REPUBLIC OF INDONESIA
THE AGENCY FOR METEOROLOGY, CLIMATOLOGY AND GEOPHYSICS OF THE REPUBLIC OF INDONESIA (BMKG)

THE PROJECT FOR CAPACITY DEVELOPMENT ON OPERATION OF EARTHQUAKE AND TSUNAMI ANALYSIS AND WARNING DISSEMINATION

PROJECT COMPLETION REPORT

APPENDIX (3/3)

APRIL 2025

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
JAPAN METEOROLOGICAL BUSINESS SUPPORT CENTER
PACIFIC CONSULTANTS CO., LTD.

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Materials for Disseminating Project Outputs at International Conferences, etc.

EARTHQUAKE AND TSUNAMI EDUCATIONAL MATERIAL FOR PERSON WITH DISABILITIES

TECHNICAL COOPERATION PROJECT FOR CAPACITY DEVELOPMENT ON OPERATION OF EARTHQUAKE AND TSUNAMI ANALYSIS AND WARNING DISSEMINATION

BMKG

JICA

Introduction of the Project

Project Name	The Project for Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Project Site	BMKG HQ (Jakarta), Model Site (Banten Province and Palu City)
Implementation Agency	BMKG (Agency of Meteorology, Climatology and Geophysics)
Related Organization	PVMBG, BIG, BNPB, KOMINFO, BRIN (LIPI), BPBD
Project Period	Feb, 2022 - Feb, 2025 (36 months)

Project Purpose	Strengthened for delivering timely accurate information on Earthquake and Tsunami to DRR agencies and Public
Project Output related to Developing Educational Material	Improve dissemination methodologies of earthquake and tsunami information.
Related Project Activities	Evaluate the revised flow by conducting information dissemination exercise in the model sites. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.

Methodology of Develop Materials

01. Preparation

Baseline survey

NOTHING ABOUT US WITHOUT US
What we did...

- Literature Review
- Online/Offline interviews with Persons with Disabilities, DPOs
- Collection of questionnaires about needs, challenges and reasonable accommodations

02. Design

03. Check

Methodology of Develop Materials

02. Design the Material

Format: Braille, audio-text, large format with clear color-contrast, screen-readable format, movie with sign language interpretation

Contents: Necessary preparation based on characteristics of disabilities, source of the official information from BMKG and explanation of the warning messages

03. Check

Methodology of Develop Materials

03.
Check
MATERIALS ARE READY!!

Check Reasonable Accommodations
After drafting and developing each material, checked with DPOs about
-Contents (Precise, easy-to-understand, needs for PwDs)
-Format (Size, color, contrast)

User Comments

(PPDI Central Sulawesi – Association of Indonesia Person with Disabilities)

- Consider that everyone with disabilities learns differently, providing a variety of formats, methods and approaches can create accessible educational materials.
- By providing educational materials with direct involvement of people with disabilities, the educational materials become more representative of the needs that can be accessed by people with disabilities according to the variety of obstacles they face.
- PPDI hopes that in the future there will be more innovations, methods and learning technologies that can accommodate the needs of various disabilities and more collaboration between educational institutions, government and communities to create inclusive materials.

Introduction of Educational Materials

- **Earthquake and Tsunami Preparedness for Person with Disabilities Booklet**
  - Comprehensive guide with tailored tips.
  - A brief explanation about Earthquake and Tsunami in Indonesia
  - Contain Information on How to Access Trusted Information from BMKG Official Website, Account, and Social Media

- **Earthquake and Tsunami Safety Guidelines**
  - Quick reference for safety protocols.
  - Contain Information on How to Access Trusted Information from BMKG Official Website, Account, and Social Media
  - Formats: Braille, large print, audio.

Output
Increasing the Capacity for person with disabilities with essential knowledge for disaster preparedness.

Educational Materials

Also available in digital version

APPENDIX 8-8

The Study of Quality Management in Maintenance for Observation System for Earthquake in Japan

The Study of Quality Management in Maintenance for Observation System for Earthquake in Japan

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

September 2020

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
EPOS	Earthquake Phenomena Observation System
NIED	National Research Institute for Earth Science and Disaster Resilience
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency

Chapter 1 Introduction

1.1 Background

In some developing countries, the operation rate of observation system for earthquakes and tsunamis is lower than in developed countries. One of the causes is that the maintenance system, including the skills of staff members and the guidelines / manuals / SOP for observation system (i.e., equipment for measuring earthquake and control system) are insufficient.

1.2 Objective of the Study

The objective of the study is to study quality management in maintenance with regard to keeping stable operations and the high quality of observed data. This is done by interviewing Japanese organizations which manage the observation system for earthquakes and tsunamis (i.e., JMA, NIED, JAMSTEC), and by analyzing basic technology or know-how which contributes toward strengthening work effectiveness and accuracy of observation.

This study can be used by other technical cooperation projects in Japan.

Chapter 2 Data Collection and Interview Survey

2.1 Outline

The quality management methods of observation system for earthquakes by Japanese major operational organizations (i.e., JME, NIED and JAMSTEC) were collected by conducting interview surveys and document researches (e.g., users' guideline, manuals for operational organizations).

(1) Method of Research

- Internet research
- Interview survey

(2) Targets of Research

- JMA: Japan Meteorological Agency
- NIED: National Research Institute for Earth Science and Disaster Resilience
- JAMSTEC: Japan Agency for Marine-Earth Science and Technology

2.2 Data Collection Survey

The following are the items collected in internet research for quality management in maintenance method or observation sites of key organizations.

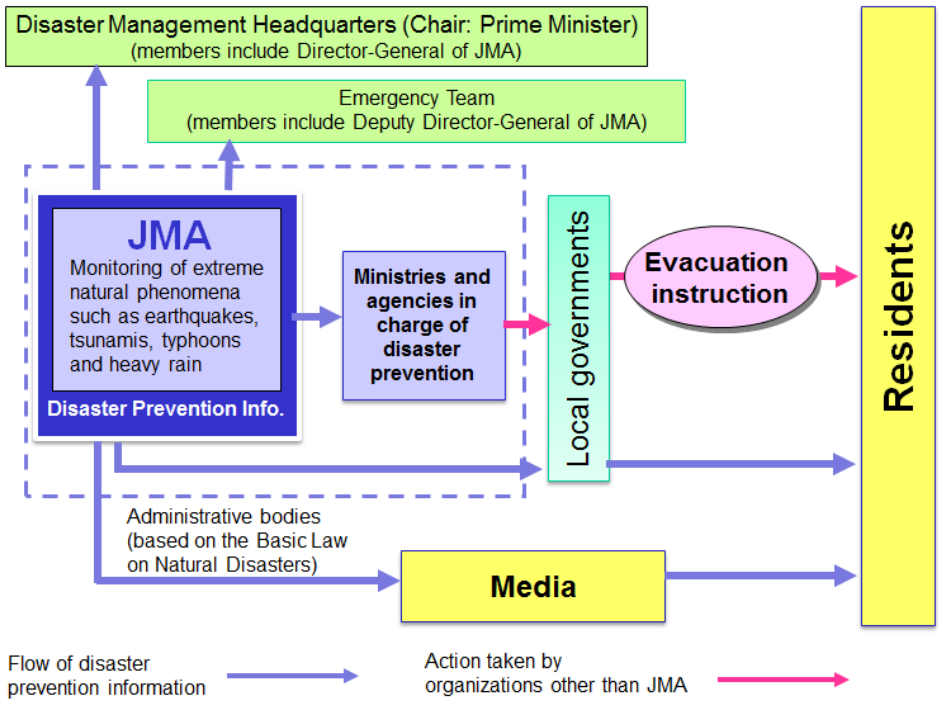
- Observation sites
- Equipment for observation
- Tender documents for operation and maintenance of observation system

