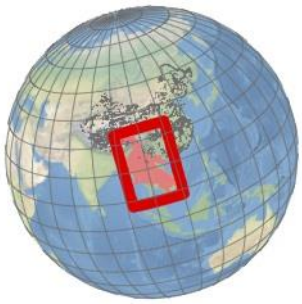
Majors River Basins of Mainland Southeast Asia



0 50 100 200 300 400 500
Kilometers
1:10,000,000

Qamdo
CHINA
INDIA
Kunming
Irrawady
MYANMAR
Chittagong
Mandalay
Red
VIETNAM
Mekong
HANOI
Hai Phong
Salween
NAYPYIDAW
LAOS
Gulf of Tonkin
Bay of Bengal
Chao Phraya
VIENTIANE
Yangon
Mawlamyine
Hue
THAILAND
BANGKOK
Andaman Sea
CAMBODIA
PHNOM PENH
Ho Chi Minh
Gulf of Thailand
South China Sea

Legend

Cities
- National capital
- Major city

Major River Basins
- Chao Phraya
- Irrawady
- Mekong
- Red
- Salween
- Lakes & reservoirs
- National boundary

Datum: World Geodetic System 1984
Coordinate System : Universal Transverse Mercator Zone 48 North
Data Sources: River basin boundary and river vector data is courtesy of the IWMI.
All other administrative and physiographic data courtesy of NOAA's National Geophysical Data Center's Global Self consistent, Hierarchical, High-resolution Geography Database.

Cartographic Design by : GEO-SYS

Early Warning System Review Report

(Final Version)

URBAN RESILIENCE TO CLIMATE EXTREME IN SOUTH EAST ASIA (URCESEA)

31st December 2019

Prepared By

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Bangkok 10400 Thailand

Contents

Glossary:

Capacity

The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use"

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events

Early warning system

The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area

Geological hazard

Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Hydro-meteorological hazard

Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Natural hazard

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Preparedness

The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions

Prevention

The outright avoidance of adverse impacts of hazards and related disasters

Response

The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected

Risk

The combination of the probability of an event and its negative consequences

Risk assessment

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend

Risk management

The systematic approach and practice of managing uncertainty to minimize potential harm and loss

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard

1. Urban Resilience to Climate Extreme in South East Asia (URCESEA):

Asian Disaster Preparedness Center (ADPC) under aegis of the Norwegian Agency for Development Cooperation (Norad) has initiated a 5-years program titled **"Urban Resilience to Climate Extremes in Southeast Asia (URCESEA)"** program with the overall aim to build resilience of the urban systems and urban communities to the current and emerging climate extremes, disasters and emergencies that are anticipated in the deltaic and coastal cities in Southeast Asia.

The URCESEA program started its inception phase (from 1st November 2018) for setting up implementation arrangements of the program activities in the two targeted Southeast Asian countries namely Myanmar and Viet Nam as well as making necessary refinement needed for the program implementation; and building regional level learning and exchanges in Southeast Asian countries. The five-year program timing is from 1st November 2018 to 31st October 2023.

The URCESEA program would aim to build resilience in urban areas to weather and climate extremes through understanding current and future risks, building capacities for preparedness, emergency management, risk reducing sectoral developments as well as bringing risk governance and learning mechanisms for sustainable risk management for the future.

Dala Township of Yangon and Nam Dinh and My Tho Cities of Vietnam have been selected to implement the URCESEA program in Myanmar and Vietnam. This technical assistance program provides an opportunity to further improve overall multi-hazard early warning system of National Hydrology and Meteorology Services (NHMS) and to connect with the stakeholders and end users in selected cities. It is also discussed and planned to get technical support of MET-Norway for this initiative as they will be working with NHMS under the Norad funding.

The URCESEA program goal will be fulfilled by achieving the following primary outcomes:

- **OUTCOME 1:** Improved Multi-Hazard Early Warning Systems and Risk Knowledge on climate extremes.
- **OUTCOME 2:** Strengthened urban community readiness and local preparedness.
- **OUTCOME 3:** Improved urban sectoral preparedness and emergency response.
- **OUTCOME 4:** Strengthened urban risk governance systems for dealing with emerging climate extremes and emergencies.
- **OUTCOME 5:** Improved knowledge and awareness on building urban climate resilience for extremes through Regional and National events and forums.

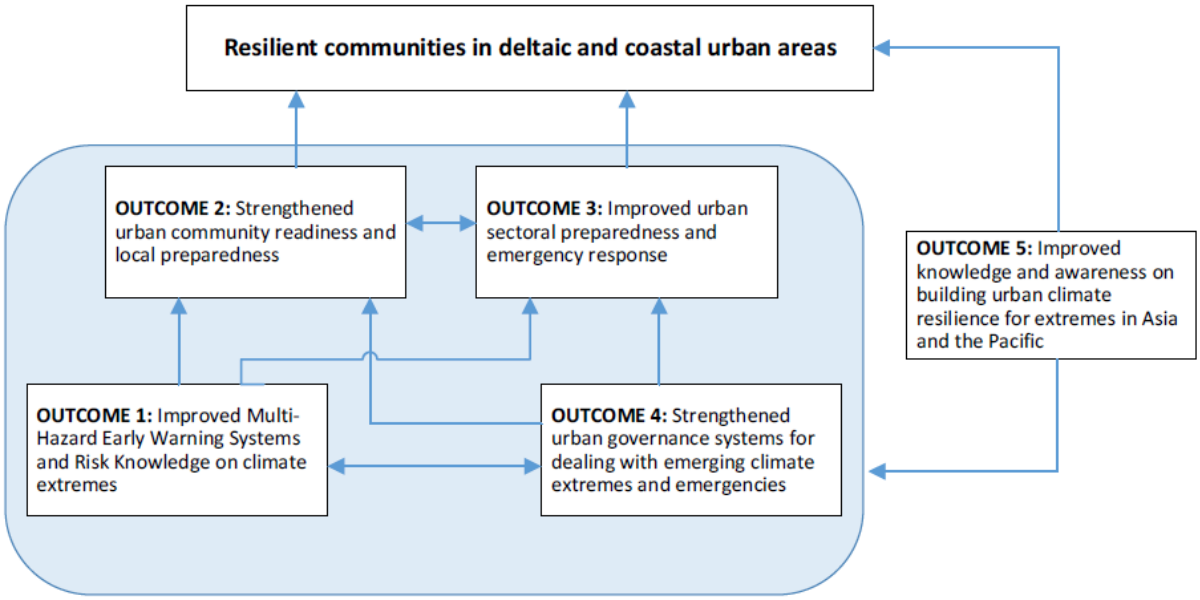
Outcome 1 will be achieved through following four outputs:

- **OUTPUT 1.1.** Technical assistance and training on 'long-lead' and 'location-specific' urban forecasting provided
- **OUTPUT 1.2.** Improved hazard monitoring and detection sub-system for target cities

- **OUTPUT 1.3.** Climate risk assessments conducted and site-specific scenarios developed for the target cities
- **OUTPUT 1.4.** Climate data and knowledge portal for urban climate resilience published for the target cities/countries

These five outcomes contribute to the achievement of the program goal as illustrated in the program theory of change, an abridged version of which is shown **Figure 1.**

Figure 1: Linkages between Outcomes and Goal



Source: URCESEA Inception Report

This literature review report (especially for Output 1) provides brief introduction of study cities, introduction of river basins, roles and responsibility of National Hydro-met Services (NHMS), Weather Forecast and Early Warning Systems, Hydrological Forecast and Early Warning Systems, Pluvial and Fluvial Flood Modeling, Climate Change Studies, Multi Hazard Risk and Vulnerability Assessment in Myanmar and Vietnam.

2. Study Cities:

The Urban Resilience to Climate Extreme in South East Asia (URCESEA) Program is being implanted in three cities in Vietnam and Myanmar. These three cities are as follows:

- Nam Dinh City (Vietnam),
- My Tho City (Vietnam),
- Dala Township (Myanamr)

2.1 Nam Dinh City (Vietnam):

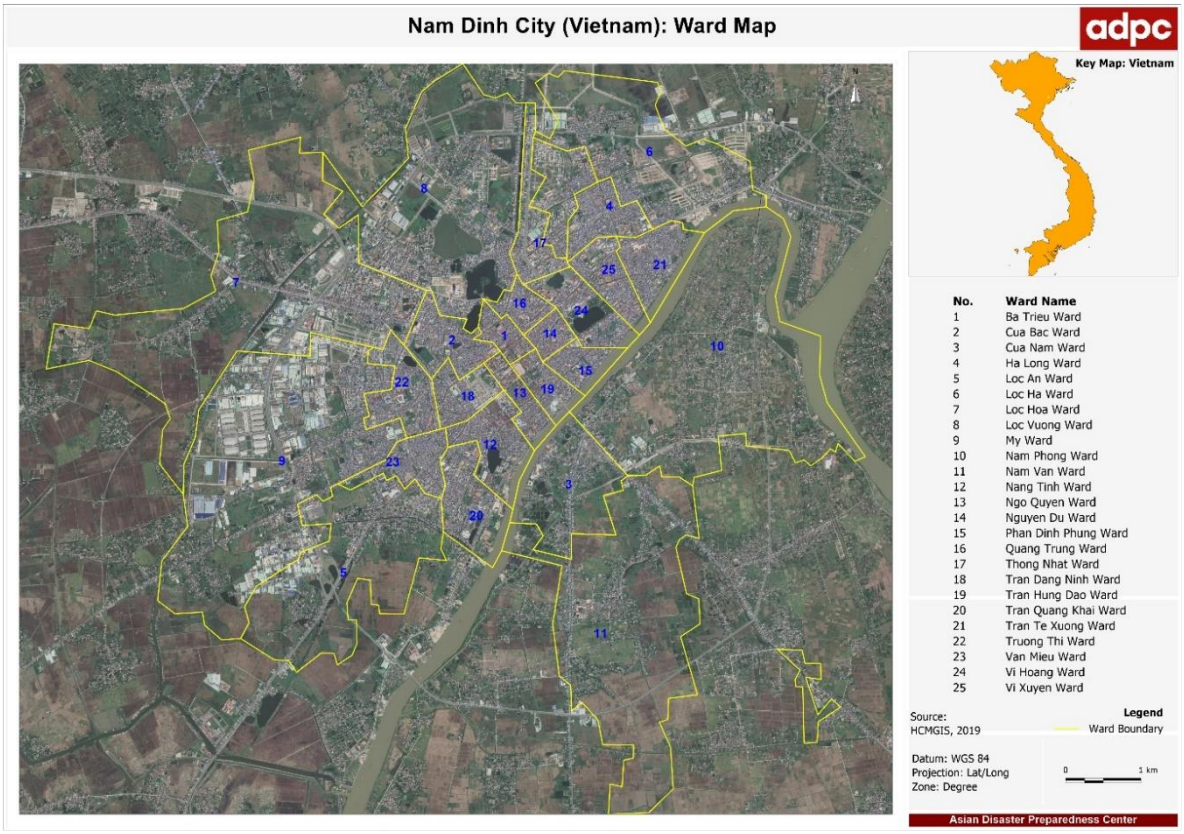
Nam Dịnh is a city in the Red River Delta of northern Vietnam. It is the capital of Nam Dịnh Province. The city of Nam Dịnh is 90 km south-east of Vietnam's capital, Hanoi. Basic summary of Nam Dinh is given in **Table 1.**

Table 1: Basic Statistics of Nam Dinh City (Vietnam)

Population	243,186 (2009)
Area (Sq. Km.)	46.6 km² (2009)
Density	5,218/km² (2009)
Elevation	5 mts.
Wards	25

Ward boundary map of Nam Dinh city is presented in **Map 1**.

Map 1: Ward Boundary of Nam Dinh City (Vietnam)



The entire terrain of Nam Dinh province is relatively flat, with two main areas being lowland plains and coastal plains, and in the northwest of the province there are few low hills and mountains. The terrain is lower from the North West to the South East, the highest point from Mount Goi is 122 m high and the lowest is -3 m above sea level in the Y Yen District lowland.

Nam Dinh province has three large rivers: Red River, Day River and Ninh Co River. In addition, the Dao River connects the Red River and the Day River, along with many other small rivers, which make waterway transportation more convenient and accretion of alluvium, irrigation for agricultural production.

2.2 My Tho City (Vietnam):

My Tho city is located in the southern province of Tien Giang. Tien Giang is surrounded by the provinces of Ben Tre, Long An and Dong Thap. The city currently has 10 wards and six communes and encompasses an area of 81.45 km^2. The city is flat with an average elevation of + 1.5 to 2.0 m above sea level.

The main waterways of the city include the Tien River which flows along the southern boundary of the city. The Bao Dinh river flows through 4 km of the city center and connects My Tho city with Tan An town. To the east, the Bao Dinh river connects with the Ky Hon - Cho Gao canal system through the Go Cat river. There also is an interconnecting canal system throughout the area. The waterways are influenced by irregular semi-diurnal tides.

The rainy season lasts from May to November. The total annual rainfall is an average of 1922 mm. The average annual temperature is 27.0^o C.

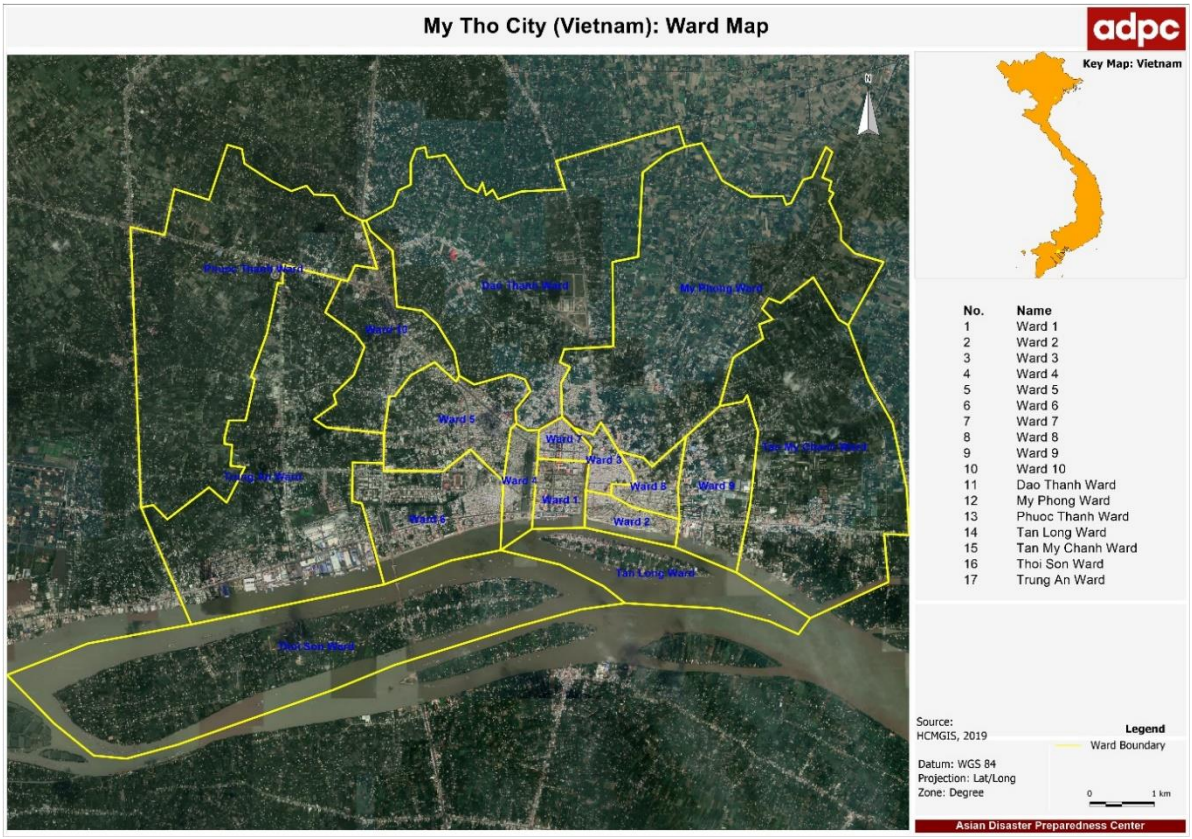
My Tho city had an approximately total population of 270,700 people in 2019. The average population density of the city is 4,240 per km^2. The population growth rate is projected at 2.6% annually. Main employment in the area is trading and services accounting for 28.6% of the work force. Basic summary of My Tho is given in **Table 2.**

Table 2: Basic Statistics of My Tho City (Vietnam)

Status	District-level City
Population	197,022
Area (Sq. Km.)	70.6 km²
Density	2,789/km²
Elevation	2 mts.
Wards	10
Commune	7

Ward boundary map of My Tho city is presented in **Map 2**.

