Kerala State Disaster Risk Financing Strategy

INCEPTION REPORT

March 2024

Prepared and Submitted By
RMSI Private Limited, India

Head Office: A-8 Sector 16, Noida 201 301, India
Tel: +91 120 251 1102, 251 2101
Fax: +91 120 251 1109, 251 0963
www.rmsi.com

In association with
NATIONAL INSURANCE ACADEMY

For the attention of:

<table>
<tr><td colspan="2">Chief Executive Officer,
Rebuild Kerala Initiative,
Planning & Economic Affairs (RKI) Department, Government of Kerala,
1A, CALSAR Heather Tower, Punnen Road,
Near Government Secretariat, Thiruvananthapuram
Email: rkisecretariat@kerla.gov.in</td></tr>
<tr><td colspan="2">Contact:
Dr. Sushil Gupta,
Project Team Leader and
Vice President, Risk Modeling and Insurance, Sustainability
Email: sushil.gupta@rmsi.com</td></tr>
<tr><td>Company Information:</td><td></td></tr>
<tr><td>Name</td><td>RMSI Private Limited</td></tr>
<tr><td>CIN</td><td>U74899DL1992PTC047149</td></tr>
<tr><td>Registered Office Address</td><td>50/9, 1st Floor, Tolstoy Lane, Janpath,
New Delhi, India – 110001</td></tr>
<tr><td>Corporate Office Address</td><td>A-8, Sector-16
NOIDA, 201 301
India
Tel: +91 120 251 1102, 251 2101
Fax: +91 120 251 1109, 251 0963
E-mail: info@rmsi.com</td></tr>
</table>

Acknowledgements

RMSI project team acknowledges the support and guidance provided by the CEO, RKI; Principal Secretary, Revenue, Disaster Management & Housing Department; OSD, Finance, Deputy CEO, RKI; Additional Secretary, RKI; and Dr. Sekhar Lukose Kuriakose, Member Secretary, KSDMA.

We also extend our sincere thanks to Dr. Krishna Vatsa, Honourable Member, NDMA; Mr. Deepak Singh, Lead DRM Specialist and Mr. Vijay Kalavakonda, Senior Operations Officer, The World Bank; and Mr. Rahul Mankotia, Sector Specialist, KfW for all the support and guidance provided to ensure that the project will benefit the state in the true spirit of its conception. We also acknowledge the support extended by the staff of the RKI and KSDMA for coordination with various line departments and data sharing.

Table of Contents

List of Figures

List of Tables

Abbreviations Used

Abbreviation/Acronym	Expanded Form
AAL	Average Annual Loss
ARC	African Risk Capacity
ART	Alternative Risk Transfer
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CEA	California Earthquake Authority
CLHS	Conditional Latin Hpercube Sampling
CMDRF	Chief Minister's Disaster Response Fund
DDMAs	District Disaster Management Authority
DEM	Digital Elevation Models
DRF	Disaster Risk Financing
DRFI	Disaster risk financing and insurance
DTM	Digital Terrain Model
ELT	Event Loss Table
EP	Exceedance Probability
FES	Finite Element Solution
FIMS	Fisheries Information Management System
FONDEN	Fund for Natural Disasters
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographic Information System
GSI	Geological Survey of India
HEC-HMS	Hydrological Engineering Center-Hydrologic Modeling System
HEC-RAS	Hydrological Engineering Center-River Analysis System
IMD	India Meteorological Department
ISRO	Indian Space Research Organization
KSDMA	Kerala State Disaster Management Authority
KSPB	Kerala State Planning Board
KSREC	Kerala State Remote Sensing and Environment Centre
LEC	Loss Exceedance Curve
LSI	Landslide Susceptibility Index
LULC	Land Use Land Cover
MDR	Mean Damaging Ratio
MOSDAC	Meteorological, and Oceanographic Satellite Data Archival Centre
NAIC	National Association of Insurance Commissioners
NatCAT	Natural Catastrophic
NBSS	National Bureau of Soil Survey and Land Use Planning
NCRMP	National Cyclone Risk Mitigation Project
NDMA	National Disaster Management Authority

Abbreviation/Acronym	Expanded Form
NDMIS	National Disaster Management Information System
NDRF	National Disaster Response or Mitigation Fund
NHO	National Hydrographic Office
NRSA	National Remote Sensing Agency
NRSC	National Remote Sensing Centre
NSRP	Neyman–Scott Rectangular Pulses
OSM	Open Street Map
PCRIC	Pacific Catastrophe Risk Insurance Company
PDSI	Palmer Drought Severity Index
PET	Potential Evapotranspiration
PMJJBY	Pradhan Mantri Jeevan Jyoti Bima Yojana
RKI	Rebuild Kerala Initiative
RP	Return Period
SAC	Space Application Centre
SDMF	State Disaster Risk Management Fund
SDRF	State Disaster Response or Mitigation Fund
SDRMF	State Disaster Risk Mitigation Fund
SMRC	SAARC Meteorological Research Center
SMS	Surface Modeling System
SPC	Segregated Portfolio Company
SPEI	Standard Precipitation Evapotranspiration Index
SRTM	Shuttle Radar Topography Mission
TCIP	Turkish Catastrophe Insurance Pool
TCRM	Tropical Cyclone Risk Model
USD	United States Dollar
USGS	United States Geological Survey

1

Introduction

1 Introduction

Kerala is highly vulnerable to a multitude of hazards, such as floods, landslides, drought, cyclones, and storm surge conditions. Spatial variation in the nature of precipitation across the state, especially due to its orographic nature, renders several districts under flooding and others under water stress and drought-like conditions. The steep gradient along the slopes of the Western Ghats adds to its vulnerability to landslides. The loss of life and property are badly impacting Kerala state due to high frequency and severity of these devastating events exaberrated due to the impact of climate change, given its location along the seacoast. During the recent natural disasters, such as Cyclone Ockhi (2017), Kerala Floods 2018, and 2019; the State has suffered huge losses in terms of buildings and infrastructure, lives and livlihoods, agriculture, health, and environment. These natural disasters caused not ony an ennormous financial liability to the State by way of rescue, relief and recovery measures, but also created a huge fiscal deficit to the State.

Govt of Kerala is working to minimize these losses due such devastating events, by initiating various mitigation measures both in structural and non-structural. As a part of non-structural measures, Govt. of Kerala, is looking for risk aversion and transfer through risk financing and reinsurance to substantially reduce the dependence of the state on external organizations for financial assistance in post-disaster related activities.

This project, viz., Consultancy Services for Developing State Disaster Risk Financing Strategy, is a vital step in initiation of this process. The project will not only help standardize and scale up the requirements for loss accounting through quality multi-hazard disaster risk assessments, but will also help assess the policy and solution landscape for disaster risk insurance in the state by reviewing and designing strategies and prototype products. The study area for this assignment covers entire Kerala State. Salient features of Kerala State are given Figure 1-1.

Geographical Area - **38,863 km2**

Capital - **Thiruvananthapuram**

Population (2011 Census**)**

33,406,061

Literacy rate - 96.2%

Number of river basins**-**

44 major rivers

3 flow eastward,

41 major rivers flow westward.

Tempe (Min/Max) **– 19.8 °C to 36.7 °C**

Annual rainfall l (Min/ Max)

ranges 1,250 to 2,923 mm

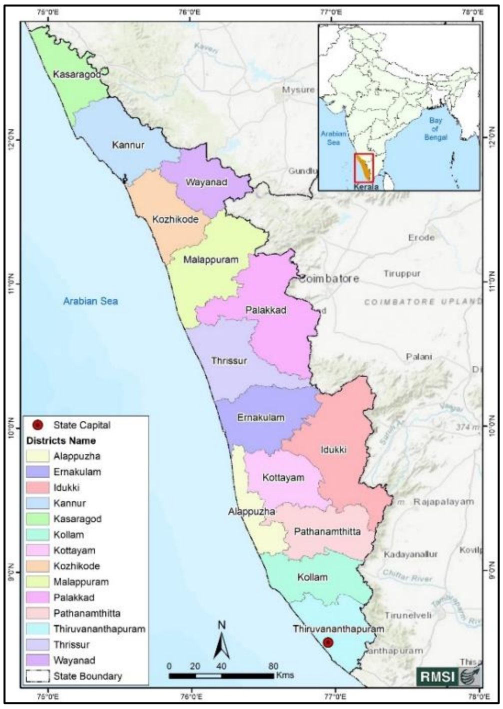

Figure 1-1: Study area map

1.1 Understanding the objectives

At a broad level, the core objective of the current assignment is to develop an understanding of the contingent liabilities faced by the Government of Kerala from natural disasters in order to develop strategies to build financial resilience in the State through sovereign disaster risk financing, catastrophe (property) risk insurance, and disaster micro-insurance.

The objectives of the study are:

1. Assessing hazard risk, creating a financial loss database, and carrying out hazard risk analysis for the state of Kerala.
2. Developing a state catastrophe risk profile/ undergoing disaster risk assessment.
3. Design Disaster Risk Financing Strategies for the State of Kerala with a greater focus on the housing sector and government buildings.
4. Design triggers for financial transactions, with focus on the housing sector and government buildings.

1.2 Scope of the study

1. To build a major historical hazard events database (i.e., floods, landslides, cyclone, storm surge, and droughts) for Kerala, especially for the past 30 years in the NDMIS portal
2. To develop a database, especially for the past 30 years, of economic and financial losses caused by major flood, landslide, cyclone, storm surge, and drought induced disasters in the NDMIS
3. To conduct hazard, vulnerability, and risk assessment of major disaster risks from floods, landslides, cyclones, storm surge, and droughts, especially during the past 30 years.
4. To use state-of-the art catastrophe risk modeling methodology, development of risk profiles for major natural perils in Kerala.
5. To design comprehensive disaster risk financing strategies for the State of Kerala.
6. To design parametric indices to be used for financial transactions (e.g., reinsurance, cat bonds, etc.)
7. To design prototype risk transfer instruments, including indemnity and parametric-based catastrophe (property) insurance products.

The key outputs of the study will be:

1. A geo-referenced catalogue for historical major events – including floods, landslides, tropical cyclones, storm surge and droughts in Kerala; hazard risks and financial losses database, and hazard risk analysis.
2. Disaster Risk Assessment report and brochures on state catastrophe risk profiles.
3. Design disaster risk financing strategies for the State of Kerala with greater focus on the housing sector and government buildings.
4. A report analyzing the risk profiles of a set a pre-agreed parametric risk transfer product(s).
5. Dissemination of material summarizing the prototype insurance policies and portfolio analysis (e.g., through a PowerPoint presentation).

2

Hazard Risk and Financial Loss Database and Hazard Risk Analysis

2 Hazard Risk and Financial Loss Database and Hazard Risk Analysis

The project team has started the data collection mission just after Kick of meeting on Jan 10, 2024. This section provides the summary of various data and reports collected till date, while this activity will continue for a major duration of the Project. The collected data/relevant reports are being reviewed scientifically and will be summarized in respective milestones. Some of the key attributes required for this study are the frequency, severity, and spatial distribution of disasters caused by key natural hazards (flood, landslide, drought, cyclone and storm surge) impacting Kerala State. The project team is also collecting the existing datasets and models for key hazards (if any) from the client and/or relevant departments.

2.1 Data collection-hazard/damage/loss reports for the state

Disaster-related economic and financial losses/expenditures data are currently available with the following sources:

- **State level**: State-wise allocation and release of the SDRF, NDRF; disbursements to districts; department-wise budget allocation for reconstruction; disbursements from the CM Disaster Relief Fund; State-level initiatives such as Rebuild Kerala Initiative, etc. and expenditures such on relief and rehabilitation; KSDMA, Department of Revenue, Housing, and Disaster Management,
- **Other sources**: Recovery and reconstruction projects supported by multi-lateral funding institutions (such as Post Disaster Need Assessment Report for Kerala, etc.), Insurance Department, Kerala Govt.; reconnaissance reports, etc.

.

The project team is systematically listing all available data and respective data sources. The project team is following up with the concerned stakeholders to collect data. The team is keeping the RKI updated about data collected and (any) pending data and additional support, if required.

2.1.1 Literature Review

2.1.1.1 *Flood and Landslide*

RMSI team has reviewed some of the research publication/Reports on floods and landslides available in the public domain and their reference along with brief details is summarized in Table 2-1. The other hazards literature review is detailed in subsequent sections.

Table 2-1: Literature review for Flood and Landslide

S. No.	Peril	Title	Details
1.	Landslide	History of landslide susceptibility and a chorology of landslide-prone areas in the Western Ghats of Kerala, India Author: Sekhar L. Kuriakose, G. Sankar, C. Muraleedharan Year: 2009 Year of Occurrence: 1984 to 2008	• This study surveyed 29 major landslide events in Kerala occurred from 1984 to 2008 and suggested that the initiation zone of most of the landslides was typical hollows generally having degraded natural vegetation. • Except coastal district of Alappuzha, majority districts

S. No.	Peril	Title	Details
			in Kerala are prone to landslides. • Wayanad and Kozhikode districts are prone to deep seated landslides, while Idukki and Kottayam are prone to shallow landslides.
2.	Flood and Landslide	Landslides and Flood Losses – 2012 Author: Department of Disaster Management, Government of Kerala Year: 2012 Year of Occurrence: 2012	• Landslides were reported from six districts namely Kannur, Kozhikode, Palakkad, Ernakulam, Idukki and Kottayam. • Due to heavy rainfall, Pazahsshi dam in Iritty town overflew aggravating the disastrous situation and led to 16 causalities. • Landslides caused severe damages to 541 Ha of perennial crops
3.	Flood, Landslide and Wind	Monsoon Calamity Losses – 2013 Author: Department of Disaster Management, Government of Kerala Year: 2013 Year of Occurrence: 2013	• Landslides were reported from Kozhikode, Palakkad, Idukki and Pathanamthitta districts of Kerala due the unexpected exceed of South West Monsoon between June 1-30, 2013 • Floods, windfall and landslides have caused severe damages to the crops.
4.	Landslide	Monsoon Calamity Losses - 2014 Author: Department of Disaster Management, Government of Kerala Year: 2014 Year of Occurrence: 2014	• Intense pre-monsoon rainfall in the month of April, 2014, especially along the southern districts of Kerala (Thiruvananthapuram to Ernakulam) led to some isolated cases of landslides.
5.	Flood and Landslide	Kerala Floods – 2018 Author: Department of Disaster Management, Government of Kerala Year: 2018 Year of Occurrence: 2018	• 96% excess rainfall than the average long period rainfall from South west monsoon caused significant damage to life and property. • Kerala State Disaster Management Plan (SDMP) identified 14.4% of the State as landslide prone and Land

S. No.	Peril	Title	Details
			Revenue Department reported 331 landslides, rock slides and landslips were reported in all districts in Kerala, of which Idukki district was the most badly affected.
6.	Flood and Landslide	Kerala Floods – 2019 Author: Department of Disaster Management, Government of Kerala Year: 2019 Year of Occurrence: 2019	• Between August 8 and 31, 2019, Kerala experienced flood and landslides due to the influence of low-pressure area and depression formed over the Bay of Bengal and strengthening of Monsoon winds, Kerala. • Kerala received 123% excess rainfall than the average long period rainfall in August. • 13 out of 14 districts in Kerala were notified as affected by floods & landslides and have caused exorbitant damage to the agriculture sector.
7.	Landslide	Land Degradation in the Western Ghats: The Case of the Kavalappara Landslide in Kerala, India Author: Nirmala Vasudevan, et. Al. Year: 2022 Year of Occurrence: 2019	• Kavalappara landslide occurred in 2019 resulted in the loss of 59 lives and considerable damage to property. • This study suggested that the human activities aggravated the slope instability such as, conversion of natural vegetation to plantations, step cutting of slopes, construction of soak pits, construction of homes on natural drainage channels, and improper methods of drainage.
8..	Landslide	Preliminary analysis of a catastrophic landslide event on 6 August 2020 at Pettimudi, Kerala State, India Author: Achu, A.L., et al Year: 2021 Year of Occurrence: 2020	• Pettimudi landslide was one of the disastrous landslides occurred in the Pettimudi village of Idukki district, Kerala and this study suggested that it was initiated on the steep slopes of Shola Forest and was slid through the tea plantations and approx. 70,125 m^2 area was

S. No.	Peril	Title	Details
			estimated to be affected by the landslide.
9.	Landslide	The tale of three landslides in the Western Ghats, India: lessons to be learnt. Author: R. S. Ajin, et. al. Year: 2022 Year of Occurrence: 2021	• This study observed three landslides occurred on 16th October 2021: Kokkayar landslide, Plappally landslide, and Kavali landslide. • Study suggested that Kokkayar landslide was completely caused by humans; Plappally landslide was affected by geomorphic and tectonic causes, and Kavali landslide was caused by forest fragmentation.
10.	Landslide	Impact of anthropogenic activities on landslide occurrences in southwest India: An investigation using spatial models Author: Jones, S., Kasthurba, A.K., et. al. Year: 2021	• This study suggests that the Landslide hotspots are concentrated in Idukki, Ernakulum, Kottayam, Wayanad, Kozhikode and Malappuram districts of Kerala. • Nearly 59.38% of total landslides in Kerala have occurred in the plantation areas and about 64.76% of the state's total landslides have happened in the human-modified land-uses.
11.	Landslide	Evaluating the relation between land use changes and the 2018 landslide disaster in Kerala, India Author: Lina Hao, et. al. Year: 2022	• LULC classes from 8 years (from 2010 to 2018) were correlated at the landslide initiation points. Highest landslide density found in the built-up areas within Idukki district and were related to cut slope failures.

As an example, a brief list of landslide inventory along with fatality details are given in Annexure 1(section 7.3). These will be detailed in the deliverable-2: A geo-referenced catalogue of historical major events.

2.1.1.1.1 Extreme Rainfall and associated floods and landslides (2012)[1]

Floods and Landslides were reported from six districts namely Kannur, Kozhikode, Palakkad, Ernakulam, Idukki and Kottayam. Flood situation prevailed in Iritty town in Kannur district as the region has experienced very heavy rainfall. As a consequence, Pazahsshi dam in Iritty town overflowed and aggravated the disastrous situation. Figure 2-1 shows the photographs depicting damages due to landslides and floods in Kerala, 2012.

- **Kannur**: Two landslides were reported from Karikottakiri and Murikkan Kara in Ayyankunnu Village, Thalasherry Taluk on 6 and 7 August. On the days, the region experienced a >100-year return interval rainfall which resulted in the flooding of Iritty township and the overflowing of Pazahsshi dam. One fatality was reported. On 26 August a landslide was reported from Thirumeni village, Thalasherry Taluk which damaged the arterial road of the village.
- **Kozhikode**: Over 35 minor and major debris flows were reported from Pulloorampara Anakkampoyil region on 6 August 2012. Acres of crop land perished and 8 fatalities were reported.
- **Palakkad**: A debris flow occurred at 100 acres, Ambalappara, Kottappadam Panchayath with in the Silent Valley National Park Buffer Zone. The event was reported on 22 August as the region is only accessible by foot and is an abode of forest dwelling tribal communities. The actual date of occurrence is unknown. The hill which was affected is the origin of Vaniyampara River and it houses numerous medicinal plants thus resulting in loss to biodiversity.
- **Ernakulam:** A major debris flow occurred in Kadavoor village of Kothamangalam Taluk on 17 August 2012. Six fatalities were reported, in addition to significant loss to property.
- Estimated loss as per CRF Norms: Rs. 2656.54 lakhs (Rs. 26.57 crores)

Figure 2-1: Various photographs depicting damages due to landslides and floods in Kerala, 2012

[1] https://sdma.kerala.gov.in/wp-content/uploads/2018/11/9.Memorandum-Landslides-2012.pdf

2.1.1.1.2 Kerala Floods & Landslides (2018)[2]

The heavy monsoon of 2018 in particular brought widespread flooding to several districts of Kerala state and triggered a large number of small to big landslides. The extreme and prolonged rainfall spell in August 2018 led to the worst flooding in Kerala in nearly a century impacting almost 5.4 million people - one-sixth of the State's population. Several districts were inundated for more than two weeks due to heavy rains induced floods. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the State, adding to the impact of floods. Nearly 341 major landslides were reported from 10 districts. Idukki district was ravaged by 143 landslides. 1,260 out of 1,664 villages spread across its 14 districts were affected. Seven districts were worst hit: Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitta, Thrissur and Wayanad where the whole district was notified as flood affected. Figure 2-2 represents spatial distribution of landslide/ mudslides occurred in 2018.

2.1.1.1.3 Kerala Floods & Landslides - 2019[3]

Year 2019 marked as yet another year when Kerala received significantly heavy rainfall all across the state. It resulted in a large number of landslide and mudslide incidences of varying intensity. Figure 2-3 Shows villages affected by floods and landslides in Kerala, 2019.

2.1.1.1.4 Extreme rain induced hazards in Kerala (2021)[4]

In October 2021, once again the state of Kerala was hit by torrential rain causing flooding and triggered a series of landslides. Extreme rainfall events in Kerala from 11th to 26th October 2021 resulted in Kerala state received widespread heavy rainfall. The cyclonic circulation in the North Andaman Sea and the neighborhood strengthened the monsoon westerlies and has caused widespread very heavy rainfall over the Kerala state. Figure 2-4 to Figure 2-7 shows photos taken from some of the locations affected by landslides in 2021.

---

[2] https://sdma.kerala.gov.in/wp-content/uploads/2019/08/Memorandum2-Floods-2018.pdf
[3] https://sdma.kerala.gov.in/wp-content/uploads/2020/03/Memorandum-pages-deleted-Copy-compressed.pdf
[4] https://sdma.kerala.gov.in/wp-content/uploads/2022/05/Event-report_October-2021.pdf

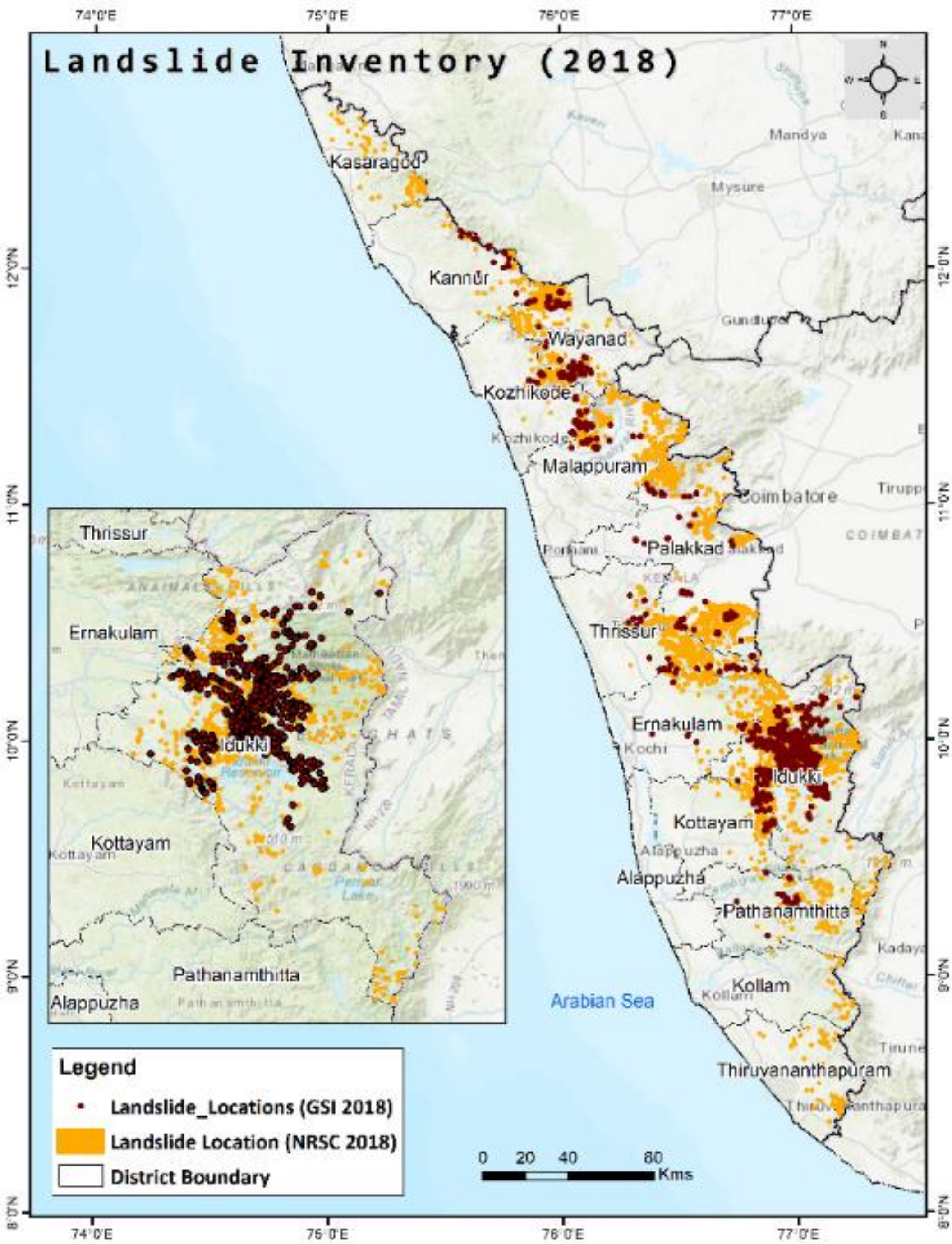

Figure 2-2: Spatial distribution of landslide locations in Kerala, 2018

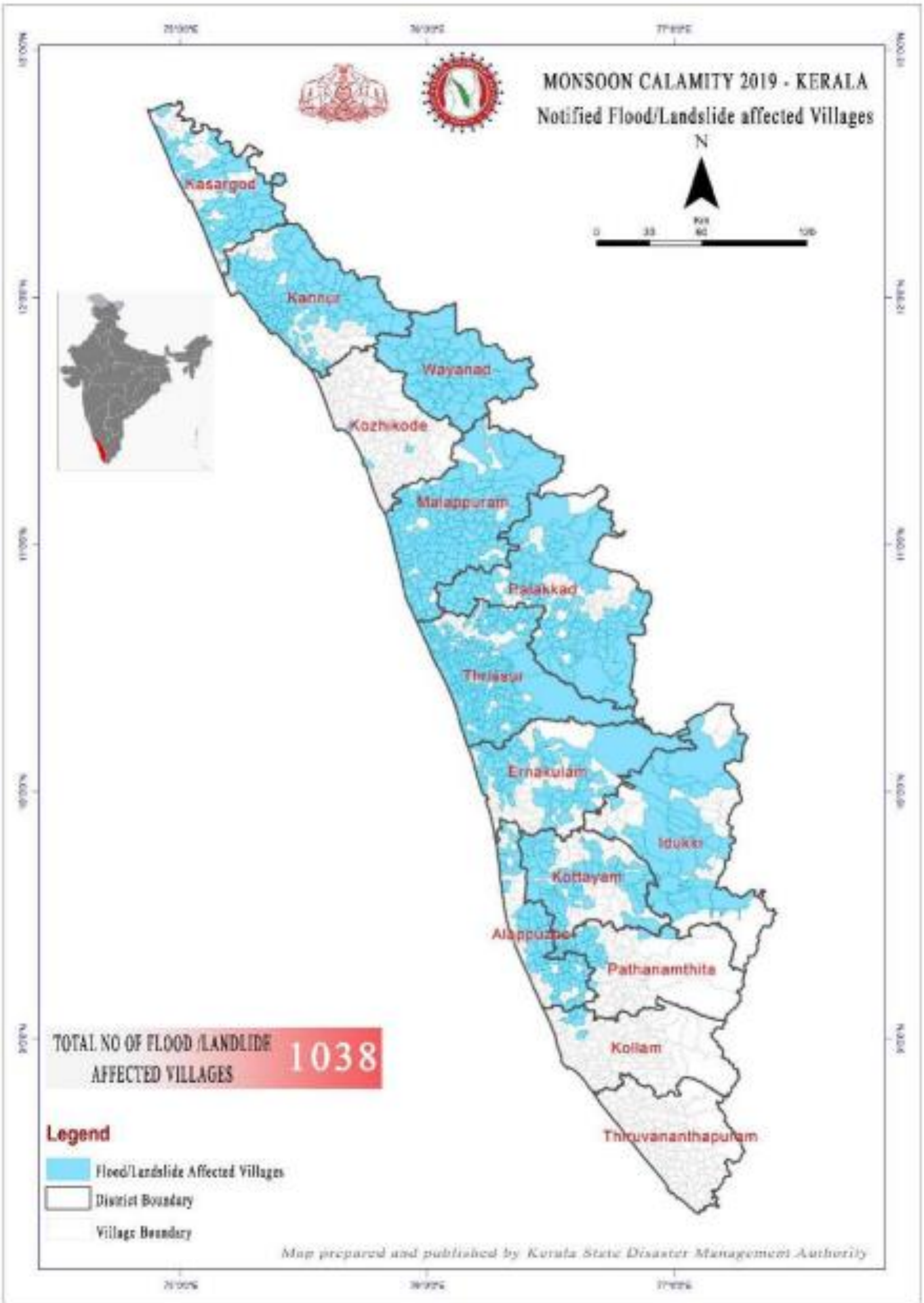

Figure 2-3: Villages affected by floods and landslides in Kerala-2019

Figure 2-4: Arial view of the Kootickal landslide location

Figure 2-5: Landslide location at Kokkayar were rescue operations are carried out

Figure 2-6: Photograph showing a destroyed house at Kootickal

Figure 2-7: Rescue operations carried out at the landslide location near Mackochi in Kokkayar village

In addition to the above, RMSI team reviewed the publications mentioned in the KSDMA website as shown in Figure 2-8.

Figure 2-8: Snapshot of KSDMA web page listed publications and reports

RMSI has also downloaded below mentioned Probabilistic flood hazard data for Kerala, from KSDMA web site:

1. Flood Hazard Probability of Kerala based on Historic Data -Flood Return Probability 5(10, 25, 50,100, 200, 500 years) - (Raster File Zip).
2. Flood Hazard Probability of Kerala based on RCP8.5 Climate Change Scenario Flood Return Probability (10, 25, 50,100, 200, 500 years) - (Raster File Zip).

These return period data sets were developed based on hydrological simulation of historic and climate change scenario (RCP – 8.5) coupled with other meteorological inputs, CIMA[6] research foundation and ACROTEC (CIMA Technology Foundation), Italy modelled the flood return probability over different years (10, 25, 50, 100, 200 and 500).

2.1.1.2 Cyclone and Storm Surge

The west coast of India is comparatively less vulnerable to storm surges than the east coast of India in terms of both the height of storm surge as well as frequency of occurrence. However, so far Kerala state (located on the Arabian Sea coast) has experienced only three very severe cyclonic storms due to its geography and low latitude (Table 2-2). There are several instances when Bay of Bengal cyclones crossed the east coast of India, maintained their intensity over land, and gradually weakened before emerging into the Arabian Sea off Kerala coast. Hence, there are a very few events that impacted the State from Arabian sea.

Table 7-2 of Annexure 7.2 shows the list of historical cyclonic disturbances that affected Kerala along with their damage details.

According to the KSDMA report titled "*An Integrated Approach to the Preparedness and Mitigation of Cyclone Tauktae: The Case of Kerala*[7]", Kerala has been hit mainly by 5 cyclones over the last 127 years. Recently, there were two cyclones, *Gaja* (16 November, 2018) and *Ockhi* (28 November- 7 December, 2017), earlier in 1912 (19-22 November 1912, 17-19 December 1912) and one cyclone in 1925 (06-10 November). The cyclone, which occurred in 1925 (November 06-10), passed through north Kerala on November 10. The cyclone that occurred in November 1912 passed through the southern coasts of Kerala and Tamil Nadu. Ockhi was the fourth cyclone to form in the Comorin Sea (South of Kerala and Tamil Nadu, and west of Sri Lanka). It was after 92 long years that a cyclone passed through the Kerala coast. But Ockhi (2017) did not cross the Kerala-Tamil Nadu coast.

On November 8, 2018, low pressure system formed between Thailand's sea and the Malay Peninsula, entered the Andaman coast in the Bay of Bengal and became the Gaja cyclone. Gaja travelled along the longest track in recent times, crossed the Indian Peninsula for the first time and entered the Arabian Sea at extreme low pressure over Kerala in the afternoon of November 16. Since 1990, when the India Meteorological Department (IMD) started monitoring cyclones accurately, this was the first cyclone that formed in the Bay of Bengal and reached the Arabian Sea through Kerala.

2.1.1.2.1 Severe cyclonic storm of November 1977

This storm reportedly caused extensive damage in Kerala and Lakshadweep. About 72 people died and 8,400 houses got damaged. Tidal waves were reported to have damaged 620 Fishing vessels in coastal areas of Kerala state. Total loss

[5] KSDMA(https://sdma.kerala.gov.in/hazard-maps/) - (Reference: UNEP, UN GRID, CIMA Italy, KSDMA, 2020; Flood Return Probability Assessment of Kerala)

[6] CIMA Research Foundation - Department of Hydrology and Hydraulics CIMA Research Foundation is a non-profit research organization committed to promote the study, scientific research, technological development.

[7] https://sdma.kerala.gov.in/wp-content/uploads/2021/10/Cyclone-Tauktae_Case-Study_09-Oct-2021_2300-1.pdf

was estimated to be about 10 crores (SMRC, 1998)[8].

2.1.1.2.2 Severe cyclonic storm of November 1992

This cyclone crossed the Kerala and Karnataka coast near Honavar town causing extensive damage to the property in the coastal districts of Tamil Nadu and Kerala. Heavy rains caused flash floods and landslides resulting in considerable damage to the standing crops and houses in Karnataka, Kerala, and Tamil Nadu. According to the press reports about 175 persons lost their lives and 160 people reported missing in Tamil Nadu and Kerala[9,10].

