Disaster Management, Response Activities and National Recovery Plan in Electricity Sector

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Abstract— According to natural disaster which occurred in Myanmar on July and August 2015, MOEE had some damages in Electricity Sector. Therefore, MOEE has compiled a damage inventory and carried out the recovery works for restoring the damaged facilities to set regular operating conditions. In this paper, Damages and Losses in Electricity Sector, Disaster Management and Response Activities (Precaution measures at normal time , Preparedness for the natural disaster, Measures to cope with during the natural disaster, Rehabilitation stage after disaster) and National Recovery Plan in Electricity Sector are mainly described.

Keywords: Disaster Management and Response Activities, National Recovery Plan.

I. INTRODUCTION

In Myanmar, the natural disaster mostly occurs in the monsoon. Therefore, in July and August 2015, widespread floods and landslides destroyed public and private infrastructure and had extensive impacts to the agriculture sector and the electricity sector. Torrential rain started on July 16, 2015, saturating the ground. On July 30, Cyclone Komen made landfall in Bangladesh, causing strong winds and additional torrential rain in Chin and Rakhine States and Sagaing, Magway and Bago Regions.

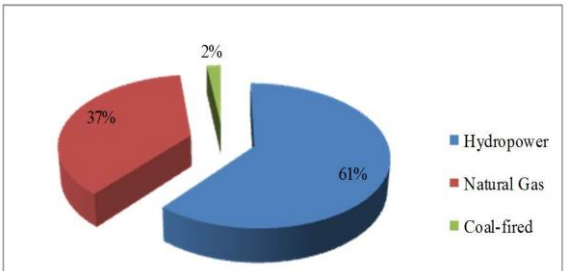
Damages to the electricity sector, which occurred in six states/regions, are relatively small compared with damages to other economic sector. Total damages are estimated to be 6,282.3 million kyats, and losses are estimated to be 623.7 million kyats. Damages and losses in the distribution subsector were mainly caused by faults**,** collapsed poles in distribution lines and power cutoffs in the flooded areas.

Damages in the transmission subsector were caused by the collapse of electric towers and poles as a result of erosion of their foundations. In the generation subsector, damages and losses were caused by damage to small and "mini" hydropower stations.

According to Disaster Preparedness, Mitigation and Management, and action-plan of MOEE, the electricity sector has been acted very quickly to restore systems and reconnect consumers to the grid. Many households were reconnected within the same day, and the longest service interruption was one month.

II. CURRENT CONDITION OF ELECTRIFICATION

At present, the power generation of Myanmar consists of four components, namely, hydropower, natural gas, coal-fired power and diesel power generation. Currently, hydropower accounts for the largest share in the entire power sector of Myanmar. As a share of total installed capacity (5274 MW) on the grid for the October 2016, hydropower in Myanmar currently accounts for 61% (3181 MW), natural gas accounts for 37% (1973 MW), and coal-fired power plant accounts for the remaining 2% (120 MW)and that generation mix is shown in Figure1.



Figure(1) Generation Mix

Moreover, small off-grid diesel and mini-hydropower units dispersed across the country have an estimated total installed capacity of about 128 MW. According to the 2014 statistics, the total population of Myanmar is 51.49 million and about 30% of population lived in town and city and the remaining 70% of population lived in rural area. Total households are 10.88 million and among these households 3.4 million (31%) are electrified households and the remaining 7.48 million (69%) are un-electrified households. Moreover, at 2011,

the total electrified villages (on grid and off grid) are 14171 but at 2015, total electrified villages (on grid and off grid) become 29516. Therefore, rural electrification achieved progress and 2015 rural electrification ratio is shown in Table I.

TABLE I.RURAL ELECTRIFICATION RATIO
(2015 DECEMBER)

	Villages	Percentage
	63860	100 %
Electrified Villages (on grid)	9631	15.1 %
Electrified Villages (off grid)	19885	31.1 %
Un-Electrified Villages	34344	53.8 %

Average annual consumption per capita for the fiscal year 2010-2011 is increased more than double (two times) compared for the fiscal year 2015-2016 and the yearly progress is shown in Table II.

TABLEII.ELECTRICITY CONSUMPTION PROGRESS

Sr. no	Description	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
1	Electricity consumption (million kilowatt hour)	6467.3	7876.72	8441.04	9795.09	11406.76	13397
2	Average annual consumption per capita	126	153	164	190	222	260

In this summer 2016, the peak demand reached only 2743 MW and MOEE fulfill the power supply to the consumers without load shedding.