Map 2: Ward Boundary of My Tho City (Vietnam)



2.3 Dala Township (Myanmar):

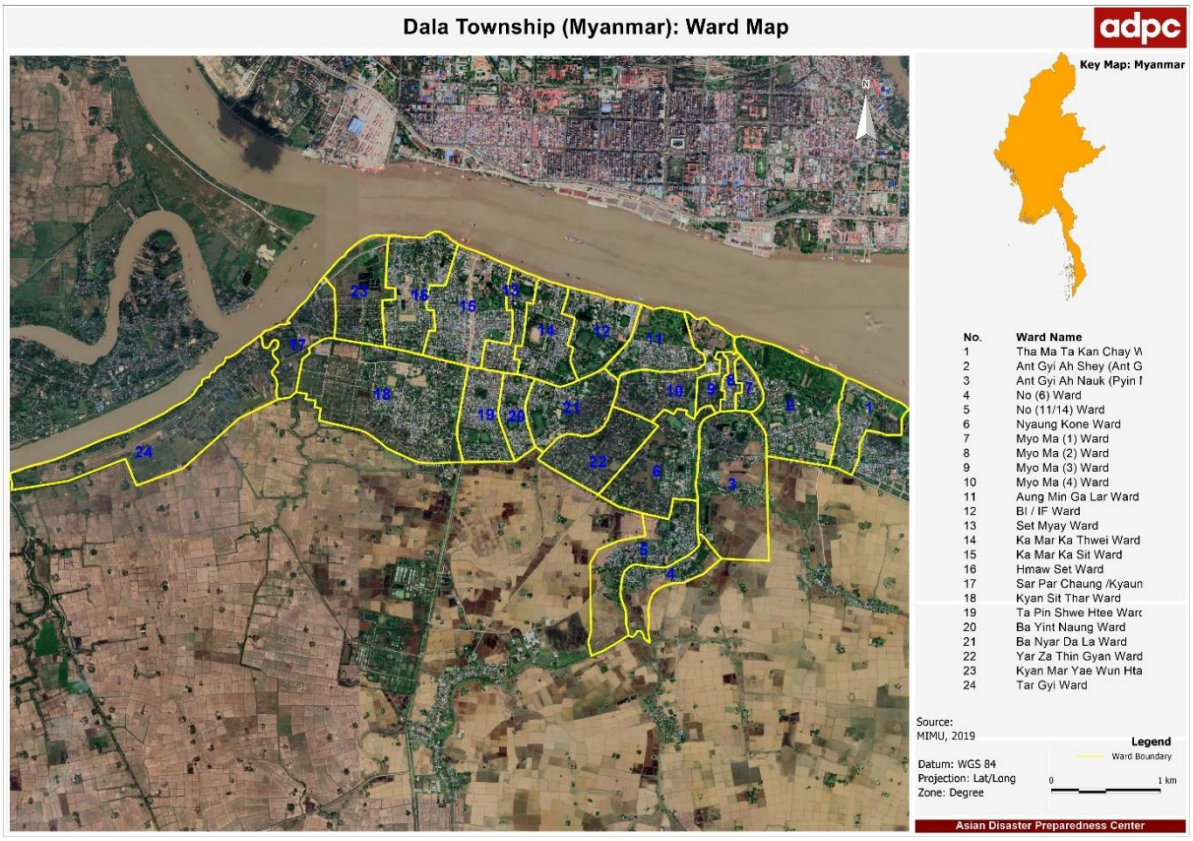
Dalla township is located on the southern bank of Yangon river across from downtown Yangon, Myanmar. The township, made up of 24 wards (including 23 village tracks and 50 villages), is bounded by the Yangon river in the north and east, the Twante Canal in the west, and Twante Township in the south. Basic summary of Dala township is given in **Table 3.**

Table 3: Basic Statistics of Dala Township (Myanmar)

Status	Township
Population	172,857 (2014)
Area (Sq. Km.)	224.1 (2014)
Density (Per Sq. Km.)	771.5 (2014)
Elevation	6 mts.
Wards	24

Ward boundary map of Dala township is presented in **Map 3**.

Map 3: Ward Boundary of Dala Township (Vietnam)


Dala Township (Myanmar): Ward Map
adpc
Key Map: Myanmar
No. Ward Name
1 Tha Ma Ta Kan Chay W
2 Ant Gyi Ah Shey (Ant G
3 Ant Gyi Ah Nauk (Pyin I
4 No (6) Ward
5 No (11/14) Ward
6 Nyaung Kone Ward
7 Myo Ma (1) Ward
8 Myo Ma (2) Ward
9 Myo Ma (3) Ward
10 Myo Ma (4) Ward
11 Aung Min Ga Lar Ward
12 BI / IF Ward
13 Set Myay Ward
14 Ka Mar Ka Thwei Ward
15 Ka Mar Ka Sit Ward
16 Hmaw Set Ward
17 Sar Par Chaung /Kyaun
18 Kyan Sit Thar Ward
19 Ta Pin Shwe Htee Ward
20 Ba Yint Naung Ward
21 Ba Nyar Da La Ward
22 Yar Za Thin Gyan Ward
23 Kyan Mar Yae Wun Hta
24 Tar Gyi Ward
Source:
MIMU, 2019
Legend
Ward Boundary
Datum: WGS 84
Projection: Lat/Long
Zone: Degree
0
1 km
Asian Disaster Preparedness Center

3. Review of Early Warning Systems:

Early warning is a major element of disaster risk reduction. It can prevent loss of life and reduce the economic and material impacts of hazardous events including disasters. To be effective, early warning systems need to actively involve the people and communities at risk from a range of hazards, facilitate public education and awareness of risks, disseminate messages and warnings efficiently and ensure that there is a constant state of preparedness and that early action is enabled.

According to the United Nations International Strategy for Disaster Reduction (UNISDR), an early warning system is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by hazards to take necessary preparedness measures and act appropriately with sufficient time to reduce the possibility of harm or losses (UNISDR 2009[1]). This definition encompasses the range of factors necessary to achieve timely warnings for effective response. A people-centered early warning system necessarily comprises four key elements: risk knowledge; monitoring and warning services; dissemination and communications; and response capability (UNISDR 2009; Phaiju et al., 2010[2]).

The Sendai Framework for Disaster Risk Reduction 2015–2030 – the successor instrument to the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters – recognizes the benefits of multi-hazard early warnings systems and enshrines them in one of its seven global targets: “Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030”.

The Sendai Framework urges a paradigm shift in the way risk information is developed, assessed and utilized in multi-hazard early warning systems, disaster risk reduction strategies and government policies. It states “in order to reduce disaster risk, there is a need to address existing challenges and prepare for future ones by focusing on monitoring, assessing and understanding disaster risk and sharing such information and on how it is created; strengthening disaster risk governance and coordination across relevant institutions and sectors and the full and meaningful participation of relevant stakeholders at appropriate levels”. The Framework aims to achieve “the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries”.

The thematic key pillars / components of early warning systems (UNISDR, 2006[3]) are presented in **Figure 2**. In addition to key pillars, governance has also been assessed

[1] UN-ISDR Terminology on Disaster Risk Reduction (2009) Available at: http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf
[2] Phaiju, A., Bej, D., Pokharel, S. & Dons, U. (2010). Establishing Community Based Early Warning System: Practitioner’s Handbook, 2010. Lalitpur, Nepal. Mercy Corps and Practical Action.
[3] Developing Early Warning Systems: A Checklist https://www.unisdr.org/files/608_10340.pdf

as a cross cutting component to support each pillar for have an effective and people-centric early warning system.

Figure 2: Key Pillars of Early Warning Systems

Source: UNISDR, 2006

These four components need to be coordinated across many agencies at national to local levels for the system to work. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; thus, roles and responsibilities of various public and private sector stakeholders for implementation of EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination, and operational mechanisms.

3.1 Risk Knowledge:

Risks arise from the combination of hazards, exposure of people and assets to the hazards and their vulnerabilities and coping capacities at a particular location. Assessments of these risks require systematic collection and analysis of data and should consider the dynamics and compounding impacts of hazards coupled with vulnerabilities resulting from unplanned urbanization, changes in rural land use, environmental degradation and climate change. The level of risk can change depending on the actual impacts and consequences of hazards. Therefore, the risk assessment must include an assessment of the community's coping and adaptive capacities. It is also important to gauge the perception of the level of risk faced by those who are vulnerable. Studies of human interaction and reactions to warnings can also provide insights to improve the performance of early warning systems. Risk assessments should be used to identify the location of vulnerable groups, critical infrastructure and assets, to design evacuation strategies including evacuation routes and safe areas, and to expand warning messages to include possible impacts. For example, maps based on risk assessments help to motivate people, prioritize needs and interventions and guide preparations for disaster risk management measures, including prevention, preparedness and response.

Myanmar: In Myanmar, the multi-hazard risk assessments and hazard mappings have been carried out mostly through joint efforts of government departments (such as DRR and DMH), and international organizations such as UN and some INGOs. Several risk assessments projects have been undertaken in Myanmar supported by World Bank and ADB[4]. These efforts have contributed to the body of risk knowledge in the country and provide good examples of risk assessment products and outputs that are used for disaster risk reduction and management in Myanmar. However, mostly driven by the interests of the parties involved or by the availability of financial and technical resources and undertaken for certain purposes.

A detailed and complied list of various multi-hazard assessments and hazard mappings in Myanmar is given below in **Table 4.**[5]

Table 4: List of Multi Hazard Risk Assessment Studies in Myanmar

Sr. No.	Name of Study	Year	Organisation
1	Seismic hazard assessment of Yangon City	2015	MGS, MEC and UN-Habitat
2	Earthquake risk assessment of Pyay City	2015	MGS, MES, MEC and UN-Habitat

[4] http://cabaret.buildresilience.org/images/NPP-Myanmar.pdf

[5] Country Report Vietnam: Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation for Industrial Agglomerated Areas in the ASEAN Region, March 2015 http://open_jicareport.jica.go.jp/pdf/1000023395.pdf

Table 4: List of Multi Hazard Risk Assessment Studies in Myanmar			
3	Multi-hazard assessment as a country report for natural disasters	2015	AHA Center and JICA
4	Earthquake risk assessment of Bago, Taungoo and Sagaing City	2013	MGS, MES, MEC and UN-Habitat
5	Earthquake Risk Assessment of Mandalay	2012	ADPC/DMH/ MEC
6	Multi Hazard Risk Assessment of Rakhine State of Myanmar	2011	UNDP/ADPC/ MES
7	Multi Hazard Risk Assessment of Nargis-affected Area, January	2011	UNDP/ TARU/ INRM/ MSR
8	Hazard Profiling of Myanmar	2009	ADPC
9	Deterministic and Probabilistic Seismic Zoning Map of Myanmar	2008 2012	Myanmar Earthquake Committee
10	Flood Hazard Mapping of Lower Chindwin River Basin	2005	DOH India
11	Flood Risk Assessment for Hpa-An City, ongoing,	2019	DMH, RRD, DUHD, UNDP and UN-Habitat
12	Flood Risk Assessment- Yangon, Mawalamyine and Mandalay -	-	DMH and ADB
13	Flood Risk Assessment of Bago River Basin	2015	University of Tokyo
14	Seismic Risk Assessment of Yangon City	-	-

Currently, Myanmar Government is implementing **the Ayeyarwady Integrated River Basin Management (AIRBM)** Project with financial support from the Word Bank (US$100 million)[6]. The objective of the AIRBM Project is to help Myanmar develop the institutions and tools needed to enable informed decision making in the management of Myanmar's water resources and to implement integrated river basin management of the Ayeyarwady Basin. The AIRBM Project includes three components: i) Water Resources Management Institutions, Decision Support System, and Capacity Building; ii) Hydro-Meteorological Observation and Information Systems Modernization; and iii) Navigation Enhancement of the Ayeyarwady.

Vietnam: In Vietnam, various multi hazard risk assessment studies have been conducted under various programme and projects supported by international and

[6] Ayeyarwady Integrated River Basin Management https://www.airbm.org/airbm/

national agencies. A detailed complied list of various multi hazard risk assessment studies has given in **Table 5**.[7]

Table 5: List of Multi Hazard Risk Assessment Studies in Vietnam			
1.	Development of Coastal Multi-Hazard Mapping, Vulnerability & Risk Assessments and Investment Framework for Coastal Interventions Coastal Communities in Vietnam	2018	ICEM
2.	Multi-hazard assessment as a country report for natural disasters	2015	AHA Center and JICA
3.	EO Support to Multi-Hazard Vulnerability Assessment in Ho Chi Minh (Vietnam) and Yogyakarta (Indonesia)	2011	ESA
4.	Synthesis Report on Ten ASEAN Countries Disaster Risks Assessment	2010	UNISDR/World Bank
5.	Key Indicators for Asia and the Pacific 2012 43rd edition	2012	ADB ASEAN (10 countries)
6	Progress Report on Flood Hazard Mapping in Asian Countries ICHARM Publication No.16, ISSN 0386-5878/ Technical Note of PWRI No. 4164	2010	UNESCO (ICHARM)/PERI
7	A Primer: Integrated Flood Risk Management in Asia 2	2005	Asian Disaster Preparedness Center (ADPC)/UNICEF
8	Climate Change Vulnerability Mapping for Southeast Asia	2009	Economy and Environment Program for Southeast Asia (EEPSEA)
9	Reducing Vulnerability and Exposure to Disasters the Asia-Pacific Disaster Report 2012	2012	ESCAP/UNISDR
10	Advancing Disaster Risk Financing and Insurance in ASEAN Countries: Framework and Options for Implementation, Volume2: Appendix 1	2011	GFDRR/World Bank
11	Flood Risk Management in the Border Zone between Cambodia and Vietnam	2009	The Mekong River Commission Secretariat
12	Program for Hydro-Meteorological Disaster Mitigation in Secondary Cities in Asia (PROMISE) 2005 to 2010	2011	Asian Disaster Preparedness Center (ADPC)
13	Flood Hazard and Risk Assessment of Hoang Long River Basin, Vietnam	2010	Water Resources University, Nakhon Pathom Rajabhat University (MIKE by DHI conference)

[7] Country Report Vietnam: Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation for Industrial Agglomerated Areas in the ASEAN Region, March 2015
http://open_jicareport.jica.go.jp/pdf/1000023398.pdf

Table 5: List of Multi Hazard Risk Assessment Studies in Vietnam			
14	Flood Vulnerability Assessment of Downstream Area in Thach Han River Basin, Quang Tri Province	2010	Hanoi University of Science, Cietnam National University
15	Global assessment report on disaster risk reduction (2009) Risk and poverty in a changing climate	2009	United Nations International Strategy for Disaster Reduction Secretariat (UNISDR)
16	VIET NAM: Natural Hazard Risks	2011	United Nations Office for the Coordination of Humanitarian Affairs Regional Office for Asia and the Pacific (OCHA-ROAP)
17	From Disaster to Reconstruction: A Report on ADB's Response to the Asian Tsunami	2005	Asian Development Bank
18	Holocene Eruption and Selected Volcanoes in Asia-Pacific	2011	United Nations Office for the Coordination of Humanitarian Affairs, Regional Office for Asia Pacific (OCHA -ROAP)
19	Overview of Early Warning in Cambodia, Indonesia, Lao PDR, Philippines and Vietnam	2002	Asian Disaster Preparedness Center
20	The Economics of Climate Change in Southeast Asia: A Regional Review	2009	UNESCO (ICHARM)/PERI
21	Weathering the Storm: Options for Disaster Risk Financing in Vietnam	2011	World Bank
22	Natural Disaster Hotspots: A Global Risk Analysis	2005	World Bank
23	Disaster risk management programs for priority countries - 2nd edition	2011	UNISDR (united nations office for disaster risk reduction)
24	Completion Report of Emergency Rehabilitation of Calamity Damage Project in Vietnam	2009	ADB
25	Geo-Information Technology for Hazard Risk Assessment - Vietnam	2009	ADB
26	Project for Building Disaster Resilient Societies in Central Region in Vietnam	2009	JICA
27	Climate Change Vulnerability Mapping for Southeast Asia	2009	Economy and Environment Program for Southeast Asia (EEPSEA)

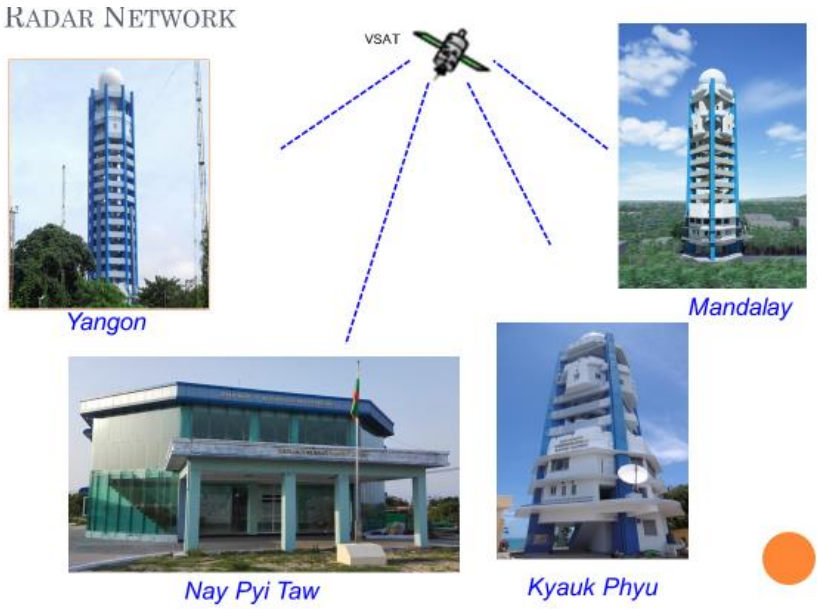
3.2 Monitoring and Warning Services:

Warning services lie at the core of an early warning system. There must be a sound scientific basis to the system and reliable technology for (i) monitoring and detecting hazards in real time or near real time; and (ii) providing forecasts and warnings 24

hours a day, 365 days a year. It must also be monitored and staffed by qualified people. Continuous monitoring of hazard parameters and their precursors (when available for a particular hazard) is essential to generate accurate warnings in a timely fashion that allow sufficient time for the affected community or communities to enact their disaster management plans appropriate for that hazard. The systems used for detection and monitoring, which could be automated, should allow for strict quality control of the data under international standards when these are available. Warning services should have a multi-hazard perspective (e.g. heavy rainfall may not only trigger flooding but also landslides, the warning for which may come from a separate authority) and be coordinated whenever possible to gain the benefit of shared institutional, procedural and communication networks and capacities. Data, forecasts and warnings should be archived in a standardized way to support post-event analysis and improvements of the system over time.

