydrometeorological monitoring and forecasting, including snowfall and snowpack monitoring, limited topographic and snowcover surveys/inventories and use of aerial photography and satellite imagery; and ii) absent numerical computer models (e.g. RAMMS) and capacities to run such models.

- Droughts: Only large-scale drought maps are available in the Hazard Web-Atlas, although they are outdated. Up-to-date maps, both large- and small-scale ones, are not currently produced due to: i) the lack of data on meteorological (e.g. rainfall, air temperature, relative humidity, wind velocity and solar radiation) and hydrological (e.g. discharge/streamflow) parameters, this being attributable to limited hydrometeorological monitoring; ii) lack of agrometeorological data (e.g. evapo-transpiration, soil moisture, leaf wetness, phenology etc.) also being attributable to extremely limited agrometeorological monitoring; and iii) lack of knowledge and capacities for deriving various drought indices.
- Strong winds: Up-to-date strong wind hazard maps are not available due to: i) the shortage of real-time meteorological data attributed to limited hydrometeorological monitoring; ii) limited weather forecasting/modeling (Numerical Weather Prediction Models) capacities; iv) limited use and integration of ground radar, lightening and satellite imagery data into existing forecasting/modelling platforms.
- Thunderstorms and hailstorms: Up-to-date thunderstorm and hailstorm hazard maps are not available due to: i) the shortage of real-time meteorological data (e.g. rain, thunderstorms, air temperature etc.) attributable to limited hydrometeorological monitoring; ii) limited weather forecasting/modeling (NWPMs) capacities; iii) lack of ground-based lightning networks and limited use and integration of ground radar and satellite image data into existing forecasting/modelling platforms.

- **Multi-hazard mapping.** The NEA does not practice multi-hazard mapping, although there does exist some limited experience in this realm in the NGO sector.
- **Knowledge gaps and needs of local academic and research institutions, NGOs and private consultancies in hazard mapping.** There is very limited experience of climate-induced hazard mapping in the NGO, academic and local private sectors, although many of these institutions, in particular those dealing with spatial information, GIS/RS, modeling and database management have a solid technical background and geospatial technologies to needed to carry out hazard mapping. There are a couple of exceptions with past and current experience within the NGO and academic sectors in hazard mapping. The absolute majority of university courses on DRR provided by some of the leading academic institutions do not include climate-induced hazard assessment and mapping, including a lack of multi-hazard mapping courses.

6.2 Recommended actions (road map) to address capacity gaps in climate-induced hazard mapping

This sub-chapter chapter contains recommended actions (a “road map”) covering the period 2018-2023 to address capacity gaps in climate-induced hazard mapping, as identified through the baseline study. The road map includes recommended actions with an indication of capacity gaps/needs, international obligations, national statutory and policy requirements, responsible parties, potential source(s) of financing/donor(s), approximate cost and the timeframe.

According to cost criteria, actions are divided into low (up to 100,000 USD), medium (100,000-1,000,000 USD) and high (above 1,000,000 USD) cost categories. According to the timeframe, actions are divided into short-term (up to one year), mid-term (up to three years) and longer-term (three to five years) categories.

#	Action	Gap	International obligation	National statutory and policy require-ment	Responsible party	Potential source financing/ donor	Cost	Time-frame	Comment
				Climate-induced hazard mapping methodologies					
1.	Developing and adopting a regulation on an international standards-based multi-hazard assessment and mapping methodology	Lack of a single regulation on a commonly-agreed international standards-based methodology for multi-hazard assessment and mapping in Georgia	UNFCCC/Paris Agreement/ INDC; Sendai Framework	Laws on Civil Safety and Emergency Situations; Charter of the NEA; NEAP-3; National DRR Strategy	MoEPA – NEA; UNDP/SDC/ GCF MHEWS project	UNDP/SDC/ GCF MHEWS project	Low	Short- to medium-term	UNDP/SDC/GCF MHEWS project plans to assist the NEA in developing and applying multi-hazard assessment and mapping methodology, funded by SDC
2.	Developing and adopting a regulation on an EU-compliant flood assessment and mapping methodology	Lack of regulation on EU-compliant flood hazard assessment and mapping methodology	UNFCCC/Paris Agreement/ INDC; Sendai Framework	Laws on Civil Safety and Emergency Situations; Charter of the NEA; Government Resolution on implementation of EUAA; NEAP-3; National DRR Strategy.	MoEPA – NEA	EU PPRD East Programme	Low	Short-term	EU PPRD East programme currently assists the NEA in developing flood assessment and mapping methodology in line with the EU Flood Directive. The relevant regulation will be completed and adopted by the end of 2018
3.	Building knowledge and capacities of public authorities and non-public sector representatives in the application of international standards-based flood and multi-hazard assessment and mapping methodologies	Lack of or limited knowledge and experience within public authorities primarily, the NEA and local governments as well as the non-public sector (e.g. research and academic, NGO and private consulting) representatives in the application of international standards-based flood and multi-hazard assessment and mapping methodologies	UNFCCC/Paris Agreement/ INDC; Sendai Framework; EUAA	Laws on Civil Safety and Emergency Situations; Charter of the NEA; Government Resolution on implementation of EUAA action plan; NEAP-3; National DRR Strategy.	MoEPA – NEA; UNDP/SDC/ GCF MHEWS project	UNDP/SDC/ GCF MHEWS project EU PPRD East project	Low	Medium-term	UNDP/SDC/GCF MHEWS project will assist country in developing local capacities in multi-hazard mapping and risk assessment funded by SDC; EU PPRD East project is currently assisting the NEA in developing EU-compliant flood assessment and mapping methodology