III.DAMAGES AND LOSSES IN ELECTRICITY SECTOR

(a) Damages and Losses Condition

According to the natural disaster which occurred in July and August 2015, Ministry of Electric Power (now MOEE) had some damages. Floods and landslides caused damages to the electricity sector in the four worst-damaged states and regions-Chin, Rakhine, Magway and Sagaing- and disrupted the power supply in Ayeyarwady and Bago. Heavy rains, landslides and high water caused damages to small hydropower stations; there were reports landslides on dam's slopes, blocked waterways at hydropower stations and washed-away earth dams, water canals, weir and penstocks. Some transmission towers (both 230 kV and 66 kV) collapsed and poles (both 11 kV and 0.4 kV) were broken. Some substations including control rooms were deeply submerged. High water speed washed away roads and fences and caused damages to the staff houses as well as the engine buildings.

According to the MOEE's record, the recent flood damaged eight small hydropower stations owned by ESE, with total capacity of 4 MW, all in Chin State. Some 230 kV and 66 kV transmissions lines were collapsed, concrete poles of distribution lines were broken, and transformers were damaged. According to the report of Chin Committee for Emergency Relief and Rehabilitation, 15 private sector mini-hydropower stations with capacity ranging from 5 kW to 30 kW were damaged. The most significant damage happened to the Line Bon small hydropower station, with the installed capacity of 500 kW; it was totally washed away and will not be repaired. And, type of damages in four worst-affected states and regions are mentioned in Table III.

TABLE III.TYPE OF DAMAGES

Chin State	Rakhine State	Sagaing Region	Magway Region
Small hydropower stations(public and private)	Engine building	Engine building	Equipment in GyiOhnGyiWa hydropower plant
66 kV tower	230 kV electric tower	66 kV and 33 kV power lines	
11 kV, 0.4 kV lines	66 kV electric supply building	11/0.4 kV transformer	66 kV electric power line
11/0.4 kV transformer	11 kV and 400 V power line tower	66/22 kV, 20 MVA electric supply building	11 kV, 400 V concrete poles
	230 kV 46 tower wall		11/0.4 kV, transformers
	Staff house	Staff house	Staff house, storage, road
	Other damages	Other damages	Other damages

(b) Damages and Losses in State and Region

MOEE has compiled a damage inventory then the information of damages and losses of each of four worst-damaged states and Region in electricity sector under MOEE is as follows:

(1) Chin State

In Chin State, disaster affected areas are seven townships (Tonzang, Tedim, Falam, Thatlang, Hakha, Matup and Mindut) and these are shown in Figure 2. As the impact of disaster, the total amount of losses became about 402,320 USD and estimated recovery cost was about 512,214 USD. And, electricity outage occurred about 1980 hours. In that condition, the recovery progress was up to 100 percent as the immediate respond and action.

Figure 2.Disaster affected area in Chin State

(2) Rakhine State

In Rakhine State, disaster affected areas are fourteen townships (Buthidaung, Maungdaw, Rathedaung, Kyauktaw, Myrauk-U, Ponnagyun, Minbya, Sittwe, KyaukPhyu, Ann, Maei, Taunggup, Thahtay and Thandwe) and these are shown in Figure 3. As the impact of disaster, the total amount of losses became about 254,686 USD and estimated recovery cost was about 346,339 USD. And, electricity outage occurred about 1431 hours. In that condition, the recovery progress was up to 100 percent as the immediate respond and action.

Figure 3. Disaster affected area in Rakhine State

(3) Sagaing Region

In Sagaing Region, disaster affected areas are ten townships (Kalay, Kalaywa, Minkin, Mawluu, Inntaw, Kawlin, Kyunhla, Kantbalu, Tazal and Shwebo) and these are shown in Figure 4. As the impact of disaster, the total amount of losses became about 645,931 USD and estimated recovery cost was about 670,323 USD. And, electricity outage occurred about 1712 hours. In that condition, the recovery progress was up to 100 percent as the immediate respond and action.