Myanmar: Department of Meteorology and Hydrology (DMH) is mainly responsible to provide the early warning system to higher authorities, local government, disaster risk reduction agencies, media, international NGOs, Myanmar NGOs, and public. In 2016, Myanmar received US$40 million from Japan to establish three weather radar stations in Yangon, Mandalay, and Kyaukphyu (a major town in Rakhine State in western Myanmar) as well as 30 automatic weather observation stations across the country in 2017[8]. **Figure 3** represents locations of weather radars in Myanmar.

Figure 3: Locations of Weather Radars in Myanmar



DMH is under administrative control of the Ministry of Transport. Main works performed by DMH are routine observation and analysis of meteorological phenomena, and providing weather and climate forecast and warning for the general public. DMH also provides meteorological and hydrological information for shipping and aviation as well as agricultural and environment activities. These tasks and

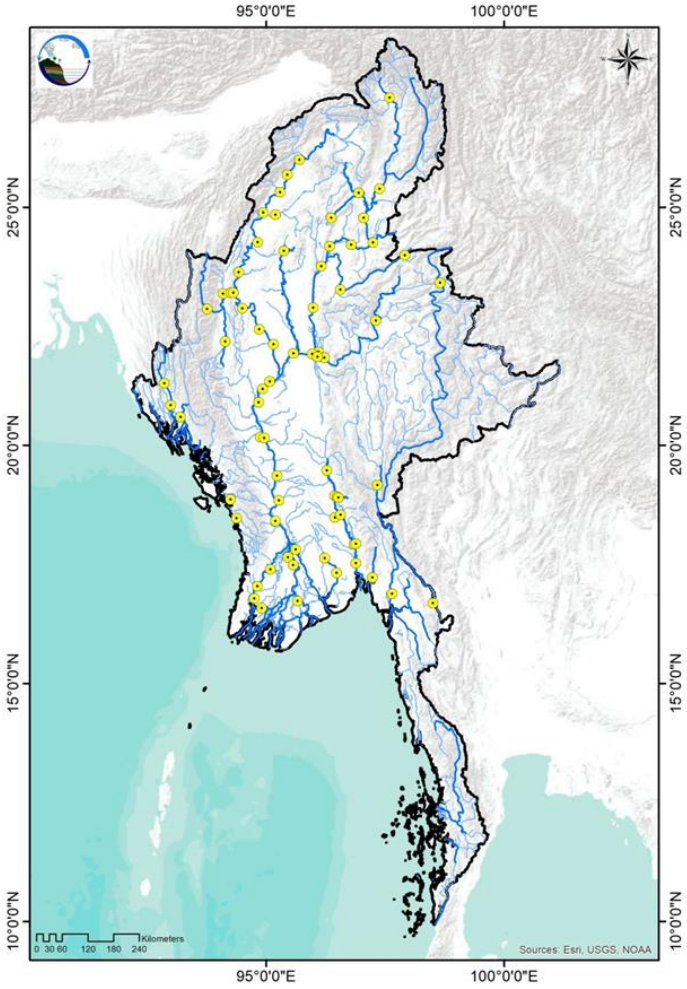
[8] Department of Meteorology and Hydrology, https://www.moezala.gov.mm/

services are performed as real-time and continuously for 24 hours. DMH provides warnings and advisories to the people in danger area through governmental organization and mass media, whenever abnormal to severe weather condition may occur in the area. This information is also provided to neighbouring countries through Global Telecommunication System of World Meteorological Organization (WMO). Through those works, DMH has been contributing and assisting to development of socio-economic activities in the Union of Myanmar and also in neighbouring countries.

- The severe weather events that impact in Myanmar are heavy rainfall (by Active Monsoon), tropical cyclone, storm surge, strong winds, thunderstorm, drought, heat wave, and cold wave.
- DMH collects and analysis of the different Numerical Weather Prediction (MWP) model outputs from global and regional centres (GFS, NCEP, JMA, BMD, RIMES, KMA, ECMWF and etc.) to be useful in enhancing the weather forecasting and monitoring system.
- DMH also operationally run the WRF model with horizontal resolution of 30km with (25) Eta - levels in the vertical and the integration is carried up to 72 hours forecast.
- DMH has applied Diana Tool (ECMWF model) and its overlay with satellite image (HIMAWARI-8) to use for improving of the short-range and medium range weather forecasting.
- DMH receive meteorological satellite data directly from HIMAWARI-8 satellite and FY-2D & FY-2E (CMAcast receiving system).
- Near real time other Satellite images (INSAT, KALPANA-1, and NOAA) receive from internet.
- (3) Weather Radars and (110) AWS and (20) Automated Surface Observing System (ASOS)
- DMH analysis synoptic chart, upper air chart, satellite images and other information source through internet for severe weather warning and tropical cyclone monitoring.
- DMH also using warnings and advisory from RSMC, New Delhi, JTWC and TMD.
- DMH use Ocean forecast (INCOIS) on SWFDP-BoB website for the Sea Route forecast for Myanmar waters.
- DMH access Global/Regional Numerical Weather Prediction (NWP) products of IMD, NCEP and ECMWF on SWFDP-BoB website. These forecast products are a good reference to use operational severe weather forecasting and warning information for Early Warning System. Not only operational forecasters but also decision makers at DMH are aware of this website and used the products in day-to-day forecast.

Map 4 represents of Hydrological Observation Stations in Myanmar[9].

Map 4: Hydrological Observation Stations in Myanmar



DMH disseminates all weather forecasts and warning information to higher Authorities, Local Authorities, Non-Governmental Organizations (NGOs), Government agencies such as, Ministry of Transport and Communications (MOTC), Ministry of Social Welfare Relief and Resettlement (MSWRR), Department of Disaster Management (DDM) (former name Relief and Resettlement Department - RRD), Ministry of Agriculture(MOA), Ministry of Health (MOH), Department of Water and Irrigation (DWIR) Office of Government- President and relevant Meteorological offices in different provinces. DMH published meteorological articles about current weather events, significant weather and updated information of meteorological conditions were published in state Newspapers, Ministry of Transport's Journal and other private Journals. DMH established a link with Myanmar Radio, MRTV, FM radios broadcasting about early warning and advisories while Tropical Cyclone approaching Myanmar Coastal areas. Latest position, expected weather, suggested actions were informed to general public effectively.

[9] Department of Meteorology and Hydrology, https://www.moezala.gov.mm/

DMH owned weather studio for effective communication with clear, understandable weather information and DMH official website www.dmh.gov.mm, Facebook and automatic weather answering phones fulfil early warning system with updated warning and news. Early Warning decision making processes are accomplished with valuable support and close cooperation with WMO and its Regional office, RSMC, New Delhi, WMO GTS, GFS, ECMWF forecast, CIMSS's analysis, WMO SWFDP BoB products and neighboring NMHSs for early warning, training and other technical support for Myanmar. **Table 5** represents Type of Forecast and Time of Issuance by DMH in Myanmar[10].

Table 5: Type of Forecast and Time of Issuance

Type of Forecast	Time of Issuance	Forecast Validity
Daily Weather Forecast	7:00Am/12:00noom/ 2:00pm/4:00pm/7:00pm	24 hours
Sea Route Forecast	10:30 Am/1:30Pm	24 hours
Special weather forecast	As per request and weather conditions	Depend on duration
Cyclone/surge	24-36 Hr before	-
Untimely Rainfall	Weather disturbance....	-
Strong Wind Warning	March (15)(31)/April(1)	Pre Monsoon Period
significant day & night temperature	If necessary	-
Heavy Rainfall/ Scarcity Rainfall Warning	If necessary	-
New Records (Rainfall/Max/Min)	when new record occur..	-
(10) Day Weather Forecast	Every Month of 8/18/28	(10) Days
Monthly Weather Forecast	Every Month of 28	(1) Month
General Weather Outlook for (SW/NE) Monsoon Season	April 28/October 28	Monsoon Season
Seasonal Weather Forecast	April 28, June 28, August 28	Early, Peak, Late Monsoon

Vietnam: The National Hydro-Meteorological Service (NHMS) is a state operational institution under Ministry of Natural Resources and Environment (MONRE), has the functions to assist the Minister in managing, exploiting the national hydro-meteorological station networks (including meteorological and hydrological basic investigations, forecasts, documentation), carrying out observations on air and water

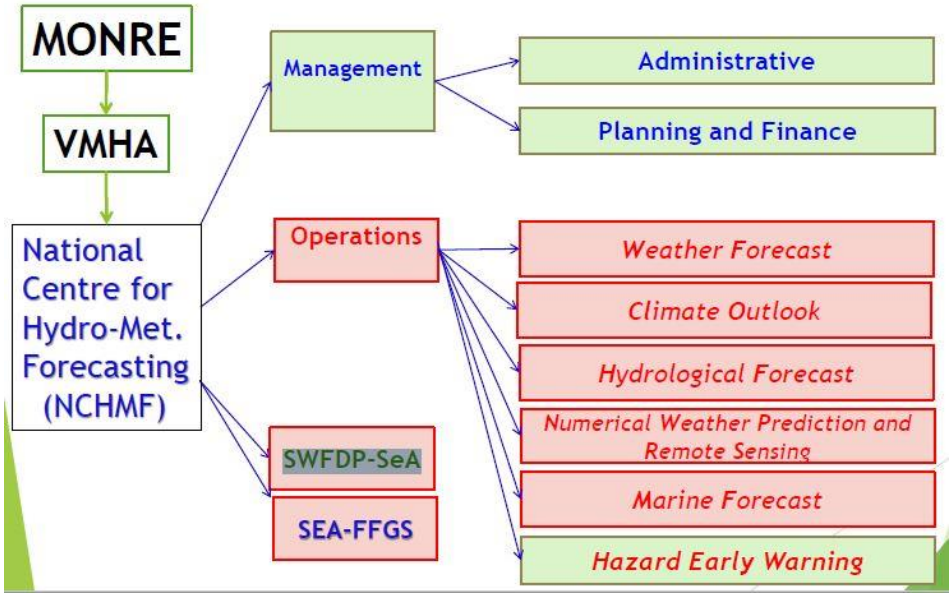
[10]Department of Meteorology and Hydrology, https://www.moezala.gov.mm/

environment to serve disaster prevention and preparedness, socio-economic development, to ensure security and defence in over the country. The NHMS of Vietnam administers offices including[11]:

- National Center of Hydro-Meteorological Forecasting (NCHMF),
- 9 regional hydro-meteorological centers,
- 63 provincial hydro-meteorological forecasting centers and observation station networks.

National Centre for Hydro-Meteorological Forecasting (NCHMF) is a governmental organization belonging Vietnam Meteorological Hydrological Administration (VMHA) with authority to issue forecasting/warning information for weather, climate, hydrology, water resource, marine weather (i.e. hydro-meteorology) and provide hydro-meteorology services. **Figure 4** represents administrative set-up of NHMS, Vietnam.[12]

Figure 4: Administrative set-up of NHMS, Vietnam



The National Center of Hydro-Meteorological Forecasting (NCHMF) has the following functions:

- Providing daily the weather forecast of Vietnam (for some big cities and 9 regions related to regional centers) and Bien Dong sea,
- Issues the Warnings of Nation-Wide High impact Weather (cold surge, extreme Heat, gale, tropical cyclones, etc.),
- Services Central Government for Decision-making,
- Services to Regional Hydro-meteorological Centers,
- Services to Public and external User Community

[11] Joint Meeting of RA II WIGOS Project and RA V TT-SU Jakarta, Indonesia / 11 October 2018 BMKG Headquarter https://www.jma.go.jp/jma/jma-eng/satellite/ra2wigosproject/documents/joint_meeting_program_presentation/CountryReport/Vietnam.pdf

[12] Joint Meeting of RA II WIGOS Project and RA V TT-SU Jakarta, Indonesia / 11 October 2018 BMKG Headquarter https://www.jma.go.jp/jma/jma-eng/satellite/ra2wigosproject/documents/joint_meeting_program_presentation/CountryReport/Vietnam.pdf

NCHMF has role of providing the meteorological background forecast for whole Vietnam and Bien Dong Sea (the east sea of Vietnam). After receiving the background forecasts, the regional centers or provincial centers will add more detail forecast and warning for their responsibility areas. NCHMF web portal focuses on the risks of heavy rainfall and strong wind and the confidence of the risk areas guiding from deterministic/ensemble global and regional Numerical Weather Prediction (NWP) models. NCHMF uses following forecast models and provides warning products:

Forecast Models:

- Meteorological model: NWP
- Hydrological model: Marine model for hydro and water level; Mike -11

Forecast Products:

Short term forecast:

- Daily weather forecast, 3-5 days
- Forecasts about storm, tropical depression (concretized from the Central news), cold front and drought
- Flood forecast
- Forest fire forecast

Long and moderate term forecast:

- Forecast for 10 days/month/crop (Winter-Spring and Summer-Autumn and take consideration into flood, storm and rain conditions)

Topical forecast (when required):

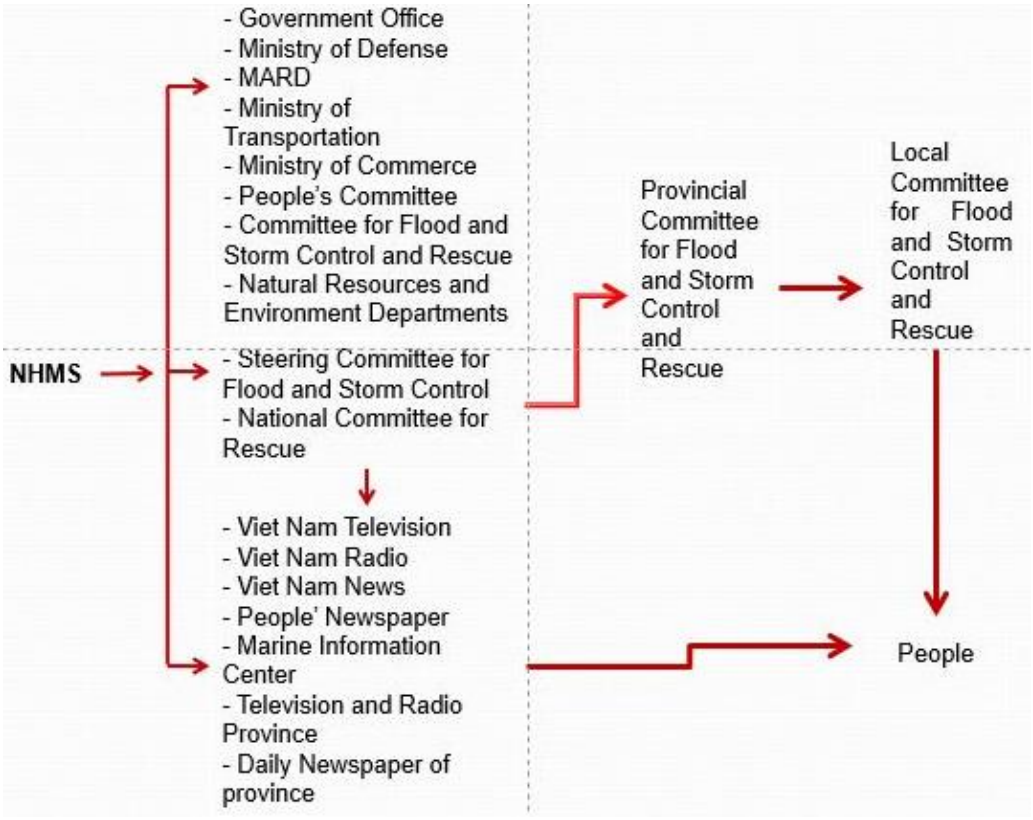
- Forecast is made to serve construction of traffic, building, irrigation and hydroelectricity

NCHMF manages following infrastructure.

- 181 surface synoptic stations,
- 354 hydrological stations,
- 6 Temperature,
- 6 pilot stations,
- 500-800 automatic rain gauge,
- 8 weather radars,
- Ground receiving satellite stations: HimawariCast, CMAcast,
- 26 marine stations (wave and water level),
- Marine radar (wave, surface current)

Figure 5 represents forecast and warning dissemination process.

Figure 5: Forecast and Warning Dissemination Process



Source: VMHA, Vietnam[13]

3.3 Dissemination and Communication:

Dissemination and communication systems (including the development of last-mile connectivity) ensuring people and communities receive warnings in advance of impending hazard events, and facilitating national and regional coordination and information exchange. Warnings must reach those at risk. Clear messages containing simple, useful and usable information are critical to enable proper preparedness and response by organizations and communities that will help safeguard lives and livelihoods. Trust is a big part of effective risk communication. If the information source cannot be trusted, those at risk may not respond proactively to the warnings – and it takes a long time to establish trust. Regional, national and local communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

There are numerous standards and protocols used by alerting authorities to transmit warnings. The Common Alerting Protocol is an international standard format for emergency alerting and public warning, developed by the International Telecommunication Union and promoted by a number of agencies. It is designed for

[13] https://slideplayer.com/slide/6381925/

"all-hazards", that is, hazards related to weather events, earthquakes, tsunamis, volcanoes, public health, power outages, and many other emergencies.

Myanmar: Weather warning messages are issued and communicated by the Department of Meteorology and Hydrology (DMH) under Ministry of Transport and Communication. Information transfer to the community level by Department of Disaster Management, Ministry of Social Welfare, Relief and Resettlement (RRD). Preparation and enhancement of the co-operation and coordination system between both agencies is essential. In normal times, the DMH is responsible for the dissemination and communication of warnings from national to local levels (as shown by the **Figure 6 and Figure 7**).

Over the recent years, many organizations or consortiums such as ADPC, RIMES, Malteser International, JICA, MRCS, MCCR and other regional/international partners have been supporting the DMH and the agencies to improve early warning systems in a multi-hazard framework. All these projects and interventions have specific interventions to improve the four components of early warning systems. DRR Working Group agencies provided information on their experience at community level in warning formulation and dissemination/communication.