2.1.1.2.3 Cyclone Ockhi - 30 November, 2017

On 30 November, 2017, the Cyclone Ockhi passed by about 70 km away from Kerala coast. Kerala in the last 100 years had not experienced a major Cyclonic Storm impact of this magnitude[11]. As per a report from KSDMA, Kerala state witnessed loss of lives of 51 persons, 234 injured, and 9,134 affected. About 3,744 houses were damaged by cyclone Ockhi in Kerala12. A few damage photographs from cyclone Ockhi in Kerala are presented in Figure 2-9 to Figure 2-11[13].

Table 2-2: Number of historical cyclone events considered for Kerala (1891-2023)

Category	No. of Cyclonic Disturbances
Depression	3
Deep Depression	3
Cyclonic Storm	8
Severe Cyclonic Storm	3
Very Severe Cyclonic Storm	15
Extremely Severe Cyclonic Storm	4
Super Cyclonic Storm	-

[8] SMRC (1998). The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SMRC-No.1, SAARC Meteorological Research Centre, Dhaka, Bangladesh, October 1998, 329 pp.
[9] IMD Report on cyclonic disturbances over North Indian Ocean in 1992- RSMC Tropical Cyclones (1993)
[10] SMRC (1998). The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SMRC-No.1, SAARC Meteorological Research Centre, Dhaka, Bangladesh, October 1998, 329 pp.
[11] Govt. of Kerala, 2017. Memorandum – Cyclone Ockhi. 30th November 2017 to 17th January 2018. Department of Disaster Management, Govt. of Kerala. Submitted on: 17-01-2018
[12] Memorandum-Ockhi-2017 by Additional Chief Secretary, Disaster Management, Govt. of Kerala (KSDMA).
[13] IMD Report: 2018, Very Severe Cyclonic Storm, 'OCKHI' over the Bay of Bengal (29 Nov - 05 Dec 2017)

Figure 2-9: A car struck in mud at Pampa, Triveni (Source: The New Indian Express 01st Dec 2017)- IMD Report (2018)

Figure 2-10: A tree fell over auto rickshaw at Sreekanteshwaram in Thiruvananthapuram[14]

Figure 2-11: Tree falls observed in Thiruvananthapuram, (Source: United News of India, Thiruvananthapuram dated 30th Nov; IMD Report (2018)

2.1.1.2.4 Extremely Severe Cyclonic Storm Tauktae 14th -19th May, 2021

Extremely Severe Cyclonic Storm Tauktae (14th -19th May, 2021) generated squally winds[15] of 50-60 kmph with gusts up to 70 kmph along and off the Kerala coast on May 15th. A total of 1,532 houses were damaged in Kerala. Figure 2-12 and Figure 2-13 depict the damage Photographs caused by the Extremely Severe Cyclonic Storm Tauktae in Kerala. Besides the above, Kerala witnessed several storms Table 2-2 ranging from tropical depressions (31-61 km/h) to very severe cyclonic storms (88-118 km/h).

14 Source:http://english.mathrubhumi.com/news/kerala/cyclone-ockhi-closes-in-on-kerala-coast-1.2424815)-IMD Report (2018)
15 IMD Report: 2021, Extremely Severe Cyclonic Storm TAUKTAE over the Arabian Sea (14th -19th May, 2021)

Figure 2-12: Indian Navy in the coastal village of Chellanam in Ernakulam district, Kerala (left) which was heavily hit by tidal waves; House Collapses into the Sea in Kasargod, Kerala due to the effect of Cyclone Tauktae (right) (Source: IMD Report, 2021)

Figure 2-13: House damaged in Malappuram district due to Cyclone Tauktae (Source: District Emergency Operations Centre, Malappuram) (left); House damaged in Palakkad district due to Cyclone Tauktae (Source: District Emergency Operations Centre, Palakkad) (right) (Source: KSDMA)

2.1.1.3 Drought

Studying long-term changes and associated extreme hydrological events over a smaller region like Kerala, a Southern Peninsular Indian state, is challenging due to the large heterogeneity in the complex terrain bounded by the Arabian Sea on the west and the Western Ghats Mountains on the east. Across the small average width of 100 km in the zonal direction over the complex terrain of Kerala, there exists significant heterogeneity in the land surface and land use characteristics.

Based on altitude, the terrain is mainly divided into three categories: lowland, midland, and highland. The unique annual and seasonal distribution of rainfall across Kerala and along the Western Ghats region, in particular, is mainly accountable for the exceptional repository of a variety of flora and fauna. The terrain height varies from a few meters in the west to a few kilometers in the east, with rugged topography having narrow and steep slopes.

Kerala has endured 66 drought years between 1881 and 2000, exacerbating water scarcity issues in both urban and rural regions due to dry rivers and declining water tables. The State has witnessed one of the most distressing droughts in the year 2016, which imposed a severe threat to both agriculture and hydrology. It is also realized that the frequency of drought years is increasing over Kerala during recent decades. Each deficit rainfall year is unique in the sense that its impact on agriculture, hydrology, and the socio-economic sector may vary. Though the southwest monsoon during 2015 was bad for Kerala, the annual water stress and severity of drought during 2015 didn't scale up to the level as that of the year 2016.[16].

It is reported that rainfall over Kerala for the period 1901–1980 is decreased by 10–20% during the second half of the time period[17]. Studies have also reported weakening trend in land-sea thermal gradient due to rapid Ocean warming in contrast to slower land warming and resulting drying of Indian subcontinent[18]. The strongest rainfall decreases are observed in July, along the southwest coast of India. In this region (the Western Ghats run parallel to a narrow coast, with an average elevation of 700 m), the reduction of precipitation is likely due to the weakening of vertical velocities caused by upper tropospheric warming[19]. The reduction in rainfall over extreme southern peninsular Indian region is caused due to the poleward shift in monsoon Low level jet (LLJ) in response to widening of tropical belt under global warming20. Consistent with this, prominent upper-level circulation feature during monsoon season known as Tropical Easterly Jet (TEJ) is also weakening due to the warming of middle to upper troposphere over equatorial Indian ocean region21,22. Any changes in the pattern of rainfall can have significant impact on the availability of water resources, agriculture and eco system. Year 2023 Kerala experienced more deficient in rainfall as compared with the year 2016 as shown in Table 2-3.

16 Changing Characteristics of Droughts over Kerala, India: Inter-Annual Variability and Trend Abhilash S.1,2 & E. K. Krishnakumar & P. Vijaykumar & A. K. Sahai & B. Chakrapani & Girish Gopinath.
17 Soman, M.K., Krishnakumar, K., Singh, N.: Decreasing trend in the rainfall of Kerala. Curr. Sci. 57(1), (1988)
18 Roxy, M., Ritika, K., Terray, P., Murtugudde, R., Ashok, K., Goswami, B.N.: Drying of Indian subcontinent by rapid Indian Ocean warming and a weakening land-sea thermal gradient. Nat. Commun. 6, (2015).
19 Rajendran, K., Kitoh, A., Srinivasan, J., Mizuta, R., Krishnan, R.: Monsoon circulation interaction with Western Ghats orography under changing climate. Theor. Appl. Climatol. 110(4), 555–571 (2012).
20 Sandeep, S., Ajayamohan, R.: Poleward shift in Indian summer monsoon low level jetstream under global warming. Clim. Dyn. 45, 337–351 (2014).
21 Sathyamoorthy, V.: Large scale reduction in the size of the tropical easterly jet. Geophys. Res. Lett. 32(14), (2005).
22 Abish, B., Joseph, P.V., Johannessen, O.M.: Weakening trend of the tropical easterly jet stream of the boreal summer monsoon season 1950– 2009. J. Clim. 26(23), 9408–9414 (2013).

Table 2-3:Comparison of rainfall deficit year in Kerala

Rainfall in Kerala 2016 Vs 2023		
Rain short fall (%)		
Month	**2016**	**2023**
June	8	67.5
July	39	2.75
August	45	85.75
Rainfall (mm)		
June-July-August	1268.6 mm (Deficit - 466.80)	909.5 mm (Deficit - 825.5)

2.2 Damage and loss from historical disasters

Historical disasters in Kerala have inflicted significant damage and loss, impacting lives, infrastructure, and the economy. Natural calamities, such as Floods, landslides, cyclones and storm surges, and drought have left enduring scars on the state's landscape and its people. The devastating floods of 2018 and 2019, triggered by unprecedented rainfall, submerged vast swathes of land, destroyed homes, disrupted transportation networks, and claimed numerous lives. Landslides, often triggered by heavy rains and deforestation, have also resulted in casualties and property damage, particularly in hilly regions.

The state faces significant vulnerability to disasters, with floods being the most prevalent natural hazard. Approximately 14.5% of the state's land area is susceptible to flooding, with some districts facing an alarming 50% risk. Along the Western Ghats in Wayanad, Kozhikode, Idukki, and Kottayam districts, landslides pose a substantial threat. Additionally, seasonal drought-like conditions occur frequently during the summer months. Kerala has endured 66 drought years between 1881 and 2000, exacerbating water scarcity issues in both urban and rural regions due to dry rivers and declining water tables[23].

Between June 1 and August 18, 2018, Kerala faced its most devastating floods since 1924. Throughout this period, the state encountered a cumulative rainfall that exceeded the normal average by 42%. The most intense rainfall occurred from August 1 to August 20, totaling 771 mm. These torrential downpours triggered numerous landslides and necessitated the release of excess water from 37 dams across the state, exacerbating the flooding. Approximately 341 landslides were documented across 10 districts, with Idukki bearing the brunt of the devastation, experiencing 143 landslides[6]. As per the latest reports from the state government, a staggering 1,259 out of 1,664 villages spanning across its 14 districts bore the brunt of the disaster[24]. The severity of the devastation was most acute in seven districts: Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitta, Thrissur, and Wayanad, where the entire district was designated as flood-affected. The catastrophic floods and landslides inflicted suffering on 5.4 million individuals, displacing 1.4 million people, and tragically claiming the lives of 433 individuals.

A few major natural hazards, such as floods and landslides, occurred in Kerala state in 2018 and 2019, resulting in extensive damage. District-wise losses for these events have been compiled in Table 2-4 from KSDMA memorandums. According to KSDMA memorandums[25], the floods in June, July, and August of 2018 caused consolidated losses amounting to 3,834 crore INR across all sectors. Additionally, the floods and landslides in 2019 resulted in losses totaling 2,574 crore INR. Similar exercise is being carried out for all other major events and an event wise consolidated database will be presented in Deliverable -2.

23 Kerala Post Disaster Needs Assessment, Floods and Landslides - August 2018

24 Government order No. (P)No.05/2018/DMD dated Thiruvananthapuram, 29.09.2018

25 https://sdma.kerala.gov.in/disaster-memoranda/

Table 2-4: Major event loss table compiled from KSDMA[26]

Event Name	Disaster Type	District	No. of Houses damaged	Infrastructure damaged (Roads)	Total Economic loss (INR Crores)	Reconstruction Costs (INR Crores)	Insured Damage (INR Crores)	Total Damage (INR Crores)	Consolidated Total Damage (INR Crores)
2018_Aug_Kerala Floods	Flood	Thiruvananthapuram	3,051	475.00	42.93	38.65	2.15	83.73	3,290
2018_Aug_Kerala Floods	Flood	Kollam	1,433	340.00	27.34	23.53	1.40	52.27	
2018_Aug_Kerala Floods	Flood	Pathanamthitta	33,516	550.00	446.86	349.15	10.09	806.10	
2018_Aug_Kerala Floods	Flood	Alappuzha	21,065	241.00	310.36	218.35	18.94	547.65	
2018_Aug_Kerala Floods	Flood	Kottayam	732	291.00	59.44	16.89	11.53	87.86	
2018_Aug_Kerala Floods	Flood	Idukki	2,299	2,105.00	112.89	49.41	11.89	174.19	
2018_Aug_Kerala Floods	Flood	Ernakulam	2,611	2,130.00	259.79	92.64	4.28	356.71	
2018_Aug_Kerala Floods	Flood	Thrissur	21,130	598.00	344.30	233.47	11.35	589.12	
2018_Aug_Kerala Floods	Flood	Palakkad	4,722	164.00	83.39	63.56	13.00	159.95	
2018_Aug_Kerala Floods	Flood	Malappuram	4,231	1,231.00	80.82	68.75	7.93	157.49	
2018_Aug_Kerala Floods	Flood	Kozhikode	1,445	332.00	39.90	23.23	1.34	64.47	
2018_Aug_Kerala Floods	Flood	Wayanad	9,952	565.00	57.24	31.64	3.00	91.87	
2018_Aug_Kerala Floods	Flood	Kannur	3,337	100.00	61.72	40.12	1.54	103.39	
2018_Aug_Kerala Floods	Flood	kasargod	77	416.45	7.36	7.02	0.34	14.72	

[26] https://sdma.kerala.gov.in/disaster-memoranda/

Event Name	Disaster Type	District	No. of Houses damaged	Infrastructure damaged (Roads)	Total Economic loss (INR Crores)	Reconstruction Costs (INR Crores)	Insured Damage (INR Crores)	Total Damage (INR Crores)	Consolidated Total Damage (INR Crores)
2018_June&July_Kerala Floods	Floods and Landslides	Thiruvananthapuram	1,319	202.00				42.90	544.54
2018_June&July_Kerala Floods	Floods and Landslides	Kollam	788	354.57				28.99	
2018_June&July_Kerala Floods	Floods and Landslides	Pathanamthitta	1,544	844.65				41.54	
2018_June&July_Kerala Floods	Floods and Landslides	Kottayam	781	no data				72.60	
2018_June&July_Kerala Floods	Floods and Landslides	Alappuzha	619	380.63				84.94	
2018_June&July_Kerala Floods	Floods and Landslides	Idukki	855	933.57				28.45	
2018_June&July_Kerala Floods	Floods and Landslides	Ernakulam	531	527.56				42.23	
2018_June&July_Kerala Floods	Floods and Landslides	Thrissur	338	557.87				32.70	
2018_June&July_Kerala Floods	Floods and Landslides	Palakkad	527	1,163.42				59.21	
2018_June&July_Kerala Floods	Floods and Landslides	Malappuram	602	760.00				12.58	
2018_June&July_Kerala Floods	Floods and Landslides	Kozhikode	2,518	666.30				27.88	
2018_June&July_Kerala Floods	Floods and Landslides	Wayanad	430	436.44				7.74	

Event Name	Disaster Type	District	No. of Houses damaged	Infrastructure damaged (Roads)	Total Economic loss (INR Crores)	Reconstruction Costs (INR Crores)	Insured Damage (INR Crores)	Total Damage (INR Crores)	Consolidated Total Damage (INR Crores)
2018_June&July_Kerala Floods	Floods and Landslides	Kannur	965	581.95				48.88	
2018_June&July_Kerala Floods	Floods and Landslides	Kasargode	285	46.70				13.90	
2019_Aug_Flood&Landslide	Flood and Landslide	Kollam	484	108.88	12.13	11.19	0.38	23.69	2,574.35
2019_Aug_Flood&Landslide	Flood and Landslide	Pathanamthitta	3,929	110.32	27.16	15.43	0.55	43.13	
2019_Aug_Flood&Landslide	Flood and Landslide	Alappuzha	15,758	56.75	90.54	81.34	5.28	177.16	
2019_Aug_Flood&Landslide	Flood and Landslide	Kottayam	26,496	323.02	94.86	79.45	4.00	178.30	
2019_Aug_Flood&Landslide	Flood and Landslide	Idukki	245	489.74	26.59	18.15	1.66	46.40	
2019_Aug_Flood&Landslide	Flood and Landslide	Ernakulam	14,064	320.53	77.81	57.61	1.84	137.26	
2019_Aug_Flood&Landslide	Flood and Landslide	Thrissur	23,144	458.96	222.22	98.01	4.58	324.80	
2019_Aug_Flood&Landslide	Flood and Landslide	Palakkad	7,179	379.48	89.71	66.86	15.11	171.68	
2019_Aug_Flood&Landslide	Flood and Landslide	Malappuram	48,012	414.76	293.93	214.43	4.03	512.39	
2019_Aug_Flood&Landslide	Flood and Landslide	Kozhikode	47,534	202.50	219.64	179.97	0.84	400.45	

Event Name	Disaster Type	District	No. of Houses damaged	Infrastructure damaged (Roads)	Total Economic loss (INR Crores)	Reconstruction Costs (INR Crores)	Insured Damage (INR Crores)	Total Damage (INR Crores)	Consolidated Total Damage (INR Crores)
2019_Aug_Flood&Landslide	Flood and Landslide	Wayanad	9,079	401.28	147.67	109.29	5.05	262.01	
2019_Aug_Flood&Landslide	Flood and Landslide	Kannur	15,185	132.03	139.19	98.71	2.46	240.36	
2019_Aug_Flood&Landslide	Flood and Landslide	Kasargod	5,146	226.21	29.43	26.67	0.62	56.71	

2.3 Develop consolidated database

2.3.1 DATA COMPILATION

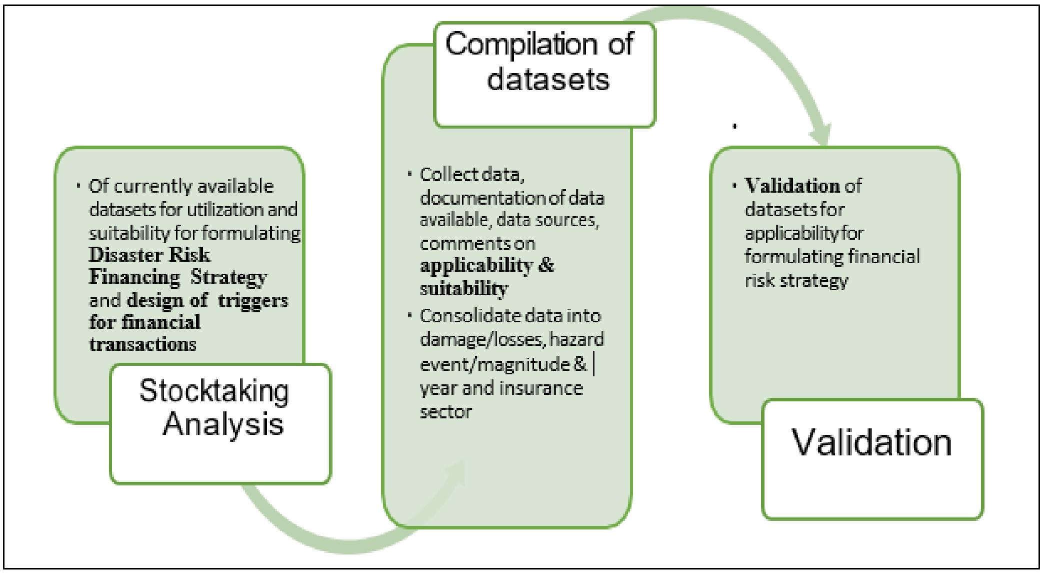

Figure 2-14: Review of damage and loss related data for risk financing

The collected datasets are being systematically documented and reviewed for their applicability in formulating disaster risk financing strategies and design of triggers for financial transactions. The team is also compiling loss data as part of database development.

The collected historical damage and loss data (of major events associated with floods, landslides, tropical cyclones - including for wind and storm surge, and droughts) is being compiled into a consolidated database of economic and financial losses and broken down into the following major classes: Damage/ losses in housing sector and government buildings that form the contingent liability of the government.

- Damages/ losses by hazard event, its magnitude and year (wherever possible)
- Damages/ losses by economic sector (provided in current local currency and USD, adjusted for inflation and or currency exchange rate)
- Damages/ losses by insurance sector (line of business, insured/reinsured, domestic/international)

Data is being collected and collated for the past 30 years depending on availability, and losses will be adjusted for inflation and currency exchange rate to normalize them to 2023 values. This is part of Deliverable -2, which is in progress as a parallel Task.

Apart from the data available with the client, in the public domain, and in other reports, the team will also collect the database available with KSDMA and DDMAs for the key events.

The database will also include, for each historical event, at least the following information – unique ID, date, location, physical characteristics, damage and losses. The database will be used to calibrate and validate the probabilistic NatCAT risk models as part of Deliverable -3. The database will also include maps of historical hazards and historical losses for the state.

Following discussions with KSDMA, RMSI has adopted the EM-DAT data format for collecting historical hazard event data. EM-DAT is a globally recognized format for creating consolidated disaster databases and compiling hazard loss information. Details of the conversation with the client are provided in section 7.4 of Annexure-1.

This change of data format has been further discussed with RKI on March 01, 2024.

RMSI team is compiling this event-wise consolidated geo-catalogue of disaster events in Kerala, which will also be available in an MS-Excel file. This file offers users the flexibility to utilize various filters and pivot tables, enabling them to access event-specific information and district-wise loss data with ease. This event wise MS-Excel file will be shared along with Deliverable -2 Report.

This comprehensive approach empowers stakeholders to effectively manage and analyze disaster-related data, thereby facilitating informed decision-making and the development of robust risk mitigation strategies tailored to the unique challenges faced in Kerala.

2.3.2 DATA GAP ANALYSIS

RMSI team will evaluate the data gaps required for hazard risk assessment with respect to available data. The team will also fill these gaps through in-house data available with RMSI, open sources and research papers.

2.3.2.1 *Data required for flood hazard assessment*

KSDMA has return period flood maps for the 06 return periods (10,25,50, 100, 200, 500) in GIS format for entire Kerala state. Example of 10 return period map for flood depth has given in ***Figure 2-15***.

These return period flood data have been generated by the CIMA Research Foundation - Department of Hydrology and Hydraulics as a part of their comprehensive Probabilistic Flood Assessment Study (2020).

CIMA Research Foundation is a non-profit research organization committed to promote the study, scientific research, technological development.

RMSI team will utilize these probabilistic flood hazard return-period maps these maps to generate stochastic flood event set.

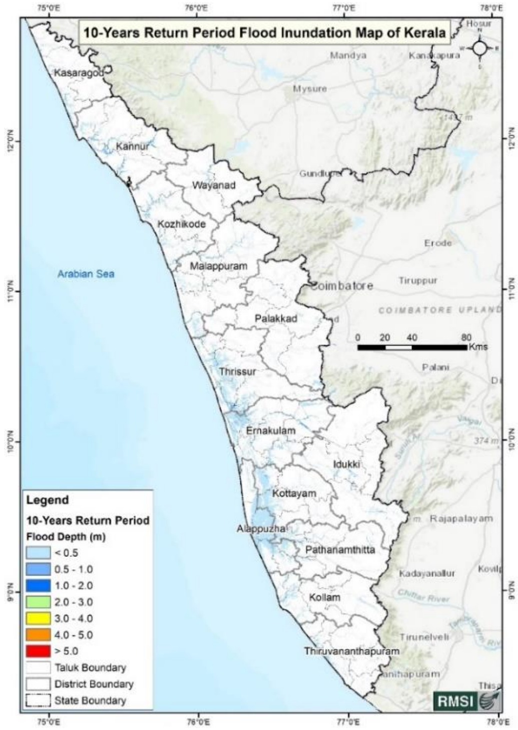

Figure 2-15: Example - 10 Return Period Map

2.3.2.2 *Data inputs for cyclonic wind modeling*

In order to achieve greater confidence in numerical cyclonic wind and surge estimates associated to cyclones, one requires good quality data as input parameters in the model. These parameters include oceanographic, hydrographic, meteorological (including the satellite derived storm characteristics), basin characteristics and coastal geometry, wind stress and seabed friction, and information on astronomical tides. These input parameters strongly influence wind and surge development along the coastal regions.

The intensity of a cyclonic disturbance is measured by the strength of the associated winds. Wind speeds associated to various categories of cyclonic disturbances provided by the India Meteorological Department (IMD) are given in Table 2-5.

Table 2-5: Classification of storms according to wind speeds (IMD[27])

S. No.	Type of disturbance	Associated maximum sustained wind
1.	Low Pressure Area (L)	Not exceeding 17 knots (<31 kmph)
2.	Depression (D)	17 to 27 knots (31-49 kmph)
3.	Deep Depression (DD)	28 to 33 Knots (50-61 kmph)
4.	Cyclonic Storm (CS)	34 to 47 Knots (62-88 kmph)
5.	Severe Cyclonic Storm (SCS)	48 to 63 Knots (89-117 kmph)
6.	Very Severe Cyclonic Storm (VSCS)	64 to 90 Knots (118-167 kmph)
7.	Extremely Severe Cyclonic Storm (ESCS)	91 to119 Knots (168-221 kmph)
8.	Super Cyclonic Storm (SuCS)	120 Knots and above (≥222 kmph)

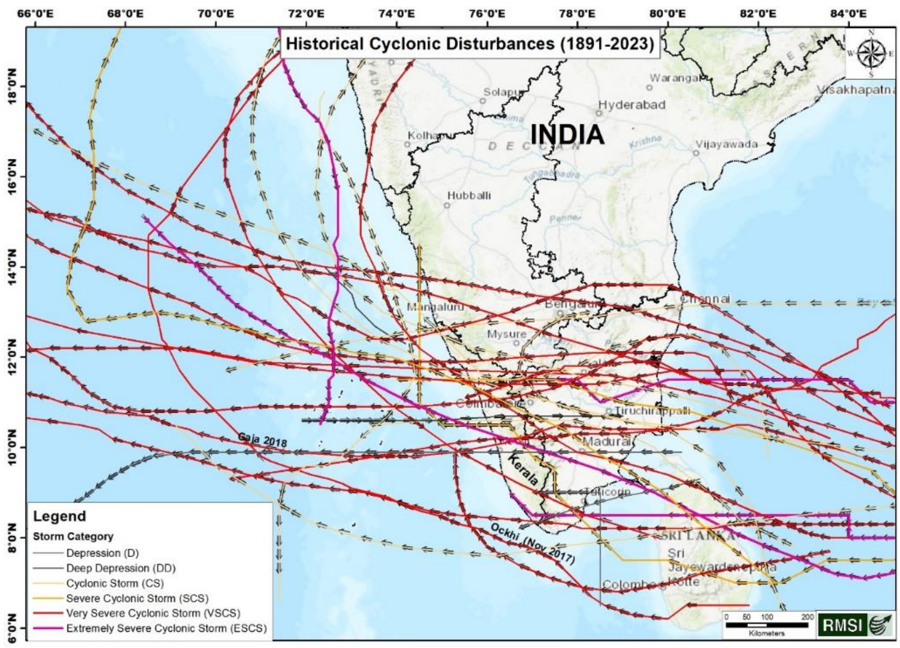

Figure 2-16: Tracks of cyclonic disturbances in and around Kerala (1891-2023)

The data available along with their sources for cyclonic wind hazard modeling are provided in Table 2-6. The basic data collected from different sources is integrated into a GIS database that provides the framework for further analysis. The tracks of cyclonic disturbances in and around Kerala State from 1891 to 2023 are depicted in Figure 2-16. The total number of storms with their categories that passed over Kerala coast considered for the study area are given in Table 2-6. The current study will also include on low pressure areas over Kerala.

[27] https://mausam.imd.gov.in/imd_latest/contents/pdf/cyclone_sop.pdf

Table 2-6: Cyclone data availability for cyclonic wind hazard modeling

S. No.	Thematic data	Data source	Data availability
1.	Storm Track Atlas	IMD	Cyclone track data for 1891-2007 is available in CD version (2008 ed.)
2.	Historical cyclone track data	IMD	Cyclone track data for 1982-2020 is available at IMD website (www.imd.gov.in)
3.	Historical cyclone track data	International Best Track Archive for Climate Stewardship[28](IBTrACS)	Cyclonic database is available on public domain at three hourly intervals from 1842-2023
4.	Historical cyclone track data	KSDMA	Cyclonic database is available at three hourly intervals from 1980-2020
5.	Historical cyclones, maximum wind, and loss information	SAARC Meteorological Research Center[29] (SMRC) report (1998), and published literature	IMD reports, SMRC report (1998), published literature and research publications, and KSDMA Disaster Memoranda[30]

Table 2-7: Data availability for storm surge hazard modeling

S. No.	Thematic data	Data source	Data availability
1.	Bathymetry- gridded/spot depths	National Hydrographic Office (NHO), Dehradun; General Bathymetric Chart of the Oceans (GEBCO)	High-resolution coastal bathymetry data (spot depths) is received from NHO and GEBCO gridded bathymetry (resolution 30 arc-second) – Open source
2.	Elevation/Topography	NRSA and SRTM 30 m	High-resolution DTM 10 m and SRTM 30 m data
3.	Tides	Le Provost tidal database	Open source – gridded 13 tidal constituents from Le Provost tidal database (Finite Element Solution FES95.2)
4.	Maximum sustained wind fields	IMD/ Storm model generated gridded wind fields	Validated storm model will be used to generate gridded winds
5.	Historical cyclones, Surge height, inundation extent, flood depth, and loss information	SAARC Meteorological Research Center[31] (SMRC) report (1998), and published literature	IMD reports, SMRC report (1998), published literature and research publications, and Disaster Memoranda[32]

[28] Knapp, K.R., M.C. Kruk, D.H. Levinson, H.J. Diamond, and C.J. Neumann (2010). The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, 91, 363-376. doi:10.1175/2009BAMS2755.1

[29]SMRC (1998). The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SMRC-No.1, SAARC Meteorological Research Centre, Dhaka, Bangladesh, October 1998, 329 pp.

[30] https://sdma.kerala.gov.in/disaster-memoranda/

[31]SMRC (1998). The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SMRC-No.1, SAARC Meteorological Research Centre, Dhaka, Bangladesh, October 1998, 329 pp.

[32] https://sdma.kerala.gov.in/disaster-memoranda/

2.3.2.3 Data inputs for storm surge Modeling

The input parameters for storm surge modelling include bathymetry, topography, basin characteristics and coastal geometry, wind stress, and astronomical tides. These input parameters strongly influence surge development and inland inundation along the coastal regions.

The data available, along with their sources, for storm surge hazard modeling are provided in Table 2-7. The basic data collected from different sources is integrated into a GIS database that provides the framework for further analysis.

2.3.2.4 Data inputs for Drought Modeling

Understanding drought in Kerala necessitates comprehensive data inputs across various domains. Meteorological data, including rainfall patterns, temperature trends, and humidity levels offer crucial insights into climatic conditions conducive to drought emergence (Table 2-8). Hydrological data, such as river discharge rates, groundwater levels, and reservoir capacities provide essential information on water availability and depletion trends during dry periods. Soil moisture content and vegetation health data help assess drought impact on agricultural productivity and ecosystem health. Historical drought records offer valuable context on past occurrences and their socioeconomic ramifications. Socioeconomic data, including population demographics, agricultural practices, and water usage patterns, contribute to understanding vulnerability and resilience to drought events. By amalgamating these diverse datasets, tailored drought monitoring and prediction models can be developed to mitigate the adverse effects of drought in Kerala.

2.3.2.5 Data inputs for Landslides Modeling

Effective landslide hazard modeling in Kerala demands a nuanced blend of data inputs. These include high-resolution digital elevation models (DEMs) to capture intricate topographic details. Geological and geotechnical data are essential for understanding soil composition, rock types, and structural stability. Meteorological data on rainfall patterns are crucial for assessing precipitation-triggered landslides. Historical landslide records offer valuable insights into past occurrences. Land cover and land use data shed light on vegetation and urbanization, affecting slope stability. Satellite imagery aids in monitoring and mapping landslide-prone areas. By integrating these diverse datasets, tailored landslide hazard models can be developed to address Kerala's unique geological and environmental dynamics.

Table 2-9 contains a list of relevant and useful data for effectively conducting landslide related study.

Table 2-8: Data required for drought hazard modelling

Input Data Requirements	Data type	Source	Remarks
Historical event data (at least for 30 years)	Daily time series rainfall, maximum temperature, minimum temperature, sunshine hour data for all available weather stations in Kerala	IMD/ KSDMA/ Hydrological and agriculture departments/ Published reports	

Input Data Requirements	Data type	Source	Remarks
Soil moisture content data		KSDMA/ Department of agriculture/ Published reports	In the event of unavailability of this data from the State, RMSI will be using USGS-NASA, Meteorological, and Oceanographic Satellite Data Archival Centre (MOSDAC) developed by SAC-ISRO.
Historical (at least for 30 years) all major crops' acreage and yield data.		KSDMA/Department of Agriculture/Statistics and Economics/Other stakeholders/Published reports	
Past drought hazard events/induced crop yield loss data /Insured loss and exposure data	Agriculture assets	KSDMA/Department of Agriculture/Other stakeholders/Published reports	Validation of modelled outputs

Table 2-9: Data required for landslide hazard modelling

Input Data Requirements	Data Type	Source	Remarks	Data Gap
Historical Landslide Inventory for last 25 to 30 years in GIS format		KSDMA/ District local bodies	Location Specific	
Geological maps		GSI	1:25K or better	Freely available geological data is available at 1:50 K from GSI
Soil data		Soil survey Dept./KSDMA	1:50K or better	Freely available soil data is available at 1:250 K from NBSS
LULC data in GIS format		KSDMA	1:10K or better	
High resolution DEM		KSDMA		Freely available DEM is available at 30 m
Daily historical rainfall data (gridded) at best available scale for at least 20 years		IMD	Daily for the past 20 - 30 years	Freely available rain data of IMD is available at 25 km and ERA5 at 9 km
Daily historical station observed rainfall data		IMD	Daily	

3

Development of Catastrophic Risk Profile

3 Development of Catastrophic Risk Profile

Project team has extensive experience in developing catastrophe risk model for the insurance /(re)insurance industries across the globe. The below section combines all the components – Stochastic event sets, hazard, exposure, vulnerability and loss (financial module) into a standard Catastrophic modeling framework as illustrated in Figure 3-1 below and explained.

Hazard Module: The main objective of this component is the development of a catalogue of simulated events representing potential future activity in the region that is statistically consistent with events occurred in the past. For every simulated event, the intensity of its effects (e.g., maximum flood depth for floods, peak gust wind speed for cyclones etc.) is computed in the area affected. The footprints of the effects of potential future events form an input to the vulnerability component for the computation of damage and losses.

Exposure Module: The exposure database comprises of housing sector, government buildings, road transport, agricultural assets etc at risk from natural catastrophes. Government buildings may consist of such as offices, schools and hospitals etc. Exposure may also include building contents along with its structural value. Characterization of assets based on their vulnerability to the effects of specific natural events is an important step in the exposure database preparation. Classification of assets, valuation (replacement cost) and aggregation by administrative units are also part of the process of exposure database development.