2.2.1 JMA

(1) Mission and Organizational Structure

As part of Japan's government, the Japan Meteorological Agency (JMA) implements its services with the following ultimate goals in compliance with the Act for Establishment of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Meteorological Service Act:

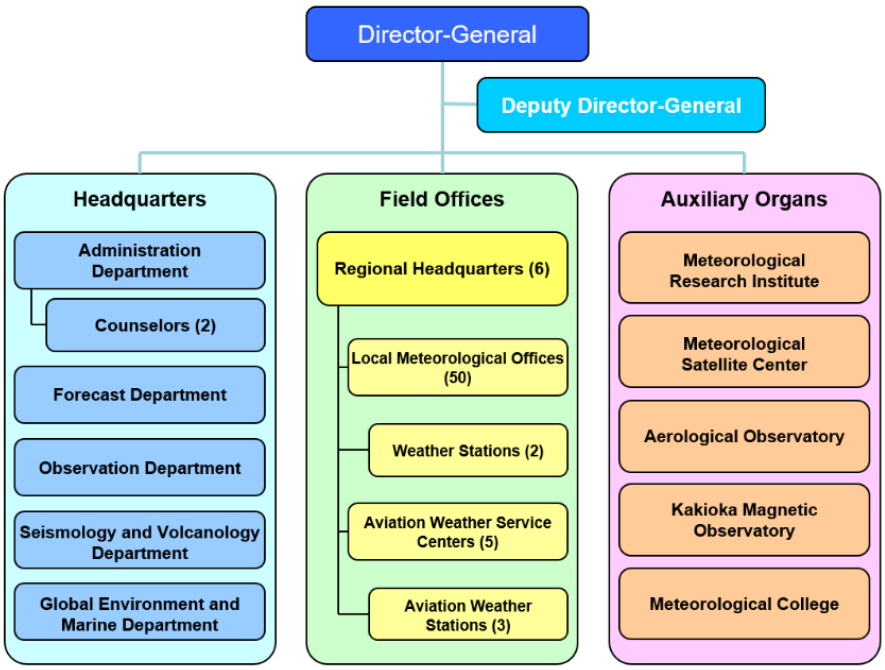
- Prevention and mitigation of natural disasters
- Safety of transportation
- Development and prosperity of industry
- Improvement of public welfare



Source:JMA

Figure 2.1 Disaster Prevention Operation Schemes and Role of JMA

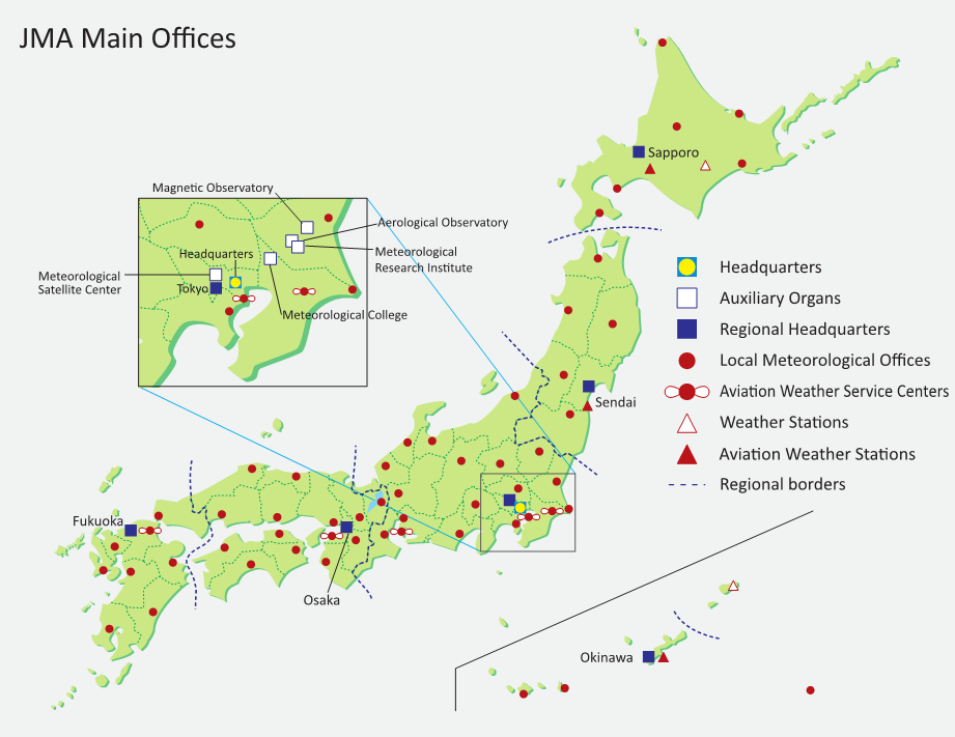
JMA is comprised of Headquarters, Regional Headquarters, Local Meteorological Offices and Weather Stations, and Auxiliary Facilities.



Source: JMA

Figure 2.2 Organizational Structure of JMA

To provide a wide range of services for local communities, JMA operates a number of observatories and weather stations across the country. The Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Okinawa Regional Headquarters (RHQs) serve as regional central offices directing 50 Local Meteorological Offices (LMOs) and 2 Weather Stations, both of which provide information services on prefectural and sub-prefectural levels.



Source: JMA

Figure 2.3 JMA Main Offices

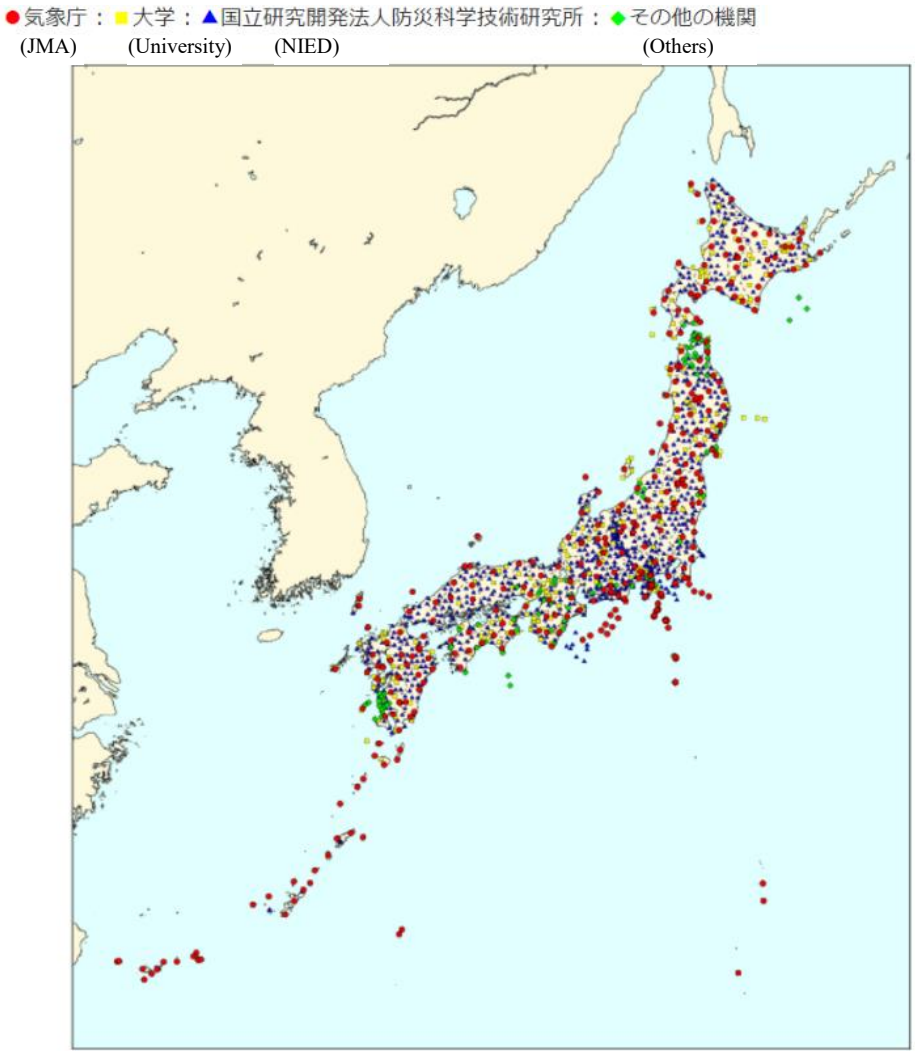
(2) Observation of Earthquakes and Tsunamis