Figure 6: Information Flow/Warning Dissemination

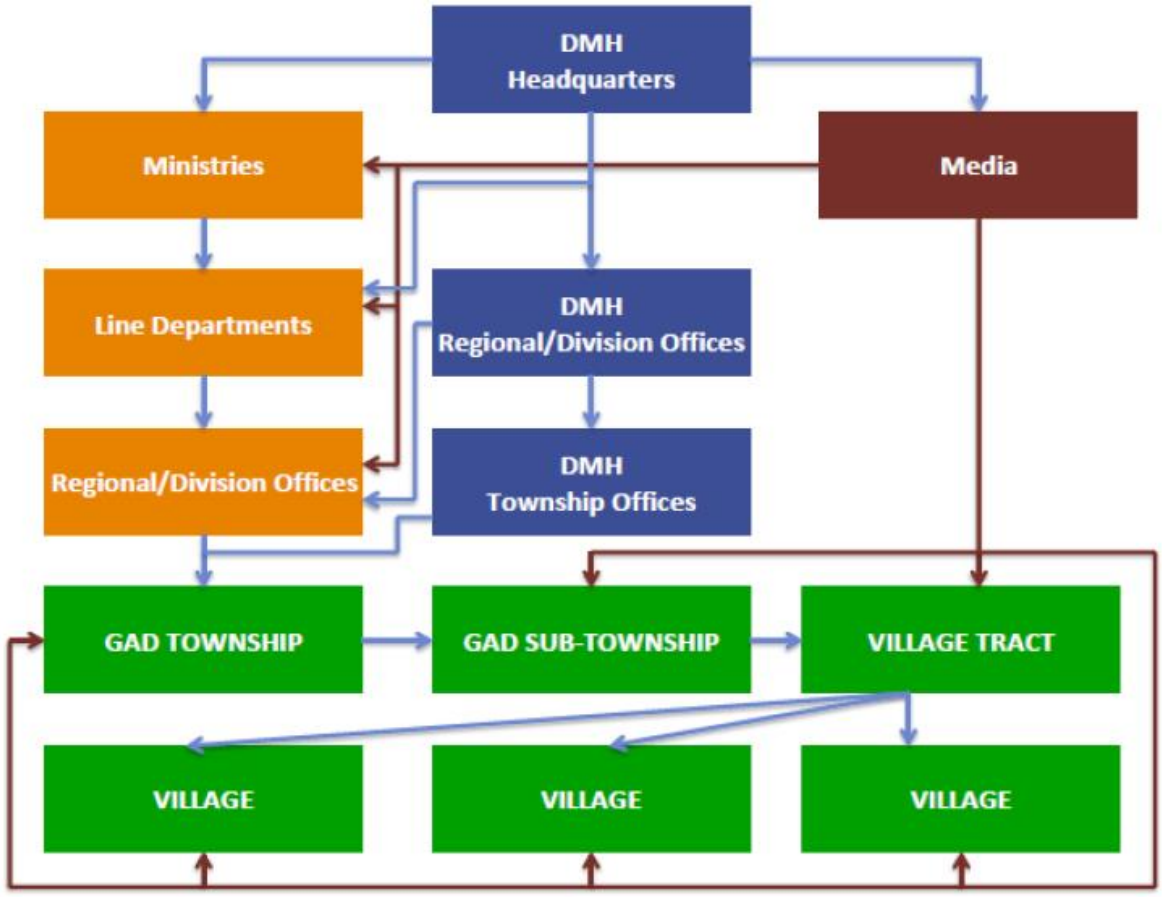
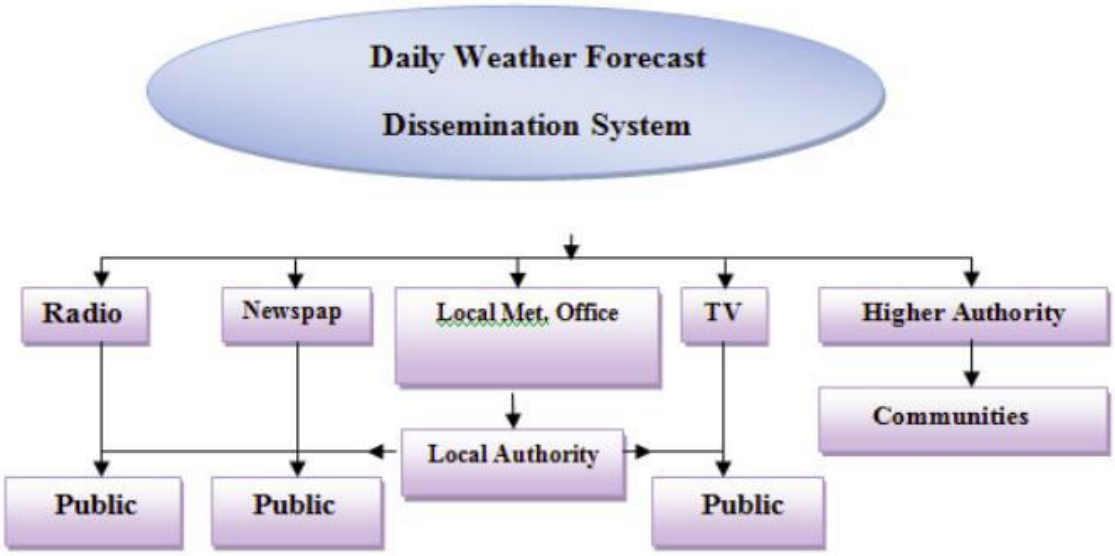
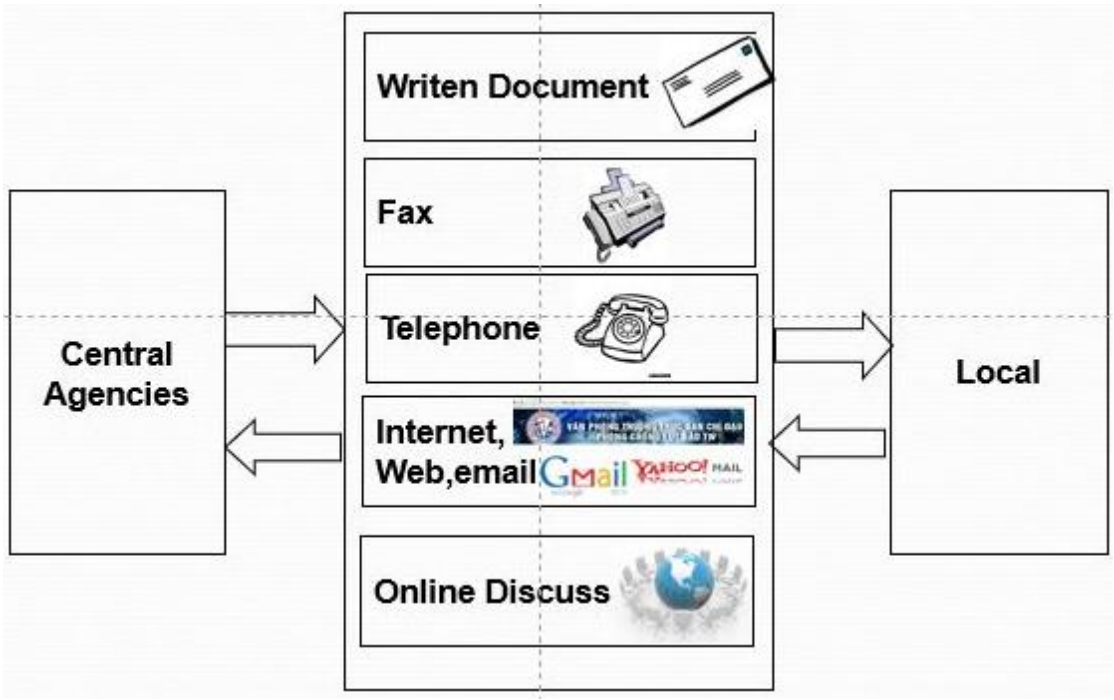


Figure 7: Warning Dissemination Channels



Vietnam: Figure 8 represents the dissemination methods:

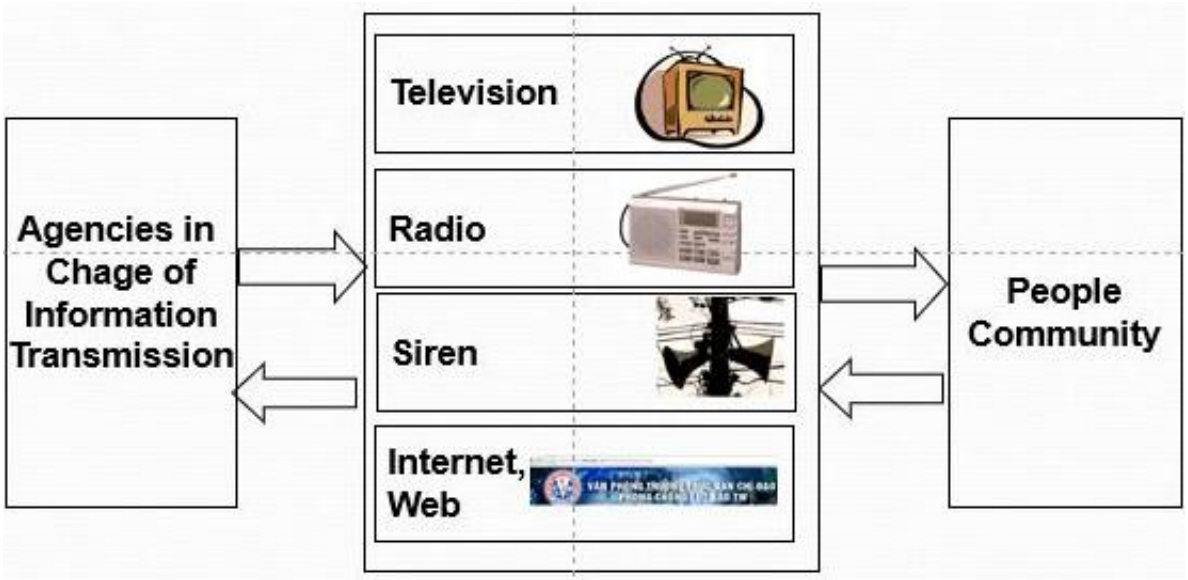
Figure 8: Dissemination Methods (from Central to Local)



Source: NHMS, Vietnam[14]

[14] ASEAN Risk Monitor and Disaster Management Review, https://slideplayer.com/slide/6381925/

Figure 9: Dissemination Methods (from Local to People)



Source: NHMS, Vietnam[15]

3.4 Response Capability:

Institutions and people enabled to act early and respond to a warning through enhanced risk education. It is essential that people understand their risks, respect the national warning service and know how to react to the warning messages. Education and preparedness programmes play a key role. It is also essential that disaster management plans include evacuation strategies that are well practiced and tested. People should be well informed on options for safe behaviour to reduce risks and protect their health, know available evacuation routes and safe areas and know how best to avoid damage to and loss of property.

Figure 9 summarizes the functional early warning systems in ASEAN Member States for seven principal hazards[16].

[15] ASEAN Risk Monitor and Disaster Management Review, https://slideplayer.com/slide/6381925/
[16] ARMOR, https://ahacentre.org/publication/armor/

Figure 9: Matrix of Functional Early Warning Systems in ASEAN

Hazard	Drought	Earthquake[2]	Flood	Landslide	Tropical cyclone	Tsunami	Volcano eruptions
ASEAN Member State							
Brunei Darussalam	N/A	N/A	Weather forecast website (BDMD)	N/A	Weather forecast website (BDMD)	N/A	N/A
Cambodia	N/A	N/A	EWS1294 (Dept. of Met)	EWS1294 (Dept. of Met)	EWS1294 (Dept. of Met)	N/A	N/A
Indonesia	Periodi -cal drought maps (BMKG)	InfoBMKG (BMKG); Magma (PVMBG)	Through web-based EWS in each major-river agency	Land movement hazard daily report (PVMBG)	Tropical Cyclone Centre (BMKG)	InaTEWS (BMKG)	Magma & Daily Report of (PVMBG)
Lao PDR	National Early Warning Centre DMH	N/A	National Early Warning Centre DMH	N/A	N/A	N/A	N/A
Malaysia	N/A	Website of MetMalaysia	InfoBanjir website (Dept. of Irrigation)	N/A	Website of MetMalaysia	N/A	N/A
Myanmar	N/A	DMH Website	DMH Website	N/A	DMH Website DAN app	DMH Website	N/A
Philippines	N/A	PHIVOLCS	PAGASA Flood alert	N/A	PAGASA TC alert	PHIVOLCS	Volcanoes daily report (PHIVOLCS)
Singapore	N/A	MSS Website	MSS Website PUB Website	N/A	MSS Website	MSS Website	MSS Website
Thailand	Thai-Water (HAII)	Earthquake TMD website & app (TMD)	ThaiWater website & app (HAII)	N/A	Metalarm (TMD) Weather Warning (TMD)	N/A	N/A
Viet Nam	N/A	N/A	NCHMF website	Landslide warning website (VN Institute of Geosciences & Mineral	NCHMF website	N/A	N/A

Source: ASEAN Risk Monitor and Disaster Management Review (ARMOR), 2019[17]

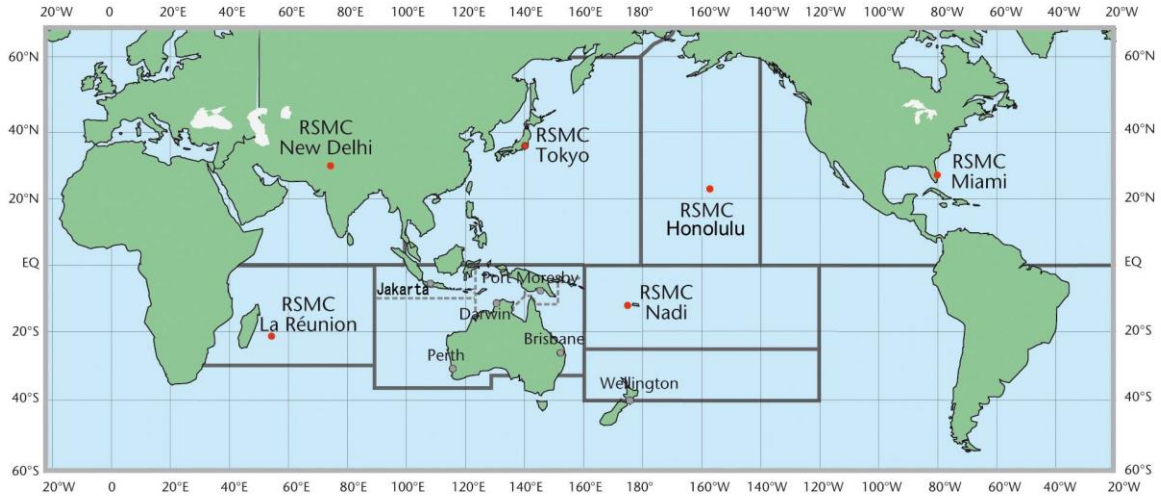
[17]ARMOR, https://ahacentre.org/publication/armor/

4. Regional Agencies and Early Warning Systems:

4.1 Regional Specialized Meteorological Centre (RSMC)- Tropical cyclone and Tropical Cyclone Warning Centres (TCWC):

The World Meteorological Organization (WMO) has designated "Regional Specialized Meteorological Centres" (RSMC)[18]. RSMC is responsible for the distribution of information, advisories, and warnings regarding the specific program they have a part of, agreed by consensus at the WMO.

Figure 10: Regional Specialized Meteorological Centre



Source: WMO, 2019

The six tropical cyclone Regional Specialized Meteorological Centres (RSMCs) together with six Tropical Cyclone Warning Centres (TCWCs) having regional responsibility to provide advisories and bulletins with up-to-date first level basic meteorological information on all tropical cyclones, hurricanes, typhoons everywhere in the world. The first-level basic information comprises reliable information from a clearly defined source on the tropical cyclone's location and size and its present and forecast movement and intensity.

4.2 ASEAN Specialised Meteorological Centre (ASMC):

ASEAN Specialised Meteorological Centre (ASMC) was established in January 1993 as a regional collaboration programme among the National Meteorological Services (NMSs) of ASEAN member countries. ASMC is hosted under Meteorological Service Singapore, National Environment Agency of Singapore.