Vulnerability Module: The goal of the vulnerability component is to estimate the distribution of damage and losses caused to assets of different classes of vulnerability by different levels of hazard intensity caused by future events. Vulnerability is represented mathematically by relationships called vulnerability curves or damage functions, which are specific to each class of assets. The main parameter of these curves is the mean damage ratio (MDR), which is defined as the ratio of expected loss to the replacement cost of the asset for a given hazard intensity. Damage functions will be developed based on engineering principles, empirical loss and damage data, and or with expert elicitation.

Financial Module: Finally, loss is calculated for each asset damaged by any simulated future event. The expected loss suffered by an asset exposed to a given intensity level of the event is the product of exposure value by the MDR provided by the damage function for that asset. Different types of losses can be computed using a financial model (Economic / Insurance loss computation). If the asset is insured, both losses carried by the insurance company and retained by the insured can be computed by applying policy conditions. Direct ground-up economic losses caused by any future event can be computed by aggregating all the losses in a portfolio of assets affected by the event without consideration for who pays for them.

Figure 3-1: Catastrophe Modeling Framework, Source: RMSI

3.1 Hazard Assessment

The below mentioned hazard assessment methodologies will be employed for the respective hazards.

3.1.1 Flood Hazard Assessment[33]

RMSI's approach is based on available return period depths data developed by CIMA. Using flood depth data of the known return period, the frequency distribution (Gumbel e, Log Person Type III) applicable (fit) will be identified.

The return period is the inverse of the probability that an event will be exceeded in a given year. In general, return period, which is also referred as recurrence interval, provides an estimate of the likelihood of any event in one year. Return periods are used to convey the risks of events rate more effectively that simply stating the probabilities. In order to understand the concept better, it could be explained through a simplistic sketch as given below. The flood water height will change from place to place.

The identified frequency distribution will help to establish relationship between known return periods and the parameters for the identified frequency distribution such as Gumbel distribution (EV1) or Log Pearson Type III can be calculated. Using these parameters, the value for unknown return periods can be derived (Figure 3-3).

RMSI will utilize available 06 return period maps for calculating flood depth map for stochastic flood events.

The workflow for calculation of flood frequency parameters mean and standard deviation is given in Figure 3-4.

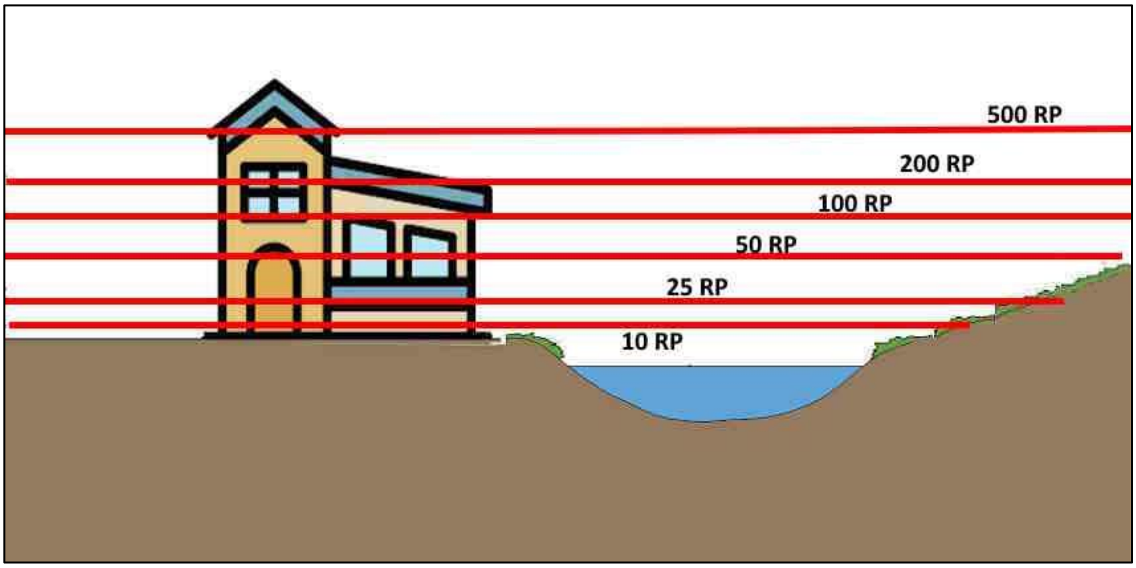

Figure 3-2: Flood depth heights for different return periods

[33]Source : https://d197for5662m48.cloudfront.net/documents/publicationstatus/112348/preprint_pdf/56cbbf96e785cdd9a00ddc2fe564a532.pdf

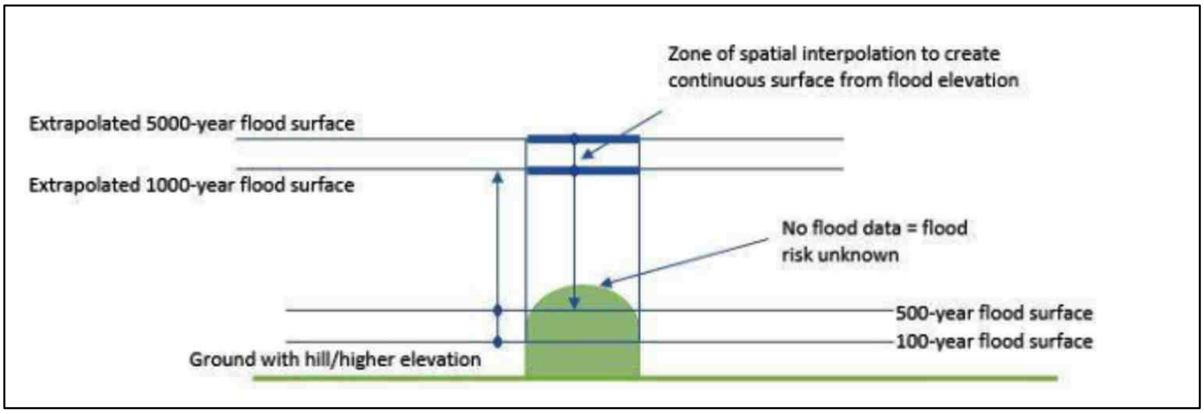

***Figure 3-3: Procedure to calculate unknown return period flood depth*[33]**

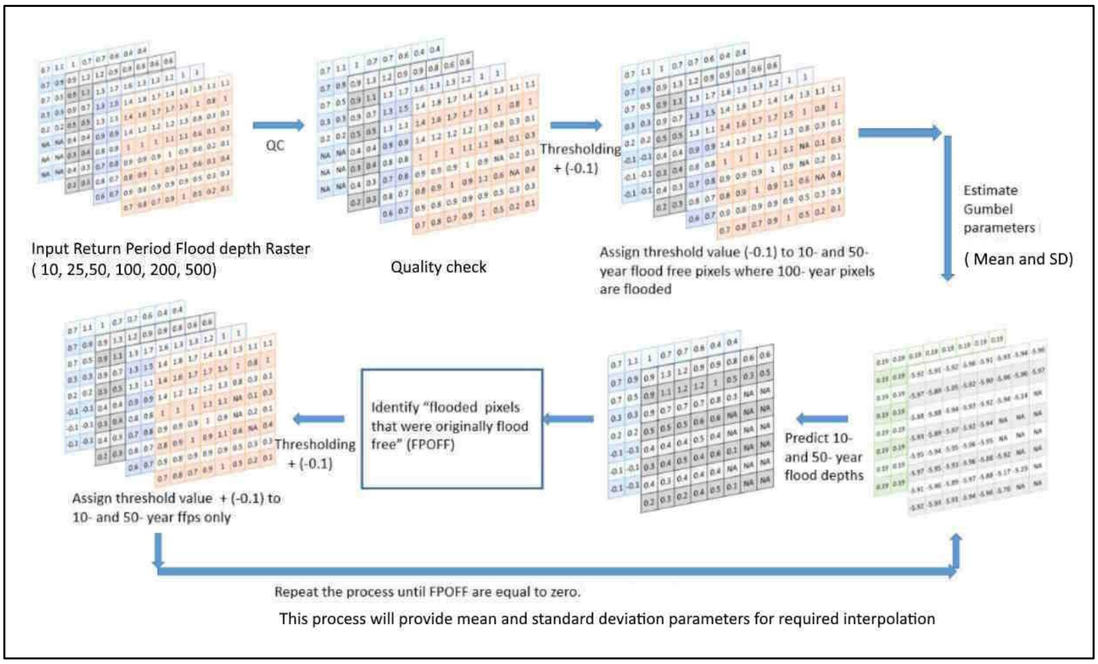

Figure 3-4: Workflow for frequency distribution parameters estimation

The widely used frequency functions are:

1. Gumbel extreme-value distribution
2. Log-Pearson type III distribution

In current analysis, RMSI will first check the best fit frequency distribution and the selected distribution will be used for stochastic flood events set generation.

The general equation for hydrologic frequency analysis:

$X^T = XBar + K\,\sigma X$ Eq (1)

Where

X^T = Value of variate x of random hydrologic series with return period T

XBar = Mean of the variate

σx = Standard deviation of the variate

K = Frequency factor which depends on return period T and type of frequency

3.1.1.1 Gumbel's extreme value distribution

A statistical distribution that originated from the theory of extremes. This distribution has a downfall in that the function is unbounded on either side, which could lead to the calculation of negative flows

To find available distribution, the return period flood values will be plotted on probability paper as shown in Figure 3-6:

The probability of occurrence of an event equal or larger than value such xo is:

$$P(x \geq x_o) = 1 - e^{-e^{y}}$$ Eq (2)

Y =a dimensionless variable, given by:
Y =α (x-a), in which; α =1.2825/ σx, and a= x -0.45005 σx

Hence; y can be written as;

$$y = \frac{1.2825(x - \bar{x})}{\sigma_x} + 0.577$$ Eq (3)

In practice, x is the value for given P that is required by Eq. (2) is transposed as;

Yp = - Ln (Ln (1- P)) Eq (4)

And since T = 1/P, so that;

Yp = - Ln (Ln (T/ T -1))

3.1.1.2 Log-Pearson Type III Distribution

The Log-Pearson Type III distribution is a statistical technique for fitting frequency distribution data to predict the flood for a given return period at some site on the river. Once the statistical information is calculated for the river site, a frequency distribution can be constructed. The probabilities of floods of various sizes can be extracted from the curve. The advantage of this particular technique is that extrapolation can be made of the values for events with return periods well beyond the observed flood events

The Log-Pearson Type III distribution is calculated using the general equation:

$$\log x = \overline{\log x} + K\sigma_{\log x}$$ Eq (5)

where x is the flood discharge value of some specified probability,

$\overline{\log x}$ is the average of the log x discharge values, K is a frequency factor, and $\sigma_{\log x}$ is the standard deviation of the log x values. The frequency factor K is a function of the skewness coefficient and return period and can be found using the frequency factor table.

3.1.1.3 Gumbel / Log Pearson type model fitting: Flood Parameter Estimation

The available return period flood depths (10,25,50, 100, 200 and 500) are plotted find the best fit frequency distribution. Based on calculated parameter such mean and standard deviation of the return period flood depth equation Eq (1) is calculated.

X^{T} = XBar + K σX Eq (6)

3.1.1.4 Generation of Stochastic Flood Depth

RMSI will use “Stochastic techniques”, based on the use of random numbers to simulate random occurrences of flood depths. A lot of probability theory was developed around gambling, hence the name Monte Carlo.

In this approach the pseudo-random values, U_i ~ Uniform [0,1] are generated. The “random number generators” usually produce values between U [0,1]. This Ui is used as cumulative probability and compute x_i as the inverse of the CDF of X. A frequency analysis on the sample xi provides the original probability distribution, i.e., P [X ≤ x].

Once the below mentioned required three required inputs are available

1. Return period (T= 1/P) – where P is the existence probability – generated using uniform random number generation U (0,1) in this step

2. Flood frequency parameters mean (XBar) and standard deviation (σX)– calculated in previous steps.

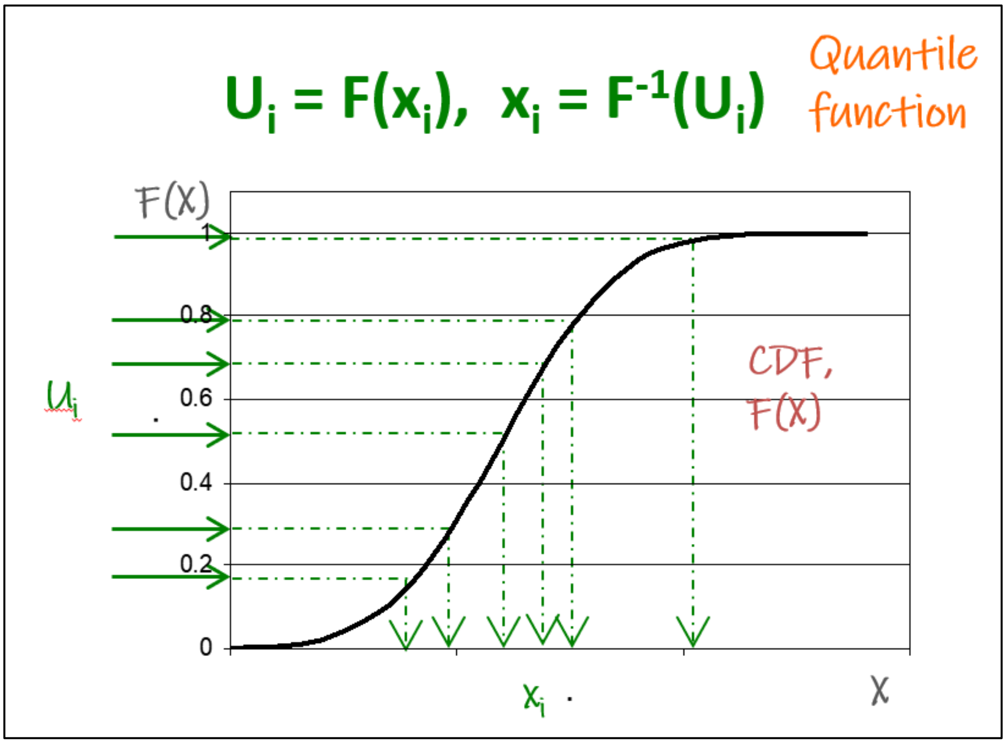

Figure 3-5: Pictorial illustration of Quantile function

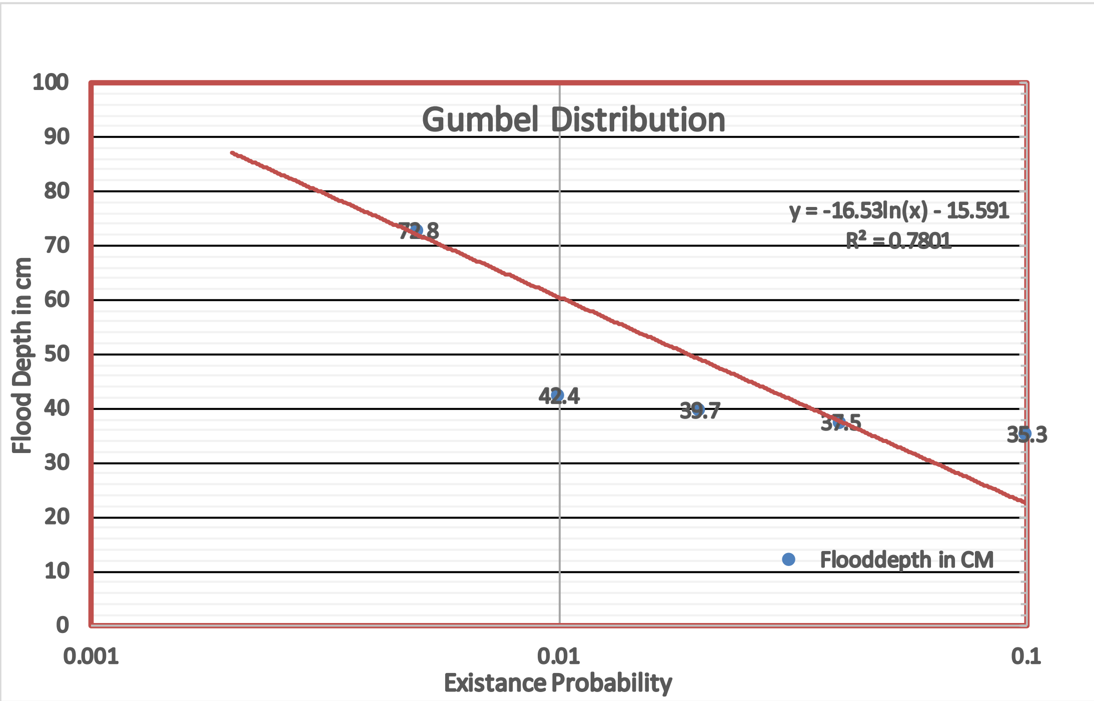

Figure 3-6 : Sample Gumbel distribution plot

3.1.2 Drought Hazard

RMSI is using PDSI or SPEI as the drought hazard index as both provide GIS compatible drought hazard layers for various key return periods (2 to 100 years). PDSI is a data intensive index as compared to SPEI as rainfall, maximum-minimum temperature and sunshine hour data are required to calculate this index. The drought hazard index selection is based on the data availability.

Palmer Drought Severity Index (PDSI): The PDSI has been developed by Palmer (1965)[34] based on a criterion for determining the beginning and end of drought or wet period spell (Karl and Knight, 1985[35]).

Standard Precipitation Evapotranspiration Index (SPEI): The SPEI is based on a criterion for determining the beginning and end of drought or wet period spell. This index is designed to take into account both precipitation and potential evapotranspiration (PET) in determining the drought. SPEI captures the main impact of increased temperatures on water demand and can be calculated for time steps from 1 month up to 48 months or more. Furthermore, we propose to use Thornthwaite method for the estimation of PET in which only rainfall, maximum temperature, minimum temperature, and sunshine hours are required as input to derive PET.

The use of a combination of vegetation and SPEI indices provides more reliable results for drought monitoring than any single index in the study area. Integrating the two indices therefore provides a near real-time indicator for drought, providing timely information for drought preparedness, mitigation and response planning, thereby helping to lower the eventual drought relief costs, protect food security and reduce the humanitarian impact on the population.

3.1.2.1 Generation of stochastic weather data set using historical data

As discussed earlier, among the natural disasters, drought has been considered as an important phenomenon due to its large spatial extent and persistence. In recent years, drought has been occurring more frequently, and their impacts are being aggravated by the rise in water demand and the variability in hydro-meteorological variables due to climate change. As a result, probabilities or return periods of different drought severity levels are a great piece of information required in planning and managing water resource systems to cope with the adverse effects of droughts. Due to this reason stochastic weather data (i.e., rainfall and temperature) is generated using internationally accepted Stochastic Weather Generator (i.e., WXGEN) based on 30 years of historical rainfall and temperature data set for longer time series, in order to generate larger number of extreme drought events and subsequently get long-term probabilities of occurrences (i.e., return period) of extreme drought hazard events .This will help the policy makers, who are involved in the water resource and agricultural sector, to make long-term plans to manage the extreme drought events in the long run.

After defining the drought index, the historical drought events are analyzed for their frequency of occurrence and their spatial variability. Historical weather data is used to simulate for agreed years and the return periods of simulated droughts. The frequency of drought over periods much longer than the period of observation is computed by using a standard stochastic weather generator (WXGEN). Further, corresponding maps will be generated based on this analysis.

34 Palmer, W.C., 1965: Meteorological Drought. Res. Paper No. 45, Office of Climatology, Weather Bureau, Washington, DC, 58pp.

35 Karl TR, Knight RW (1985) Atlas of monthly palmer hydrological drought indices for the continuous United States. National climatic data centre, USA, climatology series (3-7).

3.1.3 CYCLONE HAZARD

We are using our pre-existing models for Cyclonic winds and storm surge which were developed as part of NCRMP, Phase I & II project for NDMA for the 13 coastal states, including Kerala State. We are extending these models for updated exposure under consideration in this study beyond the immediate coast (10-meter elevation from Mean Sea Level in NCRMP-I) to cover all the districts in the state. The details of the methodology to be employed are provided in the sections below:

3.1.3.1 Stochastic Cyclonic Event Generation

For the current assignment, possible number of cyclonic event scenarios is being simulated using Geoscience Australia's Tropical Cyclone Risk Model (TCRM). The input for the TCRM model includes historical cyclone track data and intensity information for every known tropical cyclone in that area from 1901–2023, recorded at 6-hours intervals. The historical cyclone tracks data set comprises of best track data of India Meteorological Department (IMD) and International Best Track Archive for Climate Stewardship (IBTrACS).

The simulated stochastic event parameters include track location, central pressure, forward velocity, and location of landfall. All the stochastic cyclonic events are grouped according to their frequency and severity, i.e., Depressions, Deep Depressions, Cyclone Storms, Severe Cyclonic Storms, Very Severe Cyclonic Storms, Extreme Severe Cyclonic Storms, and Super Cyclonic Storms.

3.1.3.2 Cyclone Hazard Modeling Approach

Dynamic Storm Model: Surface winds associated with a tropical cyclone is derived using a dynamic storm model. Meteorological inputs required by this model include positions of the cyclone, pressure drop, and radii of maximum winds at any fixed interval of times. The main component of the storm model is a trajectory model and a wind speed profile approximation scheme. The model is used for the computation of maximum wind at each grid point of the analysis area, which is utilized as input for the surge model. The wind model is calibrated and validated using available observed data related to important past cyclones.

Figure 3-7 explains the step-by-step approach to be adopted for cyclone hazard modeling.

Furthermore, the validated wind hazard model is used to compute maximum sustained wind speeds associated with stochastic cyclonic event set that made landfall in and around the coast of Kerala. The Gumbel’s extreme value probability distribution is applied to the modeled wind speeds at each grid point of the model domain and wind speeds for key return periods (2, 5, 10, 25, 50, 100, 250, and 500 years) will be estimated.

Computing hazard footprints of wind field: Zonal statistics (geo-spatial technique) is applied on maximum sustained wind speeds to get an aggregated value at village level. Cyclonic wind hazard extent maps at village level is prepared by integrating wind speeds (model output) with various GIS themes to produce maps with varying wind speeds. The wind hazard maps being developed will represent the wind extent and wind speeds over the study area for key return periods. Finally, these wind hazard map at the village level may be used to identify strong wind prone extent delineation and would also help the state/district authorities to develop short and long-term disaster management plans in respect to cyclonic winds.

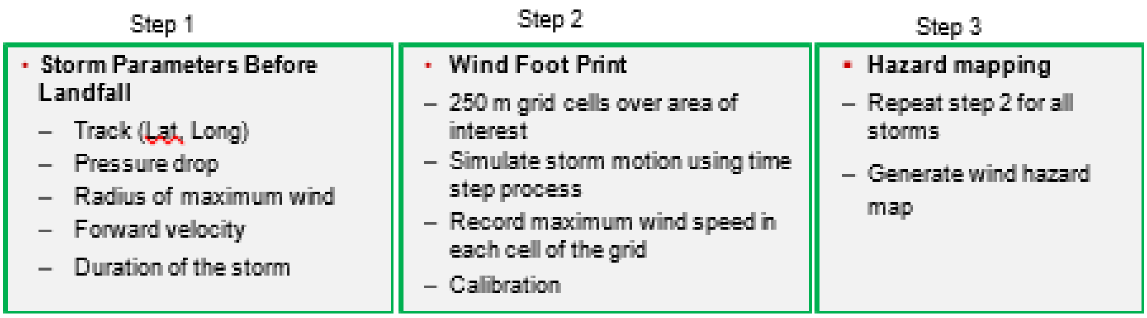

Figure 3-7: Steps for wind hazard assessment

3.1.4 STORM SURGE HAZARD

Storm surge hazard assessment identifies and demarcates areas, which are exposed to storm surge flooding. It provides information on the extent and depth of flooding for a range of events, which is the result of hazard assessment. This information is very useful to identify coastal stretches vulnerable to the impact of surge inundation. The storm surge hazard modelling approach is given in the following section.

3.1.4.1 Storm Surge Hazard Modeling Approach

Storm surge hazard modeling for the project is performed using ADCIRC-2DDI hydrodynamic finite-element model. A finite-element mesh for the study area is being constructed using the software package Surface Modeling System (SMS) (Westerink et al. 1994)[36]. A detailed description of the finite-element based hydrodynamic model ADCIRC-2DDI is available in Luettich et al (1992)[37]. The governing model equations comprise of the depth-integrated equations for mass and momentum conservation, subject to incompressibility, and Boussinesq, and hydrostatic pressure approximations. These equations are discretized in space using linear finite elements and in time by a finite-difference scheme.

Water levels along the open boundary are obtained from the Le Provost tidal database, which represent 13 tidal constituents (K_1, M_2, N_2, O_1, P_1, S_2, K_2, L_2, $2N_2$, MU_2, NU_2, Q_1, and T_2) based on Finite Element Solution (FES) Version 95.2 (Le Provost et al. (1998)[38].

Figure 3-8 shows a complete framework with step-wise methodology that we are using for storm surge hazard assessment.

The ADCIRC model requires wind forcing as an essential input parameter. For this purpose, the wind fields are calculated using the dynamic storm model of Jelesnianski and Taylor. ADCIRC model is applied for historical cyclone events using both tidal and wind forcing to estimate surge amplitude, velocity, and surge flood depths and extent over the study area. The maximum surge height computed with the model is validated against observed surge heights of important cyclone events. The validated storm surge model is then applied to estimate surge flood depths for stochastic cyclone events. The model outputs along with an appropriate statistical technique and GIS themes is used to prepare surge flood scenarios for key return periods ((2, 5, 10, 25, 50, 100, 250, and 500 years) over

[36] Westerink JJ, Blain CA, Luettich RA, and Scheffner NW (1994) ADCIRC: an advanced three-dimensional circulation model for shelves coasts and estuaries, report 2: Users manual for ADCIRC-2DDI. Dredging Research Program Technical Report DRP-92-6, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS., 156 pp.

[37] Luettich RA Jr., Westerink JJ and Scheffner NW (1992) ADCIRC: an advanced three-dimensional circulation model for shelves coasts and estuaries, report 1: theory and methodology of ADCIRC- 2DDI and ADCIRC-3DL. Dredging Research Program Technical Report DRP-92-6, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS, 137 pp.

[38] Le Provost, C, Bennett, AF and Cartwright, DE (1995) Ocean tides for and from TOPEX/Poseidon, Science, 267, 639-642.

the study area. These scenarios would form a base to evaluate potential regions prone to coastal inundation along the Kerala coast.

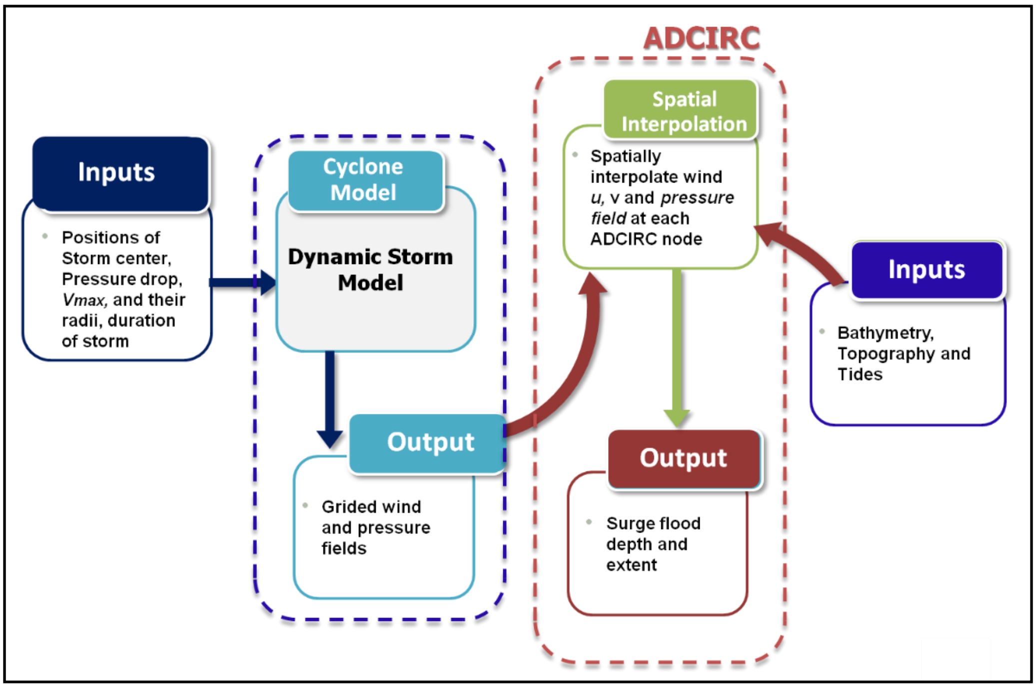

Figure 3-8: Framework of storm-surge hazard modeling

3.1.5 Landslide Hazard

The project team is currently assessing the landslide-prone areas of Kerala State and compiling historical landslide event data from diverse sources. For effective probabilistic landslide hazard modeling, a substantial dataset spanning a period of 20 to 30 years is crucial to conduct frequency analysis and generate return period maps. The overall approach for landslide modelling in the study area is represented in Figure 3-9.

To initiate this process, the team will first map most landslide events utilizing various resources. The subsequent step involves identifying input parameters influencing landslide occurrence, including slope steepness, soil type, land cover, rainfall intensity, vegetation density, and human activities. We are assessing the spatial and temporal distribution of these variables within the study area and will develop appropriate stochastic models based on statistical analysis.

Estimation of unknown parameters within selected stochastic models is performed using available historical data and fitting techniques like maximum likelihood estimation or moment matching. Validation of estimated parameters are conducted through goodness-of-fit tests and sensitivity analyses. Integration of stochastic models for individual input variables into a comprehensive landslide hazard model will be achieved by assigning weightage to each input variable based on its relative importance and sensitivity to landslide occurrence. Stochastic events will be simulated by generating random samples from the probability distributions of input variables. To accomplish this, we will employ conditional Latin Hpercube Sampling (CLHS) in Monte Carlo simulations, facilitating the generation of multiple realizations of potential landslide scenarios. This method incorporates spatial correlation among input variables to capture spatial variability in landslide hazard.

Validation is a crucial aspect, involving comparison of generated stochastic events against historical landslide events or empirical data to evaluate the model's predictive performance. Sensitivity analysis is conducted to assess the influence of different input variables and model assumptions on outcomes, aiding in the development of robust stochastic models for landslide event generation and enhancing the management of landslide risks.

From the stochastic event data sets, return period landslide hazards is estimated. Stochastic landslide events are arranged chronologically, and each event is ranked within the ordered dataset to calculate the recurrence interval using the formula:

RI=(N+1)/M

Where;

RI: Recurrence Interval (in years)

N: Number of years of record (total duration of the dataset)

M: Rank of the event in the ordered dataset

For example, if you have 50 years of data and a landslide event occurred once in that period, its recurrence interval would be:

RI= (50+1)/1=51 years

The return period (RP) is the reciprocal of the recurrence interval. It indicates the probability of a landslide event of the defined magnitude or intensity occurring within a specific period.

In absence of sufficient historical event, team will adopt methodology used in the Global Infrastructure Resilience Index (GIRI) model which is based on the model that was originally developed by (Nadim et al. 2006) in the project "Natural disaster hotspots – a global risk report" for the World Bank (Dilley 2005). Inputs used for this study are (i) susceptibility information, and (ii) gridded information of different scenarios for each of the landslide-triggering factors, including rainfall and earthquake. The output consists of global scenario-based landslide hazard maps.

Figure 3-10 shows a general flowchart of the GIRI landslide modelling approach.

This approach involves integrating different return period's rainfall data and AI/ML-based susceptibility maps to generate landslide map of different return periods. The landslide hazard maps will highlight areas prone to landslides with different probabilities of occurrence over specified return periods. Furthermore, the project will identify various exposure elements located within different levels of susceptibility under each return period scenario of landslide hazard. By categorizing exposure elements based on susceptibility levels and return period scenarios, the project will provide valuable insights into the extent of risk posed by landslides to different elements in the study area.

Overall, the project's outcomes will facilitate informed decision-making and proactive risk management strategies to mitigate the impact of landslides on vulnerable communities and infrastructure.