JMA monitors earthquakes and tsunamis by using observation data which is transmitted by the earthquake and tsunami observation stations installed nationwide. As soon as an earthquake or tsunami occurs, warnings information will be announced. As part of its monitoring activities, JMA also collects and utilizes observation data of related organizations.

JMA has also established the Earthquake Phenomena Observation System (EPOS) as a system for promptly processing earthquake and tsunami data and issuing warnings information. EPOS is installed in Tokyo and Osaka, and even if a large-scale disaster occurs in either Tokyo or Osaka, it is possible to issue warnings information.

1) Seismic observation point

Seismic observation points are used to monitor seismic activities. These are used to detect the shaking of an earthquake and determine the epicenter (location of the earthquake) and scale (magnitude).

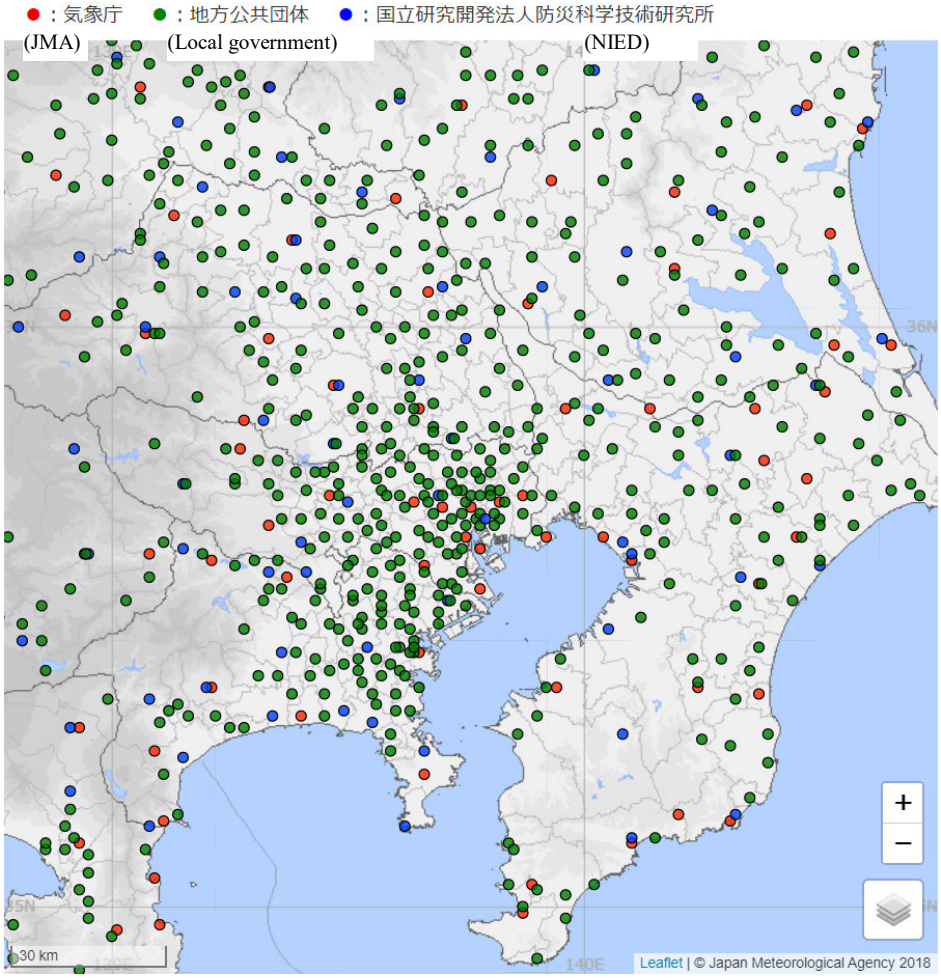


Source:JMA

Figure 2.4 Location of Seismic Observation Points

2) Seismic intensity observation point

Seismic intensity observation point can measure the strength (seismic intensity) of the ground shaking in a specific location. The seismic intensity information of each municipality announced on TV, etc., is measured at these observation points.



Source:JMA

Figure 2.5 Location of Observation Sites (Kanto Region)

Table 2.1 Number of Observation Sites

Prefecture	JMA	Local Government	NIED	Total Number
Hokkaido	88	80	169	337
Aomori	18	56	15	89
Iwate	20	39	21	80
Miyagi	16	54	17	87
Akita	13	55	17	85
Yamagata	14	40	13	67
Fukushima	18	84	22	124
Ibaraki	12	80	12	104
Tochigi	8	45	12	65
Gunma	8	59	13	80
Saitama	9	91	14	114
Chiba	20	80	11	111
Tokyo	26	96	9	131
Kanagawa	9	84	13	106
Nigata	19	98	19	136
Toyama	8	28	9	45

Prefecture	JMA	Local Government	NIED	Total Number
Ishikawa	11	27	13	51
Fukui	7	30	5	42
Yamanashi	6	61	10	77
Nagano	16	103	22	141
Gifu	11	90	15	116
Shizuoka	20	70	17	107
Aichi	15	99	10	124
Mie	11	68	8	87
Shiga	6	48	10	64
Kyoto	7	64	8	79
Osaka	8	73	8	89
Hyogo	19	75	27	121
Nara	5	46	1	52
Wakayama	11	37	9	57
Tottori	6	34	6	46
Shimane	10	53	8	71
Okayama	9	82	9	100
Hiroshima	11	77	20	108
Yamaguchi	10	54	13	77
Tokushima	7	35	12	54
Kagawa	7	40	7	54
Ehime	9	53	15	77
Kochi	13	43	13	69
Fukuoka	13	108	11	132
Saga	4	41	8	53
Nagasaki	14	57	22	93
Kumamoto	12	72	21	105
Oita	14	49	14	77
Miyazaki	14	37	16	67
Kagoshima	29	73	37	139
Okinawa	29	44	11	84
Amount	670	2912	792	4374