The main objective of ASMC is to enhance regional capacity and strengthen support in the provision of meteorological services. Under the ASEAN Regional Haze Action Plan endorsed by the ASEAN Ministers of the Environment and implemented in 1997, the ASMC was appointed to monitor and assess land and forest fires and the occurrence of transboundary smoke haze affecting the ASEAN region. The countries monitored initially covered Brunei Darussalam, Indonesia, Malaysia and Singapore,

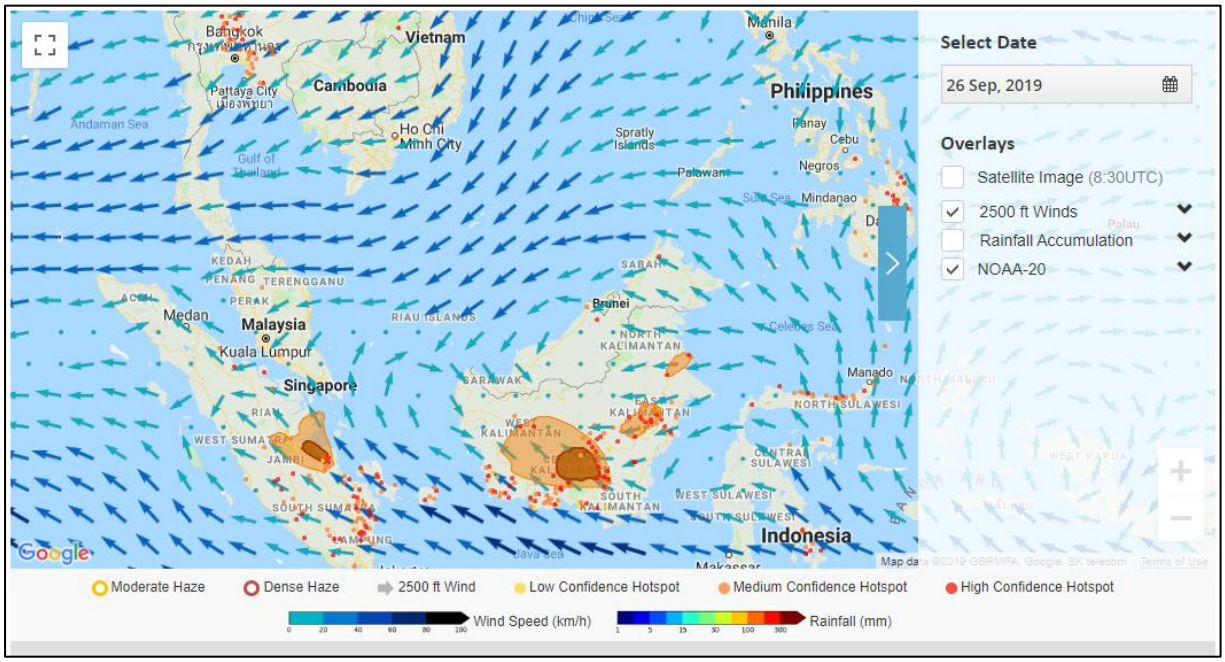
[18] World Meteorology Organisation, https://www.wmo.int/pages/prog/www/tcp/Advisories-RSMCs.html

and later extended in 2003 to cover the whole ASEAN region (Cambodia, Lao PDR, Myanmar, the Philippines, Thailand and Vietnam). ASMC also serves as a technical member for various inter-agencies committees in ASEAN region, providing information related to forest fires and smoke haze. The main roles of ASMC are:

- Monitor and assess land and forest fires, as well as the occurrence of transboundary smoke haze for the ASEAN region;
- Conduct seasonal and climate predictions for the ASEAN region;

ASMC website provides operational and regularly updated information and products on the weather and smoke haze situation in the ASEAN region[19]. The target end users are the environment, forestry, meteorological and related agencies of ASEAN member countries. The individual ASEAN NMSs and the relevant national authorities shall remain the sole authorities for issuing hazardous weather and environmental conditions in their respective countries. **Figure 12** represnets Latest weather and haze situation in ASEAN region.

Figure 12: Latest Weather and Haze Situation in ASEAN Region



Source: ASEAN Specialised Meteorological Centre

[19] ASEAN Specialised Meteorological Centre, http://asmc.asean.org

5. River Basins:

5.1 Vietnam River Basin:

Vietnam is characterized by a dense system of rivers and canals. Due to the tropical monsoon climate and mountainous area that characterizes three-quarters of the country's total land area; precipitation varies by place and time. This leads to an uneven distribution of annual precipitation, which alters the flow of rivers and causes drought during the low-flow season and flooding in the high-flow season.

With 13 large river systems, which cover 10,000 km^2 in total, Vietnam is considered to have a complex and dense river network with most of the large river systems linked. Amongst those 13 main river systems, 9 have basins which contribute to 90% of total river basin area in the whole country. The 9 main river basins are those of Red (also known as Hong), Thai Binh, Bang Giang-Ky Cung, Ma, Ca La, Thu Bon, Ba, Dong Nai, and Mekong (also known as Cuu Long) river.

The Red river and the Mekong river systems have the largest basin areas (155,000 and 795,000 km^2 respectively) as well as the highest total volume of water flow. Other than that, each river system has its own distinctive characteristics, thus environmental management approaches may vary greatly from one river basin to another, depending on socio-economic conditions, land use, environmental factors, and their economic and ecological values etc.

5.1.1 Red (Hong) River Basin:

The Red River rises in mountains south of Dali in China's Yunnan Province, and then descends 1,149 KM through Vietnam to exit into the Gulf of Tonkin. The river flows past Vietnam's capital, Hanoi. The Red River is the second largest river in Vietnam, fter the Mekong. It runs through the whole of North Vietnam, its unpredictable flow often accompanied by violent floods, ending in the vast Red River Delta, where it finally flows out gently into the Halong Bay.

Its catchment covers 26 provinces, with a surface area (49%) of nearly 70,413 km^2 (Total basin areas is 143,700 km^2). Rainfall is uneven across the basin and ranges from 700 to 4,200 mm a year, about 80% of which falls between May and October. Average annual discharge from the river is about 136 KM^3. 61% of this water is derived from Vietnam. Flooding is a significant issue on the Red River.

In the Delta, the average altitude is 3-5 meters lower than maximum flood levels. As a consequence, much hydraulic infrastructure in the basin is devoted, in whole or in part, to flood control. The Red River delta extends over 120 km^2, and is densely populated. Much of the country's economic activity is based in the delta, where nearly a third of the national rice production is grown. River basin map of Red River is presented in **Map 5.**

Map 5: Red (Hong) River Basin, Vietnam

Source: Greater Mekong Subregion Environment Operations Center[20]

5.1.2 Tien River (in Lower Mekong River Delta):

My Tho City (Tien Gian Province) is situated in the Mekong Delta of Vietnam, which is formed by the lower part of the Mekong river delta, and includes 13 cities and provinces of Long An, Tien Giang, Dong Thap, Vinh Long, Tra Vinh, Can Tho, Hau Giang, Soc Trang, Ben Tre, An Giang, Kien Giang, Bac Lieu and Ca Mau. The total natural area comprises approximately 3.96 million hectares (excluding Duc Hoa District Long An Province and Phu Quoc island province Kien Giang), accounting for 79% of the whole MD and forming 5% of the Mekong River basin.

The Mekong Delta of Vietnam is surrounded by: (a) Vietnam-Cambodia border in the North; (b) Pacific Ocean / South China Sea to the East (the so-called East sea), (c) Gulf of Thailand in the West (the so-called West sea), and (c) Vam Co Dong River and Ho Chi Minh City in the North-West.

Hydrological regimes in the Mekong Delta are affected directly by the river flow, the tidal regime of the East Sea (South China Sea) and for some parts of the delta by the tidal regime in the Gulf of Thailand (West Sea). The East Sea has a semi-diurnal and

[20] Greater Mekong Subregion Environment Operations Center, http://www.gms-eoc.org/

irregular sea-tide regime, while the West Sea is diurnal. River basin map of Mekong River is presented in **Map 6.**

Map 6: Mekong River Basin, Vietnam

Source: Greater Mekong Subregion Environment Operations Center[21]

[21] Greater Mekong Subregion Environment Operations Center, http://www.gms-eoc.org/

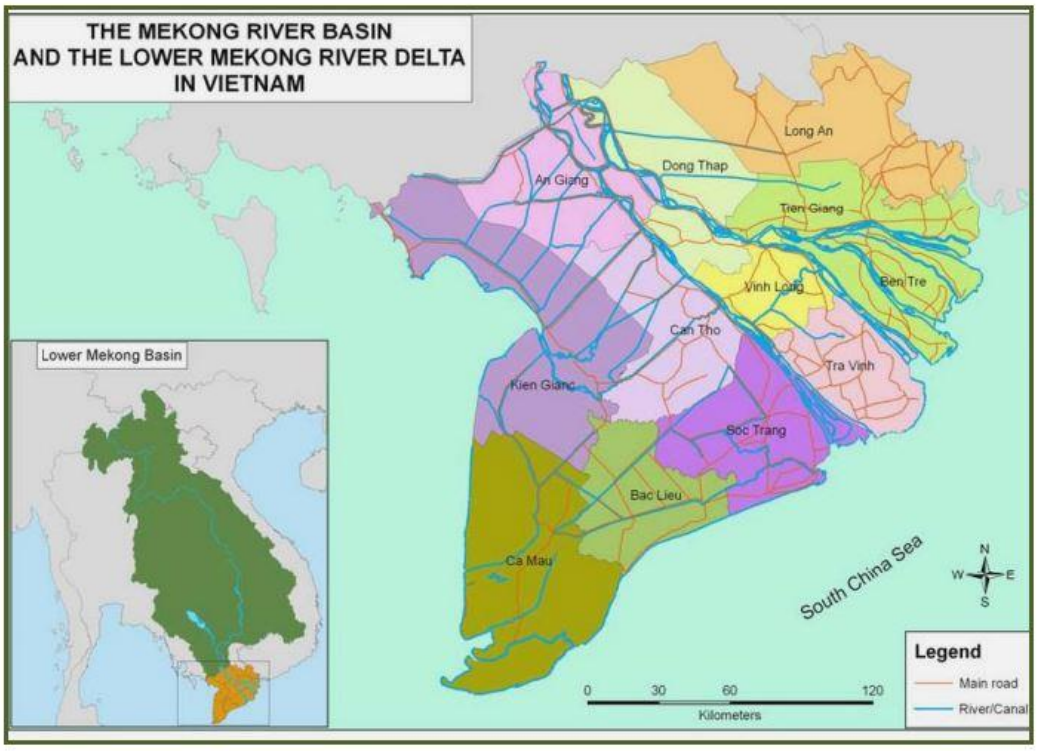
Based on the influence of these diverse tidal patterns and cycle, the Mekong Delta can be divided into three different regions hydrologically. These are:

- the northern plains, including sections of the province of An Giang and Dong Thap, an area about 300,000 ha), where the impact of the river floods is dominant;
- an area with combined river flood-tidal impacts; this region is bound by the Cai Lon river-Xeo Chit channel Lai Hieu canal - Mang Thit river and Ben Tre-Cho Gao canals with an area of about 1.6 million ha), and
- the coastal delta regions with direct influence of the primary tides; this includes the entire coastal region of the East Sea, with an area of about 2.0 million ha).

Seasonal flooding in the Mekong Delta usually begins in months June - July and ends in months November – December, with an average peak flow entering the delta of around 28,000-30,000 m^3/s. This is followed by a seasonal average dry flow of about 3,000-5,000 m^3/s. Both high and low flood regimes prevail for about 6 months.

The Mekong Delta river system comprises a relatively dense network of river courses and canals, including the natural river systems and canals. Tien River is a major source of fresh water, which flows 115 km through the territory of Tien Giang, elevation from the river bed is from 6 m to 16 m, average- 9 m. The river width varies from 600 to 1,800 m; wet section is about 2,500-17,000 m and influenced by tide throughout the year. Flow in dry season (April) around 130 – 190m^3/s. Map of Lower Mekong River Delta is presented in **Map 8**.

Map 8: Lower Mekong River Delta, Vietnam



Source: Greater Mekong Subregion Environment Operations Center[22]

[22] Greater Mekong Subregion Environment Operations Center, http://www.gms-eoc.org/

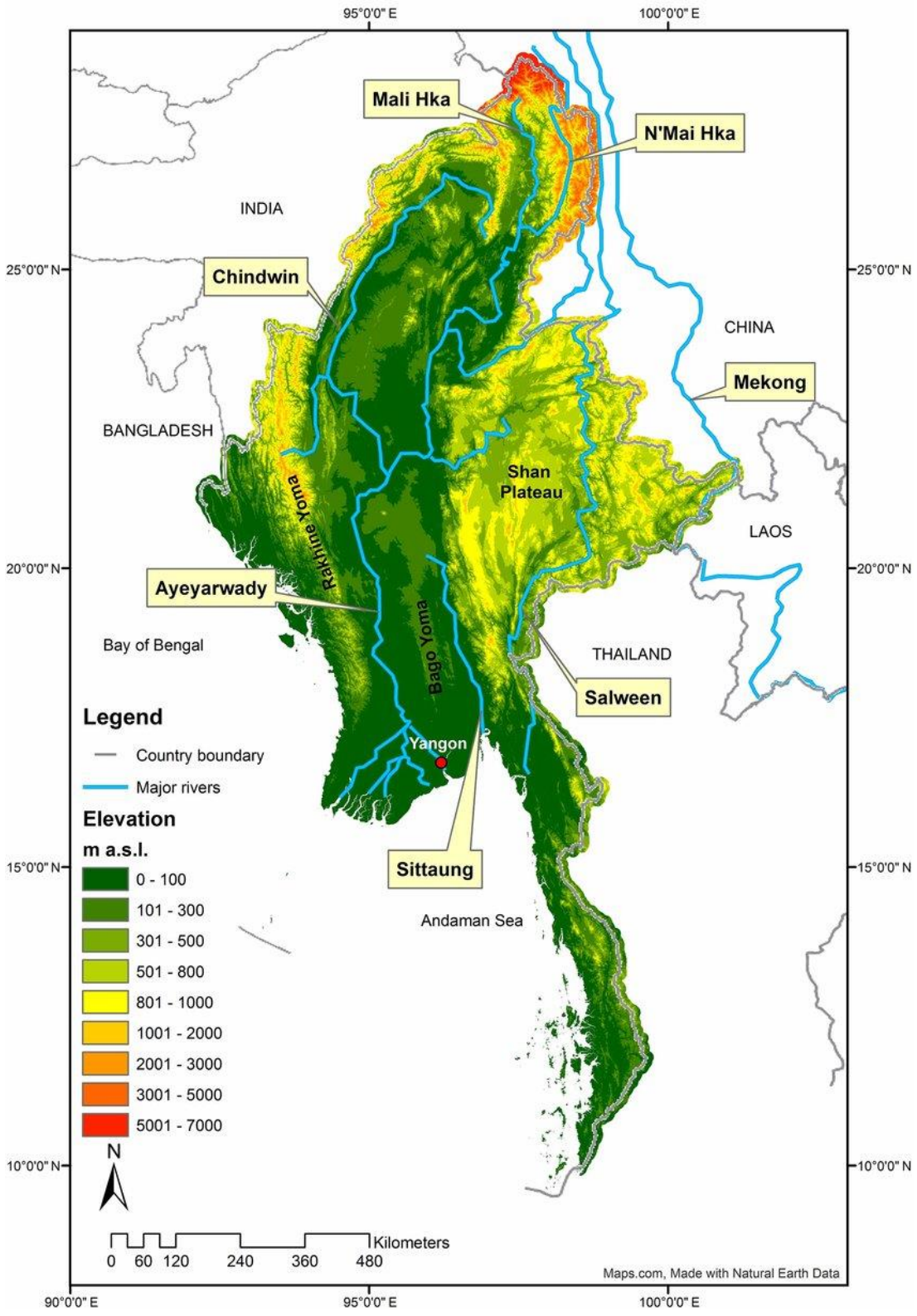
5.2 Myanmar River Basin:

Myanmar is endowed with abundant water resources with uneven spatial and temporal distribution. The monthly distribution of river flows closely follows the pattern of rainfall, which means that about 80 percent flows during the monsoon season (May-October) and 20 percent in the dry season (November-April). The north-south direction of Myanmar's mountain ranges is reflected in the flow of its major rivers, of which two are international. There are six river basins:

- Ayeyarwady (Irrawaddy)-Chindwin river basin, which is almost entirely located in Myanmar, drains 58 percent of the territory. It can be divided into three sub-basins: Upper Ayeyarwady, Lower Ayeyarwady and Chindwin.
- Sittaung river basin, which is also entirely located in Myanmar to the east of the downstream part of the Ayeyarwady, drains 5.4 percent of the territory.
- Thanlwin (Salween in Thailand, Nu in China) river basin drains 18.4 percent of the territory, mainly the Shan plateau in the east. The source of the river is in China and, after entering the country, forms the border with Thailand for about 110 km.
- Mekong (Lankang in China) river basin drains 4.2 percent of the territory in the far east and forms the border with Lao People's Democratic Republic. Myanmar is not a member of the Mekong River Commission.
- Rakhine (Arakan) coastal basin in the west drains into the Bay of Bengal.
- Tanintharyi (Tenasserim) coastal basin in the south drains into the Andaman Sea.

Map of Myanmar river basins with elevation is presented in **Map 8.**

Map 8: Myanmar River Basins and Elevation



Source: Mariele Evers and Linda Taft (2019)[23]

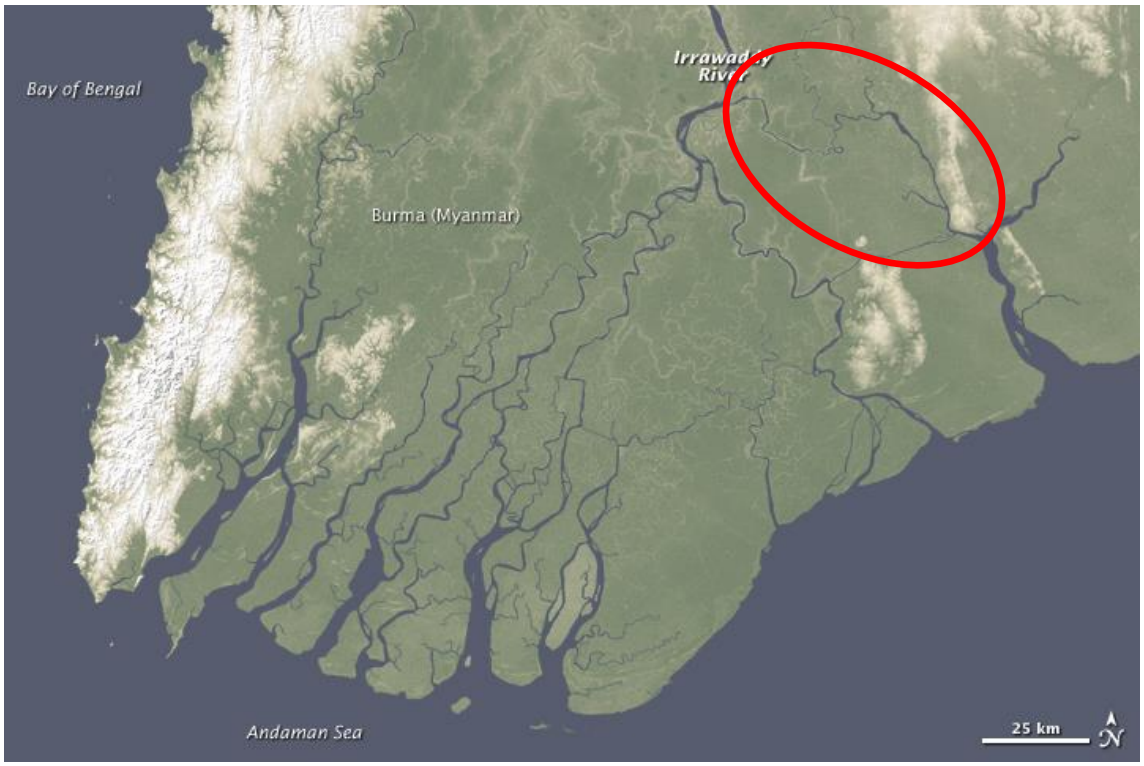
[23] *Mariele Evers and Linda Taft (2019), https://www.researchgate.net/figure/Physical-overview-map-of-Myanmar-including-state-border-lines-major-rivers-and-mountain_fig1_310824267*

5.2.1 Yangon River Basin:

The Yangon river (also known as the Rangoon river or Hlaing River), is about 40 km long (25 miles), and flows from southern Myanmar as an outlet of the Irrawaddy (Ayeyarwady) river into the Ayeyarwady delta. The Yangon river drains the Pegu Mountains; both the Yangon and the Pathein rivers enter the Ayeyarwady at the delta. It is a marine estuary that runs from Yangon (also known as Rangoon) to the Gulf of Martaban of the Andaman Sea. The channel is navigable by ocean-going vessels, thus plays a critical role in the economy of Myanmar.