Figure 4.Disaster affected area in Sagaing Region

(4) Magway Region

In Magway Region, disaster affected areas are nine townships (Ganggaw, Saytottayar, Pwintphyu, Saku, Ngaphe, Minbu, Magway, Myothit, and Taungtwingyi) and these are shown in Figure 5. As the impact of disaster, the total amount of losses became about 482,660 USD and estimated recovery cost was about 1,317,984 USD. And, electricity outage occurred about 2112 hours. In that condition, the recovery progress was up to 100 percent as the immediate respond and action.

Figure 5. Disaster affected area in Magway

(c) Energy Losses

Losses can be derived from both suppliers and customers of the electricity sector. Supplier's losses are due to discontinuation of generation, reduction of sales, higher cost of production, or increase in the system losses. Customer's losses are calculated as losses of income from productive activities due to interruption of the electricity or use of a higher-cost substitute. Losses for residential (non- productive) customers are due to their use of higher-cost fuels for the domestic purpose (such as lighting, cooking, or water pumping)

Therefore, energy losses become supplier losses and there are on grid power outage losses and off grid power outage losses. For on gird power outage losses, the total power outage duration become 6329 hours and energy losses are 1931419 kWh for end of Jun, July and August 2015. So, costs for these losses are about 91620 USD and cost for recovery works are about 142056 USD, and the average production cost for pre disaster will be 0.058 USD/kWh and post disaster will be 0.056 USD/kWh for twenty three townships and the number of consumers 149097 in state and regions. Now, all recovery works are finished and on grid power outage losses, off grid power outage losses and total power outage losses are shown in Table IV.

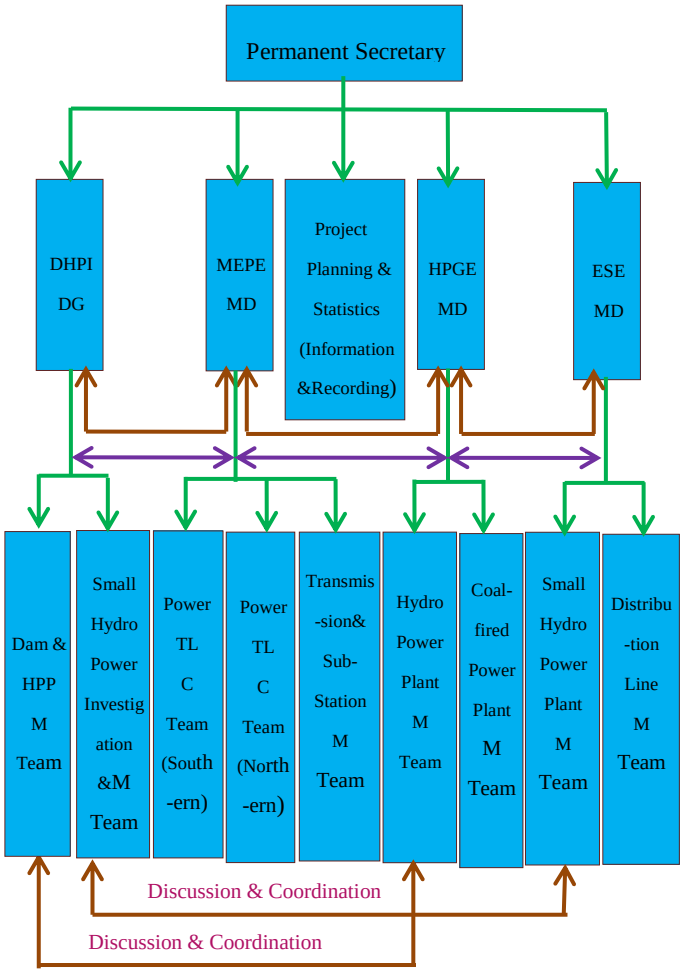
TABLE IV.TOTAL POWER OUTAGE LOSSES
(On Grid + Off Grid)

System	Power Outage Duration	Existing electrified Households		Pre Disaster Energy Unit (1 Month)	Post Disaster Energy Unit (1 Month)	Power Outage Losses		Power Recovery Cost
	Hr	Before	After	kWh	kWh	kWh	Cost (USD)	USD
On Grid	6329	149097	149097	38526349	37698799	1931419	91619.85	142056.02
Off Grid	2448	16628	16628	815195	501387	377071	14072.49	756008.32
Total	**8777**	**165725**	**165725**	**39341544**	**38200186**	**2308490**	**105692.34**	**898064.34**