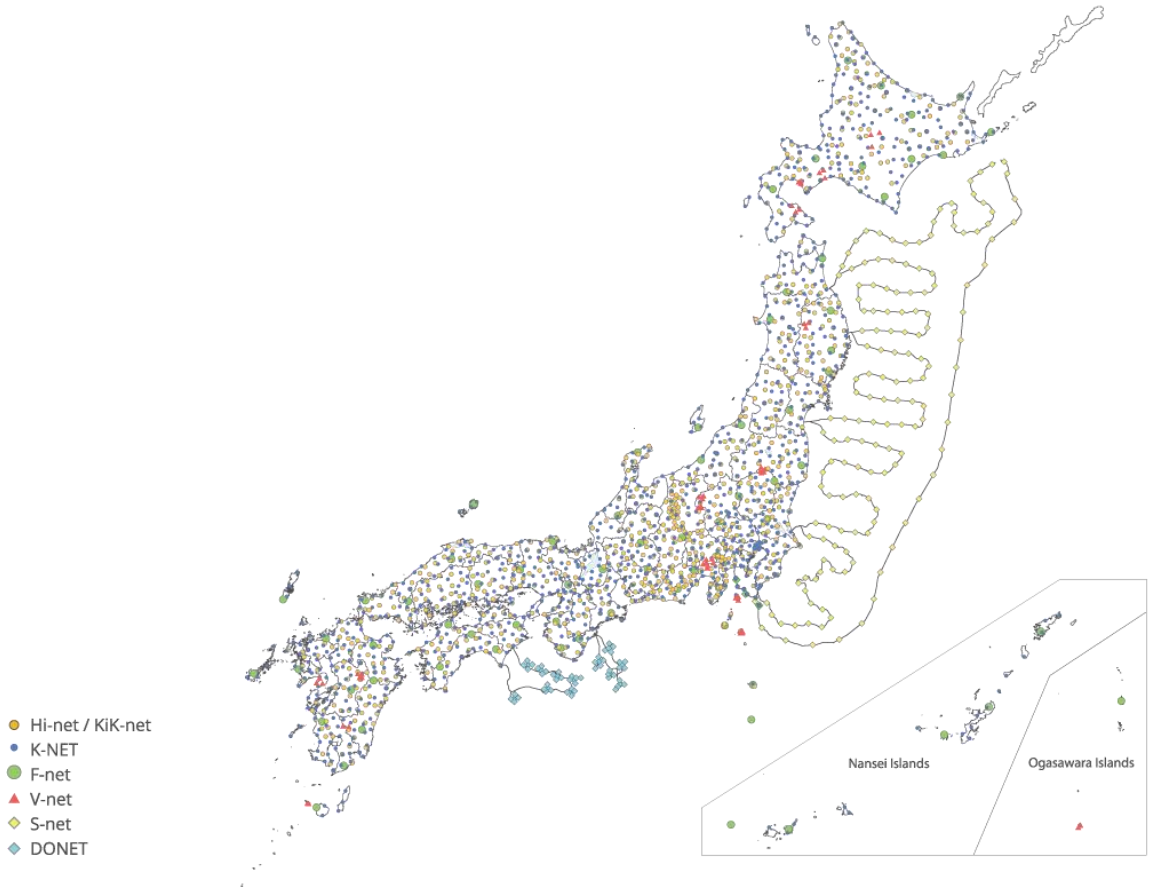
Source:JMA

2.2.2 NIED

Following the Kobe earthquake on January 17, 1995, the National Research Institute for Earth Science and Disaster Resilience (NIED) established four nationwide land observation networks –, Hi-net, K-NET, KiK-net, and F-net – to improve understanding and assessments of earthquakes and their impacts. NIED also established V-net, which consists of 55 stations at 16 volcanoes, to monitor volcanic activity.

After the Tohoku earthquake on March 11, 2011, a seafloor observation network, S-net, was installed from off Hokkaido to off Chiba Prefecture for rapid detection of offshore earthquakes and tsunamis. In April 2016, NIED took over the operation of DONET, another seafloor network in Kumano-nada and off Kii Channel, from Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Integrated operation of these networks started in November 2017, and the networks were collectively named MOWLAS (Monitoring of Waves on Land and Seafloor).

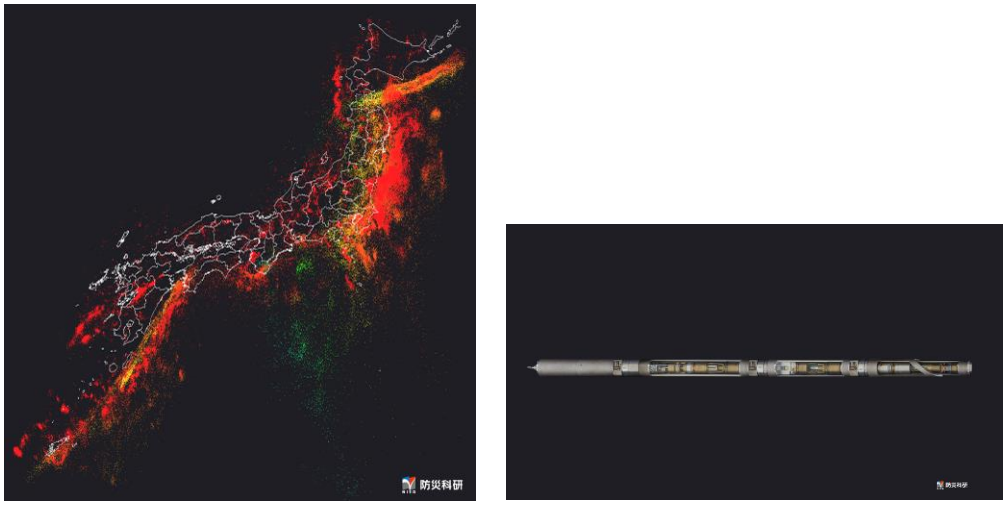


Source: NIED website, https://www.mowlas.bosai.go.jp/mowlas/?LANG=en

Figure 2.6 Observation Network of NIED

(1) Hi-net (High Sensitivity Seismograph Network Japan)

Hi-net is a high-sensitivity seismograph network consisting of nearly 800 stations with an average spacing of 20 km. The seismometers are installed at the bottom of boreholes at a depth of 100-3500 m to reduce noise caused by winds, ocean waves, and human activity. The observed data is continuously transmitted to NIED to be used for researching microearthquakes and other seismological phenomena.



Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.7 Left: 3D Distribution of Earthquakes From 2012 to 2016 Captured by Hi-net; Right: Sensor Unit

(2) K-net/Kik-net (Kiban Network / Kiban Kyoshin Network)

K-NET is a strong motion seismograph network consisting of more than 1,000 stations with an average spacing of 20 km. The seismometers are installed on the ground surface and stay on scale even during strong shaking. Most of the K-NET seismometers are officially approved as seismic intensity meters. Seismic intensity from K-NET supports government decision-making.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.8 Equipment of K-NET

KiK-net is a strong motion seismograph network consisting of pairs of seismometers installed on the ground surface and in the borehole together with the Hi-net high-sensitivity sensors. Surface and downhole observations provide important data to understand amplification of strong shaking near the surface.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.9 Equipment of Kik-net

(3) F-net (Full Range Seismograph Network of Japan)

F-net is a broadband seismograph network consisting of about 70 stations nationwide. The seismometers are installed at the end of tunnels several dozen meters from the entrance – where temperature and pressure are stable – and accurately measure ground motion over a wide frequency range. These broadband measurements provide useful implications for earthquake source mechanisms and the structure of the Earth.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.10 Left: F-net Station; Right: Three Broadband Seismometers with a Strong Motion Velocity Seismometer

(4) V-net (The Fundamental Volcano Observation Network)