The Twante Canal connects the Yangon River with the Irrawaddy Delta, once known as 'the rice bowl of Asia'. It consists of 1,000 square miles (3,000 km2) of lush teak plantations and mangrove swamps, many of which have now been cleared for rice production. **Map 9** represents Yangon (Rangoon or Hlaing) River Basin.

Map 9: Yangon (Rangoon or Hlaing) River Basin

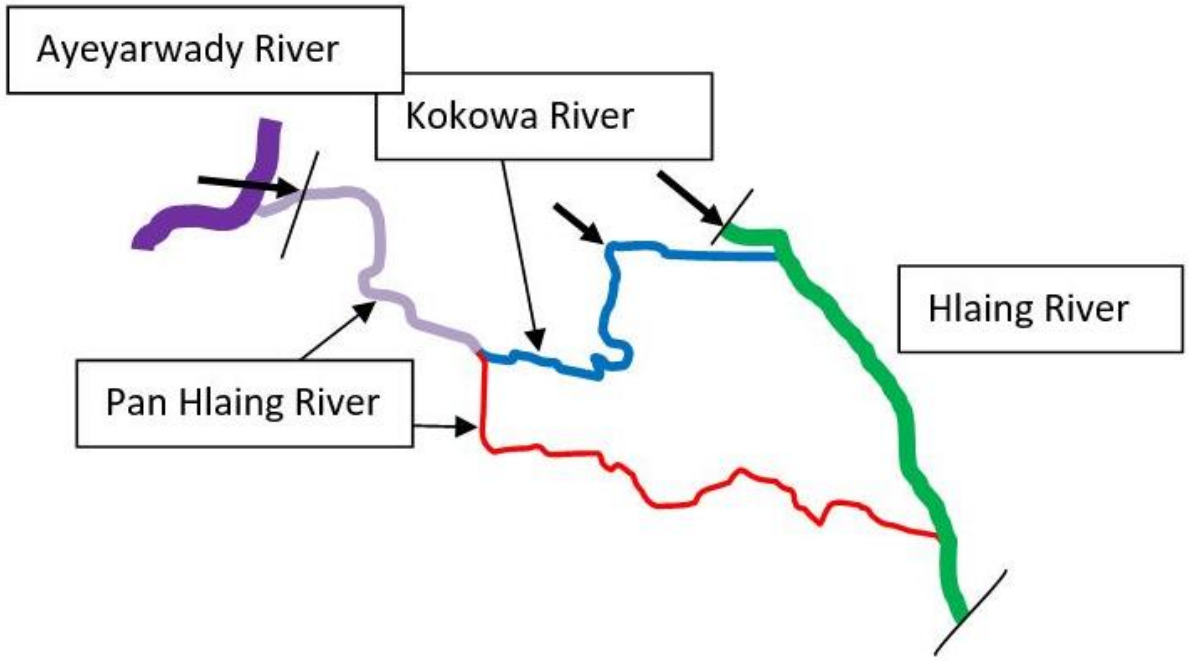


Source: NASA Earth Observatory, 2019 [24]

[24] NASA Earth Observatory, https://earthobservatory.nasa.gov/

Map 10 and Map 11 represents Yangon (Hlaing) River System in Myanmar.

Map 10: Yangon (Hlaing) River System



Map 11: Yangon (Hlaing) River System

Source: Google Earth, 2019

6. Global Frameworks and Linkages with Early Warning System:

6.1 Sendai Framework for Disaster Risk Reduction (SFDRR):

The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action. The Sendai Framework is a 15-year, voluntary, non-binding agreement which recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders. It aims for "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries". Outcome, goal, priorities and targets of SFDRR is presented in **Figure 13.**

Figure 13: Sendai Framework for Disaster Risk Reduction

Source, UNDRR, 2019

The SFDRR was adopted at the Third United Nations World Conference on Disaster Risk Reduction (WCDRR) held in Sendai, Japan, from 14th to 18th March 2015 called for enhancing and strengthening Multi-hazard Early Warning systems (MHEWS), to develop and invest in regional multi-hazard early warning mechanisms, and to achieve the global target for MHEWS. MHEWS inform the people of the potential impacts of impending natural hazards, the risks on their lives and livelihoods, and the action they should take. To be effective, this approach entails multi-stakeholder cooperation and coordination between and among national science, disaster-risk management agencies, and other relevant stakeholders. It also needs to be combined with actions to make communities more disaster resilient so that they can respond more effectively to natural hazards. The global targets of SFDRR is presented in **Figure 14**. Target 'G' of SFDRR is focused on "substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030".

Figure 14: The Global Targets of SFDRR

Source: UNDRR, 2019

6.2 Sustainable Development Goal (SDG):

Sustainable Development Goals (SDGs) are collection of 17 global goals set by the United Nations General Assembly in 2015 for the year 2030. The SDGs are part of Resolution 70/1 of the United Nations General Assembly, the 2030 Agenda. Early warning and preparedness systems have the potential to significantly reduce the loss of life and livelihoods from disasters, simultaneously building resilience and supporting the achievement of the SDGs. The global targets of SDG are presented in **Figure 15.**

Figure 15: The Global Goals of SDG

Source: SDG, 2019

Sustainable development cannot be achieved while disasters continue to undermine economic growth and social progress. No country or sector is immune to the impacts of natural hazards, many of which are increasing in frequency and intensity due to the impacts of climate change. While critical, simply preparing for disasters is not enough. To realise the transformative potential of the 2030 Agenda for Sustainable Development, governments and stakeholders have affirmed that disaster risk reduction needs to be at the core of sustainable development. SFDRR 2015-2030 was the first agreement of the post-2015 development agenda. It includes seven global targets accompanied by a comprehensive set of guiding principles that give direction to reduce the impact of disasters, while also addressing the underlying drivers of disaster risk and safeguarding current and future development gains. Progress in implementing SFDRR is therefore progress towards meeting the Sustainable Development Goals. In turn, progress on the Sustainable Development Goals can substantially build the resilience of people and governments in the face of disasters. There are a number of targets across the 17 Sustainable Development Goals that are related to disaster risk reduction. Conversely, all seven global targets of the Sendai Framework are critical for the achievement of the Sustainable Development Goals. **Figure 16** presents linkages between SDG and SFDRR.

Figure 16: Linkages between SDG and SFDRR for EWS

Source: UNDRR, 2019

6.3 New Urban Agenda:

The United Nations (UN) HABITAT-III conference in October 2016 adopted the New UN Urban Agenda1, which brings into focus urban resilience, climate and environment sustainability as well as disaster risk management. Increasingly dense, complex and interdependent urban fabrics are rendering cities vulnerable: a single extreme event can lead to a widespread breakdown of a city's infrastructure often through cascading downstream or “domino” effects.

6.4 Paris Climate Agreement:

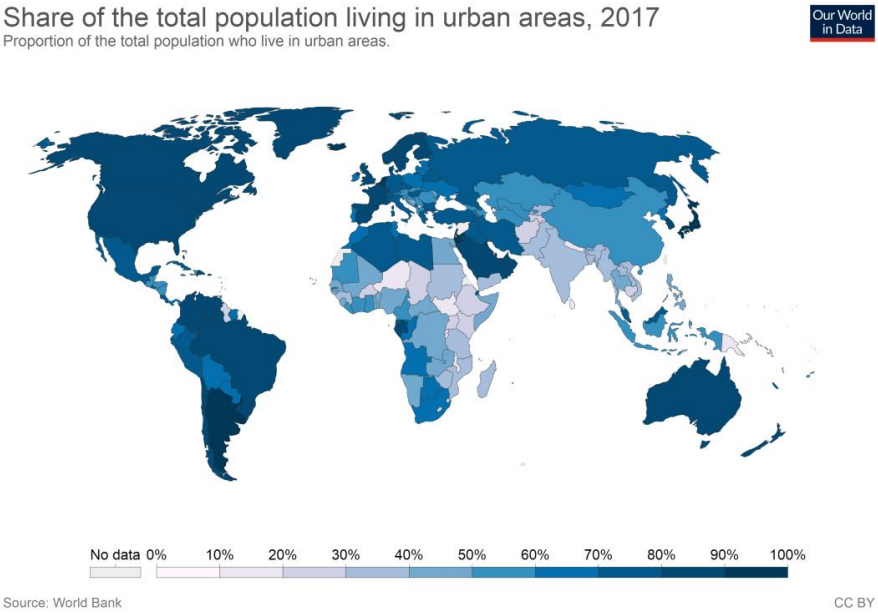
Paris Agreement was signed in year 2016 is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with various key elements such as greenhouse-gas-emissions mitigation, adaptation, and finance. It was signed during the 21st Conference of the Parties of the UNFCCC in Le Bourget, near Paris, France. Article 7 (C) and article 8 of Paris Agreement, highlights the need and cooperation on “Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making”.

7. Climate Risk Assessments:

7.1 Introduction:

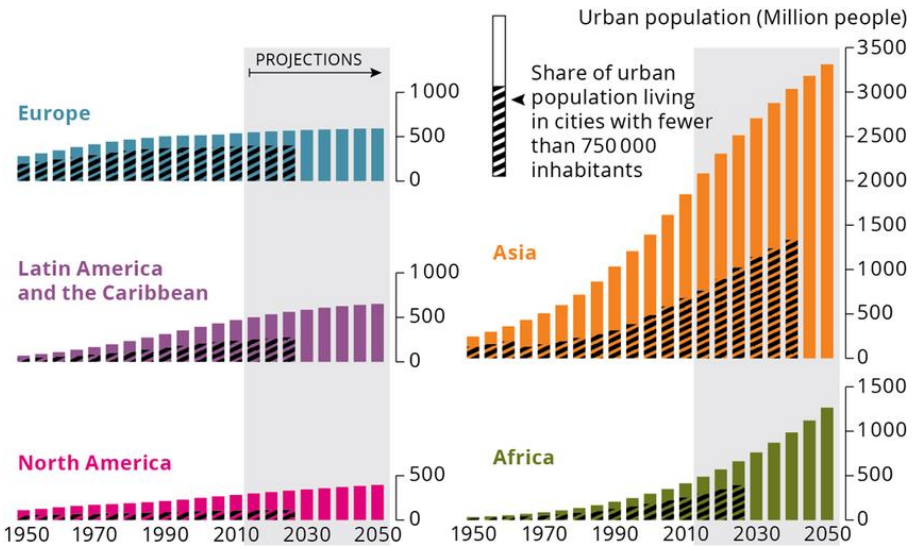
The growing population of the world is leading to rapid urbanisation especially in less-developed countries. Additionally, the migration of population from rural to urban area in search of enhanced livelihood opportunity is also resulting in unplanned expansion of cities. Studies indicate that urbanization has increased rapidly across many low-to-middle income countries over the last 50 years **(Figure 17)** and for many the share of urban population has doubled (https://ourworldindata.org/urbanization). In 1950, 746 million people lived in urban areas and by 2046, it is estimated to be over 6 billion **Map 12.**

Map 12: Country Wise Share of Total Population Living in Urban Areas



Source: https://ourworldindata.org/urbanization

Figure 17: Projected Growth of Urban Population Around the Globe with the Highest Being in Asia



Source: World Economic Forum, 2018

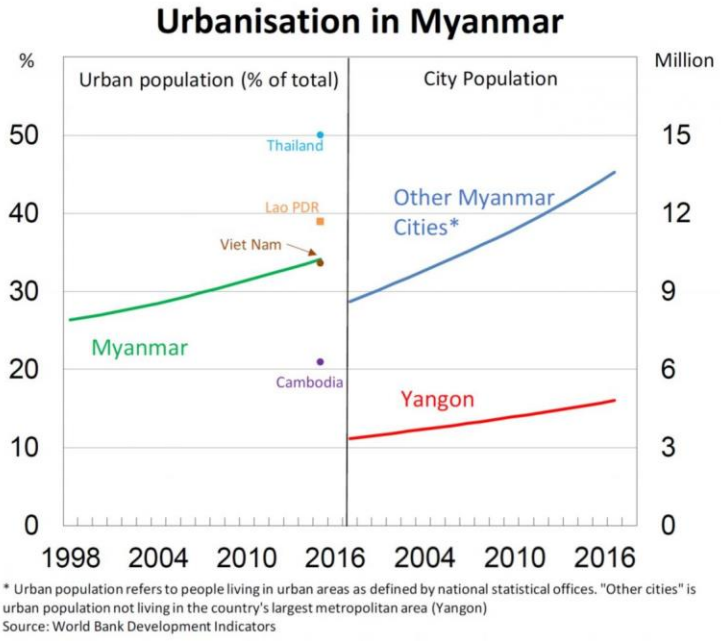
This rapid increase in urban population is leading to increase in exposure of more people and economic assets to the risk of disasters and the effects of climate change. Both the city governments as well as the residents are facing the challenge from disasters and effects of climate change. While for the city governments increased climate, variability imposes additional challenges to effective urban management and the delivery of key services, while for residents it increasingly affects their lives and livelihoods due to more frequent floods, storms, landslides, heat waves, droughts, and fires (Dickson et al., 2012). Thus, in the present-day scenario, it is essential for the cities to consider disaster and climate risk during planning and management as well as service delivery mechanism.

In order to mainstream disaster and climate risk adaptation and mitigation in urban area, knowledge on the hazard profile of the city, vulnerability of the infrastructure as well as population is essential to identify the risk prone areas for risk reduction by quantifying risk and implementing preventive program. Urban risk assessment should ideally be undertaken as a part of a cyclical process of assessing risk, developing and implementing a risk management plan, and monitoring progress in risk reduction but it has a flexible approach.

7.2 Urbanization Trend in Pilot Countries:

The program on Urban resilience to extreme climate in South east Asia is being implemented in one city / urban area of Myanmar (Dala township) and two cities of Vietnam (Nam Dinh an My tho). All the three cities are located in flood plan of major rivers. Myanmar is a rapidly urbanizing country. For several decades, growth in the urban population has been faster than total population growth. In 2014, the urban population stood at around one third of the total as seen in **Figure 18.**

Figure 18: Rate of urbanization in Myanmar



Source: McDonald and Hein, 2017

7.3 Urbanization in Myanmar and Ensuing Risk:

Myanmar ranks among one of the countries at highest risk to natural hazards, due to its degree of vulnerability to natural hazards. Both cities and towns in Myanmar are exposed to recurring rapid on-set natural hazards, such as cyclones and floods, which are exacerbated by global climatic changes and Myanmar acknowledges the need to engage early in the impending process of urbanization to create resilient, sustainable and low-carbon towns and cities, regardless their size, and over the long-term through realistic means.

The Republic of the Union of Myanmar is the largest Southeast Asian country, with a land area of 676,577 square kilometres and a population of 51.48 million as of 2014, with an average population growth rate of 1.3 percent. Of the total population, 70.4 percent (36.58 million) lives in rural areas. The remaining 29.6 percent (14.9 million) lives in urban areas, 20 percent of which reside in Yangon and Mandalay.

Due to its geophysical location, Myanmar is prone to a range of natural hazards as well as long term climate change impacts. Impacts of climate change are already being felt in terms of changes in weather patterns, and in the future, it may exacerbate disaster risks. Cyclone Nargis in 2008 was the worst natural disaster in the history of Myanmar, and the most devastating cyclone to strike Asia since 1991. Some 2.4 million people were severely affected by the cyclone, and an estimated 138,000 people were killed. While natural hazards are part of the environment, disaster risks are intrinsically linked to development.

In Myanmar, the classification of an area as urban is carried out based on increased density of building structures and population, and enjoys better infrastructural services. A township on the other hand is an administrative entity and can include several separate towns and likewise, a number of distinct villages.

Yangon Region, whose urban population had reached 70.1 percent in 2014, only exhibited a slight increase in the percent of the population residing in urban areas, although it is noteworthy that the compositions of the labour force in some areas of Yangon which are classified as rural resemble those of urban areas. The growth of population in urban areas of Myanmar in recent past has been due to

- Natural population growth which is a fundamental driver of urbanization.
- Beyond general population growth, however, the growth of urban areas typically involves a mix of socioeconomic push- and pull-factors that drive rural-urban migration.
- The shift of labour force composition due to an increasing demand in the manufacturing sector is also a driver of urbanization.