IV.ORGANIZING DISASTER RISK MANAGEMENT COMMITTEE

At that time, MOEP(now MOEE) organized the Disaster Risk Management Committee (DRMC) including concern departments and mainly operating entities to carry out the pre-protection works for natural disasters and to implement the recovery works for the impact of the disaster on electricity sector. The organization chart of DRMC (MOEP) is as follows:

Disaster Risk Management Committee (MOEP)



DHPI – Department of Hydro Power Implementation
MEPE – Myanma Electric Power Enterprise
HPGE – Hydro Power Generation Enterprise
ESE – Electricity Supply Enterprise
HPP – Hydro Power Project
TL – Transmission Line
M Team – Maintenance Team
C Team – Construction Team

Then, DRMC has prepared the Disaster Emergency Operation Plan and these are as follows:

(a) Assigns responsibility to Organization /Department and Staffs
(b) Sets forth lines of authority
(c) Describe how people and property will be protected
(d) Identifies personnel, equipment, facilities, supplies, and other resources

V. DISASTER MANAGEMENT AND RESPONSE ACTIVITIES

DRMC issued disaster management and response activities to return the community to normal condition and the goal of disaster management by DRMC includes that to reduce, or avoid, losses from hazards; to assure prompt and appropriate assistance to victims of disaster; to achieve rapid and effective recovery; and the issues of pre-disaster activities and post-disaster activities of DRMC are shown in Table V.

TABLE V. PRE-DISASTER ACTIVITIES AND POST-DISASTER ACTIVITIES

<table>
<tr><th colspan="3">Pre-disaster activities</th><th colspan="2">Post-disaster activities</th></tr>
<tr><th>Risk Identification</th><th>Mitigation</th><th>Prepared-ness</th><th>Emergency Response</th><th>Rehabilitation-Reconstruction</th></tr>
<tr><td rowspan="4">Hazard assessment

Vulnerability assessment

Risk assessment (function of Hazards and Vulnerability)</td><td rowspan="4">Structural and non-structural works and actions</td><td rowspan="3">Warning systems, communica-tion systems, protocols

Contingency planning

Networks of emergency responders</td><td>Humanitarian assistance</td><td>Rehabilitation, reconstruction of damaged critical infrastructure</td></tr>
<tr><td>Clean-up, temporary repairs and restoration of services</td><td rowspan="2">Budget management (stabilization, protection of social expenditures)</td></tr>
<tr><td rowspan="2">Damage assessment And identification of priorities for recovery and Emergency Electrification</td></tr>
<tr><td>Hazard monitoring and forecasting</td><td>Education, training and awareness about risks and prevention</td><td>Shelter facilities, evacuation plans</td><td>Mobilization of recovery resources</td><td>Incorporation of risk management in reconstruction processes</td></tr>
</table>

MOEP's action –some photo records for pre-disaster and post disasters are as follows:

Buildings of MoneChaung Power Plant (Magway Region)

Before

Fact

1. Removing mud
2. Filling Stone around the building
3. Repairing the wiring system
4. Repairing the sanitation system

After

230 kV Ann-Myauk U - Ponnakyun Transmission Line (Rakhine State)

Before

Facts

1. Tower Number (MP-96)
2. Tower Type – T_3-36
3. Collapse Time - (30-7-2015) (09:19) AM
4. Repaired Time - (13-8-2015)(16:48) PM

After

230 kV Ann-Myauk U - Ponnakyun Transmission Line (Rakhine State)

Before

Facts

1. Tower Number - (MP-61)
2. Tower Type - S_1-36
3. Collapse Time - (31-7-2015)(18:40) PM
4. Repaired Time - (13-8-2015)(16:48) PM

After

66kV Nabar-Moenyin Transmission Line (Kachin State)

Before

Facts

1. Tower Number- (409,410,411,412)
2. Tower Type - (Concrete Pole)
3. Collapse Time - (24-7-2015) (09:30) AM
4. Repaired Time - (3-8-2015)(16:01) PM

After

Another four disaster activities- precaution measure at normal time, preparedness for the natural disaster, measure to cope with during the natural disaster and rehabilitation stage after disaster, have been issued by DRMC and detail information are as follows:

(a) Precaution Measure at Normal Time

At normal time, there are seven issues to be implemented in electricity sector for precaution measure and these are as follows:

(1) Clear trees and shrubs before the rainy season to ensure is a designated free space around power lines;

(2) Install lightning arrestors to protect power lines, power distribution station, electrical equipment, control rooms and buildings from lighting hazard;