V-net is an observation network operated at 16 volcanoes in an effort to develop eruption forecast and volcano hazard mitigation. Several types of instruments are installed, including borehole seismometers, borehole tiltmeters, GPS receivers, and broadband seismometers. The borehole measurements at Mt. Miyake observed precursors to the eruption in 2000. At Mt. Asama, a radar interferometer is also installed to monitor surface deformation from magma movement before and during eruptions.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.11 V-net Station

(5) S-net (Seafloor Observation Network for Earthquakes and Tsunamis Along the Japan Trench)

S-net is an ocean bottom observation network consisting of 150 observation units from off Hokkaido to off Chiba Prefecture. Each unit contains seismometers and water pressure gauges to observe offshore earthquakes and tsunamis. All the data is transmitted to the land stations by fiber-optic cable and arrives at NIED in real-time.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.12 Left: Laying Operation of S-net; Right: Water Pressure Gauges in the S-net Observation Units

(6) DONET (Dense Ocean Floor Network System for Earthquakes and Tsunamis)

DONET is an ocean bottom observation network consisting of 51 stations in Kumano-nada and off Kii Channel, focused on monitoring of earthquakes and tsunamis in the region. A wide variety of instruments are installed, including strong motion seismometers, broadband seismometers, water pressure gauges, hydrophones, differential pressure gauges, and thermometers. The network is designed to be expandable and replaceable, allowing for adding stations and replacing instruments. The data is transmitted to research institutes and universities in real-time, and improves precision and warning times of earthquake early warning and tsunami warnings/advisories by JMA.

Source: NIED website, https://www.mowlas.bosai.go.jp/network/?LANG=en

Figure 2.13 Left: Station of DONET; Right: Ground Motion Sensing System

2.2.3 JAMSTEC

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been engaged in a variety of research and development activities as one of Japan's research institutes covering a broad spectrum of marine science and technology.

To reveal earthquakes and volcanic activities, the scientists and staff of the Research Institute for Marine Geodynamics will conduct large-scale observations around Japan and the western Pacific using JAMSTEC vessels and various state-of-the-art marine exploration technologies.

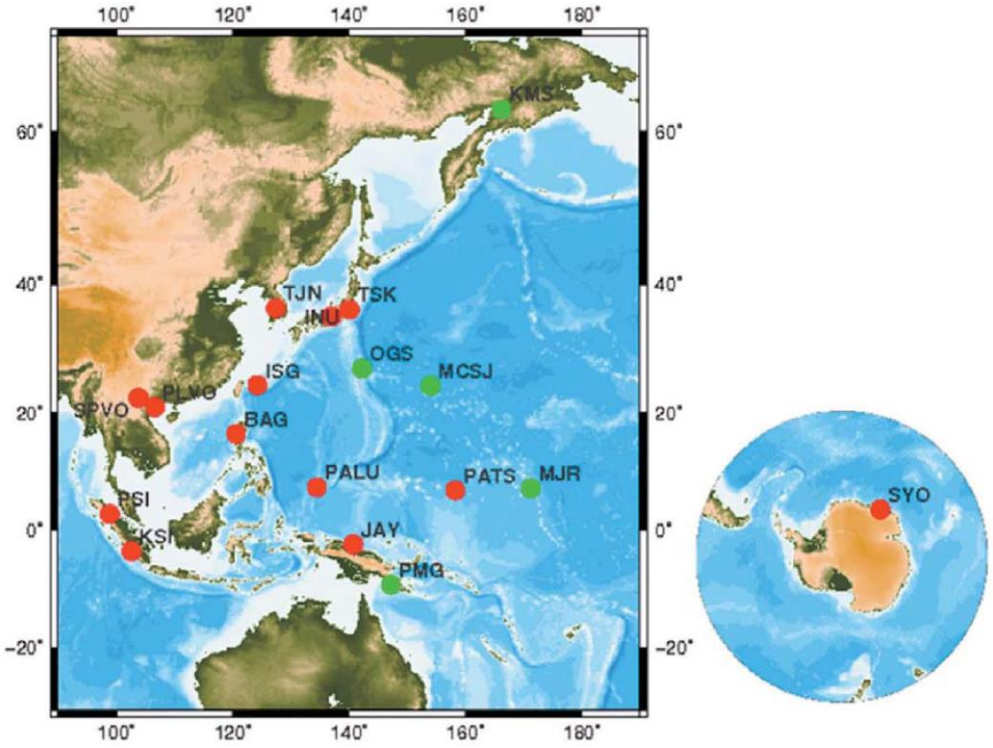
In particular, geophysical-geological surveys will be conducted in the Nankai Trough, Japan Trench, Kuril Trench, and other tectonically active zones that may be subject to a forthcoming megathrust earthquake or volcanic eruption. Moreover, the methods and systems to acquire and process data will be developed, improved, and upgraded.

Furthermore, in line with SDGs 11 (sustainable cities and communities), the institute will contribute to disaster mitigation by sharing the scientific knowledge gained by JAMSTEC with the society. JAMSTEC will also endeavor to conduct observational surveys and apply their research results in countries that are vulnerable to frequent natural disasters such as earthquakes, tsunamis, and volcanic activities.

Global seismic network is one of the powerful means to research on the dynamics of the Earth's

interior. JAMSTEC installs and operates broadband seismic network in Western Pacific Region. For the purpose of recording high-quality data, station should be operated stably without any suspensions.

Therefore, JAMSTEC constructed real-time data archive and the station's status monitoring systems. The rate of operation is much higher due to an upgrade to telemeter station from off-line recording period. It is realized that full-length seismic data set is archived with minimum interruption.



Source: JAMSTEC-R IFREE Special Issue

Figure 2.14 Broadband seismic station map operated as Ocean Hemisphere Network by JAMSTEC supported by cooperative institutes. Red mark is on-line telemeter station transmitting to OHP data center. Green mark is off-line station.

Table 2.2 List of JAMSTEC stations. Blank station in data communication column denotes off-line station.

Station	Location	Code	Lat.	Lon.	Corporative partner	Data communication
Baguio	Philippines	BAG*	16.41	120.58	PHIVOLCS	ADSL
Inuyama	Japan	INU	35.35	137.03	Nagoya Univ.	ISDN
Ishigaki	Japan	ISG	24.38	124.24		ISDN
Jayapura	Indonesia	JAY	-2.51	140.70	BMKG	VSAT/IP
Kamenskoye	Russia	KMS	62.46	166.10	RSA	
Minamitorishima	Marcus Island	MCSJ*	24.29	153.98	JMA	
Chichijima	Japan	OGS*	27.06	142.20		
Palau	Palau	PALU	7.34	134.47	PCC	DSL
Pohnpei	Micronesia	PATS*	6.84	158.31	MERIP	Optical
Port Moresby	Papua New Guinea	PMG*	-9.41	147.16	IRIS	
Parapat	Indonesia	PSI*	2.69	98.92	BMKG	VSAT/IP
Syowa Station	Antarctica	SYO*	-69.01	39.59	NIPR	**
Taejeon	South Korea	TJN	36.38	127.36	KIGAM	Internet
Tsukuba	Japan	TSK*	36.21	140.11	ERI	**
Kepahyang	Indonesia	KSI	-3.65	102.59	BMKG	VSAT/IP, **
Haiphong	Vietnam	PLVO	20.81	106.63	IGP	ADSL
Majuro	Marshall Islands	MJR	7.06	171.21		
Sapa	Vietnam	SPVO	22.34	103.84	IGP	ADSL

*FDSN station

** telemetered to cooperative institute

2.3 Interview Survey

The following are the interview survey items for quality management in maintenance method or observation sites of key organizations.