Hazard databases/maps									
4.	a) Expansion and upgrade of hydrometerological, agrometeorological and geological monitoring networks to cover all major river basins and produce hydrometeorological parameters necessary for hazard forecasting/modelling and mapping in real-time	Shortage/lack of data on climate, geographic, topographic and geological parameters necessary for mapping climate-induced natural hazards in Georgia	UNFCCC/Paris Agreement/ INDC; Sendai Framework; EUAA	Laws on Civil Safety and Emergency Situations; Charter of the NEA; Government Resolution on implementation of EUAA action plan; NEAP-3; National DRR Strategy.	MoEPA – NEA; MoEPA – NFA; UNDP/SDC/ GCF MHEWS project.	GoG UNDP/SDC/ GCF MHEWS project Other donors: WMO, Czech and Polish governments; Government of Japan, US government	High	Medium-term	Upcoming UNDP/SDC/GCF MHEWS project plans to assist the NEA in expansion and upgrade of hydrometeorological network to cover all basins, field surveys, inventories and digitization of historic data, and acquiring and processing aerial photography, radar and satellite imagery data funded by GCF One weather radar will be soon be procured and installed at Kutaisi International Airport with US government's assistance; it will be operated by the NEA. Another weather radar will be purchased by the National Aviation Service and installed in Poti. The NEA will have full access to its data
	b) Expansion of regional radar network						High	Medium-term	
	c) Expansion of ground-based lightning monitoring system (procurement of six additional detectors)						Medium	Medium-term	
	d.1) Intensification of hydrological, snow cover, geological and geodetic surveys d.2) inventory and digitization of historic hydrometeorological, geological and climate-induced data						High	Long-term	
	c) Acquisition and processing of aerial photography, satellite imagery and radar data a							Long-term	

5.	a) Updating of existing Web-Atlas on Natural Hazards and including more detailed maps	Outdated and insufficiently detailed Web-Atlas; lack of user-friendly accessible electronic hazard database within the NEA.	UNFCCC/Paris Agreement/ INDC; Sendai Framework; EUAA.	Laws on Civil Safety and Emergency Situations; Charter of NEA; Government Resolution on implementation of EUAA action plan; NEAP-3; National DRR Strategy.	MoEPA – NEA; CENN.	GoG	Medium	Medium-term	GoG will updated the Web-Atlas on natural hazards
	b) Creation of a user-friendly, accessible, electronic hazards database at the NEA				MoEPA-NEA; UNDP/SDC/ GCF MHEWS project.	GoG UNDP/SDC/ GCF MHEWS project	Medium	Medium-term	Upcoming UNDP/SDC/GCF MHEWS project plans to assist the NEA in creating a user-friendly climate-induced multi-hazard database, funded by GCF
	c) Revision of NEA's pricing policy to allow for free data access to users for research and educational purposes				NEA	NEA	Low	Short-term	NEA plans to revise its pricing policy for climate information services by allowing free data access to users for research and educational purposes
6.	a) Development of geospatial data and information standards in line with the EU's INSPIRE Directive	Lack of national standards on geospatial data compliant with the EU's INSIRE directive; Non-compliance of climate-induced hazard data and maps with EU INSPIRE requirements; No integration of existing geospatial climate-induced hazard data and maps in national Geo-Portal.	UNFCCC/Paris Agreement/ INDC; Sendai Framework; the EU's INSPIRE Directive	Laws on Civil Safety and Emergency Situations; Charter of the NEA; Government Resolution on establishing a national commission for developing a national geospatial information system; NEAP-3; National DRR Strategy.	NAPR	GoG Sida	Low	Short-term	Currently, NAPR with Sida's support is working on the setting up of a national geospatial information infrastructure in Georgia
	b) Aligning climate-induced hazard data and maps with national geospatial standards				MoEPA-NEA	NEA	Low	Short-term	
	c) Integration of the NEA's climate-induced natural hazard database in national Geoportal				NAPR; MoEPA-NEA/	NAPR/Sida, MoEPA - NEA	Low	Short-term	