Yangon City consists of 33 townships, of which 28 have an urban population of 100 percent. The census of 2014 tallied a population of approximately 5.2 million for the 33 townships, of which 4.7 million fell into the category urban population.

While climate change poses the greatest threat to Myanmar’s cities and current way of life, proper management of its natural resources and maintaining environmental integrity is an important consideration. By 2100, climate models predict ever more

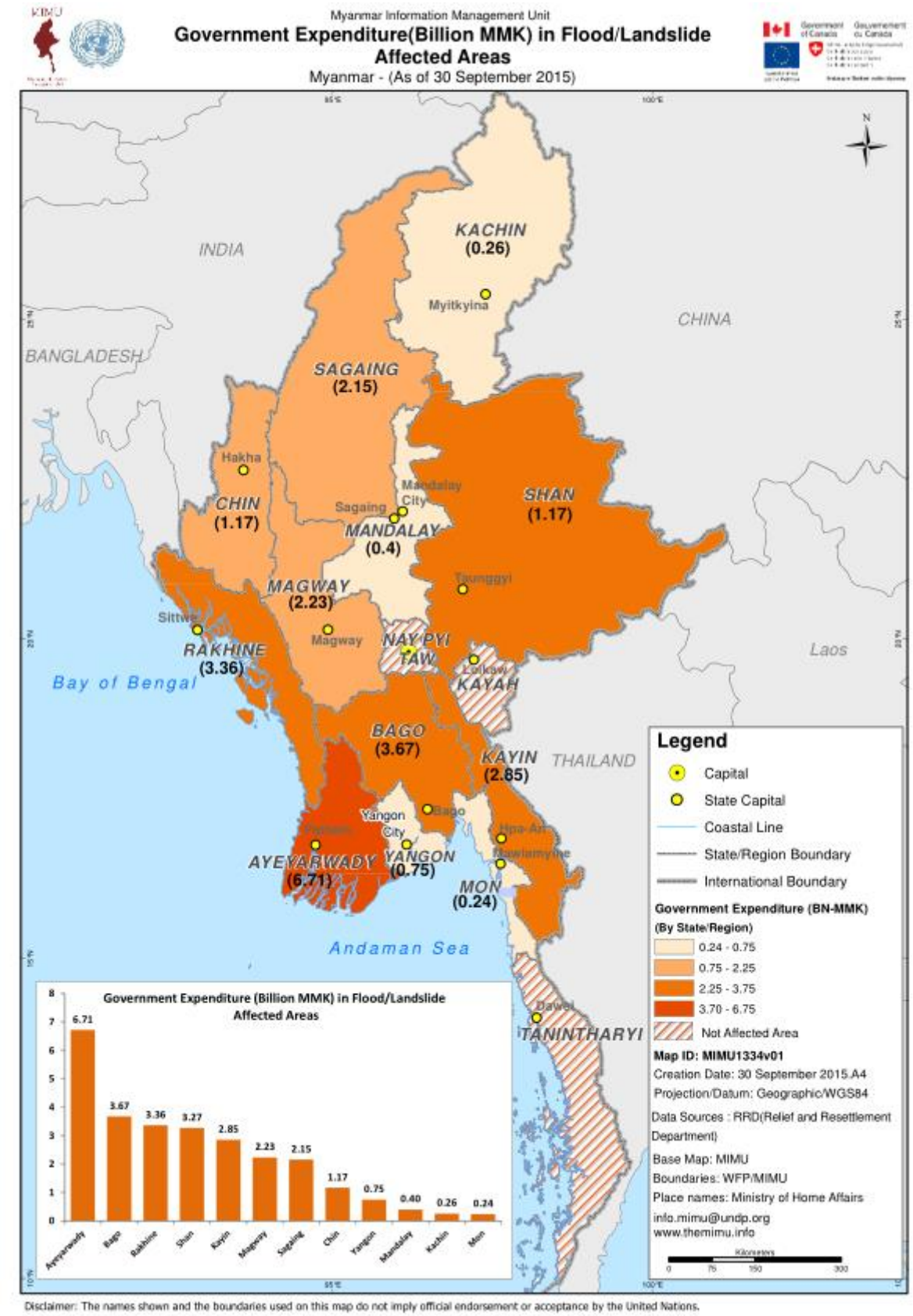
extreme changes in temperature, drought periods, changing rainfall patterns, increased risk of flooding, cyclones and strong winds, flood/storm surges and sea-level rises affecting almost all sectors and communities. Communities and businesses that are located in at risk regions and reliant on climate sensitive economic activities are particularly vulnerable to the impacts of climate change.

7.4 Review of Disasters Affecting Myanmar with Special Focus on Yangon Region:

Myanmar is one of the world's most disaster-prone countries, exposed to multiple hazards that cost the country over US$184 million annually and disproportionally affect the poor (World Bank, 2018). The country and specifically Yangon region has been prone to both natural and human induced disasters. The present review focuses mainly on natural hazards and more specifically on hydro-meteorological hazard that have affected the Yangon region till date. Floods, earthquakes, tsunamis, cyclones and landslides have been recorded as the major natural hazards in Myanmar. Among those cyclones, floods, tsunamis and earthquakes have pronounced impacts to Myanmar and the worst being Cyclone Nargis in 2008 which affected 2,400,000 people, left 138,000 fatalities and estimated damage cost of US$4,000,000 to Myanmar (JICA, 2015). 50% of the total number of disasters in Myanmar are related to floods followed by storm (23%), earthquake (15%), and mass movement-wet (12%), whereas 73% of the total affected people by disasters were due to storm followed by floods in 1980-2011. Similarly, storm is a major cause of disaster-related death and biggest estimated damage cost (86%). Earthquake (11%) and flood (3%) are next on the estimated damage cost. Additionally, due to the high degree of poverty in the rural areas, even low intensity disasters have a big impact on households. There is an absence of a centralized system for consolidating data for all types of disasters which leads to lack of systematic assessment of vulnerability. Table 4 shows the summary of damage and loss to Myanmar due to natural disasters over the period 1900 – 2014 (NIDM, 2014). Figure 4 shows the estimated government expenditure in flood / landslide affected areas in 2015 in Myanmar. **Table 6** Summary of damage and loss to Myanmar due to natural disasters over the period 1900 – 2014 (NIDM, 2014)

Hazard Type	Hazard S ub-type	No. of Events	No. of Fatality	Total population affected	Loss ('000 USD)
Earthquake	Ground Shaking	7	663	22923	4770
	Tsunami	1	71	15700	500000
Flood	General	11	134	2148690	79840
	Flash Flood	3	263	85734	1700
	Unspecified	7	161	386988	55115
Mass Movement (Wet)	Landslide	4	125	146367	
Storm	Tropical Cyclone	17	144,663	3935844	4079388
Wildfire	Forest Fire	2	8	78,588	11000

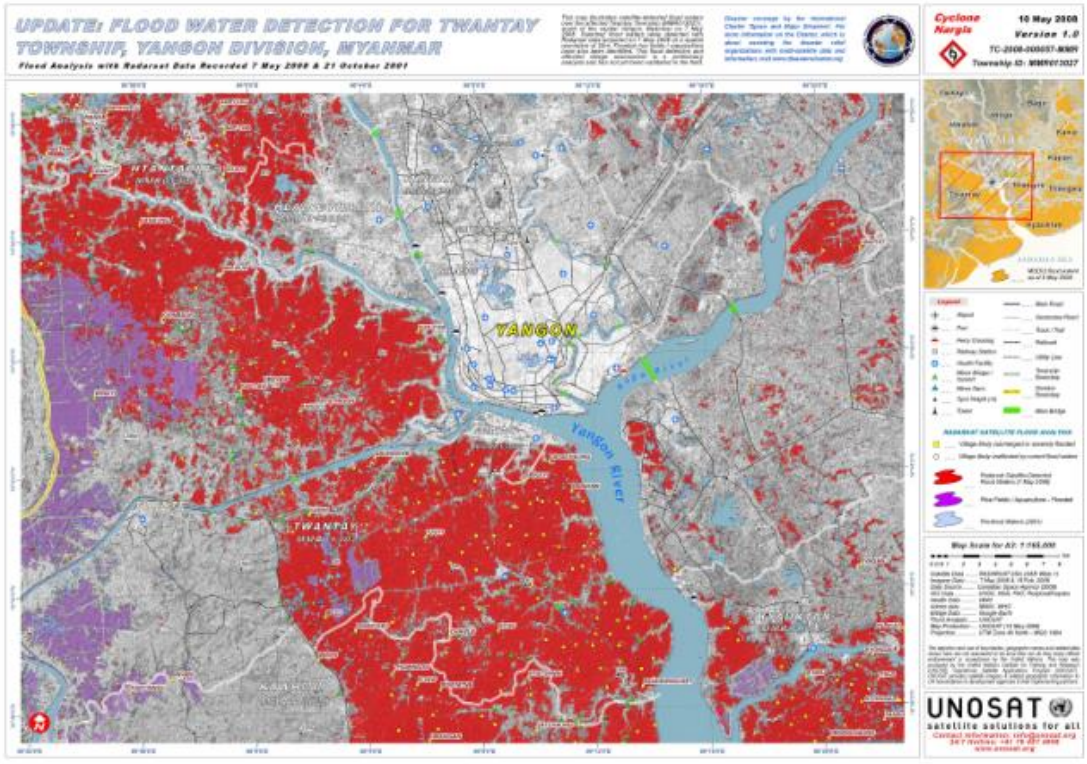
Figure 13: Government Expenditure in Myanmar Due to Flood / Landslide with Yangon Region being Less Vulnerable



A short review of the major hazards affecting Myanmar are discussed below and the review shows that storm, earthquake and flood are the major hazards which are likely to affect Yangon city and associated Dala township. Thus, while carrying out risk assessment of Dala township in the current program focus on these hazards are essential.

Tropical Cyclone – Coastal Myanmar especially the Yangon region is exposed to tropical cyclone and associated sea waves. Frequency of cyclones that made landfall on Myanmar coast was just once in about three years, but since the year 2000, cyclones crossed Myanmar coast every year indicating a sharp increasing in frequency. It has been observed that the cyclone tracks are unprecedented with respect to the latitude and pattern of recurvature. Latitude of recurvature became lower year after year and drastic change of direction of the course took place within a few hours. A study of the number of tropical cyclones forming over Bay of Bengal and the ones which hit Myanmar coast found that over a period from 1887-2005, 80 storms out of 1248 hit Myanmar and 30% of them were during the month of April and May. According to the Department of Meteorology and Hydrology the month of May is the highest possible period for the cyclone to cross Myanmar coast which has led to fatalities due to accompanying storm surges (DFID, 2009). Based on the study of cyclones that struck Myanmar coast between 1947 - 2008 it has been found that there is a probability of 3.2% of cyclones hitting Ayeyarwady delta (Yangon region). The worst tropical storm to strike the Yangon region which cause considerable damage and inundation including Dala township is Cyclone Nargis in May 2008 (**Map 14).**

Map 14 Flood Extent Map of Yangon City and Dala Township Due to Cyclone Nargis in May 2008



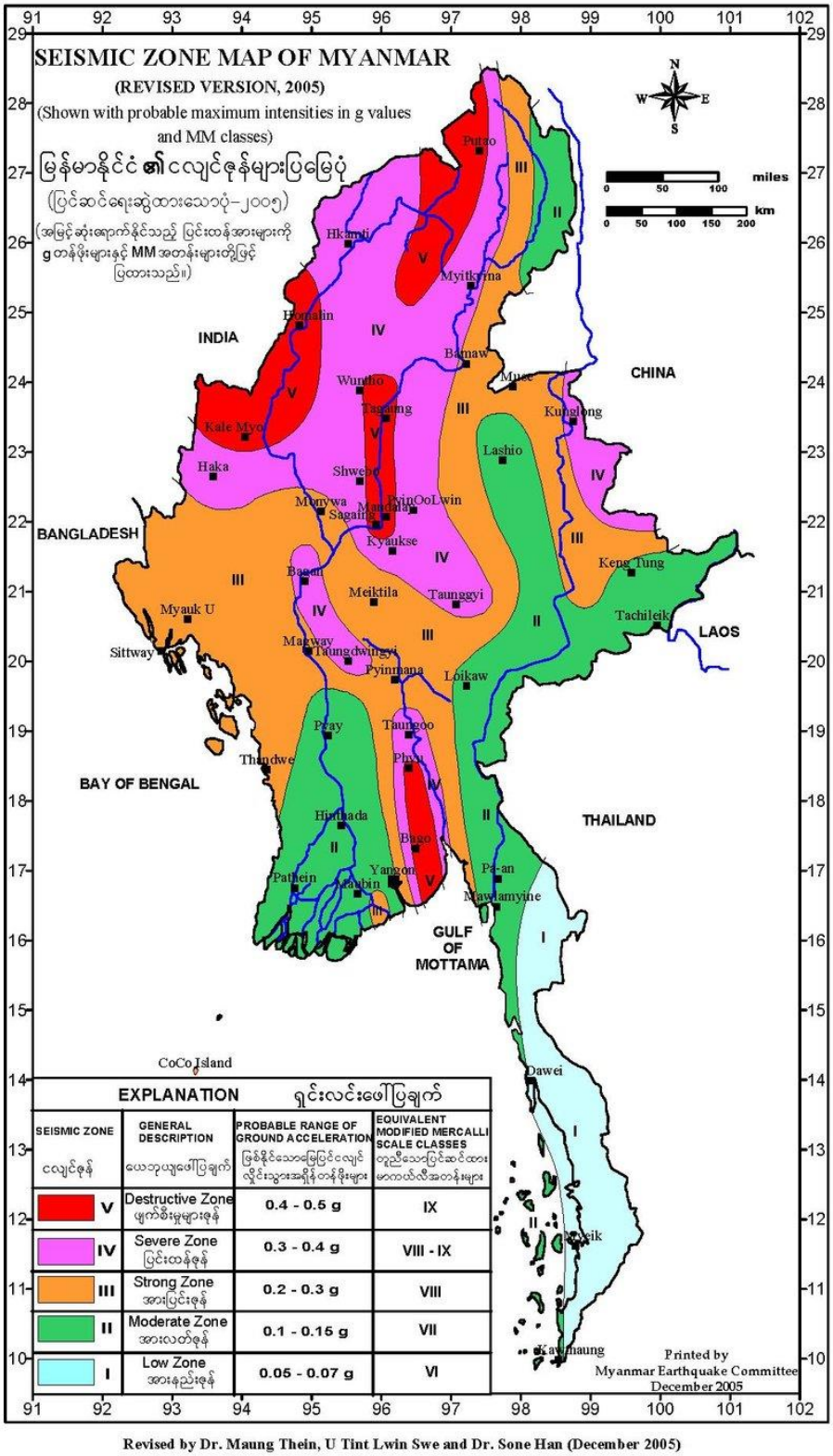
Source: http://img.static.reliefweb.int/sites/reliefweb.int/files/resources-pdf-previews/9928-CF3E661A901B9097C12574450041057D-unosat_FL_mmr080510.png)

Storm Surges – Storm surge is an extraordinary flooding due to a storm. It generally occurs due to waves generated by the strong wind in tropical revolving storms. The slope of the coastline is considered as one of the important factors controlling the intensity of storm surge. The storm surge or flooding accompanied with cyclone largely depends on the place of landfall and its path.

During 1975 Pathein cyclone, with a radius of 20 Km maximum wind and pressure drop of 22 hPa, highest surge near landfall point resulted 1.2 m and in Yangon 0.6 m. Study by the Myanmar Engineering Society shows that most of the townships in Yangon division including Yangon city falls within moderate to low storm surge hazard potential.

Earthquake – Earthquake is another major natural hazard which affects Myanmar. Geographically, a larger part of Myanmar lies in the southern part of the Himalaya and the eastern margin of the Indian Ocean, hence exposed to bigger earthquakes. Myanmar is earthquake-prone as it lies in one of the two main earthquake belts of the world, known as the Alpide Belt that starts from the northern Mediterranean in the west, and then extends eastwards through Turkey, Iran, Afghanistan, the Himalayas, and Myanmar to finally Indonesia. Earthquake in Myanmar results from two main sources – a) subduction of Indian plate below the Burmese plate at an average rate of 3.5 cm/yr and b) northward movement of the Burma Platelet from a spreading centre in the Andaman Sea at an average rate of 2.5–3.0 cm/yr (Bertrand et al., 1998; Curray, 2005). The well-known and seismologically very active Sagaing Fault (Win Swe, 1972 & 1981; Vigny et al., 2003; Soe Thura Tun, 2006) is the most prominent active fault in Myanmar, trending roughly north – south. It has been an originator of a large proportion of destructive earthquakes in Myanmar. This is due to the fact that many large urban centres lie on or near this fault (DFID, 2009). The seismic records show that there have been at least 16 major earthquakes with Richter Scale (RS) ≥ 7.0 within the territory of Myanmar in the past 170 years. Some large segments of the active faults have not exhibited any significant seismic activity in the past 50 to 75 years, indicating that the faults are apparently locked and stress is accumulating in those segments with a probability of high intensity earthquake. The inactive part is close to Yangon and Bago cities which are densely populated with a high vulnerability quotient. The Bago (Pegu) earthquake (7.3 on Richter Scale) of 5 May 1930, which caused widespread destruction of the town, is considered as a devastating disaster to occur in Yangon Bago region resulting in a considerable fatality. The earthquake was sited on the Sagaing Fault zone, and the area happened to be located on the flat alluvial plains. Seismic zonation map **(Map 15)** of Myanmar shows that 17% of Yangon Division falls with Seismic Zone V while 20%, 23% and 40% falls under Zone IV, II and II respectively.