1. Basic information on observation equipment
2. Organization for maintenance of observation equipment
3. Maintenance methods of observation system
4. Guidelines for maintenance manuals

2.3.1 JMA

(1) Basic Information on Observation Equipment

1) Systems of seismic observation network in operation

Japan Meteorological Agency processing center

- Two processing centers, the Japan Meteorological Agency's main office and the Osaka District Meteorological Observatory, are taking the same observation data. Their central systems are also supported by their own backup systems.

Communication line of Japan Meteorological Agency observation point

- Seismic station: At the main seismic stations, two different ground lines – a dedicated line and a general public line (ISDN) – are used, and a satellite mobile phone line is also maintained. The data flow is from the observation point to the processing center of the Japan Meteorological Agency.
- The point where only the measuring seismic intensity scale is installed: There are two lines – a general public line (ISDN) and a satellite communication using the meteorological satellite Himawari. The data flow is from the observation point to the processing center of the Japan Meteorological Agency.

Seismometer owned by the local government

- The data flow is as follows: Observation Point-> Prefectural Processing Server-> Local Meteorological Observatory-> Japan Meteorological Agency Processing Center.
- The processing server of the prefecture and the local meteorological observatory are connected by a dedicated line. The local meteorological observatory and the processing center of the Japan Meteorological Agency communicate with each other through a dedicated communication network of the Japan Meteorological Agency.

2) Operating rate / failure rate

- The operating rate and missing measurement rate are not managed in the database.
- The materials will be provided at a later date.

3) Frequency of system updates / replacements

- As a guide, 5 years for the system and 10 years for the equipment. Updates will be planned at the Earthquake and Volcano Department and a budget will be applied.
- An update of the analysis software will be developed by the Earthquake and Volcano Department and implemented by a subcontractor.
- In general, the specifications of the analysis software are developed by the Japan Meteorological Agency, and a contractor creates the software.

(2) Organization for Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- The main body is the Earthquake and Volcano Department of the Japan Meteorological Agency.
- Operations personnel are organized as a group within the department, but not as a separate organization.

2) System and scale of management / operation department

- The Earthquake and Volcano Department has about 250 people in the main office and about 250 people in the regions.

3) Utilization status of outsourced / seconded staff, etc.

- If maintenance / repair is required at the observation point, a one-off maintenance contract would be made between the manufacturer and JMA.
- For central systems (NEC and Meisei Electric), on-call maintenance is available 24 hours a day.
- The communication line is specified in the contract with the communication company.

(3) Maintenance Method of Observation System

1) Policy

- The Earthquake and Volcano Department monitors the central processing system.

2) Defect detection method and recovery method

- Monitored by the Earthquake and Volcano Department.
- The processing when a problem occurs and recovery methods is summarized in the database of Japan Meteorological Agency. The contents are fed back to the procurement specifications from the next fiscal year onward.
- The state of each observation point is checked once a day from the central system. In addition, the self-check function of the observation points are set so that information on failures, etc., would be provided each time a failure or quality abnormality is detected. Waveforms are also visually checked twice a day.

3) Regular inspections

- The status of each observation point is checked once a day from the central system. Regarding the local situation such as visual confirmation of the equipment and observation environment, the staff members are checking them when checking other observation points (nearby meteorological observation points, etc.).
- The observation points are outsourced for inspection about once every two years.

(4) Maintenance Status of Manuals, Guidelines, etc.

- JMA has manuals as specifications when procuring or outsourcing maintenance.
- The following specifications will be sent at a later date.
  - Overall observation system
  - Software
  - Central processing system
  - Communication system
  - Observation point equipment

2.3.2 NIED

(1) Basic Information on Observation Equipment

1) Contents and composition of the seismic observation network in operation

- There are seven observation systems with different purposes. They are called High-net, K-net, Kik-net, F-net, S-net, DONET, and V-net, respectively, and they are collectively called MOWLAS (Monitoring of Waves on Land and Seafloor). The contents and purpose of each seismic observation network are detailed on the MOWLAS website.
- The total number of observation points exceed 2100, and these observation data are transmitted by EarthLAN, which was originally developed based on IP-VPN for real-time observation, and by ISDN line for event observation. Satellite communications or mobile data networks are not used except in special cases.
- A sub-server has been installed in Miki City, Hyogo Prefecture to ensure the redundancy of the observation server.

2) Operating rate / failure rate

- There is no data on the failure rate because the definition of failure in the seismic observation system depends on applications. The target for missing data is 5% or less, and the target has been achieved except in special cases such as during the Great East Japan Earthquake.

3) Frequency of system updates / replacements

- 10 years is the standard for the surface equipment. The equipment inside a hole are designed to operate for 10 years or more, but if the temperature inside the hole is high, the interval may be shorter than 10 years. Server equipment will be upgraded every 5 years.
- Software is often updated when the server device is updated. For software improvement, the staff develops the algorithm and outsources its implemenation.

(2) Organization for Maintenance of Observation Equipment.

1) Organizational position of the management / operation department

- In general, the NIED Earthquake Tsunami Volcano Network Center in Tsukuba City is the main body in charge of operation and management.

2) System and scale of management / operation department

- Apporoximately 26 staff members are assigned to the center, and seven seismic observation networks are managed by six management rooms (K-net and Kik-net are one management room).

3) Utilization status of outsourced / seconded staff, etc.

- The maintenance and management work (annual contract) of the observation system is outsourced.
- In case of equipment failure, a one-off maintenance contract would be made.
- Include one year of maintenance when delivering individual observation equipment and system software. Update them annually if necessary.
- For communication lines, NIED has a contract with a communication company (i.e., NTT).

(3) Maintenance Methods of Observation System

1) Policy

- At the Tsukuba Center, maintenance is being carried out by making maximum use of remote monitoring and self-diagnosis functions for observation point data nationwide. Staff

members and contractors are conducting monitoring during business hour, but not 24 hours a day. Failures such as line disconnection are automatically detected and sent by email to the concerned personnel.

2) Defect detection method and recovery method

- During working hours, the staff in the management room does the monitoring. During off-duty hours, it is monitored by remote monitoring / self-diagnosis function.
- When a problem occurs, investigate the situation of the problem by remote login from the management room to the observation point equipment and check the log. If there is a need for repair, request a contractor to repair by one-off contract.
- Equipment and devices installed at observation facilities have never been stolen. There is only one surveillance camera installed. Although it seems that it is not necessary to fence up, about half of the observation facilities are fenced up in response to the request of the landowner to clarify the boundary of responsibility.

3) Regular inspections

- Remote monitoring is the basic method, and the timing and contents of regular inspections are not specified.
- General inspection is carried out when a staff goes to the site for repairs, etc.

(4) Guidelines for Maintenance Manuals

- No integrated manual for maintenance management has been prepared because the observation system is complicated and diverse, and there are limited number of outsourcers who can be entrusted with the maintenance.
- Instruction manuals for individual observation instruments are delivered at the time of procurement.

2.3.3 JAMSTEC

(1) Basic Information on Observation Equipment.

1) Contents and composition of the seismic observation network in operation

- Earthquakes have been observed at 20 locations around the West Pacific Ocean, including Indonesia. If there is basic data such as the coordinates of the observation points, it will be provided at a later date.
- JAMSTEC's seismic observation network has the most important role of acquiring and providing high-quality scientific data without omission to be used for research purposes. Real-time data collection is a secondary position.
- There are three observation stations in Indonesia. If a contract is signed between JAMSTEC and BMKG, a fourth observation point will be set up and the number of observation stations will increase.