Hazard assessment and mapping									
7.	Development of hydrological models for all major river basins	Lack of up-to-date maps on high probability floods, flash floods, flood depth, flow velocity or direction, landslides, mudflows, avalanches, droughts, strong winds and hail storm hazards Shortage of hydrometeorological, geodetic and geological data; Limited weather modelling, hydrological and hydraulic modelling capacities; Limited use of ground radar and satellite imagery data and their integration into forecasting and modelling platforms; Lack of modelling software and knowledge on numerical models (e.g. Swiss-based RAMMS); Lack of knowledge and capacities of public and non-public sector representatives in international standards-based multi-hazard assessment and mapping	UNFCCC/Paris Agreement/ INDC; Sendai Framework	Laws on Civil Safety and Emergency Situations; Charter of the NEA; Government Resolution on implementation of EUAA action plan; NEAP-3; National DRR Strategy.	MoEPA – NEA; UNDP/ SDC/GCF MHEWS project;	MoEPA – NEA UNDP/SDC/ GCF MHEWS project GoG – Ministry of Finance	High	Longer-term	Upcoming UNDP/SDC/ GCF MHEWS project plans to assist the country in building the NEA's capacities in climate-induced hazard mapping, and risk assessment; funded by SDC; multi-hazard forecasting platforms will be funded by GCF RAMMS mass flow numerical model can be procured through GoG funding and technical assistance of Geographic company having knowledge and capacity in running this model can be utilized.

8.	Development of hydraulic models based on 1D-2D/MIKE Basin for all river basins						High	Lon-ger-term	
9.	Setting up of near-real-time flood forecast platforms for all river ba-sins and integrating various-scale weather forecasting models and all available data into them, including monitoring, radar and satellite data						Medium	Lon-ger-term	
10.	Training the NEA's staff in hydrologi-cal and hydraulic modelling						Low	Short-term	
11.	Development of flood and flash flood maps for all major basins as well as for smaller watersheds with higher hazards						Medium	Lon-ger-term	
12.	a) characterization of nearly all parameters of Georgian glaciers based on complex integrated use of high-quality satellite monitoring, along with rich historical data, cur-rent data from fieldwork and expert knowledge b) implementation of the quality assessment and quality control (QA/QC) procedures to obtain highly accurate and high-quality results c) carrying out research for indication of modern regional climate change impact on glaciers: definition of large glaciers' retreat and changes of small glaciers' amount determination of glaciers degradation dynamics according to CC scenarios based on the hydrological modelling estimation of potentially existing fresh water resources contained in the glaciers determination of the glacial runoff share of the country's water balance and its change						High	Lon-ger-term	

13.	Setting landslide, mudflow and avalanche forecasting platforms for all major river basins as well as for smaller watersheds with higher hazards and integrating weather forecasting platforms and all available data into them, including radar data						High	Longer-term	
14.	Development of landslide, mudflow and avalanche numerical modelling capacities of the NEA through procuring, calibrating and applying these numerical models (e.g. RAMMS) for all major river basins as well as for smaller watersheds with higher hazards						Medium	Longer-term	
14.	Development of landslide, mudflow and avalanche hazard maps for all major river basins as well as for smaller watersheds with higher hazards						High	Longer-term	
15.	Training the NEA's staff in landslide, mudflow and avalanche hazard modelling; e.g., application of numerical models (such as RAMMS)						Low	Short-term	

16.	Setting up drought forecasting platforms for all river basins and integrating weather forecasting platforms and all available data into them, including radar data						High	Lon-ger-term	
17.	Training of NEA's and NFA's staff in drought assessment (calculating various drought indices (e.g. SPI, PDSI, etc.)), forecasting/modelling, mapping						Low	Short-term	
18.	Developing drought hazard maps for major river basins						Medium	Lon-ger-term	
19.	Setting up near-real-time strong wind, thunderstorm and hail fore-casting and integrating all available data, including monitoring, radar, ground-based lightning detection and satellite data into the database						High	Lon-ger-term	
20.	Training NEA's and NFA's staff in in strong wind assessment, forecasting and modelling						Low	Short-term	

21.	Development of strong wind, thunderstorm and hail hazard maps for all major river basins as well as for smaller watersheds with higher hazards						High	Longer-term	
22.	Development of climate-induced multi-hazard maps for all major river basins as well as for smaller watersheds with higher multiple hazard risks						Medium	Medium-term	

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