(3) Right the leaning power line poles and provide support;

(4) Check the foundations of power line poles and build new foundations where necessary;

(5) Inspect power line poles and install stay cables where necessary;

(6) Install sufficient reserve diesel generators to resume electricity supply to important install-ations such as water pumping stations, hospitals, CNG outlets immediately after storms;

(7) Store diesel fuel required to run the reserve generators

(b) Preparedness for the natural disaster

DRMC planned and issued how to respond the natural disaster and the following items are described for preparedness;

(1) To inspect electricity usage, enforce rules, conduct educational activities and form a staff team led by a skilled junior technician (electricity) at projects and base camps of factories to inspect power lines and equipment.

(2) To monitor river water levels day and night near electricity pylons;

(3) To take precautionary measures such as moving power lines, power line poles and transformers away from areas vulnerable to rising waters and replacing cables with broken insulation as they can be dangerous when wet;

(4) To relocate villages and communities in the reservoir area upstream from the hydroelectric main dam to downstream are as systematically in coordination

with departments and organizations concerned;

(5) To undertake protection measures for ongoing projects;

(6) To make technical calculations and take measures for the protection of dams reservoirs and power stations from disaster risk;

(7) To set up a small meteorology and hydrology center in the project/ stations area to make meteorology and hydrology measurements.

(c) Measure to cope with during the natural disaster

During a disaster, to be able to respond effectively, the following actions are issued to be carried out;

(1) To submit reports of the flood situation together with the losses and damage data to higher level departments promptly.

(2) To undertake preparedness activities during disasters and relief and reconstruction activities to prevent losses caused by natural disasters as disaster-related losses and damage to office building, site camps, warehouses, work-shops, machinery, vehicles, staff housing belonging to projects under the Ministry.

(3) To cut off power from the distribution point supplying the area in which an electrical fire is occurring due to the disaster, take measures to protect other electrical cables from the fire and to prevent electric shocks caused by contact with severed electrical cables;

(4) To conduct relief operations through search and rescue teams with the participation of the entire local population.

(5) To put in place mechanisms for the distribution, control and suspension of electricity during emergencies;

(6) To raise awareness on do's and don'ts during emergencies;

(7) To plan diversion and barriers for dams and reservoirs in earthquake prone areas if necessary;

(8) To designate shelters to enable evacuation of affected staff at short notice during natural disasters; protect power lines, power distribution stations and substations from damage and take precautionary measures to prevent electric shocks;

(d) Rehabilitation stage after disaster

After disaster, recovery and reconstruction of the damages for rehabilitation stage will be implemented by three entities of the electricity sector, namely the ESE, HPGE and MEPE accordance with the guidance of DRMC. Although these three entities already have the technical and institutional capacity to recover the damages but the speed of reconnection to the customers is based on the nature of the damages and financial capacity of these three entities.

VI. NATIONAL RECOVERY PLAN IN ELECTRICITY SECTOR

MOEP(now MOEE) has compiled a damage inventory and prepared a recovery plan after setting up Disaster Risk Management Committee (DRMC). Therefore, immediate recovery works have been completed by three entities accordance with the guidance of DRMC. And, DRMC has prepared short-term plan and medium-term plan for recovering damaged equipment and facilities and long-term plan for prevention and preparedness to natural disaster. Recovery works for short-term plan are to be finished within four months and recovery works for medium-term plan are to be finished within one year. Sometimes, the works will be continued beyond one year to make the system more resilient. Therefore, hard job which is to be taken extra time and prevention and preparedness works are included in long term plan and that plan is to be finished within one to five years after disaster. And, these three plans are as follows:

(a) Short-term plan

(1) Restore the distribution networks as fast as possible to enable customers to resume their business and to provide energy for residential uses.

(2) Inspect the submerged distribution systems, lines, and substations to determine any safety issues, and fix them.

(3) Replace the submerged meters, and place the new ones in a safe place, above the level of the recent flood.
(4) Ensure that effective cooking stoves and lighting solutions are provided in the relief package.
(5) Provide solar lighting solutions in shelters, schools, and WASH (water, sanitation and hygiene) facilities to help reduce security-related risks.

(b) Medium-term plan

(1) Ensure all the impacted customer are reconnected, and check all impacted in-house connection and in-house wiring.