2) Operating rate / failure rate

- The operating rate (data acquisition rate) has been 99% or more for the past 10 years or more. The quality associated with a failure varies depending on the condition of the observation station.

3) Frequency of system updates / replacements

- The oldest sensor has been used for 30 years. If there is a problem with a logger, it is replaced as appropriate (As a guide, it is replaced in about 10 years).
- As for Indonesia, it is being prepared to replace old equipment with a simple, new one, since the maintenance of old equipment is difficult. Although the replacement schedule depends on the COVID-19 situation, it is preferable to do the replacements when the timing

is right. At the same time, JAMSTEC has expressed its intention to inform BMKG about the equipment's maintenance. JAMSTEC is also considering remote and interactive instruction.

- Observation huts in which the sensors being installed were built by BMKG based on a blueprint given by JAMSTEC. The loggers were installed in the local BMKG office.
- The quality of the observation huts (pits and pedestals) depends on the local staff. The huts are made well when Japanese side specify the requirements, though some people in charge cut corners. We had a difficult time working on JISNET due to local staff cutting corners.
- Generally speaking, the equipment items have never been stolen. There are no problems reported because the equipment are located in the BMKG office.

(2) Organization for Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- The main parts (sensor, logger) are managed and operated directly by JAMSTEC. JAMSTEC are instructing local collaborators not to touch the parts. Communication and power supply are monitored by local collaborators.
- The services of local providers are used for communication. No satellite communication is used. A communication line is contracted at each observation point. Restoration work is outsourced to local people.
- Local services are also used for electricity. Restoration work is also handled by local companies.

2) System and scale of management / operation department

- Three staff members (substantially 2.5 people) in JAMSTEC carry out everything from observation to data collection and archive management.

3) Utilization status of outsourced / seconded staff, etc.

- In general, the policy is to implement the work within JAMSTEC. In case of urgent need or when the staff cannot handle the work, some cooperation of universities, etc., may be requested or some tasks may be outsourced to a contractor.
- Since a constant budget for the operation of the seismic observation network is not guaranteed, reliance on outsourcing makes it difficult to maintain the operation if the budget is insufficient. Therefore, the observation network is operated in-house as much as possible so that it can be maintained with a small amount of resources.
- BMKG has been allotted a budget unlike in the past. BMKG's maintenance is also well outsourced, but considering resource management, it is doubtful whether outsourcing to that extent will lead to stable operations as well as doing mostly paperworks.
- Although it may be acceptable to outsource for short-term observation, this would be a problem when it comes to long-term maintenance of the network.

(3) Maintenance Methods of Observation System

1) Policy

- JAMSTEC's network operation is different from JMA and NIED. Since JMA and NIED monitor networks as a business, high monitoring levels are required. On the other hand, JAMSTEC has no obligation as a monitoring business. The mission is to acquire the Earth's basic scientific data and keep a stable record of it as continuously as possible without any gaps. Immediacy is an effort, but it is not the first priority.

2) Defect detection method and recovery method

- Observed data is monitored in real-time at observation points. Not only waveform and status data, but also temperature sensor, etc., are attached as an option. It is monitored by 0.5 people (in principle, during business hours from 9:00 to 17:00). A detailed observation situation can be obtained by using the status data after a long period of monitoring activity.

3) Regular inspections

- The sites are visited once a year to check the sensors and others. If it is determined that early action is necessary, JAMSTEC makes an effort to visit earlier.
- We visit BMKG central office once a year, staying for a relatively long time to check the situation. Although the condition of accelerometer is easy to understand, r it is very difficult to know exact condition of the broadband seismomete. Therefore, follow-up is being carried out during a longer stay. It is made sure that the existing issues are extracted.

(4) Guidelines for Maintenance Manuals

- There is no integrated manual for Indonesia. Regular maintenances such as storage replacement are explained in memos, etc., every time. In general, the idea was that JAMSTEC did not want local staff to touch the equipment items, though this would no longer be the case in the future.
- Depending on the situation of the partner country, a detailed manual is made and explained well in some countries.
- There is a collection of manuals within JAMSTEC for data management and data archiving. Since the observation items are very simple, the manufacturer's manual is sufficient.

(5) Others

- How to incorporate Japanese operations into BMKG is the most important issue in implementing the project. It will be difficult to imitate it as it is. There are also issues regarding maintaining the level of technology and maintenance-related technology, including how to allocate expenses. It is important to know how much BMKG can do the operations autonomously.
- In the management of observation quality, the issue is how many people in BMKG can determine if the waveform is behaving strangely or not. There is no manual that specifies that something is wrong with the waveform.
- If drum records are taken consistently on a daily basis, it would be able to identify if there is any abnormal activity. In particular, it would be able to detect a faulty waveform recording of broadband seismographs as BMKG gets used to drum records.
- For example, if one year of drum records were obtained, it could be identified if something went wrong in the middle part of the records. Such training should be carried out. This method is outdated, but yields the fastest result. JAMSTEC has an experience in printing out the drum records and explaining them to the person at the observation station. It might have become difficult to detect defects since the records have been digitized and are no longer printed out.
- JAMSTEC is also consulted by BMKG regarding the utilization of strong motion seismographs. There was a request for a study session, but the content has not been examined. It appears that BMKG is also concerned about the handling of the broadband strong motion velocity seismometer installed through a Japanese grant free of charge. JAMSTEC would like to work on that in collaboration with this project.
- Power supply and mass position are required for broadband monitoring status data. Logger data and temperature data should also be checked.

2.4 Summary of the Survey

The results of the interview survey are summarized in Table 2-4-1 and Table 2-4-2, respectively. The results of the interview survey and the desktop collection are listed below:

(1) Operation rates of all observation system are higher than 99%.

(2) Policy of operation and maintenance highly depends on main purpose (real-time performance or scientific accuracy) of the system.

(3) Organization system for operation and maintenance reflects the scale of the system, necessity of real-time performance and required scientific accuracy of the system.

(4) System failure is detected by monitoring remotely from the central system.

(5) Japanese observation system stands on the reliability of basic infrastructures such as communication system and power supply system.

(6) There is no integrated manual or guideline for system maintenance and failure detection, although manuals for other parts are organized. Staff members in charge of operation and maintenance are educated mainly through OJT (on-the-job training) and trained by suppliers of procured devices / systems.