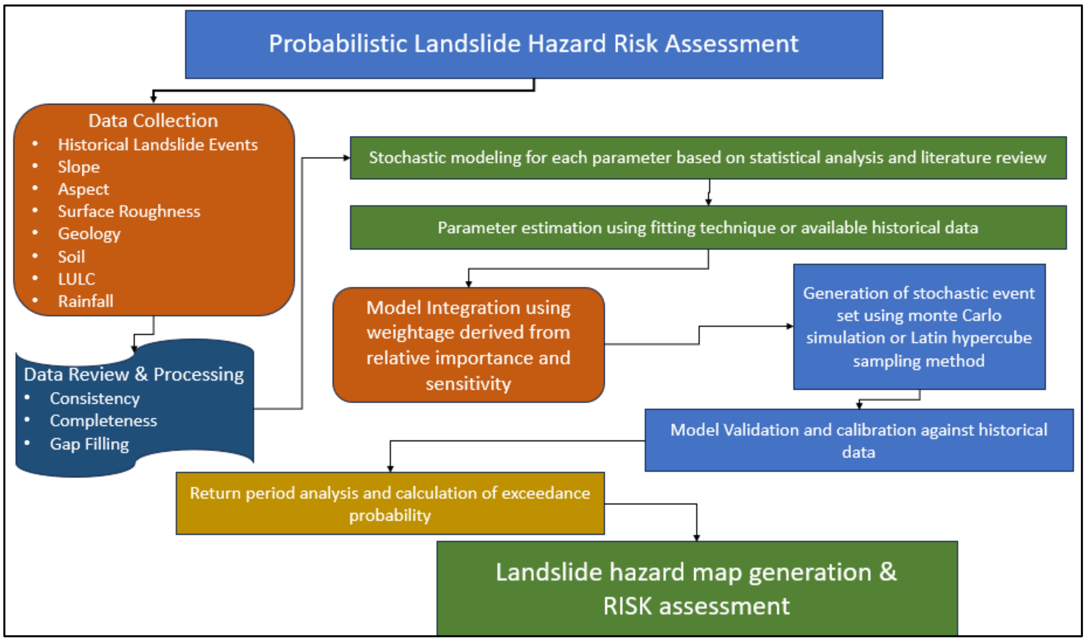

Figure 3-9: Overall approach for Landslide modelling

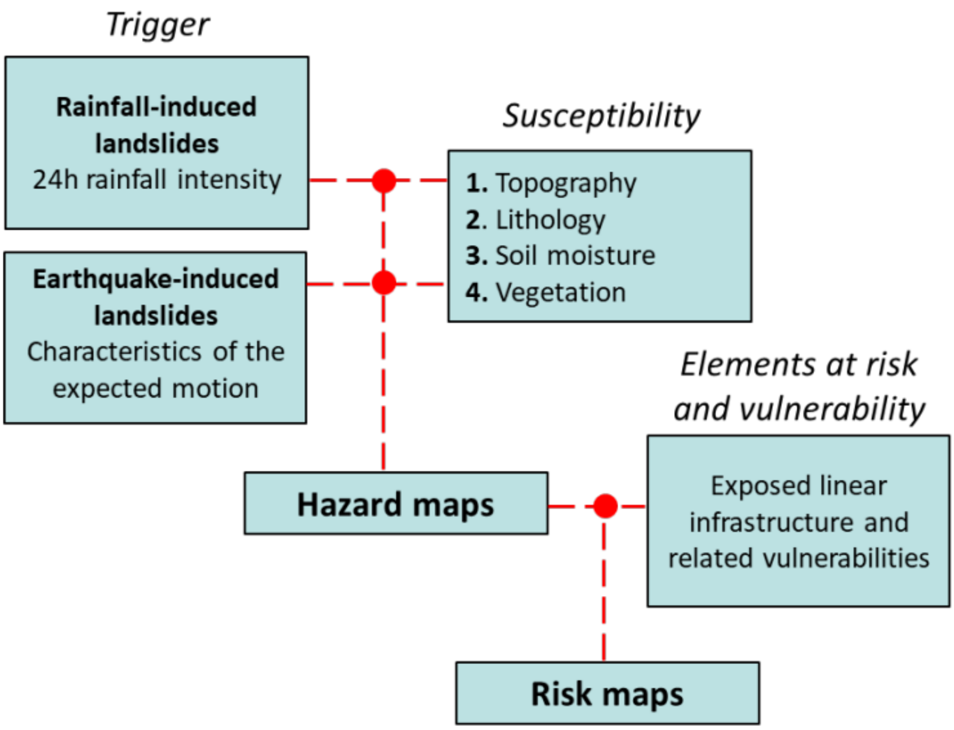

Figure 3-10: General flowchart of the GIRI landslide modelling approach

3.2 Exposure Data Development

Exposure data development in Kerala involves the comprehensive identification, categorization, and mapping of assets, infrastructure, and agriculture, susceptible to various hazards prevalent in the region. This process encompasses gathering detailed information on the spatial distribution, characteristics, and vulnerability of built environments, critical facilities, and economic sectors, across the state. Exposure data development integrates various sources, including satellite imagery, land use maps, census data, administrative records, and field surveys, to create a comprehensive database of elements at risk. The aim is to facilitate informed decision-making, risk assessment, and disaster preparedness by providing stakeholders with a clear understanding of the potential impact and vulnerability of assets and populations to natural and man-made hazards in Kerala.

Figure 3-11 shows the broad categories of assets that will be considered for this study. Since assets are potentially exposed to various hazards, so these are together called exposure.

In addition to this, the missing features of asset type will use other data source as mentioned below for enhancing the asset database, especially in those areas which are in high-risk zones. RMSI team will apply the standard approaches such as Remote Sensing /GIS, Field visits, Crowd sourcing, Secondary data sources and AI/ML based approaches.

Based on the above exercise, a spatial exposure database will be created which will consist of required exposure maps of government buildings, housing sector, transportation system and population. The output of exposure will be calculated from the total monetary value by asset category.

Data collection and data processing: The team will obtain available exposure data from client /key stakeholders at the onset of the project, however, if some datasets become available during later stages of the project, then team will take care to incorporate them for data processing to bring the available data into usable format. The team will carry out the QA/ QC of the data during different stages of the data processing.

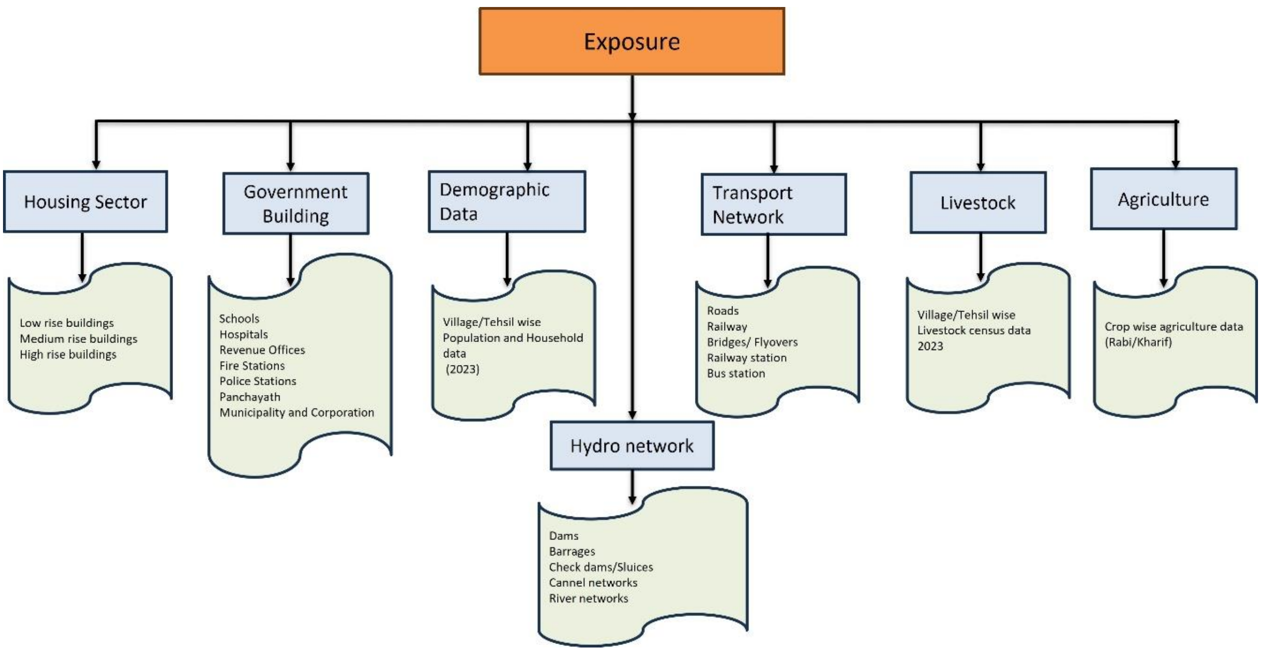

Figure 3-11: Exposure elements

Table 3-1: Components of asset database and required attributes

Housing Sector:	
Residential	The residential building location information will be collected from the KSDMA. Missing data will be created using machine learning techniques and data available in OSM. Unit replacement costs will be estimated using building authorization data and by taking inputs from local experts. Occupancy type will be defined based on the interpretation of ancillary data.
Demographics:	
Population	Population and household's information disaggregated by administrative units will be collected from relevant sources, e.g., Census, land registers, etc.
Government Buildings:	
Administrative headquarters	The common attributes that need to be captured are location, construction type, year of construction, cost of construction, number of stories for buildings, etc.
Educational establishment including school/ colleges	The common attributes that need to be captured are location, construction type, year of construction, cost of construction, number of rooms, number of students, number of stories for buildings, etc.
Health establishment	The common attributes that need to be captured are location, construction type, year of construction, cost of construction, number of beds, number of staff, number of doctors, number of stories for buildings, etc.
Fire stations and Police stations	The common attributes that need to be captured are location, construction type, year of construction, cost of construction, and the number of stories for buildings. Location of fire stations, emergency services, police stations, and their respective areas of interest/ response. For police stations attributes like type, contact number, number of staff and their designations are important.
Transport:	
Road network	Road network information will be required in GIS format with information on types of roads as well as the construction material. In addition, corresponding unit replacement costs will also be collected for calculating the asset values.
Bridges	Information related to bridges including location, structural type, length, number of lanes, and number of spans will be collected. In addition to this, replacement cost by structural type and span will be collected.
Agriculture	
Crop	Crop distribution, yield estimates and cost value for key crops
Livestock	Information related to livestock number and cost will be collected

Note: The above table provides data requirements for developing a good asset database. In case, there is a lack of data in any of the items mentioned above, the team will use proxy methods. Data sources including details of proxy data used will be explained in the meta data for future reference.

Exposure Data Review, Gap Identification and Approaches for Gap Filling

In the inception phase of the project, some data was provided by the KSDMA (Kerala State Disaster Management Authority) in the form of spatial data, shape files, etc. which were structured and subsequently reviewed for identification of data gaps for further data collection. Similarly, OSM data has been downloaded for review.

3.2.1 Data Review and Gap Identification

The following sections elaborate on the data received from the KSDMA. features and attributes available, identified gaps and challenges, spatial spread, and statistical representations of reviewed data are documented in subsequent sections for each data theme and their underlying layers.

Potential data sources were identified for the attributes that were missing from the data provided by the KSDMA (Figure 3-2). Various agencies and departments as well as other sources were determined for data acquisition and gap filling.

given comprehensive data required for exposure modeling with their current status of data availability. In the below table, available data layers are represented in green color, data gaps are represented in yellow color and the relevant gaps to be filled are in orange color. The highest priority would be given to data collected from line departments, particularly for buildings related to critical infrastructure, transport, population, agriculture, and livestock activities. However, some attributes may not directly available in line departments, such as number of floors, roof types, construction types, plinth area, etc. These attributes will be populated using Google Street view imageries and Google photos, which will be further validated through inputs from the local team.

Table 3-2: Exposure data availability status from KSDMA

EXPOSURE SPATIAL DATA LAYERS	Data from (KSDMA)	Data Gap and Filling Approach	Feature Counts	Remarks
Administrative Boundary				
District Boundary	Available		14	
Taluk Boundary	Available		78	
LSG Boundary	Available		1035	
Village Boundary	Available		1589	
Ward Boundary	Available		19552	
Municipality Boundary	Available		87	
Corporation ward Thrissur	Available		54	
Corporation ward Trivandrum	Available		100	
Corporation ward Kannur	Available		55	
Corporation ward Kochi	Available		74	
Corporation ward Kollam	Available		55	
Corporation ward Kozhikode	Available		75	
Housing Sector (Building Footprint)				
Low rise buildings Building Footprint	Available	OSM Platform, High resolution imagery		Five cities building

EXPOSURE SPATIAL DATA LAYERS	Data from (KSDMA)	Data Gap and Filling Approach	Feature Counts	Remarks
Medium rise buildings Building Footprint	Available	OSM Platform, High resolution imagery		footprint data (Kozhikode, Thrissur, Ernakulam, Kollam, Thiruvananthapuram)
High rise buildings Building Footprint	Available	OSM Platform, High resolution imagery		
Residential Cluster	Available			
Commercial Cluster	Available			
Industrial Cluster	Available			
Government Building				
Govt. School	Available		11685	
Private School	Available		3069	
Technical School	Available		49	
Hospitals	Available		1225	
Revenue Offices	Not Available	Govt. official sites		
Fire Stations	Available		160	
Police Stations	Available		460	
Ration Shop	Available		13462	
Panchayat Offices	Available		919	
Municipality and Corporation	Not Available	Govt. official sites		
Cyclone Centre	Available		17	
Govt. Offices	Available		497	
Transport Network				
Roads	Available			
Airport	Available		6	
Railway Line	Available			
Railway Station	Available		132	
District Headquarters	Available		14	
Taluk Headquarters	Available		77	
Bridges/Flyovers	Not Available	OSM Platform		
Bus Station	Available		304	
Agriculture	Not Available	Govt. official sites		
Livestock	Not Available	Govt. official sites		
Demographic (Population and Household)				
Census 2011 at village level	Available		1034	
Age Above 60 at village level	Available		1035	
Disability at village level	Available		1042	
Land use/Land cover				
LULC (2015-2016)	Available			
LULC 2020	Available			

3.2.1.1 Building Footprints/ Building Cluster

The data received from the KSDMA includes building footprints polygons data for 5 cities (Kozhikode, Thrissur, Ernakulam, Kollam and Thiruvananthapuram) of Kerala state, which has information about building names. Building cluster (Residential, Commercial and Industrial) data also received from KSDMA. In addition, KSDMA is following up with KSERC to get additional building footprints database and these will be further updated in the Deliverable Report. Moreover, some of the buildings details are also available from OSM, which contain names and types of the buildings, these would be utilized in filling the gaps.

Figure 3-12 presents building footprint data in Kozhikode city of the study area. Figure 3-13 presents building cluster data availability in Kerala State.

Figure 3-12: Map showing locations of building footprint in Kozhikode city (Source: KSDMA)

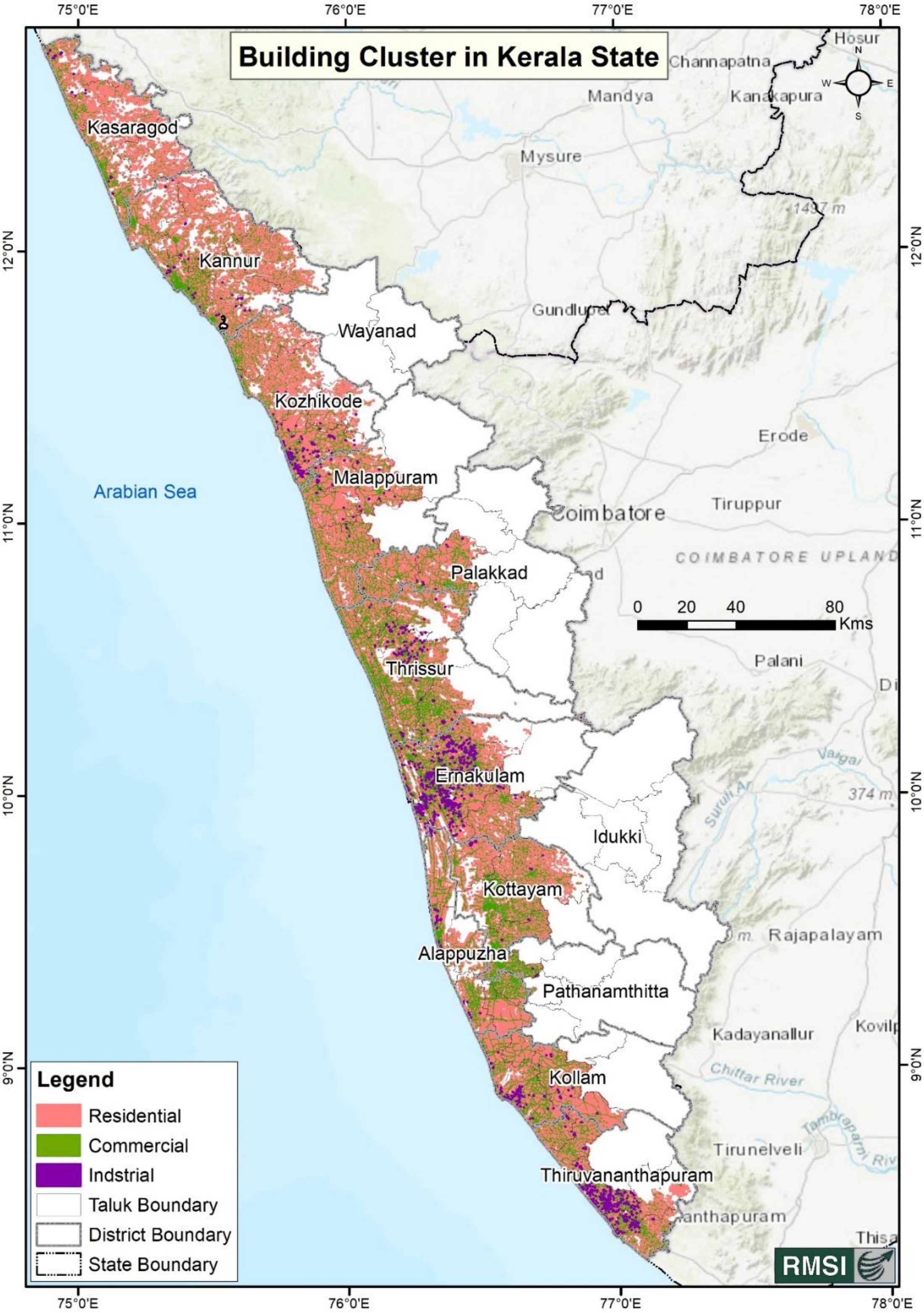

Figure 3-13: Map showing building cluster in Kerala state (Source: KSDMA)

3.2.1.2 Hospitals

A total of 1,225 hospitals point features have been received from the KSDMA for the entire Kerala state. KSDMA has provided two types of hospital data, [government (419) and private (806)]. Figure 3-14 presents state level distribution of hospitals in the study area.

Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

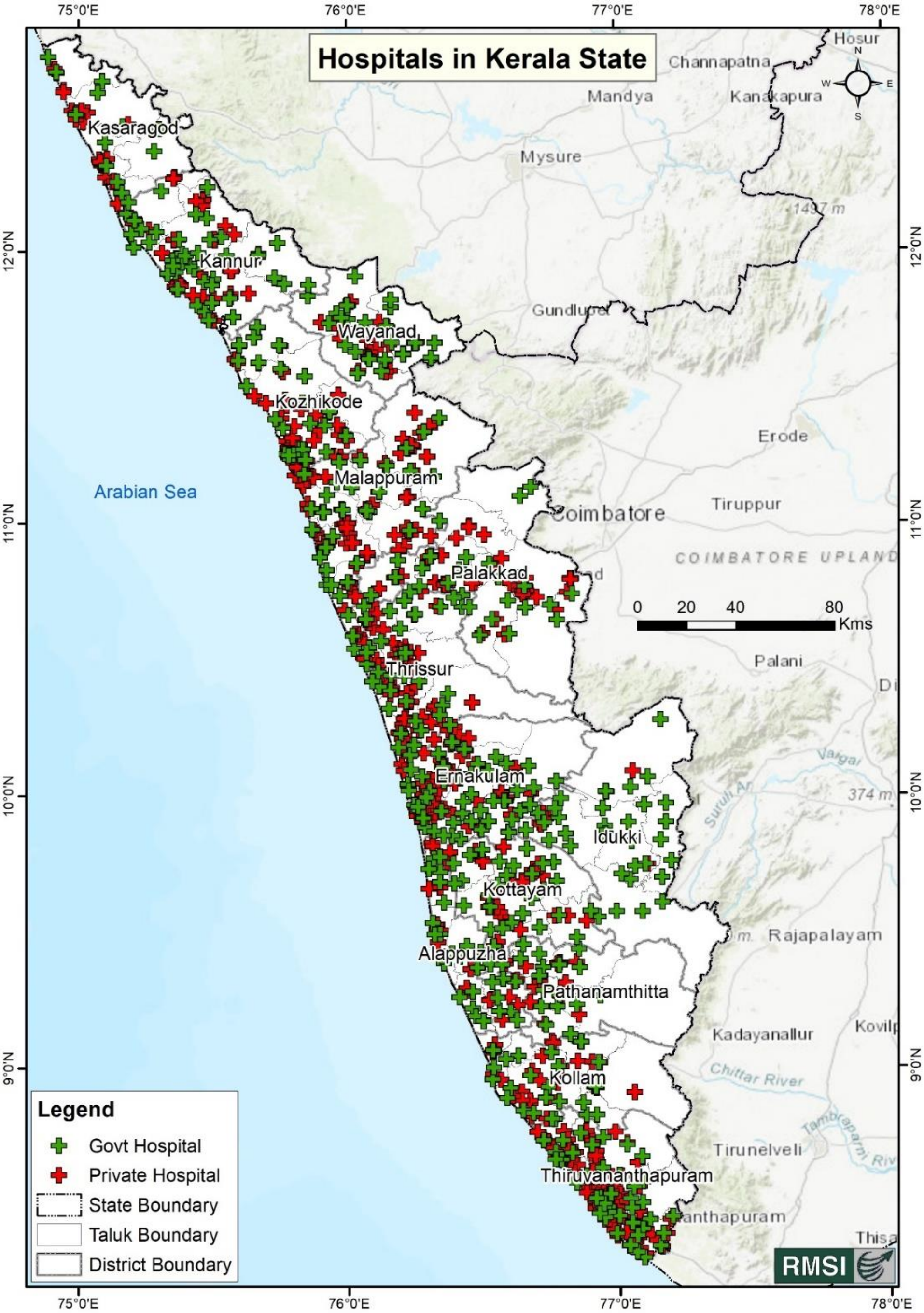

Figure 3-14: Map showing locations of hospitals in Kerala (Source: KSDMA)

3.2.1.3 Police Station

A total of 460 police station point features have been received from the KSDMA for the entire Kerala state.

Figure 3-15 presents state level distribution of police stations in the study area. Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

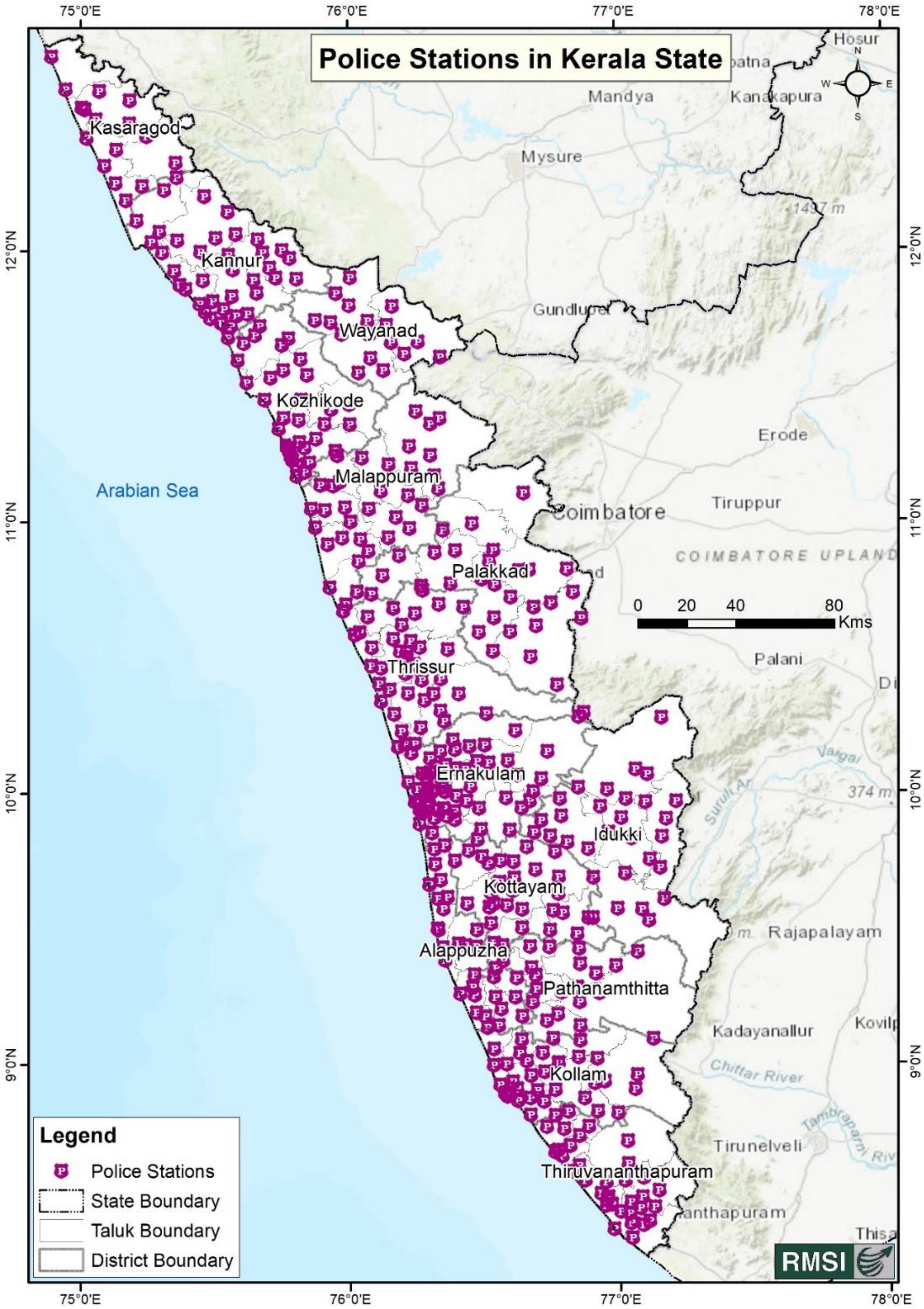

Figure 3-15: Map showing locations of police stations in Kerala (Source: KSDMA)

3.2.1.4 Fire Stations

A total of 160 fire station point features have been received from the KSDMA for the entire Kerala state.

Figure 3-16 presents state level distribution of fire stations in the study area. Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

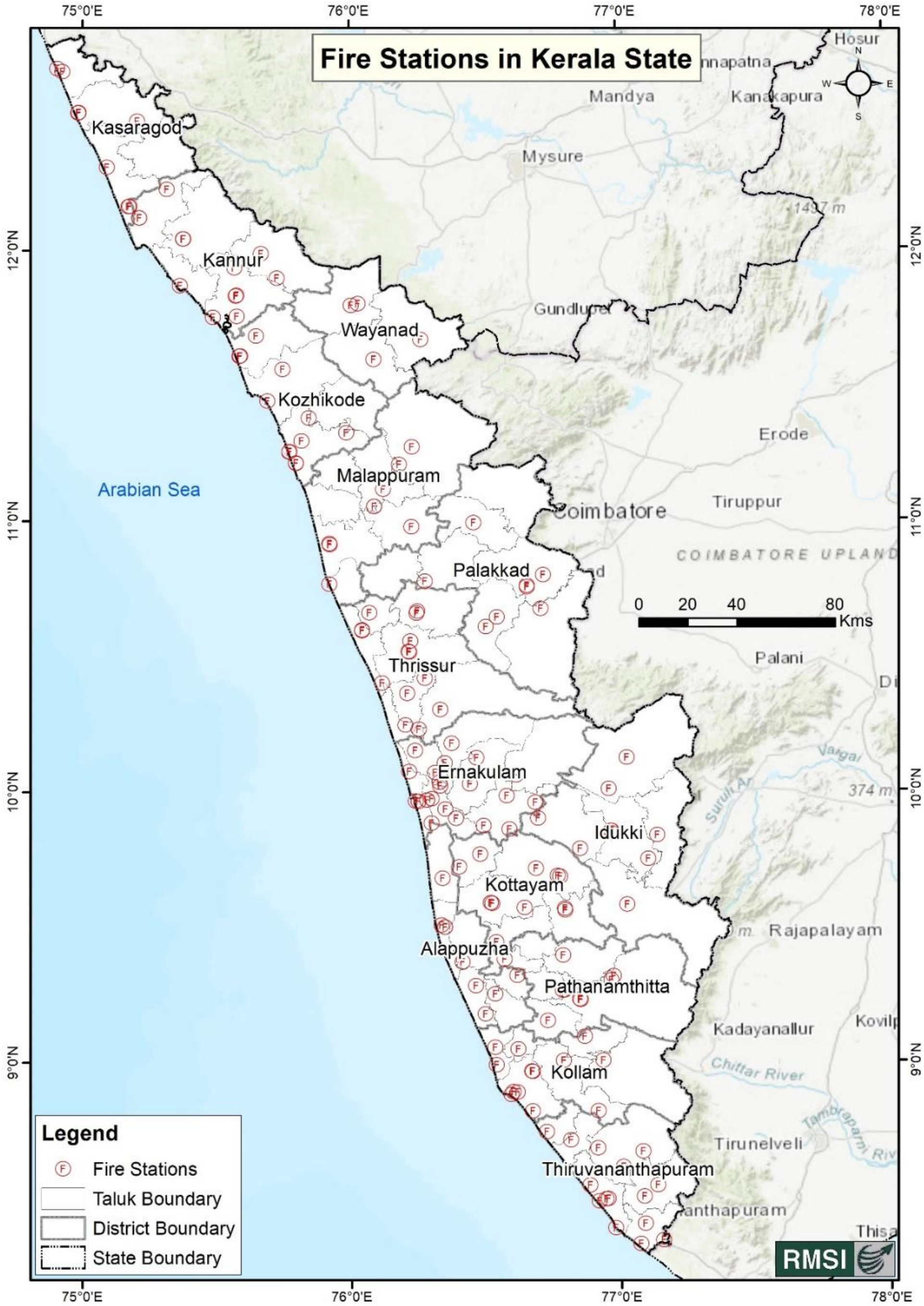

Figure 3-16: Map showing locations of fire stations in Kerala (Source: KSDMA)

3.2.1.5 Cyclone Centre

A total of 17 cyclone shelter point features has been received from the KSDMA for the entire Kerala state.

Figure 3-17 presents state level distribution of cyclone shelter in the study area.

Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

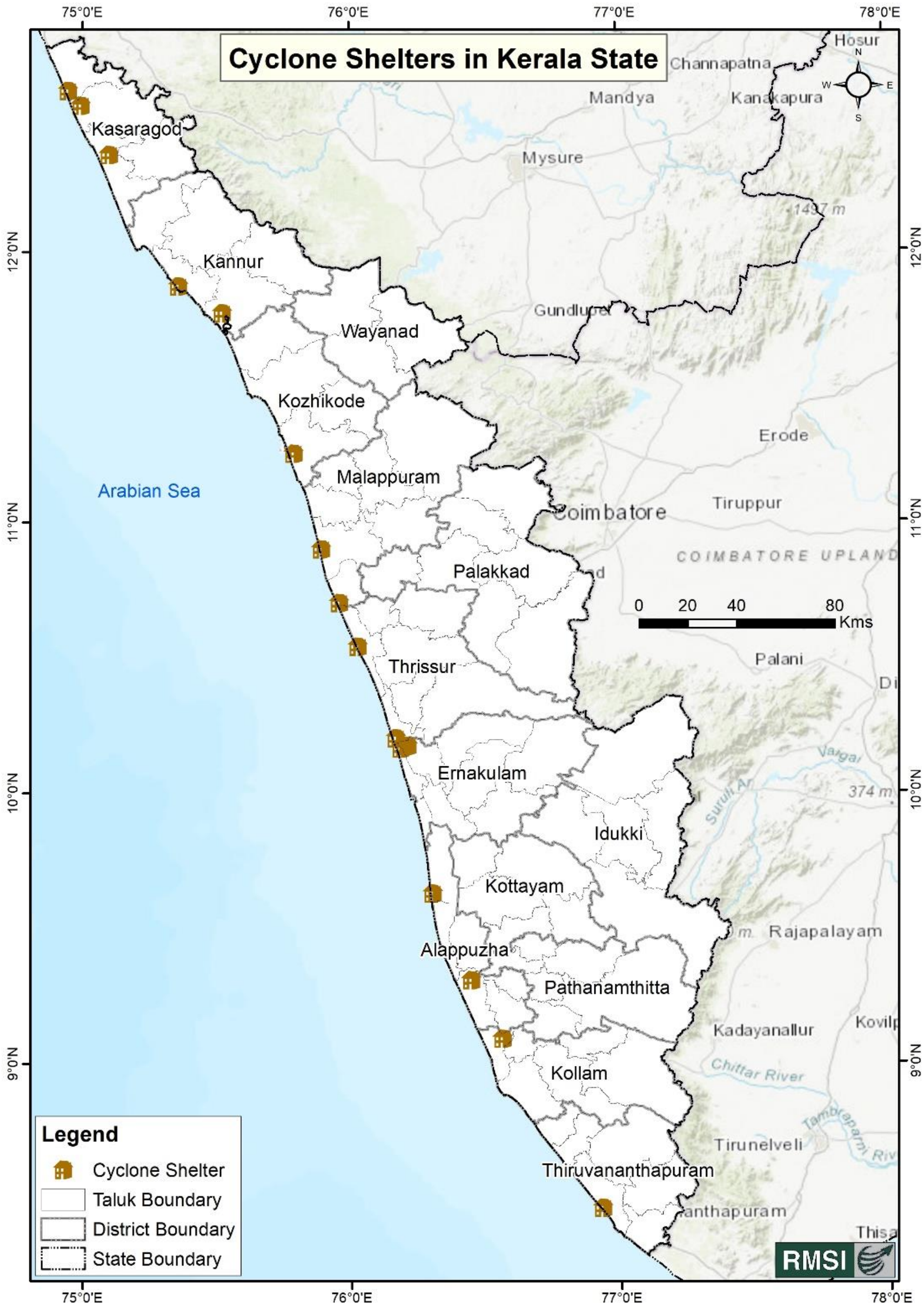

Figure 3-17: Map showing locations of cyclone shelters in Kerala (Source: KSDMA)

3.2.1.6 Ration Shops

A total of 13,462 ration shop point location has been received from the KSDMA for the entire Kerala state.

Figure 3-18 presents state level distribution of ration shop in the study area.

Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

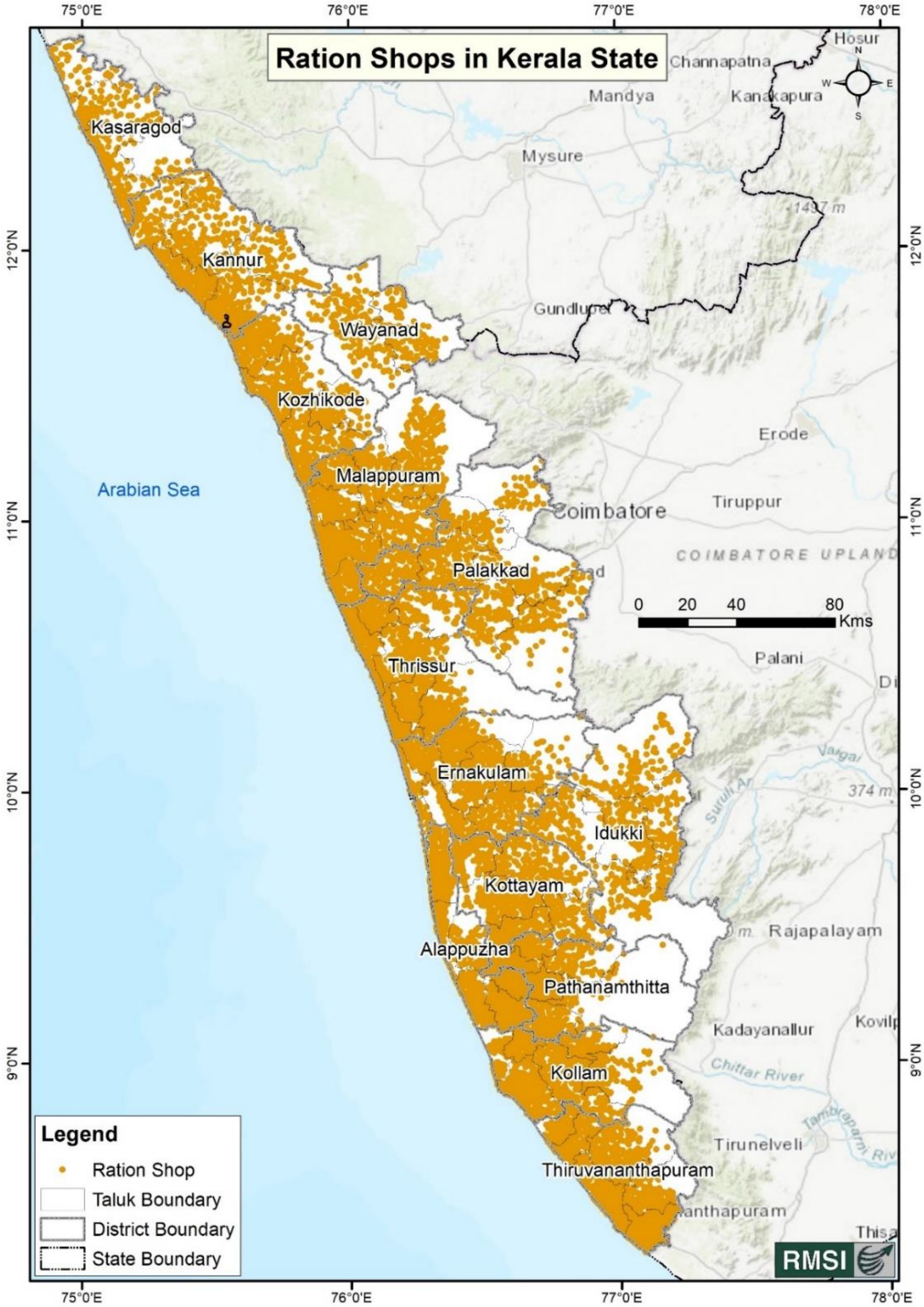

Figure 3-18: Map showing locations of ration shops in Kerala (Source: KSDMA)

3.2.1.7 District and Taluk Headquarters

A total number of 14 district headquarters and 77 taluk headquarters point location has been received from the KSDMA for the entire Kerala state.

Figure 3-19 presents state level distribution of district and taluk headquarters in the study area.

Location validation of these data will be done using Google Street View photographs.

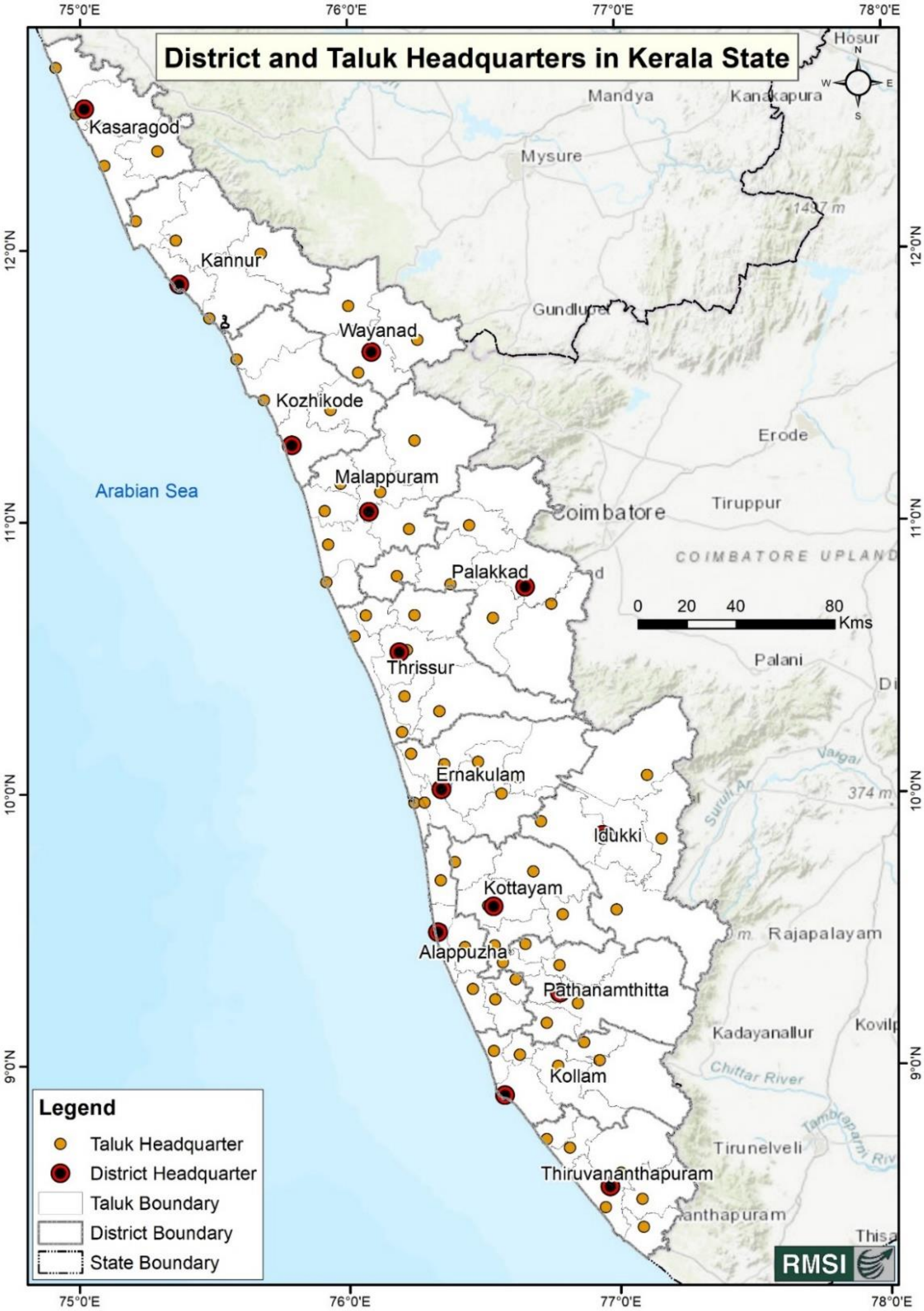

Figure 3-19: Map showing locations of district and taluk headquarters in Kerala (Source: KSDMA)

3.2.1.8 Government Offices

A total number of 497 government offices point location has been received from the KSDMA for the entire Kerala state.

Figure 3-20 presents state level distribution of government offices in the study area.

Location validation of these data will be done using Google Street View photographs.

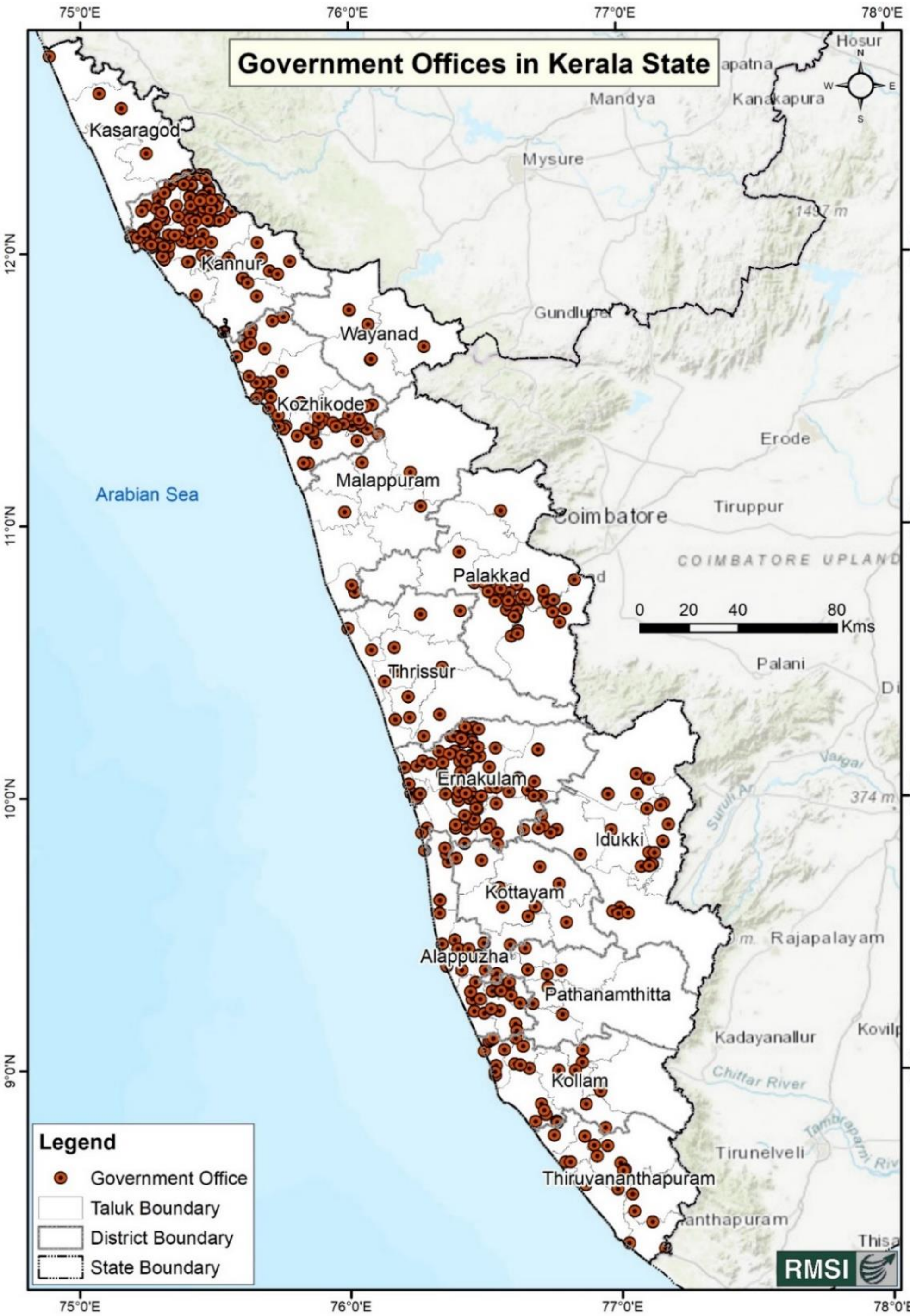

Figure 3-20: Map showing locations of government offices in Kerala (Source: KSDMA)

3.2.1.9 Panchayat Offices

A total number of 919 panchayat offices point location has been received from the KSDMA for the entire Kerala state.

Figure 3-21 presents state level distribution of panchayat offices in the study area.

Location validation of these data will be done using Google Street View photographs.

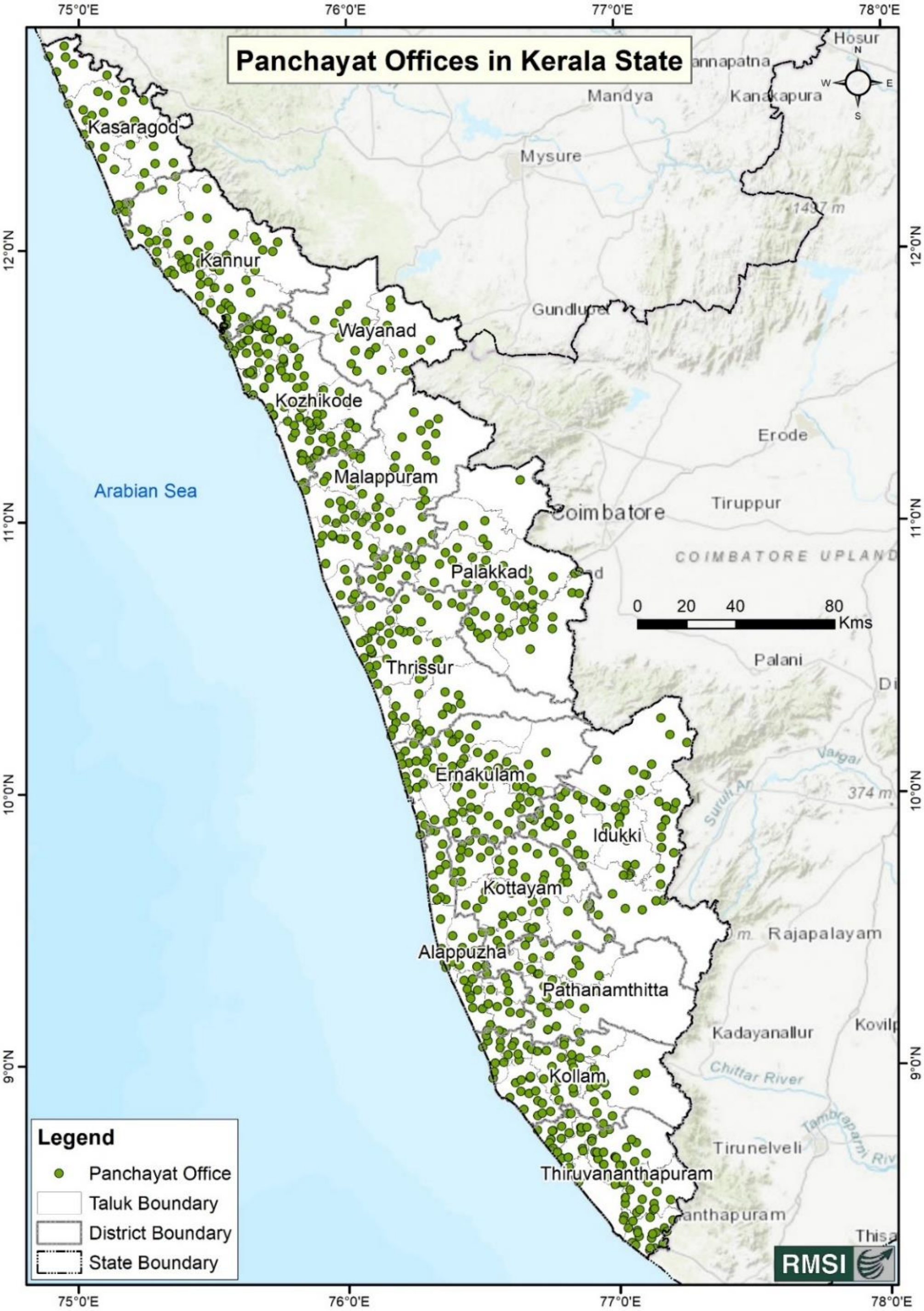

Figure 3-21: Map showing locations of panchayat offices in Kerala (Source: KSDMA)

3.2.1.10 Transport

Transportation infrastructure plays the essential role of connectivity, connecting people to amenities and supporting economic activities. In the event of a disaster, transportation networks are the lifeline, especially in evacuation, rescue, and recovery operations. This includes roads, bridges, railways, airports and their associated infrastructure. Various attributes like length, capacity, construction type, material, etc. help to determine the value of the structures.

69,519 km of road network data has been received from the KSDMA for the entire state. The National highway length is 1,489 km in Kerala state, others road types and length detail are given in Table 3-3 and Figure 3-22 shows the coverage of available road network data from KSDMA data.

Table 3-3: Length (km) of different road types

Road Types	Length in Kms
National Highway	1,489.12
State Highway	7,048.58
Metalled Road	52,039.07
Unmetalled Road	8,920.23
Footpath	22.50

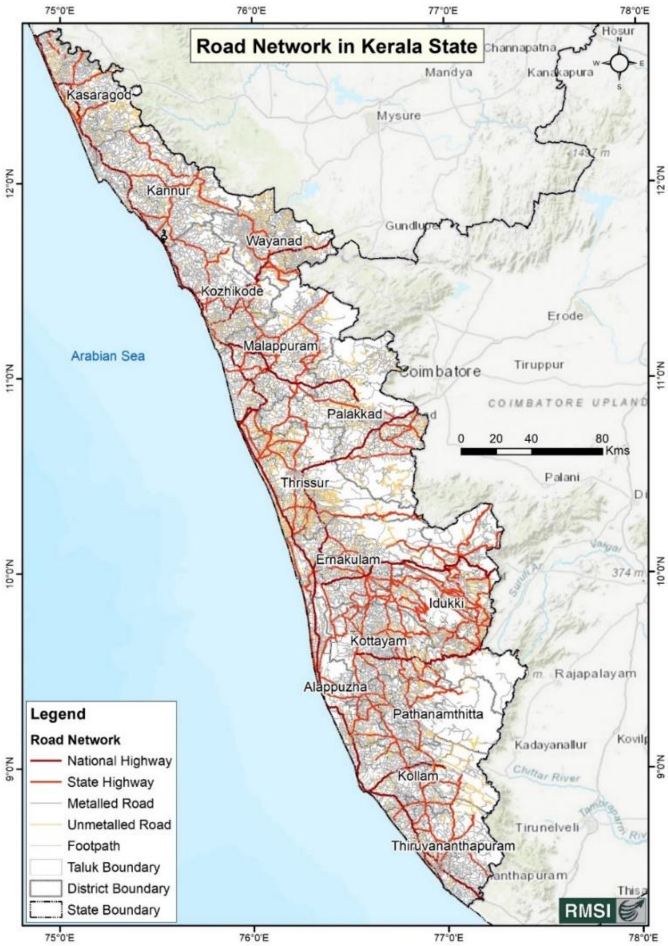

Figure 3-22: Map showing road features coverage in Kerala (Source: KSDMA)

3.2.1.11 Railways

Railway network data has been provided by the KSDMA for the entire Kerala state. The data received from the KSDMA includes 1,065 km of railway network for the entire state. Figure 3-23 shows the coverage of available rail network data.

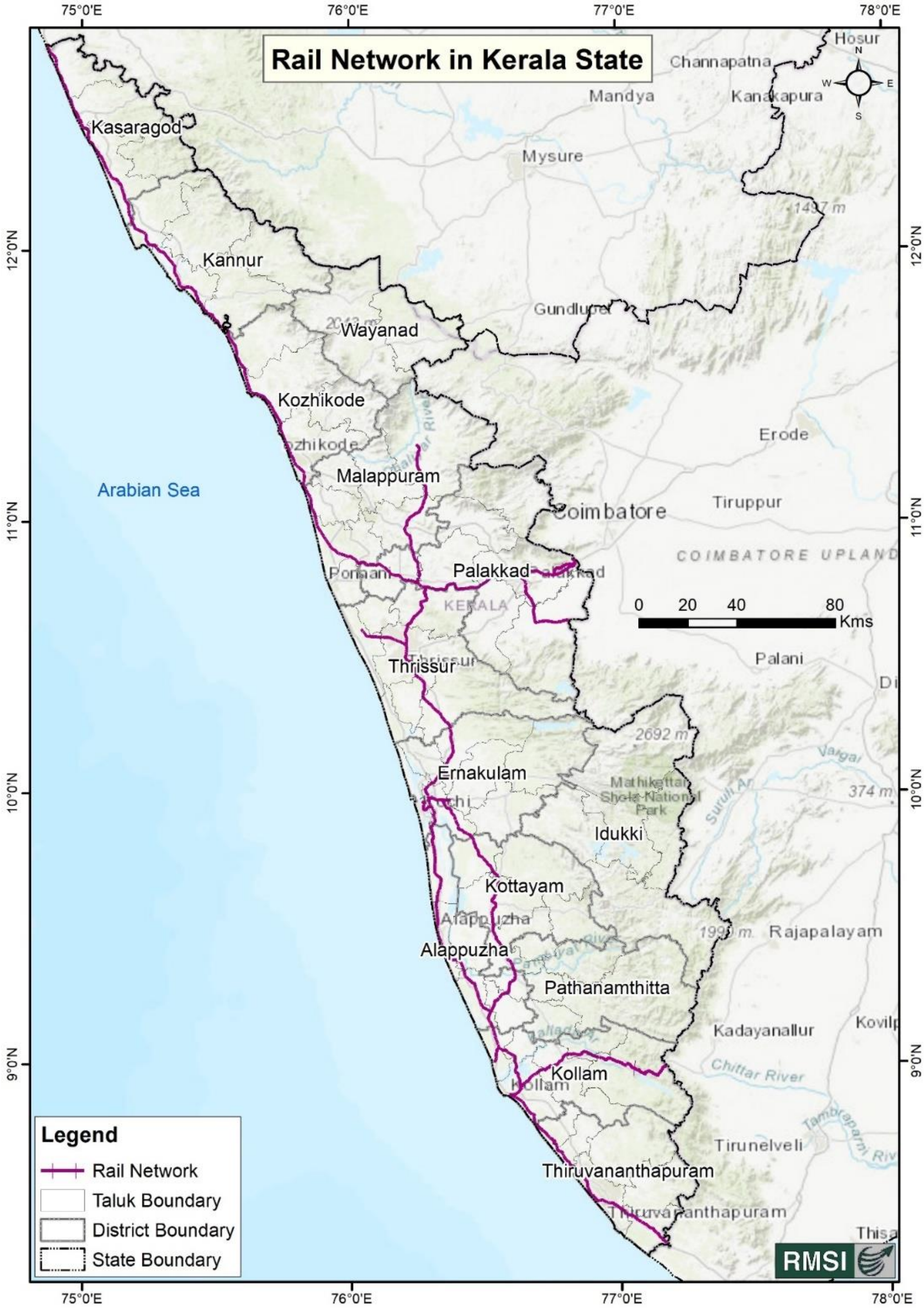

Figure 3-23: Map showing rail network in Kerala (Source: KSDMA)

3.2.1.12 Railway Stations

Railway station data has been provided by the KSDMA for the entire Kerala state. The data received from the KSDMA includes 131 railway stations for the entire state. Figure 3-24 shows the coverage of available railway station data.

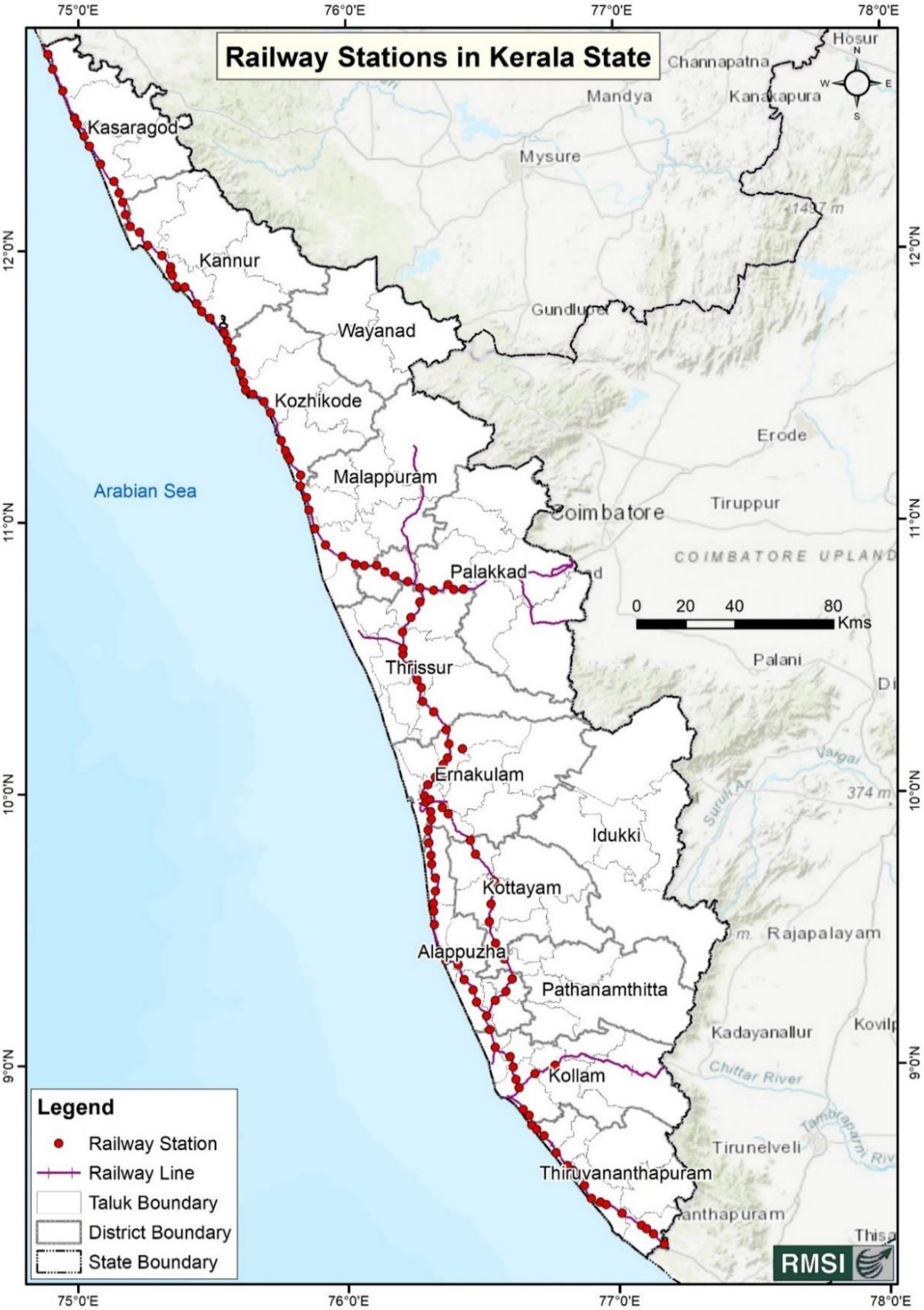

Figure 3-24: Map showing railway stations in Kerala (Source: KSDMA)

3.2.1.13 Airports

Airport data has been provided by the KSDMA for the entire Kerala state. The data received from the KSDMA includes 6 major airports for the entire state. Figure 3-25 shows the coverage of available airport data.

Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

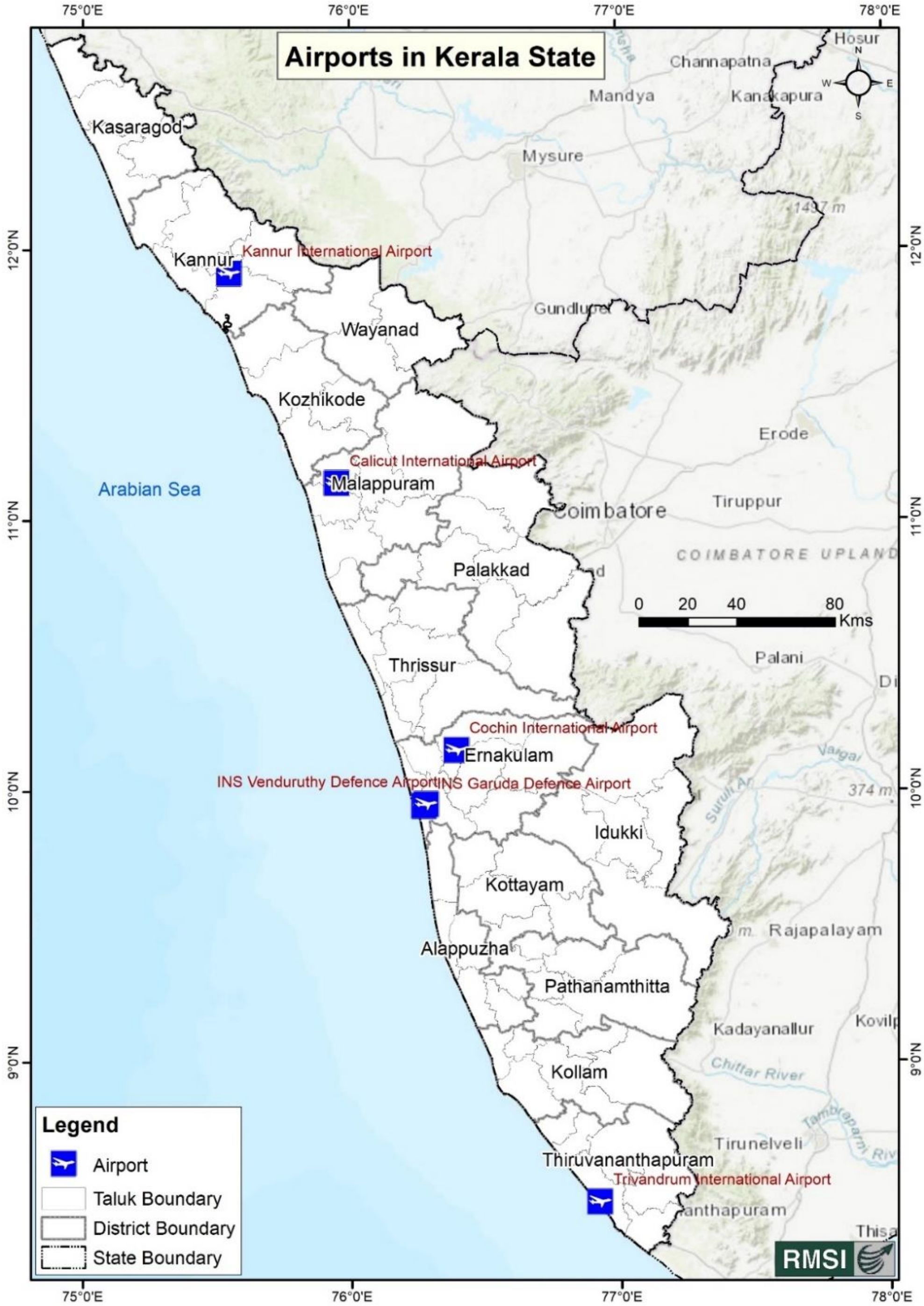

Figure 3-25: Map showing airports in Kerala
(Source: KSDMA)

3.2.1.14 Bus Stations

Bus station data has been provided by the KSDMA for the entire Kerala state. The data received from the KSDMA includes 304 bus stations for the entire state. Figure 3-26 shows the coverage of available bus station data.

Location validation of these data will be done using Google Street View photographs. During this process, duplicate/ overlapping data will be removed.

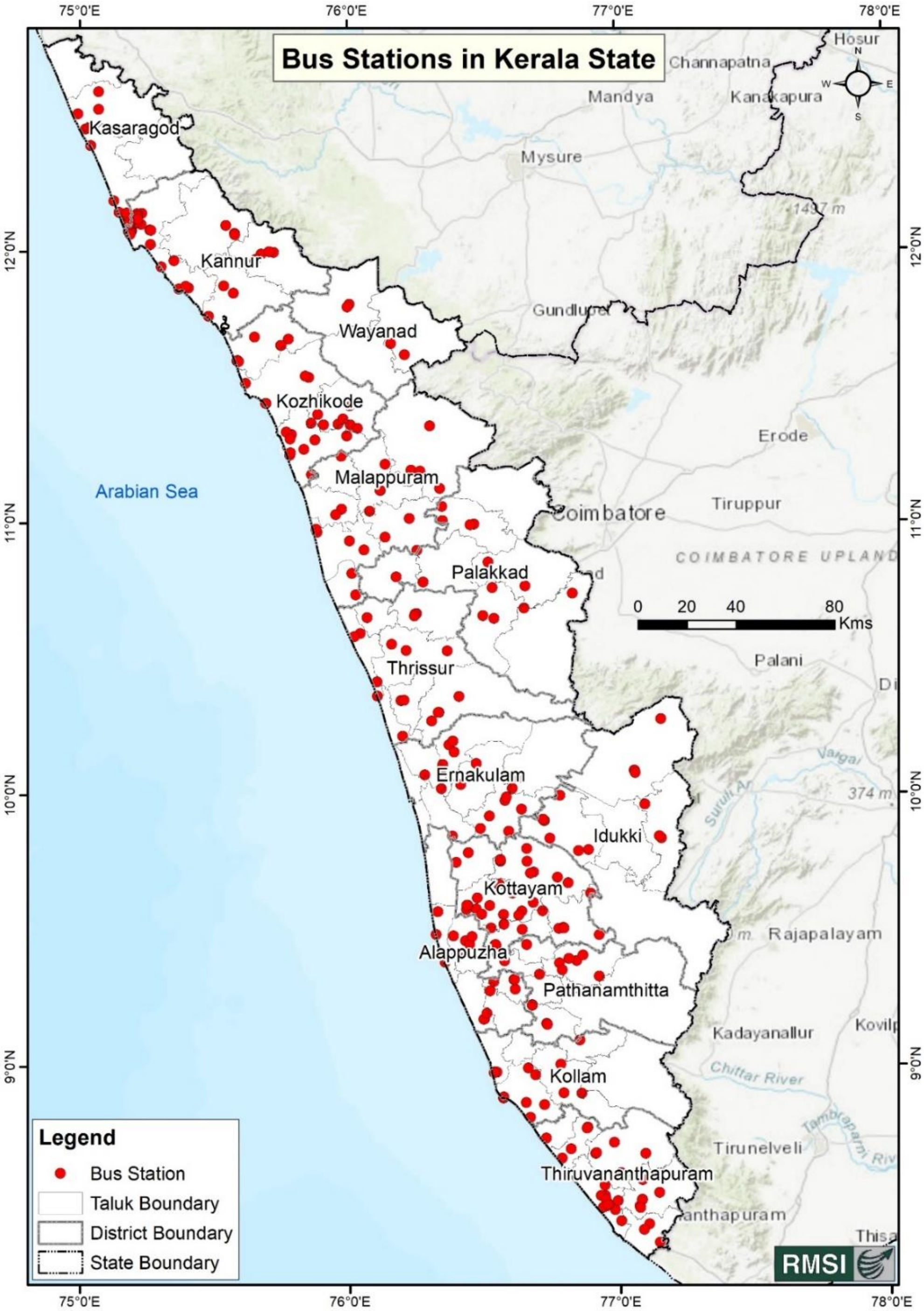

Figure 3-26: Map showing bus station in Kerala
(Source: KSDMA)

3.2.1.15 Land use/ Land cover

Land use and land cover data of 2015-16 and 2020 in polygon feature format has been received from the KSDMA for the entire Kerala state. Figure 3-27 shows the available classes of Land use\ Land cover data in 2015-16 and Figure 3-28 shows the available classes of Land use\ Land cover data in 2020.