(2) Ensure all the affected facilities are completely restored with better disaster resilience capacity.
(3) Develop a guideline/manual for the electricity sector that (i) accounts for risks from geophysical, metrological, hydrological, and climate-logically hazards to different types of generation, trans-mission lines, substations, and ancillary equipment; (ii) includes countermeasure for each type of disaster for each subsector; and (iii) includes a plan and resources for recovery.
(4) Conduct a dam safety program.
(5) For residential uses, promote the use of one-phase trans-formers, which could be placed on the top of the poles to minimize the possibility of submerging.
(6) Strengthen women's participation in the village electricity committees. This will ensure that women have access to information, will involve them in making decisions, and allow them to monitor the implementation of recovery plans at the village level. Consult with women's groups for restoration of energy services.
(7) Coordinate with international and domestic NGOs in the areas to support village renewable energy programs for affordable solar energy and clean stoves.

(c) Long-term plan

(1) Relocate the existing sub-stations to, and construct new substation in, places where ground level is higher than the design flood level.
(2) Develop electric systems, including all type of generations, transmission lines, substations, and ancillary equipment, with specifications of higher standard for disaster resilience.

The condition of Immediate Recovery Works, Short Term Plan, Medium Term Plan and Long Term Plan Recovery Works are shown in Table VI to XI.

TABLEVI. IMMEDIATE RECOVERY WORKS

	State & Region	Number of Works	Losses (USD)	Estimated Cost for Recovery (USD)	Remarks
1	Kachin	2	340	340	already implement-ed
2	Kayah	1	1,995	2542	
3	Chin	14	162,320	15,958	
4	Mon	1	176	176	
5	Rakhine	17	229,269	311,322	
6	Northern Shan	1	2,400	3,600	
7	Sagaing	15	483,107	120,940	
8	Bago(East)	4	14,772	14,772	
9	Bago(West)	9	1936	2944	
10	Magway	14	47,310	47,122	
	Total	**78**	**943,625**	**519,716**	

TABLE VII. SHORT TERM PLAN
(TO BE COMPLETED WITHIN 4 MONTHS)

	State & Region	Number of Works	Losses (USD)	Estimated Cost for Recovery (USD)	Remarks
1	Chin	2	13,600	20,800	On Going Projects
2	Rakhine	7	25,417	35,017	
3	Sagaing	7	77,224	193,403	
4	Magway	4	21,600	21,600	
	Total	**20**	**137840**	**270,820**	

TABLEVIII. MEDIUM TERM PLAN (TO BE COMPLETED WITHIN 12 MONTHS)

	State & Region	Number of Works	Losses (USD)	Estimated Cost for Recovery	Remarks
1	Chin	6	226,400	389,378	On Going Projects
2	Sagaing	2	85,600	97,440	
3	Magway	1	413,750	267,000	
	Total	**9**	**725,750**	**753,818**	

TABLE X. LONG TERM PLAN
(WITHIN 1 TO 5 YEARS)

	State & Region	Number of Works	Losses (USD)	Estimated Cost for Prepared-ness Plan (USD)	Remarks
1	Chin	6		86,078	Prevent-ion & Preparedn ess Plan
2	Sagaing	2		258,540	
3	Magway	8		982,262	
	Total	**16**		**1,326,880**	

TABLE XI. SUMMARY FOR RECOVERY WORKS AND PLAN

	Plan	Number of Works	Losses (USD)	Estimated Cost for Recovery and Prepared-ness Plan (USD)
1	Immediate Recovery	78	943,625	519,716
2	Short Term Plan (within 4 months)	20	137,840	270,820
3	Medium Term Plan (12 months)	9	725,750	753,818
4	Long Term Plan	16		1,326,880
	Total	**123**	**1,807,215**	**2,871,234**

VII.CONCLUSION

This paper was only intended for the impact of natural disaster which occurred by strong winds and torrential rain during the monsoon of 2015 in Myanmar and the assessment of the damages was based on the actual inventory of damages. The losses were estimated based on actual data along with certain assumptions. And, in order to achieve overall objectives for disaster preparedness, mitigation and management, the following priority work streams should be carried out to reinforce.

(a) Awareness rising and community engagement through community-based Disaster Risk Management
(b) Strengthening risk assessment and risk information systems
(c) Disaster Risk Management
(d) Strengthening disaster risk governance and mainstreaming
(e) Strengthening Recovery Works to return the community to normal condition
(f) Enhancing disaster preparedness

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