Map 15: Seismic Zonation Map of Myanmar



Revised by Dr. Maung Thein, U Tint Lwin Swe and Dr. Sone Han (December 2005)

The present project deals mainly with climate extremes and its influence on hazards that are likely to affect urban areas. Thus, the risk assessment will mainly cover hydro meteorological hazard.

Floods: In Myanmar, majority of big cities and towns which are economically strategic places in the country are situated along four major rivers, namely Ayeyarwady, Chindwin, Sittaung and Thanlwin. While the existing intricate river systems provide easy access of water transportation, creating prosperous urban centers along the waterways, the flooding in these rivers devastate the lives of the inhabitants. Though water retaining and flood control structures are being built in areas considered vulnerable to floods, with the increased population in the big cities, development of living quarters and settlement lands has been encroaching upon natural catchment areas similar to other cities in the region.

Map 16: Flood Hazard Map of Yangon showing Depth of Inundation (100 Year Return Period)

Source: https://www.moezala.gov.mm/sites/default/files/2.Flood%20Hazard%20Maps%20of%20Yangon%20(100-Year%20Flood)_Page_1_1.jpg

Flooding has always been one of the major hazards in Myanmar, accounting for 11% of all disasters. The Ayeyarwady River basin alone, the largest in the country, covers 404,200 square kilometer (60%) of the country. Over 2 million people are exposed to flood hazard in Myanmar every year. The country receives practically all its rainfall between mid-May and October, the rainy season, during which flooding and landslides are common. In Myanmar, the threat of flooding usually occurred in three waves each year: June, August and late September to October with biggest danger arriving in August as peak monsoon rains occurred around that time. Yangon region (including Dala City) are thus prone to flood during the monsoon season due to the intense rain occurring in the upper catchment. Figure 7 shows hundred year return period flood hazard map of Yangon city.

Landslide – Landslide is a major hazard which affect the mountainous terrain of the country. Tectonically and geomorphologically, Myanmar can be subdivided into three provinces: namely, the Western Fold Belt (WFB) in the west (southern continuation of Himalayan Fold Belt), the Central Lowland (CL) in the middle, and the Shan-Tanintharyi Block in the east. Therefore, geologically, Myanmar has two mountainous provinces: namely, the Western Ranges and the Eastern Highland. These provinces are inherently unstable areas of the country. They have steep slopes, unstable geology, and intense monsoon rains. These features make the mountainous areas the most hazard-prone regions in Myanmar. The major river of Myanmar, Ayeyarwady River flows from north to south in the central lowland. Because of flooding and erosion, landslides occur along the banks of this river and its distributaries. More recently there has been an increase in human settlement of hazard-prone areas as a result of population growth, as well as improvement in accessibility by road and the onset of other infrastructures.

Yangon area is situated at the southern extremity of a long narrow spur of the Bago Yoma. The most notable feature of the topography is the central ridge known as Shwedagon Mingladon anticlinal ridge. Therefore, the central part of the area is higher than its limbs. Most types of the landslides occurred in this areas are creeps, earth flow and slumps or block slides. Soil creeps are occurred at Shwe-Taung-Kyar, Botahtaung and Hninsigon Bobwa Yeiktha. Earth flow types of landslides are observed at Dhamazedi Road. Slumps or block slides are noted at Inya Myaing, University Avenue Road, and Cantonment, west of Yangon Zoological Garden. The Dala township being in the river flood plain area has no threat from landslide though the upper part of the Yangon region bordering Bago region is vulnerable.

Tsunami - Tsunami record in Indian Ocean has not been well documented until now. After 2004 Tsunami, scientists from Geological Survey of Japan could find at least three large tsunami records in the Bay of Bengal and Andaman Sea region during 2800 years' time span. The last one before 2004 was dated as of 550 to 700 years ago (Jankaew et al., 2008). Therefore, it can be assumed that big tsunami might occur in about 500 to 700 years. But based on the location of Yangon region and Dala township and seismic belt they are located, tsunami can cause considerable damage to the region. No study exist on the threat to Dala townhip area from Tsunami hazard.

7.5 Hazard & Risk Assessment in Yangon and Dala Township:

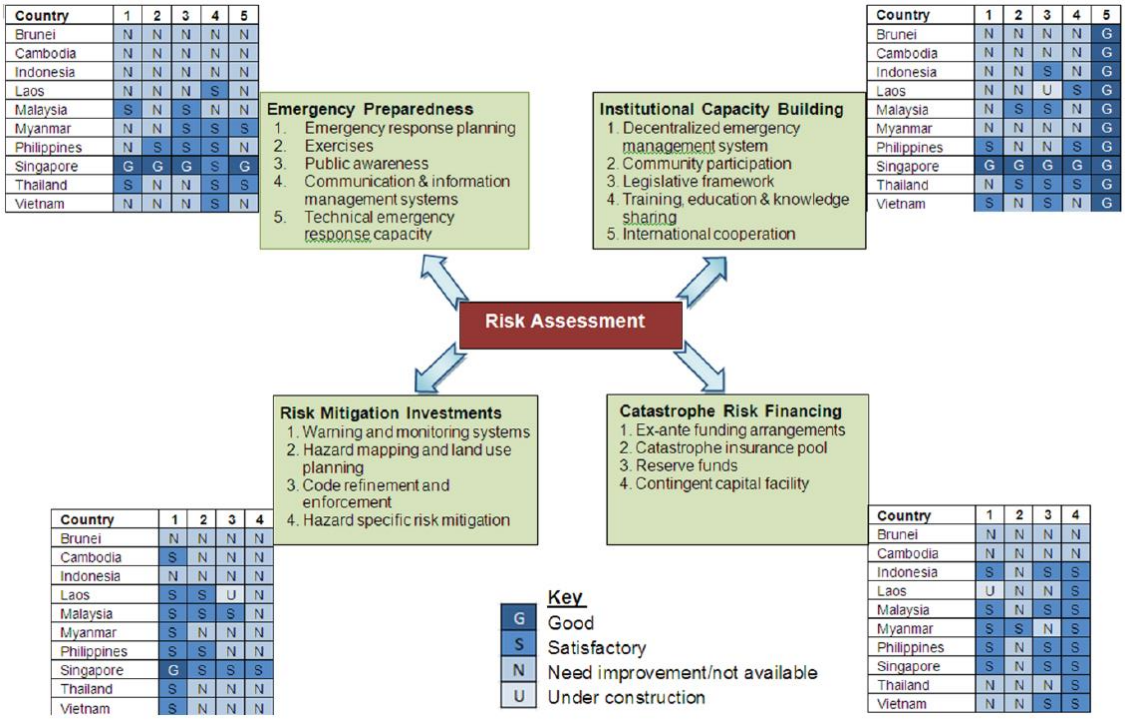
A review of the past Hazard and risk assessment of Myanmar as a whole and Yangon and Dala township was also carried out. A number of risk assessment exercise has been carried out in Myanmar mostly concentrating in the Rakhine state (UNDP, ADPC, OCHA-ROAP). The only study that concentrates more on the Yangon region is Multi-hazard Risk Assessment in Nargis Affected Areas, Myanmar carried in 2011 by UNDP post Nargis Cyclone. Some of the studies focused on Seismic risk to Myanmar. Department of Meteorology and Hydrology carried out a study in 2010 on Flood Forecasting and Mitigating in Myanmar but mainly concentrated in upper catchment of the tributary of the Ayeyarwady River. Country level disaster risk assessment of ASEAN countries including Myanmar was carried out in 2010 by UNISDR. A status of risk assessment framework was assessed by country to view the current capacity of risk assessment. Climate Change assessment including observed and projected trends of the ASEAN region was part of the study.

The assessment of Myanmar shows the following:

Myanmar	*Temperature and Rainfall* According to IPCC 2007, the probable temperature rise in Myanmar by 2100 could range between 1.8-4.0 ºC, whereas possible temperature rise by 2100 is predicted to be 1.1-6.4 ºC (World Vision A P, 2008)
	Sea Level Rise and Coastal Zones IPCC 2007 projected a probable sea level rise of 18-59 cm. Countries like Myanmar with a long coastline and densely settled low-lying land are particularly vulnerable to rising sea levels. Even diminutive rises in sea level vertically can lead to enormous erosion horizontally in the country (World Vision A P, 2008). According to Alan Sharp of the Australian Government Bureau of Meteorology, “the flat nature of the delta region, cleared of mangroves for agriculture, offers no impedance to the force of the storm surge, allowing it to penetrate well inland”. Rising sea levels, stronger cyclones and ecosystem degradation mutually reinforce each other, exacerbating the fallout from seaward disasters (World Vision A P, 2008)
	Agriculture The World Bank has ranked Myanmar as the world’s eighth most vulnerable nation to sea level rise in terms of “agricultural land impacted”. According to the United Nations Food and Agriculture Organization (FAO), about 2,000 square km, or 16 percent of the delta’s agricultural land suffered severe salinity damage from the surge that swept salt water up to 35 km inland (World Vision A P, 2008)

The study also developed a status framework of hazard risk assessment in ASEAN countries as seen in **Figure 17.**

Figure 17: Hazard Risk Management Framework – Status of ASEAN Countries

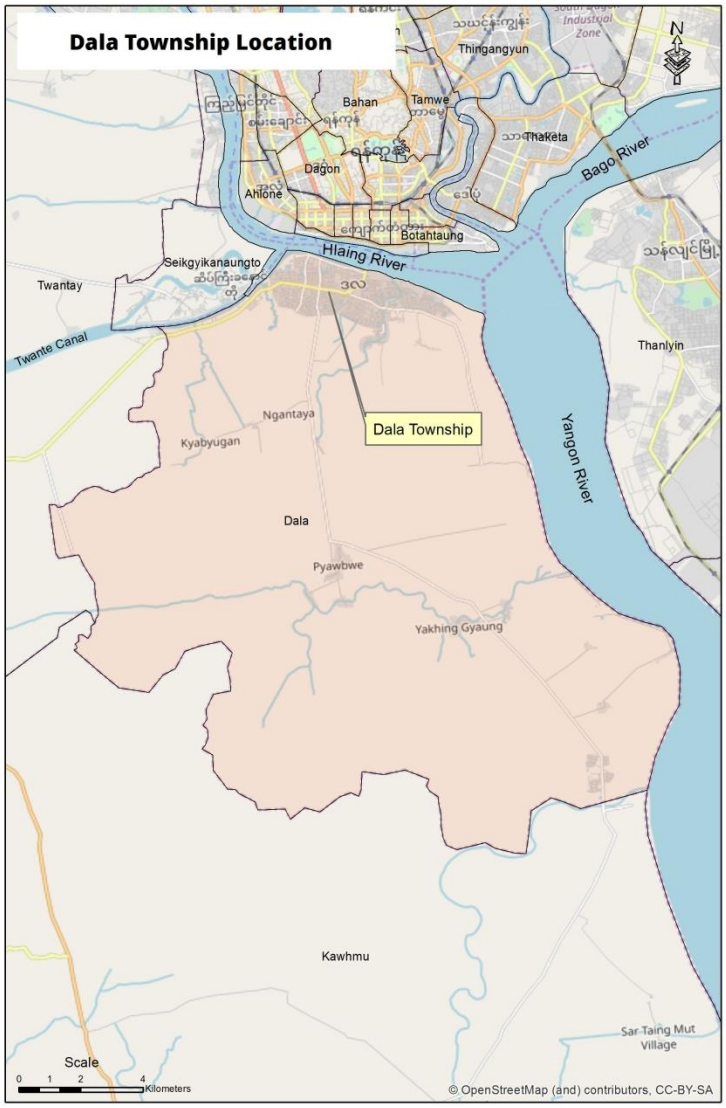


Source: UNISDR, 2010

The only study that concentrates on urban areas was carried out by ADB which summarizes vulnerability of urban cities to flood in Asian and Pacific counties including the ASEAN region. The floods were classified as coastal flood and inland flood that may affect urban cities. Vulnerabilities were estimated by population and areas % at risk of flooding. Top 40 cities in Asian countries with 1 million populations or more that are vulnerable to flooding were listed. But risk assessment for Yangon city has been carried out only for seismic hazard. No study on risk assessment for Dala Township exists till date.

The pilot site, Dala township is located south of Yangon (**Map 14**) and is bounded by Hlaing river to the north, Yangon river to the east and Twante canal to the west. It consists of 23 wards and 23 village tracts. The Dala urban area consists of informal houses and some areas of the township has been earmarked for Special Economic Zone (SEZ).

Map 15: Location of Dala Township



7.6 Hazard Proneness of the Dala Township:

Being located on the floodplain of the river as well as within the southernmost province of the country, the township is prone to hydro-meteorological hazards like flood (Figure 9), cyclone, high tide and storm surges. Dala has been affected by major flood in 2015 along with 14 other townships of the region causing losses of more than K11 billion (US$8.5 million). Cyclone Nargis in 2008 devastated the township causing considerable loss and damage. A post Nargis study showed that inundation penetrated 50 km inland inhibiting last-minute evacuations owing to the lack of high ground at most locations (Fritz et al., 2009). Fritz et al., 2009 also suggested in the study that the widely deforested, low-lying and densely populated Ayeyarwady delta with its poor housing construction remains extremely vulnerable to future storm-surge flooding, potential sea-level rise or tsunami.

Figure 17: High Tide Floods One of the Streets at Arntgyi Ward in Dala (on 01 September 2019)

Thus, the risk assessment to be carried out of Dala township of Yangon region needs to consider both urban and rural setting. Moreover, as most of the settlements are informal and the terrain being the delta region vulnerability quotient is very high. A limited field survey supported by secondary data from the government on vulnerability will enable a comprehensive risk assessment to support the local authorities for future urban expansion of the township.

The review also indicates that for Dala township tropical cyclone, storm surge inundation and tsunami hazard assessment and ensuing risk is required to be explored.

8. Next Steps:

ADPC team (CLR, GEO and UR) will visit Myanmar and Vietnam in months of October and November for an introductory/kick-off meeting. The purpose of this kick-off meeting is to present URCESEA program and to have discussions with Meteorological and Hydrological Divisions of DMH on current status of multi-hazard early warning system in Myanmar.

During this visit detailed EWS review on existing monitoring, forecasting and warning system will be carried out based on international standards including WMO (World Meteorological Organization) EWS (Early Warning Systems) guidelines, standards and procedures. A systematic ***evidence-based*** review will be carried out of meteorological and hydrological services (including forecast & warning) in Vietnam and Myanmar. This review will consist of various parameters, including;

- *Existing governance and institutional arrangements,*
- *Existing hazard monitoring, forecasting, and mandates for warning development,*
- *Development of understandable, authoritative, recognizable and timely warnings,*
- *Warning dissemination mechanisms,*
- *Emergency preparedness and response activities (national to sub-national to local),*
- *Development of warnings and related products and services for the disaster risk management user community*
- *Overall operational framework of early warning systems*

This review will be based on a set of key activities including ***stakeholders mapping, interview with key stakeholders, city visits and reconnaissance survey, rapid assessment of national and local capacity for delivering timely, accurate and appropriate (locally applicable) warning service***s, with a particular focus on existing capacity of service providers, decision makers and users' (last mile). Special attention will be given to the vulnerable dimensions of weather information services as well as to understanding their needs and priorities.

During the week of field mission under this assignment, a detailed EWS ***review*** will be carried out, including national and sub-national guidelines of ***National Hydro-Meteorological Service (NHMS)***, provincial and city disaster management plans and programmes, technical documents from national and inter-governmental institutions, relevant research and NGO reports. This review will focus on hydro-met services including water and disaster risk reduction sectors. Also, during this period, various user groups we will be identified and consulted to assess their warning information needs, opportunities and barriers – including an analysis of impacts on the most vulnerable (including women and girls). Our line of enquiry will be centered on consideration of decisions that the wide spectrum of users are faced with, how existing interventions have (or have not) supported these processes and the gaps that remain.

This EWS review will be based on a set of ***key questions for stakeholders***, to include: what is the current technology including density of meteorological and

hydrological network in basin, what weather-related decisions need to be supported and which of these are priorities (i.e. sectors / populations / regions); what information is required to make these decisions?; where is information currently sourced from/ who are the providers (including private sector providers, their motivations, capabilities, clients, future expansion/investment plans etc.)?; how is this information interpreted and disseminated (content, details, frequency, quality, delivery mechanisms etc.)?; what are the barriers to access or use of this information (scale, delivery mechanism, ability to interpret and use information etc.)?; what support has been/is being/will be provided and how did/will they support user decision making?; what further support is needed (operational and R&D)?; what is the best method to deliver this support (alliances, partnerships, regional collaborations etc.)?

Detailed consultation will be carried out with stakeholders of national and sub-national (provincial) and local users, producers, processors and disseminators of information, as well as those who understand the organizational issues and policies involved, including: national government (NHMS, sectoral departments at different levels etc.); inter-governmental institutions; donors and development agencies (WB, ADB etc.); regional groups and initiatives, parastatal entities; private sector providers; academic, research and resource organizations; civil society organizations (especially those representing women and young people) and communities.

This review will also look in ***past, current and planned weather information and services programmes*** to extract ***best practices*** and identify whether/how user decision-making is/may be supported currently/in the future. These interventions will be categorized according to their focus area (e.g. national, sub-national and local) and the sector they are linked to (disaster etc.). A detailed questionnaire will be developed for stakeholders involved in these interventions to understand their experiences and perceptions of the relative success/failure/limitations/merits/ etc. of these programmes.

The ***stakeholder mapping*** exercise will enable us to explore opportunities for scaling-down strategies and experiences at national and regional levels, thus building on existing knowledge and promoting learning between countries. We will also identify ***gaps*** in these programmes and the main barriers to progress, especially with regards to protecting the poorest and most vulnerable communities.

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