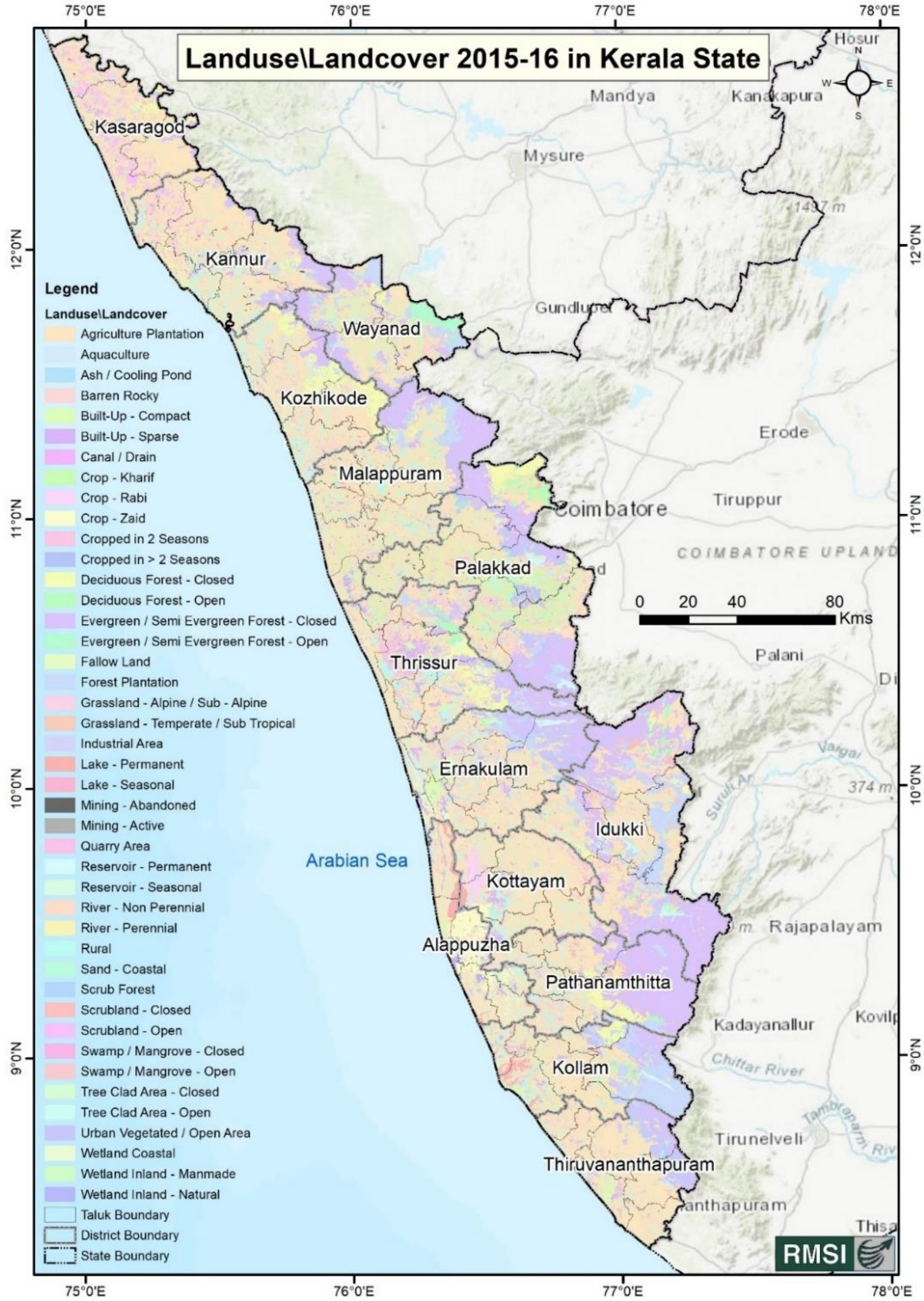

Figure 3-27: Map showing Landuse\ land cover coverage2012-16 in Kerala (Source: KSDMA)

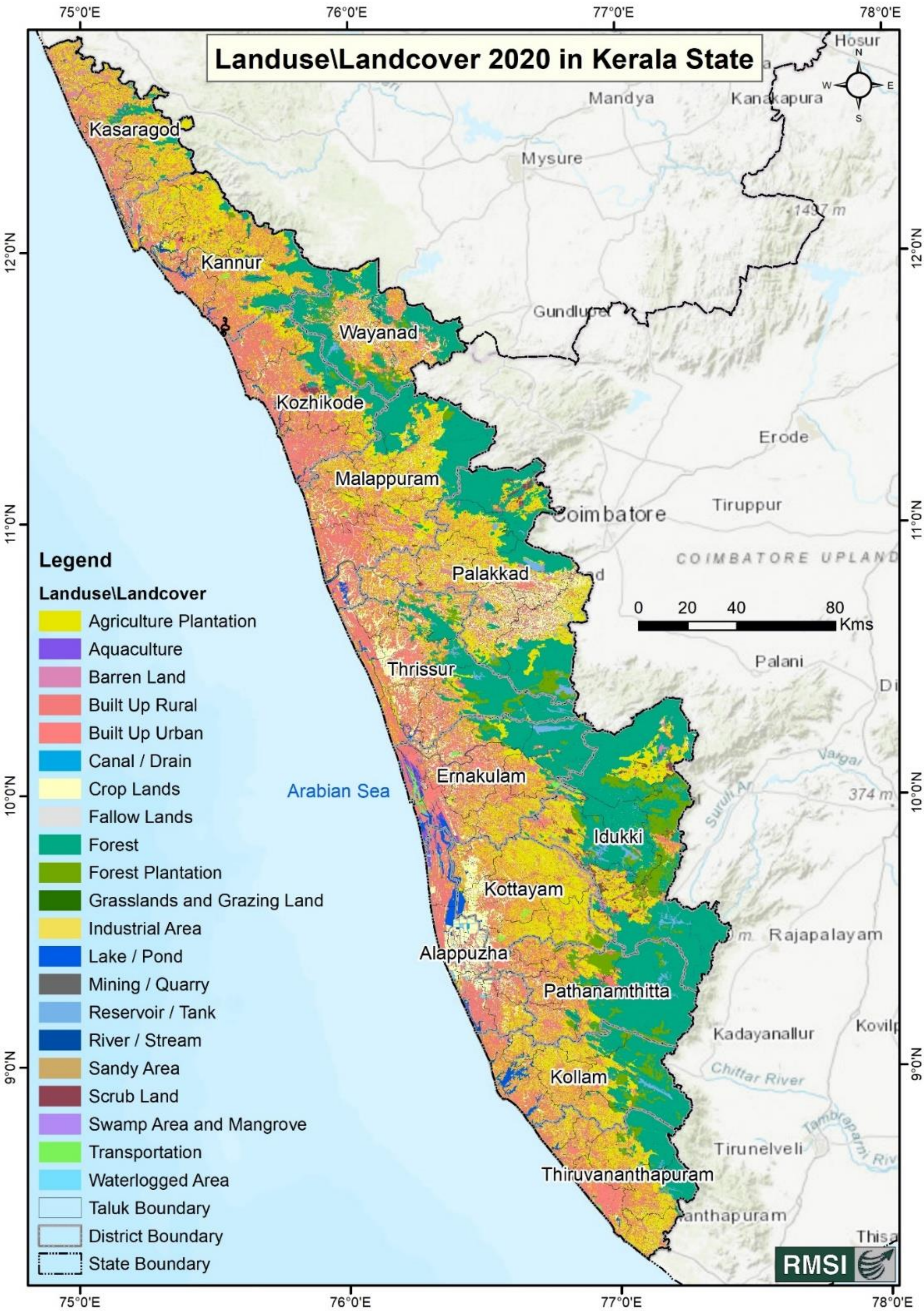

Figure 3-28: Map showing Landuse\ Landcover coverage2020 in Kerala (Source: KSDMA)

3.2.1.16 Demographic data

Population and household data has been provided by the KSDMA for the Kerala state at village level. The data received from the KSDMA includes 1034 villages. Source for population and household data is the Census of India 2011. Population disability and age above 60 population data also received from KSDMA.

Figure 3-29 shows the spatial distribution of age above 60 populations in Kerala state

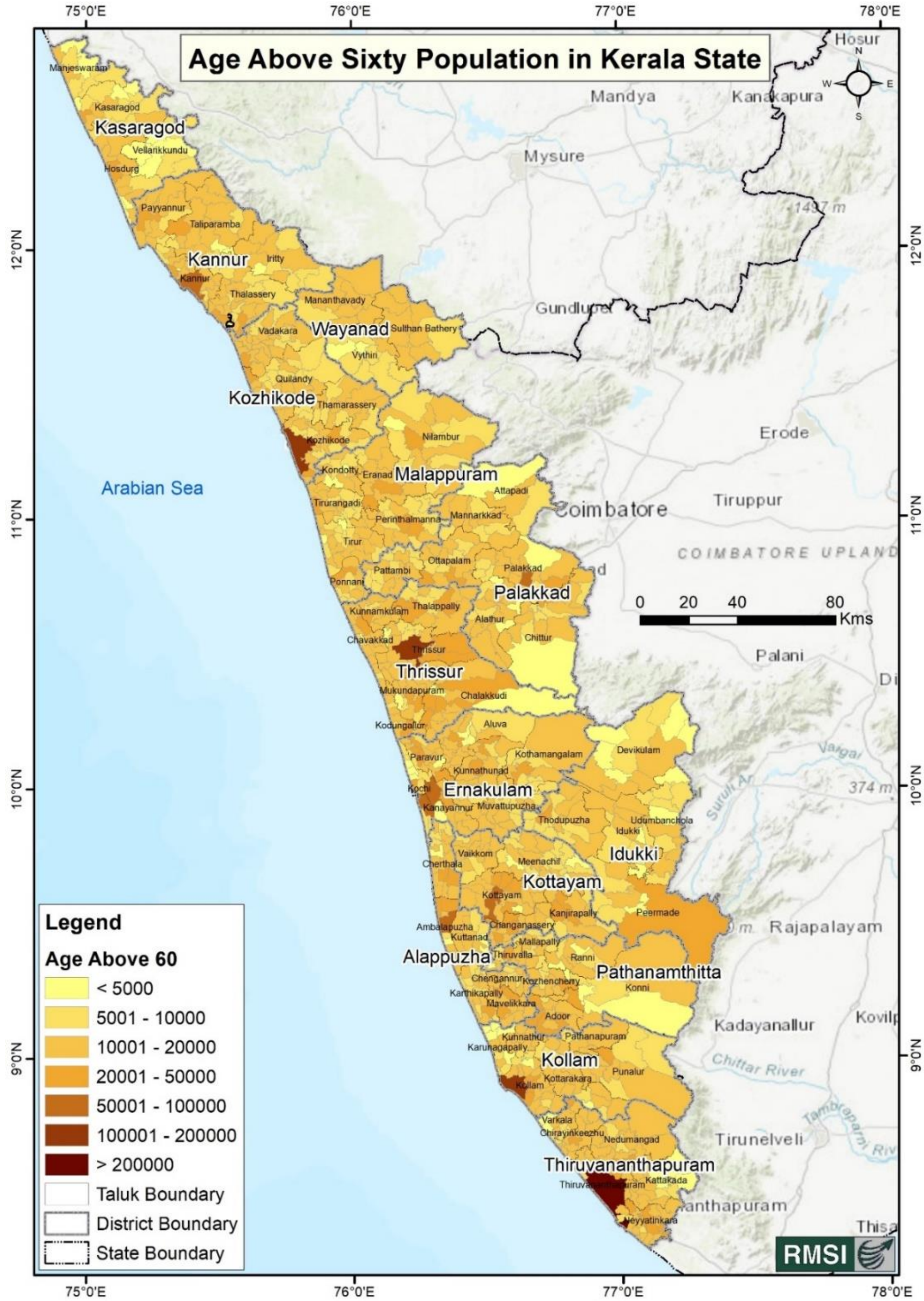

Figure 3-29: Map showing age above 60 population distribution in Kerala (Source: KSDMA)

3.2.1.17 Vulnerability Analysis

The vulnerability assessment is a very complex phenomenon, which needs very comprehensive understanding of hazard and its interaction with elements at risk. There are several ways by which the damageability can be defined. RMSI Team will develop the vulnerability curves for Kerala using the following approaches:

- Historical damage datasets
- In-house available vulnerability curves (with appropriate modifications)

Historical Damage Data:

The most straightforward way, but requires good quantum of data, is to derive vulnerability curves using actual damage data from past events. Project team will collect as much damage data as possible from the past events, from the relevant departments/ agencies or from global sources for developing the vulnerability curves.

In-house available vulnerability curve:

By virtue of implementing NCRMP project (Phase-1 & II), RMSI has vulnerability curves readily available for different exposed elements for major hazards for Kerala state. Sample vulnerability curve (developed by RMSI) for residential building types has been shown in Figure 3-30.

The team will suitably update/ modify the available vulnerability curves based on the above information to generate the applicable damage curves for the state of Kerala.

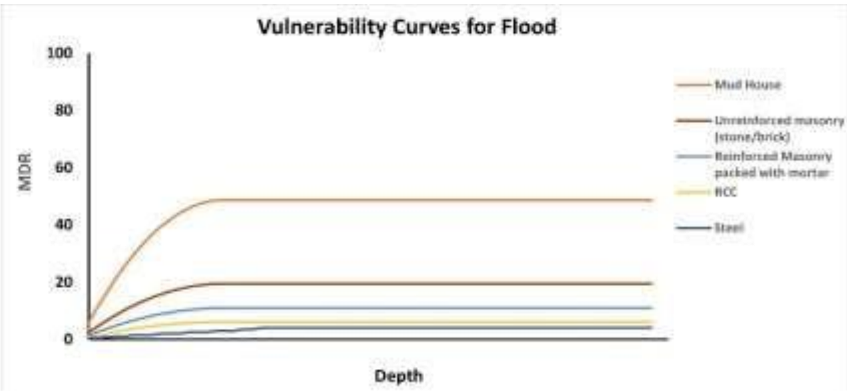

Figure 3-30: Vulnerability curves for residential building types due to floods (sample)

3.2.1.18 Catastrophe Risk Model

A Catastrophic Risk Model will be developed, calibrated and validated with major historical events where loss data is available. For each of the historical events, the model will run on current exposure developed to obtain modeled loss today ("as-if" analysis). This modeled loss will be then compared with observed/ reported loss. To make the comparisons meaningful, the observed losses will be disaggregated by peril, different admin levels, and economic sector, wherever required, using the available information.

Development of Calibrated Risk Parameters: The assessment of risk starts with the estimation of losses to an exposure (a portfolio of assets) for every historical or stochastic event for which the hazard is assessed. These losses will be used to generate an Event Loss Table (ELT) for that exposure with columns of Event ID, Loss, Annual Rate of Occurrence and Standard Deviation (in a simplified form). Two most important risk metrics generated using an ELT are Average Annual Loss (AAL) and the Loss Exceedance Curve (LEC).

AAL is calculated using the following equation:

$$\sum_{i=0}^{n} L(i,j) * R(i)$$

Where,

L (i,j) = Loss for event 'i' and exposure type 'j' R (i) = Rate of occurrence of even

The abscissa of the LEC is loss and the ordinate is the probability of loss. Small losses occur frequently and large losses occur rarely, so the curve slopes downward to the right. The probability weighted average of all possible losses is the Average Annual Loss, or AAL, which is the area under the LEC curve. LEC or EP curves are used to read the losses for key return periods, such as 5, 10, 25, 50, 100, 200, 500, and 1,000 years or as agreed in TOR.

Estimation of Economic/Financial Loss and Damage

The direst economic loss will be calculated in terms of monetary value which happens due to the direct impact of flood on different exposure elements. The loss typically is quantified as the replacement or repair cost. The content values of the assets are also considered here. Loss is a function of the damage ratio translated into currency loss by multiplying the damage ratio by the value of exposure at risk.

L = MDR(j,h) * Value_At_Risk(j)

Where:

MDR(j,d) = Mean Damage Ratio for an exposure type 'j' at a specific flood depth 'd' Value_At_Risk(j) = Replacement cost of the exposure type 'j'

Return Period is explained as follows. For example, by "25-year loss" we mean a loss that will occur on average once every 25 years, given what we know about the hazard, exposure, and vulnerability. Such a "25-year loss" in actuality has a 1/25 = 0.04 probability or 4% chance of exceedance in any given year. Similarly, a "100-year loss" has 1/100 = 0.01 probability or 1% chance of exceedance in a year.

A final report presenting the risk profile by risk zone (e.g., hazard, direct losses, population losses, agricultural losses, and emergency losses) of Kerala will be submitted to the client. Brochures on catastrophe risk profiles for the state of Kerala will be drafted from the final report in a didactic manner to inform and sensitize policy and/or decision makers in the state (e.g., visuals, hazard maps, risk maps). The team will design and develop a template and will take approval from the client before utilizing the same for developing the brochure.

4

Development of Risk Financing Strategy for Kerala State

4 Development of Risk Financing Strategy for Kerala State

As the frequency and severity of climate extremes continues to rise, governments have to consider new ways of meeting the growing financial consequences of natural disasters. In post-disaster situations, the requirements for critical and rapid expenditures can lead to governments using slow or expensive instruments, such as budget reallocations or borrowing on unfavorable terms. In an attempt to be better financially prepared for disasters, there is an increasing interest amongst governments in implementing comprehensive sovereign Disaster Risk Finance strategies, defined by World Bank Group (2014) as "the bringing together of pre- and post-disaster financing instruments that address the evolving need of funds – from emergency response to long-term reconstruction – and are appropriate to the relative probability of events".

This study aims to build an institutional capacity on disaster risk financing and risk transfer mechanism suitable for the state of Kerala. Disaster risk financing and transfer methods would consider both sovereign risk financing and private insurance instruments, examining the available risk financing and transfer methods currently available, evaluating them in terms of its suitability and enabling the state to take certain important policy decisions to strengthen the existing disaster risk financing framework. The major scope of the DRF strategy that will be undertaken in this study, is presented below.

4.1 Scope of DRF Strategy for the State:

1. Examine the current DRF structure of the State - Extent of Contingent Liabilities, Govt. Priorities on DRF/ Budgetary resources/ Post Disaster Budget allocations, etc.
2. Examine the current WB Disaster Risk Financing Framework
3. Study Existing Insurance Options (Govt. Schemes- Housing Schemes, Group Insurance- Life PA & Health for Govt. Employees/SHG/Fisherman etc.) – Competitive Risk solutions (CAT Risks) for different types of Assets – Residential & Govt. Buildings, Public Assets including critical infrastructures
4. Work out appropriate risk protection covers for different sections of people including vulnerable sections (BPL/APL) of the society (yellow/pink/blue ration card) through direct and indirect insurance models.
5. Develop Parametric Insurance solutions for the selected NatCAT perils.
6. Evaluate various Risk Financing options including augmenting revenue/ minimizing financial liability/ DRR measures.
7. Examine other risk transfer solutions like Captives, Risk Pools, ART (Alternative Risk Transfer) products/ Sovereign Bonds/Contingent Credit Bonds, etc.

India is one of the most vulnerable countries for disasters. A series of disasters (2015 to 2022) impacted most of our states, particularly, Tamil Nadu, Kerala, Maharashtra, Gujarat, Orissa, and Assam, etc. The state of Kerala also experienced natural catastrophic events during the last 5 years, starting from 2017 – Cyclone Ockhi, the 2018 and 2019 floods, and various landslides, etc., causing huge financial losses resulting from massive damages to buildings, critical infrastructure, crops, animals, and human life and also causing a huge environmental and ecological imbalance. These natural disasters cause not only a huge financial loss to the individuals and residential houses, public assets, and critical infrastructures as they are highly vulnerable to the disasters, they also cause a huge financial liability to the Government by way of immediate mitigation response, rescue and relief measures, and rebuilding the housing and critical infrastructure. All these lead to a huge protection gap and fiscal deficit to the state.

This necessitates a need to develop a sustainable Disaster Risk Financing mechanism, which would help in building an ex-ante disaster relief fund reducing the financial burden on the people, industries and commercial organizations, and the Government. This requires evaluating the various risk transfer mechanisms including risk pool, insurance, and reinsurance solutions, and suggesting the appropriate risk mitigation measure which can help in an optimum risk financing solution to reduce the financial liability significantly and also use sustainable resources necessary for rebuilding the infrastructure with adequate risk protection to human life and property.

The countries, which adopted the Sendai Framework for Disaster Risk Reduction (SDFRR, 2015-2030), aim to achieve a substantial reduction in disaster risk and losses from extreme events by adopting a comprehensive Risk Transfer Mechanism including direct and indirect insurance, reinsurance, risk pool, and alternative Risk Transfer Mechanisms like ART and Parametric risk solution, etc.

The primary objective of Risk Financing is to examine the various risk financing and transfer mechanisms available for effective risk reduction or mitigation and evaluate them in terms of the pros and cons of each risk financing measure to identify the most effective and efficient disaster risk financing strategy for the state.

The Government of Kerala has implemented many schemes, policies, and programs such as government housing subsidy program, group insurance – life, personal accident, health insurance, state crop insurance, group accident insurance for fishermen, etc., to protect the people from natural catastrophic events, which can be seen as risk transfer mechanisms. Similarly, there are many risk financing mechanisms such as SDRF, SDMF, CMDRF, budgetary allocations, also already available in the State. However, these existing risk financing or risk transfer mechanisms are inadequate for meeting the losses and damages caused by natural catastrophic events in recent times, creating a heavy financial burden on the State and the people. Particularly, the costs of rebuilding the damaged property and houses, and critical infrastructure like roads, bridges, airports, etc., after the disasters are the major financial liabilities for the State government. Secondly, the insurance protection gap (difference between the economic loss and insured loss) is also very high (more than 90%) in the State, which leads to greater financial requirements for the State to provide relief and rebuild property and infrastructure. Thus, it is essential for the State to consider the suggested risk financing and risk transfer mechanisms for effective disaster risk management.

4.2 Disaster Risk Financing Framework (adopted by the World Bank)

Examination of various documents available with World Bank sources indicates that disaster risk financing basically starts from risk assessment of the disasters to risk prevention and reduction, risk preparedness, risk financing, and building risk resilience (Figure 4-1). Disaster risk assessments are done using natural catastrophic (NatCAT) risk modeling which help assess the hazard probability of the disaster events and help identify disaster prone regions and vulnerability of human populations. Further, hazard, exposure, vulnerability and risk assessment provide details on the risk matrix (AAL, LEC, PML, etc.). The risk matrix can help in preparing for the disaster risk prevention and reduction activities in advance. Risk prevention and disaster risk reduction measures (like land use planning, building codes, coastal protection, livelihood diversification etc., can help in preventing the possible hazard from happening and most effectively it would enable in reducing the loss severity of the property damages and people loss from the disasters. It will also aid in early warnings, evacuations, and contingency planning, etc.

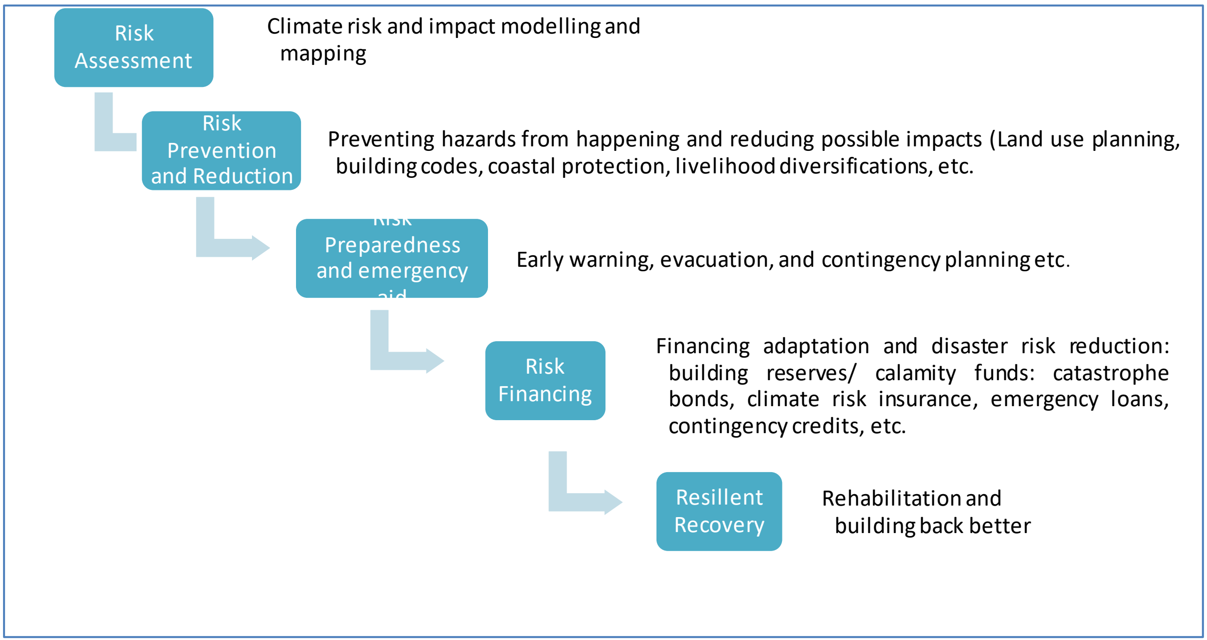

Figure 4-1: Framework on Disaster Risk Financing (Source: World Bank Framework on Disaster Risk Financing)

Risk financing activities basically focus on evaluating various risk financing, disaster risk reduction, and risk transfer mechanisms. These include building reserves, developing ex-ante disaster risk funds or pools, climate risk insurance, parametric insurance, and also examining various alternative risk transfer mechanisms like catastrophe bonds, captives, emergency loans and contingency credit bonds, etc. The final objective of disaster risk financing is to ensure that people, communities, and government buildings are more disaster risk resilience through climate risk reduction, rehabilitation, and rebuilding back better.

4.3 Existing Disaster Risk Financing Structure of the State

The study examined the current DRF structure of the State - different funding mechanisms that are currently available in the state for disaster risk financing. i.e. mainly SDRF, NDRF, and CMDRF, etc., and understand the primary purpose for which they are being used; whether they are mostly used to finance disaster relief measures or part of it is being used for disaster risk mitigation measures and other developmental purposes, etc. The team has collected the details of these various funds and existing amounts of funds available up to 2021 and Post Disaster Budget allocations, etc.

As per the recommendations of the XV Financial Commission, the state maintains two types of Disaster Mitigation Funds, namely, State Disaster Response or Mitigation Fund (SDRF) and State Disaster Risk Management Fund (SDMF). The allocation of the funds is made in a ratio of 75% to SDRF and 25% to SDMF. However, as per 2020-21 budget estimates, the ratio of these allocations were revised and now stand at 80% for SDRF and 20% to SDMF.

4.3.1 State Disaster Response Fund (SDRF)

In SDRF allocation of 80 per cent, there are three sub-allocations: response and relief (40 per cent), recovery and reconstruction (30 percent), and preparedness and capacity-building (10 per cent). While the funding windows of SDRF and SDMF are not interchangeable, there is flexibility for re-allocation within the three sub-windows of SDRF. Brief details of SDRF and SDMF of the state from 2015 to 2021 is given below:

Following are the details of SDRF fund statistics from 2015 to 2021.

Out of this SDRF, 10% of the fund may be used for state-specific disasters. The expenditure on the procurement of essential search, rescue, and evacuation equipment, including communication equipment, etc., for disaster response is to be incurred from SDRF only. Expenditure on such account should not exceed 10% of the annual allocation of the SDRF. The expenditure for capacity building should not exceed 5% of the annual allocation of SDRF.

The major expense incurred by the State is for the repair to houses, repair and restoration of damaged roads and bridges, and food and clothing distribution due to floods. Funds for Covid 19 containment also were drawn from SDRF subject to the norms set by Government of India. As a result of continuous floods in 2018, 2019, and 2020, the expense from the heads of account on flood was high. The major expense of the government went towards grants for house damages. Since the SDRF was not adequate in meeting the relief and response cost of floods, funds from the CMDRF were dovetailed with assistance under SDRF to enhance the quantum of assistance.

The financial year-wise allocation of the SDRF fund from 2021-22 to 2025-26 is presented below (

Table 4-2): The total SDRF allotted to Kerala for the financial years from 2021- 22 to 2025-26 is INR 1,852.8 crore.

Table 4-1: SDRF Fund Allocation and Expenditure Details (2015 to 2022)

SDRF Fund Allocation & Expenditure (2015-16 to 2021-22)				
Year	**Budget Provision (₹ in Crore)**	**Allotment Amount (₹ in Crore)**	**Expenditure Amount (₹ in Crore)**	**Surrender Amount (₹ in Crore)**
2015 - 16		159.54	135.70	23.84
2016 - 17		220.09	152.39	67.70
2017 - 18		246.05	199.78	46.01
2018 - 19		477.26	8.81	468.44
2019 - 20		1465.59	1366.21	80.96
2020 - 21	1018.05	597.45	500.28	517.77
2021 - 22	903.35	847.42	77.19	731.42

Source: Disaster Management Department, Government of Kerala

Table 4-2: Annual Allocation of fund under SDRF for the period 2021-26

Year	Central Share (75 %) (Rs in Crores)	State Share (25 %) (Rs in Crores)	Total (Rs in Crores)
2021-22	251.2	84.0	335.2
2022-23	264.0	88.0	352
2023-24	277.6	92.0	369.6
2024-25	291.2	96.8	388.0
2025-26	306.4	101.6	408.0
Total	1390.4	462.4	1852.8

Source: XV Finance Commission Report (2021), Volume II

4.3.2 State Disaster Mitigation Fund (SDMF)

The Disaster Management Act, 2005 provides for the establishment of a financial mechanism for mitigation purposes at the national and state levels. The Act states that the State Government shall, immediately after notification of constituting the State Disaster Management Authority, establish for the purposes of this Act a fund to be called the State Disaster Mitigation Fund. Disaster Management Act defines 'mitigation' as measures to reduce the risk, impact, or effects of a disaster or a potential disaster situation.

Accordingly, the State of Kerala has made a budgetary provision such as "State Disaster Mitigation fund' as per the G.O (P) No. 660/2011/DMD for disaster mitigation and prevention. The SDMF allocated for the State of Kerala for the 2021-26 period is ₹463.2 crores i.e., 20% of ₹2,316 crores. The year-wise allocation of the fund for the years 2021-26 as per the report of XV Finance Commission is presented in Table 4-2.

The total amount of accumulated fund (SDMF) for the last 2 years (2021 to 2023) is INR 171.8 crores. The main objective of this SDMF is to implement various risk mitigation activities including preparation, mitigation, and resilience building for the state. For the last 2 years, the state has been implementing various projects towards disaster risk mitigation for effective utilization of the fund. This study will further analyze the risk mitigation activities carried out during the last 2 years and suggest measures to ensure effective utilization of the fund.

4.3.3 Chief Minister's Distress Relief Fund (CMDRF)

CMDRF provides financial assistance to people affected by major natural calamities like flood, drought, fire etc. Educational, cultural, and charitable institutions of a public nature, which are affected by such calamities and whose financial position does not enable them to repair the damage caused to their property are also eligible for financial assistance from the fund. It is an emergency assistance granting relief to deserving families and individuals in case of loss of life, medical treatment for major diseases, etc.

After the 2018 floods, the CMDRF received contributions from thousands of individuals and organizations across India and overseas. CMDRF allotment and expenditure during the period from 2015-16 to 2019-20 in Kerala is presented in the following table.

The CMDRF mobilized a fund value of Rs. 7,043.61 crores in 2018-19 after the devastating floods of 2018. Regarding the allotments (Expenditure), Rs. 4,978.44 crores were spent from the total receipt resulting in a balance of Rs. 2,065.16 crores.

The Government allocated the CMDRF fund of Covid-19 for various purposes of urgent nature such as the distribution of food grain kits to family card holders, for financial assistance to BPL and AAY families, etc. A major portion of the fund had been expended for rebuilding damaged houses / buying land, and building houses. The creation of CMDRF resulted in boosting the mobilization and allocation of funds for various activities. This has helped the Government to respond quickly to distress situations without waiting for external assistance or budgetary funds.

Table 4-3: CMDRF Allotment and Expenditure in Kerala (in Crores)

Year	Allotment Amount	Expenditure Amount	Surrender Amount	Expenditure as a percentage of Allotment
2015-16	159.54	135.70	23.84	85.06
2016-17	220.09	152.39	67.70	69.24
2017-18	244.67	200.41	46.03	81.24
2018-19	7043.61	4978.45	2065.16	70.68
2019-20	1465.59	1366.21	80.96	93.22

Source: http://donation.cmdrf.kerala.gov.in

Table 4-4: Comparison of Average Annual Loss with SDRMF and Recovery & Reconstruction Source: Verisk & Guy Carpenter Study, 2023

Particulars	Amount (in Rs Crores)
Average Annual Loss (AAL)	Rs.1,799 Crore
Uninsured AAL	Rs.1,758 Crore
SDRF	Rs. 419 Crore
Recovery & Reconstruction	Rs. 126 Crore
Ratio of SDRF to AAL	24%
SDRF Funding Gap	76%
Ratio of Recovery & Reconstruction to AAL	7%
SDRF Funding Gap	93%

The present study will also explore the extent of Contingent Liabilities that the state has; what are the priority sectors for which primarily these DRF funding should be used for; what are the budgetary resources allocated for disaster risk financing for the State; and what are the primary basis in which these funds are provided?

Assess State Disaster Risk Exposures through NatCAT Models (Flood, Landslide, Cyclonic Wind, Storm-Surge, and Drought) – Return Period / Exceedance Probability Curve, Exposure, AAL, etc.

Estimating the contingent liability of the state government requires a thorough understanding of the selected hazards' vulnerabilities and the financial liabilities arising out of the occurrence of these natural disasters. Currently, the state government may not have an estimation of the amount of financial liability, a 1 in 25-year event can trigger. By understanding the loss potential of natural disasters, particularly in terms of frequency of occurrence (1 in 10 years, 1 in 25 years, or 1 in 50 years, etc.,) and its associated financial losses, the state can plan its contingent liability and also the extent of public intervention that it requires in recovery efforts.

4.4 Assessment of SDRF Adequacy

The study will examine the adequacy of the current level of SDRF – particularly available for relief and rehabilitation measures. We will evaluate the adequacy of SDRF by comparing it with actual disaster financial liabilities that a disaster event will cause. For this purpose, the annual average loss and the exceedance curve probabilities generated by the catastrophic risk models will be used along with PML to compare the relief and rehabilitation costs of the current SDRF. This would help measure the adequacy of the disaster risk fund in meeting the relief and rehabilitation costs arising in case of a 1 in 25-year or 1 in 50-year event.

For example, a recent study by Verisk and Guy Carpenters indicates that a one in 25-year event in Kerala state would cause a loss of Rs. 14,000 crores for the recovery and reconstruction of residential building and an average annual loss (AAL) of Rs. 1,799 crores for residential and public infrastructure (

Table 4-4).

The State Disaster Risk Mitigation Fund (SDRMF) was Rs. 419 crores as in 2022, and the recovery and reconstruction fund value were Rs. 126 crores. When we compare this SDRMF value with the (uninsured) Average Annual Loss of Rs. 1,758, we find that the current value of SDRMF fund as well as the recovery and reconstruction fund is highly inadequate causing a financial gap of 76% and 93% respectively. This analysis indicates that the current fund of SDRMF is highly inadequate to meet the recovery and reconstruction value if a 1 in 25-year event strikes the state.

The study will examine what the additional funding requirements are to meet the increasing disaster risk financial liabilities both for relief and rehabilitation measures and for rebuilding or reconstruction of public assets and critical infrastructures. For this purpose, a comparison of the recovery and reconstruction portion of the SDRF and Average Annual Loss (AAL) would be done which would help to measure the SDRF fund adequacy. The total value of the AAL or exposures of all the uninsured units would be compared with the recovery and reconstruction fund of SDRF. It would help the State / Central Governments understand the actual values of the fund's deficiencies and determine the additional financing requirements.

The study will further evaluate the cost implications for utilization of the fund – do cost impact analysis if the part of the DRF fund is used for developmental activities of the state, what amount of fund deficiencies it would contribute to, and what sectors significantly get affected? Besides, it will analyze how important it is to have sufficient funds being used for the rebuilding or reconstruction of public assets and critical infrastructure.

4.5 Develop Catastrophic Risk Insurance

Study will develop competitive risk solutions (CAT Risks) for different types of assets – residential and govt. buildings, and public assets including critical infrastructures. It will work out appropriate risk protection covers for different sections of people including vulnerable sections (BPL/APL) of the society (yellow/pink/blue ration card) through direct and indirect insurance models. Some of the options that the study will examine are given below:

- Introduce **Climate Risk Insurance** – Property Insurance covering natural catastrophic risks protecting residential and commercial property and critical infrastructures.
- State can adopt **universal coverage** for the entire section of yellow and pink ration cardholders i.e., *38.32 lakh households* – through Group Insurance through Trust or Assurance mode.
- Appropriate cost of insurance shall be estimated with selected sum insured and risks.
- Cover **non-priority subsidy households** (blue card holders) – *22.26 lakh households* through compulsory insurance at **premium subsidy** of 50% (State pays 50% & household pays 50%).
- On a priority basis, Govt. can cover **vulnerable people from unorganized groups** in coastal and hilly regions at no cost mode.
- **Full-Cost Mode** for the **non-priority category** (white card holders) with appropriate coverage and cost details, shall be worked out.

The study would examine development of exclusive Catastrophic Risk Insurance based on the disaster risk profile of the regions. While designing the insurance coverage, a minimum sum insured of Rs.10

lakhs to Rs.12 lakhs would be advised based on the agreed value concept of property valuation. This minimum value shall be decided keeping in mind the relocation cost and build-back perspective, irrespective of the type of the house and its location.

- **Residential & Govt. buildings** Property insurance with appropriate coverage, Sum Insured (SI) minimum INR 10/12 Lakhs for total value of property/IDV (relocation and build-back perspective, cost of insurance will be worked out
- **Critical Infrastructures** – Property insurance with appropriate coverage and cost of premium to be worked out.

Similarly, catastrophic risk cover for public assets, including government buildings, and critical infrastructures shall be decided keeping in mind a similar concept and the future value of rebuilding better.

Policy Interventions of the State Government relating to Housing Relief:

As given in the policy guidelines of the state relating to minimum standard of Housing Relief, the following fixed minimum value of relief compensation under SDRF & CMDRF shall be released by the state to the people in the disaster affected regions (Table 4-5).

For the purpose of speedy disbursement of relief measures, the policy guidelines specify the minimum standards to be adopted while assessing housing damages. The Damage assessment criteria has clearly laid down the conditions and what minimum amount of relief shall be disbursed (Table 4-6).

Further, the policy guidelines clearly specify the composition of the assessment team and the assessment methodology using GPS-driven smart phone applications. The following diagram indicates the assessment weightage to be adopted and also the team composition (Figure 4-2).

Table 4-5: Minimum Standards – Housing Relief

% Damage	Hilly Areas (In Rs)		Plains (In Rs)		Total (In Rs)
	SDRF	CMDRF	SDRF	CMDRF	
15	5200	4800	5200	4800	10000
16 -29	30500	29500	28500	31500	60000
30 – 59	51000	74000	47500	77500	125000
60 -74	76500	173500	71000	179000	250000
75 - 100	101900	298100	95100	304900	400000

Source: KSDMA

Table 4-6: Minimum Standards – Damage Assessment Criteria

% Damage	Criteria
15	Knee deep water inside the house with minor damages/10 % or less damage to roof/Electrical or Plumbing damages/Household utensils damaged
16 -29	Water damaged the flooring & electrical or plumbing damages/10-25 % damage to roofing & electrical or plumbing damages/Debris accumulated inside house/50% damage to roofing
30 – 59	Cracks to wall/50% damage to roofing but no damage to the roof structure (for non-RCC roofs)
60 -74	Structural damage to one or more walls but no damage to the roof structure (for non-RCC roofs)
75 - 100	Structural damage to the whole building with total damage to roof (including RCC roof structures)/Total damage to flooring/unliveable as certified by

% Damage	Criteria
	Engineer/Identified as in hazard susceptible area based on site investigation by a team of Geologist/Engineer, Soil Conservation Officer and Hazard Analyst

Source: KSDMA

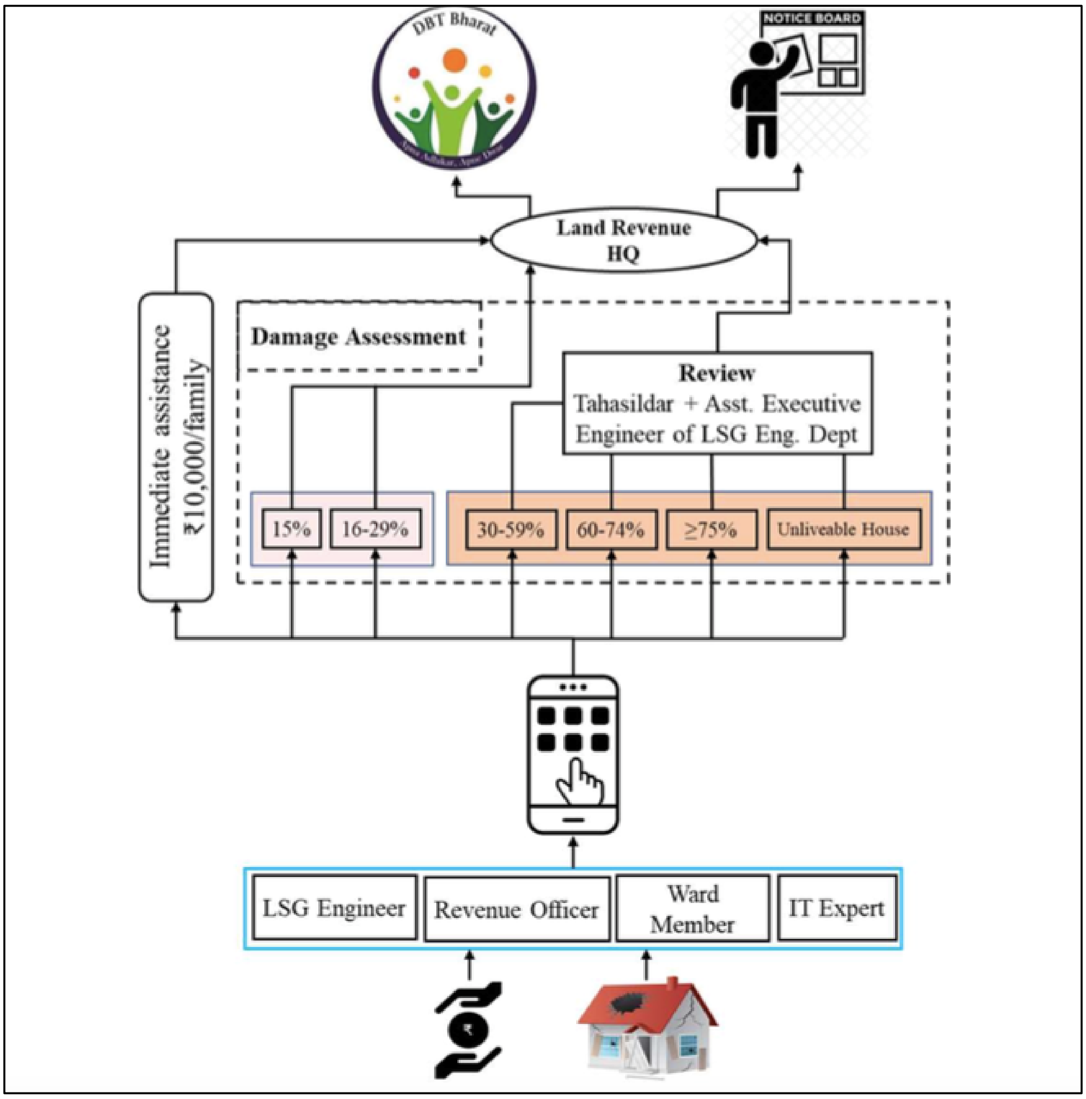

Figure 4-2: Assessment weightage and team composition (Source: KSDMA)

The team comprises of a LSG Engineer, Revenue Officer, Ward Member and an IT Expert who would carry-out a fair and reliable timely assessment of the damages. Once the assessment is done, instantly, a minimum compensation amount as specified in the above table shall be disbursed through computer based direct transfer to the affected person. This methodology would also help in assessing minimum premium rates for the residential houses in the state. Further, the KSDMA has also implemented the standard disaster safety codes to new constructions in disaster-prone regions. The team will consider the above assessment methodology and compensation structure and the minimum sum assured of Rs. 10 to 12 lakhs under agreed value (sum insured) for residential and government buildings while designing the Catastrophic Risk Insurance for the State. The minimum value shall be decided keeping in mind the relocation cost and build-back better perspective, irrespective of the type of the house and location.

4.6 Other Disaster Risk Financing Mechanisms

Apart from Disaster Management Department and Kerala Disaster Management Authority, presently, there are many disaster risk financing mechanisms undertaken by other departments of the government.

The team has carried out a detailed check of the existing insurance schemes available, both government and private for the housing sector i.e., life, housing board insurance subsidy scheme, housing loan waiver scheme, fishermen housing schemes, and tribal housing schemes, support for housing and relocation schemes, SC housing schemes, disaster linked reconstruction schemes, etc. Further, the study would also examine life & group insurance schemes covering life, personal accident and health insurance for Govt. employees/SHG/fishermen etc.).

4.6.1 Group Accidental Insurance Scheme for Fishing Community

This was implemented for fishermen and allied fishermen communities within the age group of 18-60. These are those fishermen registered under the Kerala Fishermen Welfare Fund Board and enrolled in the Fisheries Information Management System (FIMS) - a database of Fisheries Department. This is a one-year term insurance cover stretching from December 17 to December 16 of the next year, renewable from year to year. This insuring process takes place every financial year in which new fishermen and allied fishermen are enrolled and some of them are cancelled. The insured amount for death and permanent disability is Rs 10 lakhs and for partial disability is Rs 5 lakhs and for hospitalization Rs 25,000/-. The premium amount for fishermen is Rs 342/- and for allied workers of the fishermen community is Rs111/-. The premium amount is contributed from the plan fund of the Fisheries Department.

4.6.2 Kerala State Crop Insurance Scheme

State crop insurance scheme has been operating in the State by the Agricultural Department since 1995 covering 25 major crops grown. This scheme was restructured in 2016-17 by bringing considerable enhancements in the crop loss compensation and the scheme now covers 27 major crops. The participants that contribute to the fund for the operation of this scheme are farmers by providing a registration fee and premium and the State Government contribution. Not only major crops, but minor crops like vegetables, fruits, and apiculture perennial crops are also covered under the scheme. During the financial year 2020-21, an amount of Rs 2,000 lakhs was earmarked for the scheme.

4.6.3 Contingency Programme to meet Natural Calamities and Pests & Disease Endemic

This scheme is intended for creating a buffer stock of seeds of paddy and other annual crops for distribution to affected farmers in the event of natural calamities and resultant crop damages. Assistance for strengthening of funds to prevent breaches during floods and for removal of debris will be on a need-based manner - a much-needed financial support to the affected farmers, and an amount of Rs.750.00 lakh was provided for the scheme during 2020-21.

4.6.4 Pradhan Mantri Jeevan Jyoti Bima Yojana (PMJJBY)

The Scheme was launched in 2015 by the Union Government offering insurance cover to bank account holders in the age group of 18 to 50 years. The age group was extended up to 70 years in the later years. This is a one-year term insurance cover stretching from June 1 to May 31, renewable from year to year. It offers life insurance cover for death due to any cause, and the nominees/ heir will receive the claim amount. The risk coverage under the scheme is Rs.2 lakhs for accidental death and full disability, and Rs. 1 lakh for partial disability. The premium of Rs. 324

per annum is to be deducted from the account holder's bank account through 'auto-debit' facility in one instalment. The insurance was applicable to even persons dying due to Covid-19 who happened to buy this policy in the financial year 2020-21. Those who lost a family member could claim the insurance amount of Rs 2 lakh. The scheme is being offered by Public Sector General Insurance Companies or any other General Insurance Companies who are willing to offer the product on similar terms with necessary approvals and tie ups with banks for this purpose. If you have lost a family member to COVID-19, there is a government insurance scheme that may make you eligible for Rs 2 lakh insurance amount.

4.6.5 Pradhan Mantri Garib Kalyan Package: Insurance Scheme for Health Workers Fighting COVID-19

The Union Government launched this scheme under the Pradhan Mantri Garib Kalyan Package. This is a comprehensive personal accident cover of Rs. 50 lakhs for 90 days to a total of around 22.12 lakh public healthcare providers including community health workers, who might have been in direct contact and care of Covid-19 patients and who may have been at risk of being impacted by the virus. On account of the unprecedented situation, private hospital staff, retired, volunteer, local urban bodies staff, contract staff, daily wage staff, ad-hoc staff, outsourced staff requisitioned by States and Central hospitals, autonomous hospitals of Central and States/UTS, AIIMS & INIs of Central Ministries were also covered subject to numbers indicated by the Ministry of Health, Family & Welfare. This was funded through the NDRF budget operated by the Health Ministry. Actual payment of coverage was undertaken by insurance companies under certification of the authorized Central/ State Government officials.

4.6.6 Others

Some of the other existing risk financing mechanism in the state are mentioned below which are not solely used for the purpose of disaster. The insurance schemes undertaken by the Government of Kerala include Comprehensive Health Insurance Schemes - Rashtriya Swasthya Bima Yojana and Senior Citizens Health insurance scheme by the Health Department; Vidarbha Package, Gosuraksha – Cattle Insurance Scheme, and Duck Insurance by the Animal Husbandry Department; Group Insurance Scheme and Kerala State Life Insurance Scheme by the Kerala State Insurance Department for government employees;

General Insurance Branch include Fire Insurance Branch, Marine Insurance Branch, Miscellaneous Insurance Branch, Act Liability Insurance, Motor Accident Claims Tribunal Cases by the Kerala State Insurance Department; and Insurance of Commercial Vehicles by the Motor Vehicle Department. There are many other programmes and schemes undertaken by the State Government for the welfare of the people and the society, which also come under the risk financing mechanism. Some of the welfare funds like Kerala Motor Transport Workers Welfare Fund Board, Kerala Abkari Workers' Welfare Fund, Kerala Agricultural Workers' Welfare Fund Board, Kerala State Anganwadi Workers' and Helpers' Welfare Fund, Kerala Autorickshaw Workers' Welfare Fund Board, Kerala Co-operative Development and Welfare Fund Board etc., are undertaken by the State Government. Thus, risk financing mechanisms are not a new concept for the Government of Kerala and for its people.

Many schemes, policies and programmes undertaken by the Government of Kerala, in one way or the another, come into risk transfer mechanism. Knowingly or unknowingly, most of these are successfully implemented in the state. To face disasters, there are many risk transfer mechanisms that are already present in the state like SDRF, SDMF, CMDRF, budgetary allocations, State Crop Insurance, Group accident Insurance for Fishermen etc. The State has already many disaster risk financing mechanisms, even though all these are not enough for covering the losses and damages faced by it, creating a heavy burden on the state.

The financial burden from house damage and infrastructural damage after a disaster is one of the major ones. As the assistance by SDRF/NDRF norms and items for house damage and infrastructural loss and damage is comparatively less, the burden falls on the state to compensate the difference of amount as much as possible. The state has to provide a substantial amount so that only a small part of the damage or loss incurred by the people can be given as assistance. In the case of infrastructure, the whole financial burden to rebuild it falls on the state. Thus, it is essential that states like Kerala implement stable, regular, and efficient risk transfer mechanisms to reduce their financial burden due to disasters.

4.7 Development of Ex-Ante Disaster Risk Pool

The study examines the need for developing an ex-ante disaster risk fund and also suggest the appropriate structure of the disaster risk fund or pool (Figure 4-3). The team is evaluating various financing or funding options including ways to increase or augment the funding to mitigate the financial aspects of disasters.

- Need to set up an **ex-ante State Disaster Risk Pool** (SDRF Pool) with a contribution from SDRF, taxes, voluntary donations, funding from corporate under CSR, etc.
- **SDRF pool** can finance not only the cost of insurance, but also costs associated with climate change, sustainable development, disasters, natural hazards for safety and protection of people, and crop, animal, and property damage from disasters.
- Structure of the pool – Accounting (DR Pool Account) & Financing options – SDRFP (State Disaster Risk Fund Pool) – part of SDRF, taxation (cess on property/old bldg./CSR/ Donations)
- Nodal Authority to supervise and regulate matters relating to SDRFP/ DRPA and insurance will be suggested after discussions with various stakeholders.

For the purpose of developing a disaster risk fund or pooling model, different levels of risk layering would be developed using the frequency and severity of disaster events. For each layer, the cost of reinsurance and rate online will be estimated for different perils for the State considering multiple risk scenarios. This information will be very useful for the State Government to understand the cost of reinsurance for different layers in the selection. Similarly, the risk layering model would also estimate direct or indirect insurance costs for every risk and the aggregate risks based on correlation. It would also help the states to determine the amount required to protect these risks through direct insurance solutions.

The study will examine developing an ex-ante Disaster Risk Pool model wherein the pool can directly finance the relief measures and compensations for damages up to Rs. 4,000 crores by direct or indirect insurance. The second layer is where the risk pool can purchase reinsurance protection by way of CAT XL cover for the NAT CAT losses above Rs. 4,000 crores and up to Rs. 20,000 crores with a parametric solution. The third layer, where the NatCat losses exceed Rs. 20,000 crores but are below Rs. 50,000 crores, is the use of alternative risk mitigation strategies, particularly CAT Bonds.

The Disaster Risk Pool can get funding from various local bodies, including social organizations, NGOs, corporate entities, individuals, etc., apart from the State and Central governments. In addition, the unutilized fund, which was allocated for disaster relief, can ideally be parked under the 'Catastrophic Risk Pool', and once the pool has an adequate fund, it can be used to pay for disaster risk losses and damages in the State. This will help expedite relief measures within the State and promote disaster risk reduction. The pool can finance the insurance premium, ensuring adequate risk protection for property damages, life, health, and critical infrastructure for the State.

Such a risk pool will strengthen the State Government's fiscal and financial resilience through a Pooling Fund for Disasters. This pool will become the central mechanism through which post-disaster financing can flow from different sources. The pool will look to leverage domestic and international markets to provide financial capacity to strengthen the pool.

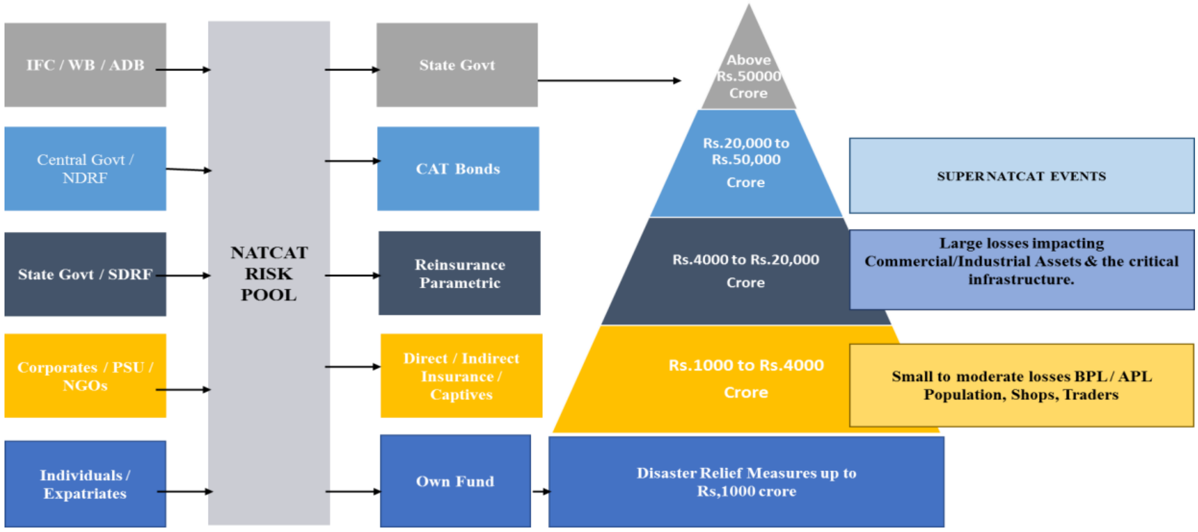

Figure 4-3: Proposed Disaster Risk Pool

4.8 Parametric Insurance with Reinsurance support

Parametric Insurance is index-based insurance wherein the coverage is given on the occurrence of a catastrophic natural event (flood, cyclone, drought, etc.) resulting in a breach of the selected parameters on a fixed severity scale or trigger point. Parameters can be the weather perils (rainfall/precipitation, temperature, wind speed, etc.) applied over fixed locations during a predefined period (May to October, October to January). Parametric Insurance provides an immediate pay-out with a recourse action (% of sum insured) on post-loss assessment to the insured population in the affected location. The loss shall only be admissible if the Nat-Cat event has breached the set parameters for a given location or an area.

Swiss Re Corporate Solutions states that “Parametric Insurance or index-based insurance solutions are a type of insurance that covers the probability of a predefined event happening instead of indemnifying the actual loss incurred”. National Association of Insurance Commissioners (NAIC), Washington, has stated, “The term parametric insurance describes a type of insurance contract that insures a policyholder against the occurrence of a specific event by paying a set amount based on the magnitude of the event, as opposed to the magnitude of the losses in a traditional indemnity policy”. As per Munich Re, “The basic concept of parametric solutions is quite simple: parametric insurance covers the probability of a predefined event happening (e.g., a major hurricane or earthquake) and paying out according to a predefined scheme instead of a lengthy claims adjustment process”.

Need for Parametric Insurance Solution: The frequency and severity of natural catastrophic events are rising now due to climate change and not all the perils/ losses are covered under traditional insurance schemes. Most of the catastrophic perils are offered as add-on covers under conventional insurance. On average, most of the Indian states have 95% of uninsured losses caused by natural catastrophic events. Parametric Insurance is simple index-based insurance that provides an instant payout to the insured, which can be immediate relief in times of crisis. Unlike traditional Insurance, there are no exclusions and deductibles. Customized parametric products for each risk exposure at a given location can be designed for major perils like floods, cyclones, landslides, etc.

In the above case, the Airport in Taiwan was covered by Parametric Insurance for a maximum loss of USD 2 million (Figure 4-4). The parametric insurance was based on the cyclone path and the severity of the cyclone. Under this parametric Insurance, depending on the severity of the cyclone (Category 2, 3, 4 & 5) occurrence at the selected location, the predefined % of insured value was paid to the insured. For instance, in this case, a category-III cyclone had breached the outer circle of the airport within a 100-meter radius. Referring to the payout structure of the scheme, a claim payout of $ 0.50 million, which is 25% of the maximum insured amount of $2 million, was immediately paid by the insurance company (AXA Insurance company). Thus, parametric Insurance provides an instant payout to the insured. Today, with the availability of Block chain technology and Artificial Intelligence, the payout can be automated on the occurrence of the predefined events triggering the strike points at the selected location.

Figure 4-5 exhibits the various parametric insurance solutions available in developed markets. As seen in the diagram, different types of parametric insurance cover various natural catastrophic events, i.e., earthquakes, cyclones, Storms, Floods, Business interruptions, etc.

REAL TIME APPLICATION OF PARAMETRIC PRODCUTS

Cyclone Protection Cat in a circle concept. Airport in Taiwan

Problem
An airport is looking for an insurance coverage that could protect against the loss of revenue due to the property damage as well as against the decline in passenger traffic after a tropical cyclone that passed through the areas Concern points High level deductibles, exclusion in terms of goods that are covered by traditional insurance.

Parametric Solutions
It is customized to client's tropical cyclone exposure. A client chooses a radius to create a circle around the insured locations. If a cyclone tracks through the circle, a payout triggered depending on the pre-determined speed/ category. The amount is pre-defined in the payout table.

Working
A loss of 0.5 Mn was paid in the year 2017-18 for CAT 3 which has breached outer circle.
Payout limit- $2 Mn x 25%(as CAT 3 breached 100 km)

Parametric Insurance Cover			
Index	Cyclone path and scale		
Threshold	Cat 2 cyclone inside the 100 km circle		
Payout Structure	Radius	50 Km	100 Km
	CAT	Payout (%) of Insured Value	
	CAT 2	25 %	0 %
	CAT 3	50 %	25 %
	CAT 4	75 %	50 %
	CAT 5	100 %	75 %
Max Payout Limit	USD 2 Mn per event		
Exit	Cat Cyclone inside the 50 km circle		

There are two circles:
Inner is with radius of 50 Km
Outer is with radius of 100 Km

Source: Webinar AXA XL and AXA Climate Parametric Insurance accessed on March 27, 2021

Figure 4-4: Applications of Parametric Insurance

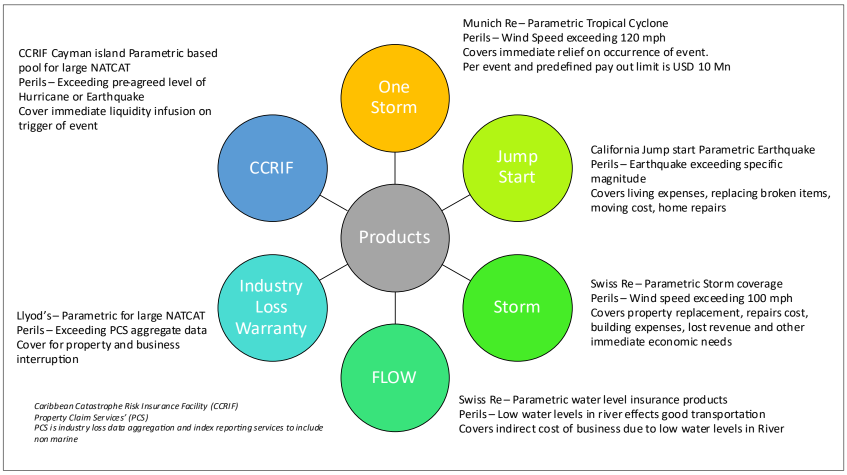

Figure 4-5: Existing Parametric Insurance products

Lloyds has introduced a Parametric Insurance solution for the Large Natural Catastrophic Perils covering the Caribbean region providing compensation for property damage and business interruption losses. Munich Re's parametric insurance covers tropical cyclone perils wherein when the wind speed in the selected areas exceeds the pre-agreed trigger points, i.e., 120 miles per hour, the insurer automatically compensates the insured for the pre-agreed percentage of loss on the sum insured. Swiss Re parametric covers storm-related perils with a wind speed exceeding 100 miles per hour. This cover provides immediate relief for property replacement, repair costs, business expenses, lost revenue, and other economic needs.

A similar Parametric Insurance solution can be structured for disaster risks in the State of Kerala, covering all the major districts and critical infrastructure. Figure 4-6 and Figure 4-7 explain the product design and structure for disaster risks.

A parametric insurance cover was designed by Tata AIG Insurance Company & Swiss Re for the State of Nagaland. The case experience of Parametric Insurance designed for disaster risks in the selected locations of Nagaland State is discussed below.

This cover provides immediate relief to the insured persons in the selected localities of Dimapur, Kohima, Wokha, Zuheboto, Mokokchung, and Nagaland, in the occurrence of disasters chosen risks from 1st June 2020 to 31st March 2021. The parameters triggering the defined precipitation/rainfall trigger index was exceeding 385 mm cumulatively in 7 consecutive days in any month of the policy period.

The product has two strikes I & II. Strike-I, where the cumulative index exceeds 385 mm but is less than 405 mm, 15% of the sum insured will be paid as the pay-out. For Strike 2, if the cumulative index exceeds 405 mm but is less than 435 mm, 45% of the sum insured is paid to the insured. The Exit strike rate is 435 mm, where if the cumulative rainfall exceeds 435 mm, then 100% of the sum insured is paid as compensation to the insured.

Thus, the **main advantage of parametric insurance** is an **immediate payment of claims** - the claims settlement process in parametric insurance can easily be automated and claims can directly be credited to the insured accounts without the customers having to report the losses to the insurance company. Secondly, the **premium under parametric insurance could comparatively be cheaper,** and most importantly, the **coverage can be customized for a particular region** or a specific location covering the most prominent NAT CAT perils in the area i.e., flood, cyclone, lightening, landslide, and forest fire, etc.

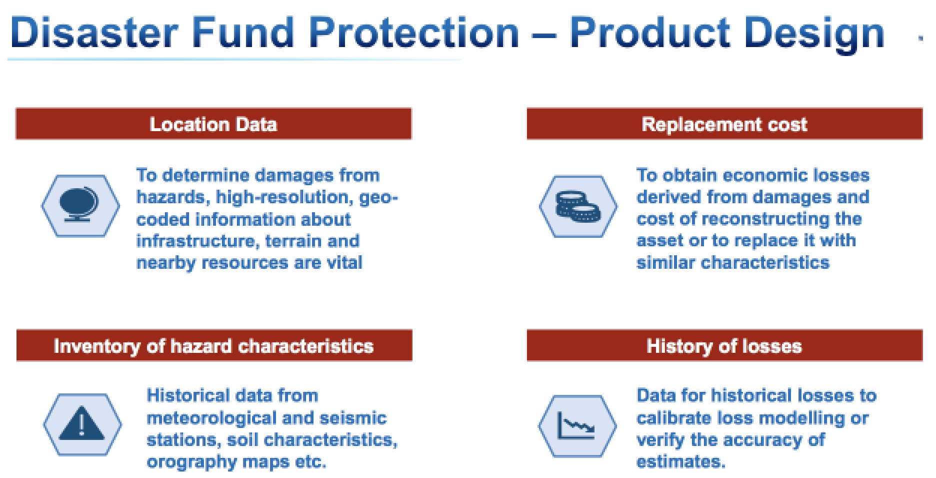

Figure 4-6: Parametric Insurance for disaster risks

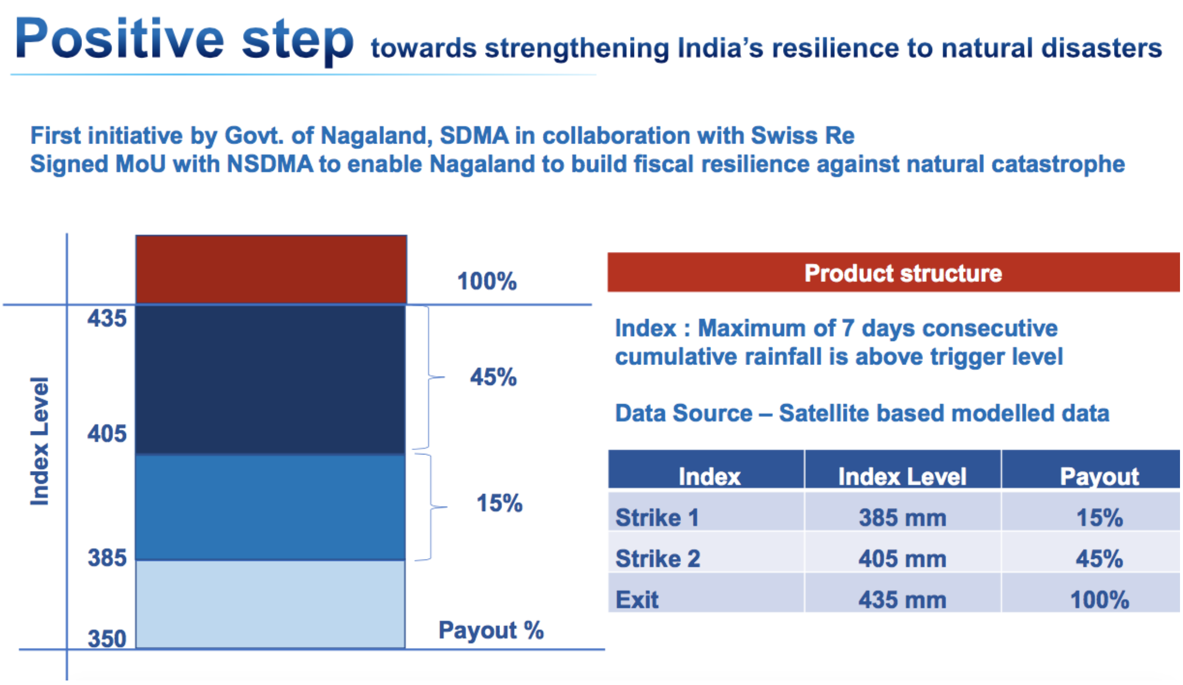

Figure 4-7: Parametric Insurance for disaster risks – product structure

4.9 Examine other risk financing and transfer mechanisms

The study team will examine other Risk Transfer solutions like captives, risk pools, ART (Alternative Risk Transfer) products/ sovereign bonds/contingent credit bonds, etc. In this regard, the team has already collected details about various risk pools available in other developed markets. Some of them are given below:

Risk Pools - Sovereign Schemes:

- ARC – African Risk Capacity
- CCRIF – Caribbean Catastrophe Risk Insurance Facility
- PCRIC –Pacific Catastrophe Risk Insurance Company
- FONDEN – Fund for Natural Disasters

Government Sponsored Risk Pools

- EQC – Earthquake Insurance Cover provided by New Zealand Government for home and residences.

- TCIP - Turkish Catastrophe Insurance Pool
- CEA – California Earthquake Authority
- FLOOD RE Flood Re is a joint initiative between the Government and insurers in UK. Its aim is to make the flood cover part of household insurance policies more affordable.
- Norsk Naturskade Pool – Norwegian Natural Catastrophe Risk Pool

CCRIF

In 2007, the Caribbean Catastrophe Risk Insurance Facility was formed as the first multi-country risk pool in the world and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. In 2014, the facility was restructured into a segregated portfolio company (SPC) to facilitate offering new products and expansion into new geographic areas and is now named CCRIF SPC. It is owned, operated, and registered in the Caribbean.

CCRIF SPC limits the financial impact of natural hazard events to Caribbean and Central American governments by quickly providing short-term liquidity when a policy is triggered. CCRIF offers parametric insurance policies for tropical cyclones, earthquakes, excess rainfall and the fisheries sectors.

FONDEN

FONDEN (Natural Disasters Fund), Mexico's fund for natural disasters, was established in the late 1990s as a mechanism to support the rapid rehabilitation of federal and state infrastructure affected by adverse natural events. FONDEN was first created as a budget line in the federal expenditure budget of 1996 and became operational in 1999. Funds from FONDEN could be used for the rehabilitation and reconstruction of

1. Public infrastructure at the three levels of government (federal, state, and municipal);
2. Low-income housing; and
3. Certain components of the natural environment.

FONDEN consists of two complementary budget accounts, the FONDEN program for reconstruction and FOPREDEN program for prevention, and their respective financial accounts. The FONDEN program for reconstruction is FONDEN's primary budget account. It channels resources from the federal expenditure budget to specific reconstruction programs. The FOPREDEN program for prevention supports disaster prevention by funding activities related to risk assessment, risk reduction, and capacity building on disaster prevention. The FONDEN system is continuously evolving to integrate lessons learned over the course of years of experience[39].

Turkish Catastrophe Insurance Pool is a compulsory Earthquake Insurance Scheme.

The introduction of the Turkish Catastrophe Insurance Pool (TCIP) in 2000, provides a reliable method for compensation to homeowners in Turkey without reverting to government budget, and social solidarity and risk sharing are effectively maintained through payments of affordable insurance premiums. The World Bank helped the Turkish Government develop the Turkish Catastrophe Insurance Pool (TCIP) to limit the financial burden earthquakes place on the government budget, focus government relief funds on low-income residents, and access international reinsurance capacity in a cost-effective manner.

The TCIP is a legal public entity that provides compulsory property earthquake insurance for owners of private dwellings built legally on registered land. Premium rates are actuarially sound, not subsidized, and vary with construction type and property location. Covered risks include earthquakes and fire. The catastrophe risk financing strategy of the TCIP relies on

[39] Source: World Bank. 2012. FONDEN: Mexico's Natural Disaster Fund--A Review. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/26881 License: CC BY 3.0 IGO."

both risk retention and reinsurance. The TCIP retains the first USD 80 million of losses through its reserves (initially complemented by a USD100 million World Bank contingent loan facility) and transfers excess losses to the international reinsurance markets. The Turkish Government covers losses that would exceed the overall claims paying capacity of the TCIP, which is currently sufficient to withstand a 1-in-350-year earthquake. Economies of scale are obtained through country-wide pooling of the risk, which results in more affordable premium rates.

Annual premium is around USD 62/homeowner on average, depending on construction type and location. Deductible is 2%. Covered perils are earthquakes and fires following earthquakes Covers Residential buildings that fall within municipal boundaries. Maximum coverage is approximately USD 92,000 per policy (as of Jan. 1, 2009). Policy distribution is through around 30 insurance companies.

The pool, which covers only earthquake risk currently, is expected to provide insurance coverage against floods, landslides, storms, hail, frost, avalanches and other hazards. The developments of this expanded compulsory natural disaster insurance scheme are expected to be completed shortly.

CEA – California Earthquake Authority

With more than 1 million policyholders, CEA is one of the world's largest providers of residential earthquake insurance. Since 1996, CEA has been encouraging California homeowners, mobile homeowners, condo-unit owners and renters to reduce their risk of earthquake damage and loss through education, mitigation and insurance. CEA’s not-for-profit mission makes California residential earthquake insurance affordable and flexible. More than 1 million California policyholders trust CEA’s USD 18 billion claim-paying ability. It helps homeowners, mobile home owners, condo-unit owners, and renters before and after large earthquakes.

It works with 25 participating residential insurance companies to offer California homeowners, mobile homeowners, condo-unit owners, and renters home insurance policies.

FLOOD RE (UK)

Flood Re is a joint initiative between the Government and insurers in UK. Its aim is to make the flood cover part of household insurance policies more affordable. Flood Re is widely hailed as an innovative approach to disaster risk insurance. This paper offers a mixed-methods evaluation of the new pool, asking whether it is “fit for purpose” and “fit for the future.” The investigation considers the roles of the public and private sectors, risk modelling and risk communication, technical underwriting, distributional aspects, and the behavioral implications of Flood Re, particularly with regards to risk reduction and prevention. The paper concludes that the new pool is a transitional reinsurance arrangement that supports the private insurance market and secures affordability of flood insurance in the UK through premium subsidies. However, this approach is likely to come under pressure in the face of rising flood risk as it fails to incentivize flood risk management and risk reduction efforts.

Norsk Naturskade Pool – Norwegian Natural Catastrophe Risk Pool

The Norwegian Natural Perils Pool was formed on January 1st, 1980. Its activities are governed by the Natural Perils Insurance Act and the Rules for the Norwegian Natural Perils Pool. Natural perils insurance is a compulsory cover linked to fire insurance in Norway. All insurers providing fire cover in Norway must be members of the Pool.

The Pool is an equalization mechanism whereby claims and costs are distributed between members in proportion to their share of the Pool, which corresponds to their share of the market for fire insurance in Norway.

Mechanism: The Pool is an equalization mechanism whereby claims and costs are distributed between members in proportion to their share of the Pool, which corresponds to their share of the market for fire insurance in Norway.

Membership: Companies intending to write fire insurance in Norway must immediately contact the Pool to arrange membership in the NNPP.

Procedures: Natural perils premiums are based on the total sum insured against fire are collected and retained by the individual insurer to cover claims and costs are specified in customers' insurance contracts. If the premiums earned exceed the insurer's relative share of claims payments made via the Pool and provisions for outstanding claims, the difference is allocated to a special natural perils reserve at the insurer.

This provision belongs to the insurer and is to be used exclusively to cover future natural perils claims. The premium rate is set by the Pool's board. The premium rate and excess are the same for all insurance segments nationwide. Natural perils claims are settled by the individual insurer and are reported to the Pool as soon as possible using the NINA claims reporting system**.**

Terms for settlement through the Pool: Settlement is governed by the provisions of the Insurance Contracts Act of 16 June 1989 and Natural Perils Insurance Act of 16 June 1989. Insurers settle with their own customers based on their own terms. New terms for settlement through the Pool came in from 1 January 2016. These terms are the maximum that insurers may settle through the Pool and are limited to the insurer's own terms for fire insurance for the damaged object. The Natural Perils Insurance Act will apply nonetheless where it specifies a different extent of cover or calculation of indemnity.

Distribution formula: The distribution formula reflects members' share of the Pool and is calculated on the basis of the total sum insured against fire as at 1 July each year. Companies starting/ceasing to write fire insurance are to report the sum insured against fire on a quarterly basis during their first/last year of membership.

Their share of the Pool in those years is the average sum insured against fire on the final day of each quarter. Until the new distribution formula is available, the previous year's formula is applied temporarily. Insurers' shares for the full year are adjusted once the new formula is available. Pool costs are calculated in January and July which cover the Pool's administration and reinsurance costs. The pool costs are distributed between members in proportion to their share of the Pool.

5 Project (activity) Plan

Task	Deliverables	Target (from effective date of the contract)
Project Inception	• Inception Report	18th March 2024
Component-1	• A geo-referenced catalogue of historical major events - including, tropical cyclones, landslides, and flood in Kerala. The list of parameters to be included in the database will be discussed and agreed with the client. The catalogue will be provided based on a format to be agreed with the client. • Database of historical economic and financial losses caused by natural disasters in the past. • A technical report describing the data collected and their limitations. • Maps of historical hazards and historical losses, for the state of Kerala • Disaster Risk Assessment report	3rd July 2024
Component-2	• A report presenting the risk profile by risk zone (national, provincial and local) (e.g., hazard, direct losses, population losses, agricultural losses, and emergency losses) of Kerala. • Brochures on catastrophe risk profiles for the state of Kerala drafted from this report in a didactic manner to inform and sensitize policy and/or decision makers in the state (e.g., visuals, hazard maps, risk maps). A template will be developed by the consultant and approved by the client. Once the template is approved by the client, the brochure will be professionally edited and provided in both electronic and paper copies.	3rd September 2024
Component-3	• A report presenting the Disaster Risk Finance Strategy for the state of Kerala • Summary of menu of financial options/ instruments, or between different combinations of options/ instruments.	3rd October2024
Component-4	• A report presenting (i) the methodology for the design of prototype (first generation and second generation) parametric risk transfer products for each major peril; and (ii) the proposed prototype parametric risk transfer products	3rd November 2024

Task	Deliverables	Target (from effective date of the contract)
	• A report analyzing the risk profiles of a set of pre-agreed parametric risk transfer product(s). • Dissemination material summarizing the prototype insurance policies and the portfolio analysis (e.g., PowerPoint presentation).	

6 Project Timelines

Task	Sub-Tasks	Deliverables	Months 1	2	3	4	5	6	7	8	9
Project Inception Phase	Kick-off meeting	Inception Report									
	Desk Review										
	Submisison of inception report			◊							
Component 1: Hazard risk and financial loss database and hazard risk analysis	Collect hazard, exposure and risk reports available for the Kerala State	A geo-referenced catalogue of historical major events - including, tropical cyclones, landslides, and flood in Kerala. The list of parameters to be included in the database will be discussed and agreed with the Client. The catalogue will be provided based on a format to be agreed with the client						◊			
	Collect disaster damage/loss reports for the Kerala state	Database of historical economic and financial losses caused by past natural disasters.						◊			
	Review damage/losses reports collected	A technical report describing the data collected and their limitations.						◊			
	Develop consolidated database	Disaster Risk Assessment report						◊			
Component 2: Develop catastrophe risk profile	Stocktaking Analysis	A report presenting the risk profile by risk zone (national, provincial and local) (e.g., hazard, direct losses, population losses, agricultural losses, and emergency losses) of Kerala						◊			
	Hazard Model Development - Flood Hazard - Landslide Hazard - Drought Hazard - Cyclone & Storm Surge hazard								◊		
	Exposure Data Development								◊		
	Vulnerability Analysis								◊		
	Catastrophe Risk Model	Brochures on catastrophe risk profiles for the State of Kerala drafted from this report in a didactic manner to inform and sensitize policy and/or decision makers in the State (e.g., visuals, hazard maps, risk maps). A template will be developed by the Consultant and approved by the Client. Once the template is approved by the Client, the brochure will be professionally edited and provided in both electronic copy and paper copies (200 copies).								◊	
Component 3: Develop risk financing strategy for Kerala State	Develop risk financing strategy for Kerala State	A report presenting the Disaster Risk Finance Strategy for the State of Kerala									◊
		Summary of menu of financial options/ instruments, or between different combinations of options/ instruments									◊
Component 4: Design of parametric indices for financial transactions with focus on housing sector and Government Building	Design of parametric indices for financial transactions with focus on housing sector and Government Building	A report presenting (i) the methodology for the design of prototype (first generation and second generation) parametric risk transfer products for each major peril; and (ii) the proposed prototype parametric risk transfer products									◊
		A report analysing the risk profiles of a set a pre-agreed parametric risk transfer product(s).									◊
		Dissemination material summarizing the prototype insurance policies and the portfolio analysis (e.g., PowerPoint presentation)									◊
	Completed										
	In Progress										
	Initiated										
	To be initiated										

7 Annexure 1

7.1 Projection coordinates information

As RMSI has received all the database requirements from the client in "WGS_1984_UTM_Zone_43N" projection system, and will use the same for future projections and map preparations to deliver to the client.

7.2 Cyclonic Disturbances and Reported Losses, 1891-2023

Table 7-1: List of cyclonic disturbances in and around Kerala during (1891-2023)

S. No.	Type of Disturbance	Day	Month	Year	Maximum wind speed (km/h)
1	Very Severe Cyclonic Storm	05	11	1898	119
2	Cyclonic Storm	30	12	1908	83
3	Very Severe Cyclonic Storm	19	11	1912	119
4	Very Severe Cyclonic Storm	15	10	1916	119
5	Very Severe Cyclonic Storm	01	11	1919	119
6	Very Severe Cyclonic Storm	25	11	1922	119
7	Very Severe Cyclonic Storm	06	11	1925	119
8	Cyclonic Storm	05	05	1930	83
9	Deep Depression	20	05	1932	56
10	Very Severe Cyclonic Storm	11	11	1935	119
11	Deep Depression	12	11	1940	56
12	Very Severe Cyclonic Storm	30	11	1941	119
13	Cyclonic Storm	09	12	1941	83
14	Cyclonic Storm	31	10	1946	65
15	Cyclonic Storm	14	11	1946	65
16	Very Severe Cyclonic Storm	17	11	1958	120
17	Depression	27	11	1959	46
18	Depression	09	11	1961	46
19	Cyclonic Storm	13	05	1962	65
20	Cyclonic Storm	05	12	1965	65
21	Very Severe Cyclonic Storm	31	10	1966	120
22	Very Severe Cyclonic Storm	07	11	1966	120
23	Very Severe Cyclonic Storm	01	12	1972	120
24	Very Severe Cyclonic Storm	03	11	1978	148
25	Very Severe Cyclonic Storm	19	11	1978	167
26	Cyclonic Storm	10	10	1980	65
27	Severe Cyclonic Storm	25	10	1981	111
28	Very Severe Cyclonic Storm	27	11	1984	213
29	Severe Cyclonic Storm	11	11	1992	102

S. No.	Type of Disturbance	Day	Month	Year	Maximum wind speed (km/h)
30	Depression	08	11	1993	46
31	Deep Depression	02	11	1997	56
32	Extremely Severe Cyclonic Storm	26	11	2000	189
33	Very Severe Cyclonic Storm	23	12	2000	167
34	Very Severe Cyclonic Storm - Ockhi	29	11	2017	157
35	Very Severe Cyclonic Storm - Gaja	10	11	2018	130
36	Extremely Severe Cyclonic Storm - Taukate	14	05	2021	185

Table 7-2: Loss details due to extreme cyclone events during (1891 -2023) for Kerala

S. No.	Date	Landfall Location	Damage Details
1	November 13 - 23, 1977 (Severe Cyclonic Storm)	Crossed between Mangalore and Honavar, Maharashtra	Kerala, Lakshadweep, and Maharashtra were affected due to this storm; 72 people were killed; 8,400 houses were damaged, and 620 fishing vessels were damaged in Kerala coast; total loss was estimated to be about INR 10 crores[40].
2	November 4, 1978 (Deep Depression)	Crossed Tamil Nadu coast near Cuddalore	About 50 persons died in Kerala due to floods; considerable damage to crops and houses were reported from Tamil Nadu and Kerala[41]
3	November 11-17, 1992 (Severe Cyclonic Storm)	Crossed Karnataka coast near Honavar	According to the press reports about 175 persons lost their lives and 160 people reported missing in Tamil Nadu and Kerala; heavy rains caused flash floods and landslides resulting in considerable damage to the standing crops and houses in Karnataka, Kerala, and Tamil Nadu[42,33]
4	29 Nov - 05 Dec, 2017 (Very Severe Cyclonic Storm Ockhi)	Crossed Sri Lanka coast and then crossed south Gujarat coast between Surat and Dahanu	Damage over Kerala: As per report published by KSDMA, Kerala state witnessed loss of lives of 51 persons, 234 injured, and 9,134 affected. About 3,744 houses were damaged by cyclone Ockhi in Kerala[43,44]
5	14th -19th May, 2021 (Extremely Severe Cyclonic Storm Tauktae)	Crossed Gujarat coast near Diu	As per the report published by KSDMA,11 people lost their lives, 22 injured, 7,063 affected and a total of 4,419 houses were damaged in Kerala[45]

---

[40] SMRC (1998). The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SMRC-No.1, SAARC Meteorological Research Centre, Dhaka, Bangladesh, October 1998, 329 pp.
[41] Srinivasan, V., Ramakrishnan, A. R., & Jambunathan, R. (1980). Cyclones and depressions in the Indian seas in 1978. MAUSAM, 31(4), 495-506.
[42] IMD Report on cyclonic disturbances over North Indian Ocean in 1992- RSMC Tropical Cyclones (1993)
[43] Memorandum-Ockhi-2017 by Additional Chief Secretary, Disaster Management, Govt. of Kerala (KSDMA).
[44] IMD Report: 2018, Very Severe Cyclonic Storm, 'OCKHI' over the Bay of Bengal (29 Nov.-05 Dec. 2017)
[45] An Integrated Approach to the Preparedness and Mitigation of Cyclone Tauktae: The Case of Kerala: 2021(KSDMA).

7.3 Landslides

Table 7-3: Historical landslide event list of Kerala

S. No.	Longitude	Latitude	Event Date	District	Fatality
1	77.0090	8.4557	13-11-2013	Thiruvananthapuram	0
2	76.9517	8.4863	13-11-2013	Thiruvananthapuram	0
3	76.9210	8.4951	13-11-2013	Thiruvananthapuram	0
4	76.9352	8.5269	10-11-2001	Thiruvananthapuram	0
5	76.8979	8.5587	06-05-2017	Thiruvananthapuram	0
6	76.9793	8.5845	13-04-2017	Thiruvananthapuram	0
7	76.8902	8.7420	12-09-2009	Thiruvananthapuram	1
8	76.7853	9.2626	21-04-2021	Pathanamthitta	0
9	76.7947	9.2668	17-05-2021	Pathanamthitta	0
10	76.9656	9.3926	17-10-2021	Pathanamthitta	0
11	76.9371	9.4237	06-08-2011	Kottayam	0
12	76.9371	9.4237	06-08-2011	Kottayam	0
13	77.0824	9.4311	17-08-2020	Pathanamthitta	-
14	76.8696	9.4974	08-06-2011	Kottayam	-
15	77.0198	9.5207	06-02-2011	Idukki	-
16	76.8864	9.5371	17-10-2021	Kottayam	-
17	76.8859	9.5375	12-11-2021	Kottayam	-
18	76.9299	9.5527	17-08-2012	Idukki	-
19	76.7802	9.5539	01-08-2022	Kottayam	-
20	76.7874	9.5595	17-10-2021	Kottayam	-
21	76.8957	9.5753	04-12-2021	Idukki	-
22	76.8980	9.5754	17-10-2021	Idukki	-
23	76.9734	9.5766	02-08-2022	Idukki	-
24	76.8866	9.5846	17-10-2021	Kottayam	-
25	76.8851	9.5872	17-10-2021	Kottayam	-
26	76.5218	9.5913	29-07-2020	Kottayam	-
27	76.5289	9.5988	06-08-2011	Kottayam	1
28	76.9137	9.6298	05-11-2021	Kottayam	-
29	76.9793	9.6320	04-07-2022	Idukki	-
30	76.9792	9.6326	01-06-2011	Idukki	-
31	76.8168	9.6991	17-08-2012	Kottayam	-
32	76.8081	9.7268	17-08-2012	Kottayam	-
33	76.8030	9.7285	17-08-2012	Kottayam	-
34	76.8403	9.7327	25-05-2008	Kottayam	-
35	77.0897	9.7512	27-06-2017	Idukki	-
36	77.0611	9.7967	15-06-2016	Idukki	2
37	76.9006	9.8012	31-05-2011	Idukki	-
38	77.1498	9.8232	17-08-2012	Idukki	-
39	76.9408	9.8306	02-06-2011	Idukki	-
40	76.8661	9.8350	07-08-2013	Idukki	-
41	76.9681	9.8538	09-06-2018	Idukki	-

S. No.	Longitude	Latitude	Event Date	District	Fatality
42	76.9468	9.8539	05-08-2013	Idukki	1
43	77.1321	9.8628	24-07-2021	Idukki	-
44	76.7705	9.8678	27-10-2010	Idukki	2
45	76.7046	9.8721	02-06-2011	Idukki	-
46	76.9683	9.8790	05-08-2013	Idukki	2
47	76.9346	9.8957	05-08-2013	Idukki	1
48	76.3902	9.8988	24-09-2010	Ernakulam	-
49	77.0110	9.9147	04-08-2013	Idukki	3
50	77.1027	9.9205	19-05-2021	Idukki	-
51	76.9659	9.9363	12-11-2021	Idukki	-
52	76.9658	9.9370	12-11-2021	Idukki	-
53	76.3738	9.9431	02-08-2014	Ernakulam	-
54	77.0795	9.9509	09-06-2018	Idukki	-
55	76.9992	9.9737	09-06-2018	Idukki	-
56	76.9968	9.9740	09-06-2018	Idukki	-
57	76.7898	9.9903	17-10-2011	Idukki	1
58	76.7329	9.9983	22-06-2014	Ernakulam	-
59	77.0309	9.9995	04-08-2013	Idukki	2
60	76.7416	10.0011	17-08-2012	Ernakulam	6
61	76.7105	10.0070	17-08-2012	Ernakulam	2
62	76.9891	10.0172	09-06-2018	Idukki	-
63	77.0472	10.0176	09-06-2018	Idukki	-
64	77.0162	10.0191	09-06-2018	Idukki	-
65	77.0472	10.0235	20-08-2018	Idukki	-
66	77.0407	10.0254	11-06-2018	Idukki	-
67	77.0468	10.0257	15-08-2019	Idukki	-
68	77.0376	10.0266	05-08-2013	Idukki	-
69	76.8472	10.0455	09-06-2018	Idukki	-
70	77.0700	10.0458	01-10-2017	Idukki	-
71	76.7606	10.0486	05-08-2013	Ernakulam	-
72	76.4788	10.0533	23-07-2013	Ernakulam	2
73	76.8294	10.0539	05-08-2013	Idukki	-
74	76.8298	10.0539	05-08-2013	Idukki	5
75	76.6350	10.0604	17-08-2012	Ernakulam	4
76	76.6331	10.0606	07-08-2013	Ernakulam	-
77	76.3220	10.0770	22-10-2012	Ernakulam	-
78	77.0696	10.0838	02-06-2011	Idukki	-
79	77.0575	10.1047	12-08-2019	Idukki	-
80	77.1982	10.1421	09-08-2022	Idukki	-
81	77.0381	10.1423	10-08-2020	Idukki	-
82	77.1905	10.1497	06-08-2022	Idukki	-
83	77.0203	10.1586	07-08-2020	Idukki	-
84	77.0112	10.1624	24-07-2021	Idukki	-
85	76.4505	10.1762	10-08-2019	Ernakulam	-

S. No.	Longitude	Latitude	Event Date	District	Fatality
86	77.1711	10.3018	11-08-2009	Idukki	1
87	76.7604	10.3031	07-08-2013	Thrissur	-
88	77.1949	10.3104	24-07-2021	Idukki	-
89	76.4319	10.3228	04-08-2013	Thrissur	1
90	76.4319	10.3228	05-08-2013	Thrissur	1
91	76.5648	10.4659	13-06-2018	Palakkad	-
92	76.3948	10.7763	05-08-2022	Palakkad	-
93	76.6544	10.7879	16-05-2021	Palakkad	-
94	76.6544	10.7879	07-08-2020	Palakkad	-
95	76.5516	10.9654	10-09-2014	Palakkad	-
96	76.5745	10.9704	12-06-2018	Palakkad	-
97	76.5745	10.9704	12-06-2018	Palakkad	-
98	76.5549	10.9766	12-06-2018	Palakkad	-
99	76.0723	11.0509	12-08-2020	Malappuram	-
100	76.0293	11.1361	14-08-2019	Malappuram	-
101	76.0879	11.1361	14-08-2019	Malappuram	-
102	76.0880	11.1368	09-08-2019	Malappuram	-
103	76.1810	11.2517	14-06-2018	Malappuram	-
104	75.7832	11.2569	25-07-2020	Kozhikode	-
105	75.7832	11.2569	10-08-2020	Kozhikode	-
106	75.7831	11.2583	10-08-2020	Kozhikode	-
107	76.1383	11.2615	14-06-2018	Malappuram	-
108	76.1150	11.2625	14-06-2018	Malappuram	-
109	76.2227	11.2695	19-09-2009	Malappuram	-
110	76.1465	11.2706	14-06-2018	Malappuram	-
111	76.1504	11.2721	15-06-2018	Malappuram	-
112	76.1493	11.2726	14-06-2018	Malappuram	-
113	75.8275	11.2738	25-06-2007	Kozhikode	-
114	76.0441	11.3041	14-06-2018	Kozhikode	-
115	76.0441	11.3041	09-06-2018	Kozhikode	-
116	76.1109	11.3191	14-06-2018	Kozhikode	-
117	76.0883	11.3221	14-06-2018	Kozhikode	-
118	76.2118	11.3622	15-06-2018	Malappuram	-
119	76.2126	11.3772	14-06-2018	Malappuram	-
120	76.0376	11.4050	22-07-2012	Kozhikode	-
121	75.9337	11.4105	24-08-2019	Kozhikode	-
122	76.2454	11.4105	24-08-2019	Malappuram	-
123	76.0854	11.4302	13-06-2018	Kozhikode	-
124	76.0802	11.4335	14-06-2018	Kozhikode	-
125	75.9931	11.4337	14-06-2018	Kozhikode	-
126	75.9931	11.4337	06-06-2018	Kozhikode	-
127	76.0881	11.4390	12-06-2018	Kozhikode	-
128	76.0889	11.4404	12-06-2018	Kozhikode	-
129	76.0739	11.4450	13-06-2018	Kozhikode	-

S. No.	Longitude	Latitude	Event Date	District	Fatality
130	76.0739	11.4450	09-06-2018	Kozhikode	-
131	76.0959	11.4475	12-06-2018	Kozhikode	-
132	75.8289	11.4477	03-10-2009	Kozhikode	-
133	76.1014	11.4492	12-06-2018	Kozhikode	-
134	76.0429	11.4562	12-06-2018	Kozhikode	-
135	76.0429	11.4562	09-06-2018	Kozhikode	-
136	76.0379	11.4616	13-06-2018	Kozhikode	-
137	76.0379	11.4616	09-06-2018	Kozhikode	-
138	75.9248	11.4633	14-06-2018	Kozhikode	-
139	75.9337	11.4653	14-06-2018	Kozhikode	-
140	75.9337	11.4653	06-06-2018	Kozhikode	-
141	75.9213	11.4708	14-06-2018	Kozhikode	-
142	75.9306	11.4747	14-06-2018	Kozhikode	-
143	75.9957	11.4816	03-10-2009	Kozhikode	-
144	76.0235	11.4891	14-06-2018	Kozhikode	-
145	76.0235	11.4891	09-06-2018	Kozhikode	-
146	75.8647	11.4978	14-06-2018	Kozhikode	-
147	75.9931	11.5062	18-08-2019	Kozhikode	-
148	76.1361	11.5062	18-08-2019	Wayanad	-
149	75.8817	11.5076	14-06-2018	Kozhikode	-
150	76.0379	11.5110	08-08-2019	Wayanad	-
151	76.1211	11.5110	08-08-2019	Wayanad	-
152	76.0185	11.5119	27-06-2017	Kozhikode	-
153	76.0151	11.5148	14-06-2018	Kozhikode	-
154	76.0151	11.5148	09-06-2018	Kozhikode	-
155	76.0293	11.5294	14-06-2018	Wayanad	-
156	76.0293	11.5294	09-06-2018	Wayanad	-
157	76.0077	11.5419	10-08-2019	Wayanad	-
158	76.0556	11.5419	10-08-2019	Wayanad	-
159	76.0739	11.5489	11-08-2019	Wayanad	-
160	76.1269	11.5489	11-08-2019	Wayanad	-
161	76.1352	11.5552	07-08-2020	Wayanad	-
162	76.0077	11.6066	15-06-2018	Wayanad	-
163	76.0077	11.6066	09-06-2018	Wayanad	-
164	76.1308	11.6854	07-08-2020	Wayanad	-
165	76.0235	11.6881	24-08-2019	Wayanad	-
166	76.1215	11.6881	24-08-2019	Wayanad	-
167	76.0842	11.7030	03-08-2022	Wayanad	-
168	76.0740	11.7095	25-06-2007	Wayanad	4
169	75.4856	11.8348	27-07-2015	Kannur	2
170	75.8565	11.8371	17-08-2012	Wayanad	-
171	75.9927	11.9275	06-08-2020	Wayanad	-
172	75.9927	11.9275	08-08-2020	Wayanad	-
173	75.6723	11.9852	02-08-2022	Kannur	-

S. No.	Longitude	Latitude	Event Date	District	Fatality
174	75.7581	12.0709	12-06-2018	Kannur	-
175	75.7581	12.0709	10-06-2018	Kannur	-
176	74.9880	12.5001	12-09-2020	Kasaragod	-
177	74.9848	12.5099	22-06-2020	Kasaragod	-

7.4 Change of Database Format NDMIS to EM-DAT

From: Kerala State Disaster Management Authority <keralasdma@gmail.com>
Sent: 29 February 2024 15:35
To: Sushil Gupta <sushil.gupta@rmsi.com>
Cc: RKI Secretariat <rkisecretariat@gmail.com>; rkisecretariat@kerala.gov.in
Subject: Re: Regarding building a database of major historical hazard events, and developing economic and financial losses caused by major disasters of past 30 years under Component 1

You don't often get email from keralasdma@gmail.com. Learn why this is important

CAUTION EXTERNAL EMAIL: If unknown sender, do not click links/attachments. Never share your user ID or password.

Dear Sushil,
Yes, as discussed, the database format may be that of EMDAT and if needed, you may support us through a script to convert to NDEM or NIDMS formats. You may get the formal clearance from RKI Department and include this in the inception report.
yours faithfully
Dr. Sekhar

On Thu, 29 Feb 2024 at 15:28, Sushil Gupta <sushil.gupta@rmsi.com> wrote:
Dear Dr. Sekhar,

Thank you very much for sparing your valuable time for meetings and discussions with RMSI team during our third mission from Feb 26-Mar 01, 2024.
As we have reviewed and discussed the formats of NDMIS, and NDEM disaster databases *(access allowed to authorized users only and are password protected)*, both the formats are not suitable to develop event-wise disaster database that is expected as part of Component 1 of this study. Further, as we have also reviewed the EM.Dat (https://www.emdat.be/) database format, which is the International disaster database format, being followed worldwide; is in a much better format to develop and present geospatial event-wise disaster database/catalogue of major disasters for Kerala State.
Hence, you are kindly requested to approve the change of using EM.Dat format instead of NDMIS format (given as per TOR of this study under Component 1).

Best Regards,

Dr. Sushil Gupta
Project Team Leader

Sushil Gupta, Ph.D., MBA, M. Tech., FISET, FGS
Vice President
Risk Modeling and insurance, Sustainability
RMSI, A-8, Ground Floor, Sector -16
Noida - INDIA 201301
T +91 (120) 2511102/ 4040500
M +91 8826100332
E Sushil.Gupta@rmsi.com
E sushilgupta74@gmail.com
W www.rmsi.com

RMSI Pvt. Ltd.
A-8, Sector 16
Noida 201301, INDIA
Tel: +91-120-251-1102, 2101
Fax: +91-120-251-1109, 0963
www.rmsi.com