Table 2.3 Summary of the Survey (1)

	JMA	NIED	JAMSTEC
1.Basic information			
(1) Contents and component of earthquake observation system	#This is the earthquake observation system based on "the Meteorological Service Act" and the act states it to keep function. #Observation system: composed by two systems which are the earthquake observation system to provide epi-center/magnitude and the instrumental seismic intensity meter network to issue seismic intensity information. #Number of stations: 300 for earthquake observation system (most of stations are shared by seismic intensity observation), 400 for instrumental seismic intensity meter network #Communication system: For main earthquake observation stations, dedicated land line and ISDN for normal situation and satellite communication line as backup. For seismic intensity meter, ISDN as primary line and Satellite (HIMAWARI) as backup. Observed data flow from stations to central system at JMA. #Central system (data server): Duplicated by Tokyo as main and Osaka as slave. Each system is also duplicated. #Seismic intensity data by local government: Transmitted from observation station -> processing system at local government -> District/local meteorological agency -> Central system at JMA. #Processing system at local government is connected to district/local meteorological agency and district/local meteorological agency is connected to central system at JMA, both by dedicated line.	#This system is the biggest multi-purpose earthquake observation system shared by JMA. #Observation system: 7 systems with different purpose (High-net, K-net, Kik-net, F-net, S-net, DONET, V-net), collectively called as MOWLAS (Monitoring of Waves on Land and Seafloor) are working. #Number of stations: more than 2100 #Communication system: EarthLan developed based on IP-VPN by NIED and NTT is used for real-time observation system. ISDN is used for event-trigger observation. Satellite or mobile network is not used in normal situation. # Central system: Duplicated by Tsukuba city and Miki city.	#Main role of JAMSTEC's earthquake observation system is obtaining scientific fundamental data of whole earth continuously and stably. Real-time performance is not primarily requirement to this system. #Observation system: West pacific ocean broadband earthquake observation system called as Pacific21. #Number of stations: 20 at Vietnam, Philippine, Indonesia, Palau, Micronesia, Japan, etc. In Indonesia, 3 stations are located and 1 more station is planed to install. #Communication system: Internet (via local provider) #Central system is located at JAMSTEC.
(2) Operation rate, failure rate	#Operation rate or data missing rate is not compiled as database. (Based on the Ministry of Internal Affairs and Communications, failure happened 107 times during three years (2010 to 2012) for 397 seismic intensity stations including 95 times with short recovery (within 2 days). Data missing rate can be calculated by PF/PO as lower than 0.1%, where PF is period of failure, PO is total period of observation multiplied by number of stations.)	#Failure rate is not determined because definition of failure depends on how to use it. #Data missing rate is designed as lower than 5%, and mostly it is satisfied. (Based on the Ministry of Internal Affairs and Communications, operation rate was more than 99% in the period from 2016 to 2018.)	#More than 99% operation rate has been achieved during recent 10 years.
(3) Period of update/replace the system	# 5 years for observation system, 10 years for equipment. Seismological and Volcanological Department of JMA plan to update/replace, and request budget. # Software company develops updated system as a specification provided by JMA based on developed system by Seismological and Volcanological Department.	# 10 years for surface equipment. For post hole equipment, though it is designed more than 10 years operation, incase of high temperature condition inside the hole, it is replaced within shorter than 10 years. # 5 years for server equipment. # Software mainly replaced at the same time as server equipment. For improvement of software, a researcher develops algorithm and outsource to implement it.	# Some sensor has been working around 30 years. # As for logger, it is replaced one by one depending on its performance. Normally 10 years.

Table 2.4 Summary of the Survey (2)

	JMA	NIED	JAMSTEC
2.Policy, organization, and method of operation and maintenance			
(1) Policy	# Basically, Seismological and Volcanological Department monitor the observation system through 24 hours 365 days on the central system for operation and maintenance.	# Data from all over Japan is monitored remotely from Tsukuba office by the maximum use of self-diagnosis function implemented to each equipment at stations. Though the system works 24hours, monitoring staffs work in normal working hour. Communication failure is detected automatically and inform to staffs in 24 hours.	Operation and maintenance are done by JAMSTEC researchers by own power.
(2) Organization structure and scale of operation and maintenance section	# The Seismological and Volcanological Department is the main actor of operation and maintenance. # About 20 staffs of the department are involved to operate/maintain the system as a group. # About 250 staffs are working in the Seismological and Volcanological Department and 250 staffs at local.	# 6 laboratories in the Network Center for Earthquake, Tsunami and Volcanoes of NIED Tsukuba are responsible sections for operation and maintenance. # Totally 26 staffs/researchers assigned to the 6 laboratories manage 7 earthquake monitoring systems (K-net and Kik-net are managed by one laboratory).	# Research Institute for Marine Geodynamics is the responsible section for the Pacific21 in JAMSTEC. # 3 staffs/researchers (2 are dedicated, 1 is 50% assigned) manage operation, data collection and archive.
(3) Use of outsourcing	Maintenance and repairment are done by temporal contract to supplier/manufacturer. The central system is maintained by 24 hours "on call " contract. Communication system is maintained based on contract with communication company.	# Maintenance and management of the observation system is outsourced on annual contract. # Repairment of equipment is done by closing contract one by one. # Contract for procurement of equipment or the system software must include 1 year warranty. The period of warranty can be extended if necessary. # For the communication line, maintenance and management are included to contract with the communication company.	# Main parts of observation system such as sensors or logger are managed/operated by JAMSTEC directly, keeping them not to be touch by local staffs. Communication line and power line are monitored by local staffs from BMKG. JAMSTEC request to local company/staffs to recover the trouble. # If the situation is emergency or too much serious, outsourcing to a skilled company or University by spot contract. # Because permanent budget for operation and maintenance is not secured, and the observation system could not keep function when the budget would be less, the observation system should be managed by internal staffs as much as possible to keep function by even less resources.
(4) Method of failure detection and recovery	# By the Seismological and Volcanological Department # Response on system failure and recovery method are compiled as database. These information is feedbacked and referred to make a specification of procurement at the next year. # Monitoring condition of all stations from the central system once per day. By self-diagnosis function at stations, any failure of the system can be detected and the failure status is sent to the central system automatically. # Monitoring of observed waveform is carried out twice per day.	# During working hours, staffs at the laboratories monitor the system. After working hours, monitoring is done by self-diagnosis function. # Status of detected failure is investigated by remote-login to equipment and reading log-file from the network center. In case of repairment necessary, a manufacturer is requested to fix the problem on the condition of spot contract. # There is no experience that equipment is stolen. Monitoring camera is installed at only one station. Around half of stations are surrounded by fence just because land owner wants to show boundary of the land, not because of secure.	# Observed data is monitored in real-time. Additional devices such as temperature sensor are used for monitoring the system as well as watching waveform and SOH(Status of Health) information. # One staff spends half of the day for the system monitoring. # SOH information is useful to know actual condition of the equipment by skilled and experienced staffs. # Equipment have never been stolen. In Indonesia, all equipment is installed inside BMKG office.
(5) Use of periodical inspection and its contents	# Condition of stations is monitored from the central system once per day. # For visible investigation of equipment and surroundings, staffs check when they go to neighboring facilities. # Once per two years, inspection of stations are conducted by subcontractor.	# Basically, monitoring is done remotely. Schedule and contents of periodical inspection are not planed. # If some staffs go to station by any reason, equipment and system are inspected by the staffs.	# Staffs visit the station and check the sensor once per year. In case of earlier reaction necessary, staffs visit the station more frequently. # Staffs visit BMKG once per year. As for accelerometer, it is easy to know the condition shortly, but for broadband seismometer, it takes more days to find actual situation. Therefore duration of stay at BMKG is longer enough to find actual situation and follow up. # In Indonesia, it is very hard to maintain old equipment, therefore replacement to easy maintenance equipment from the old one is now being planed. BMKG will be explained about operation and maintenance of the new one. Also, remote lecture using tele-conference system can be one possible way to train them.
3.Preparation of manuals/guidelines			
	# Described in the specification.	# There is no integrated manual for maintenance and management of the observation system, because the system is too much complicated and outsources who can manage the system are very limited. # Operation manual for each parts is delivered and explained by suppliers at delivery of the parts.	# Because the system is simple enough to use manuals supplied by each equipment and systems, there is no integrated manual or guideline, except internal technical documents for data management or archives. # For some countries, manuals and explanations are provided to local staffs but nothing for Indonesia.

More descriptions of the above results are specified below.

① **Operation rates of all observation system are higher than 99%**

Based on the result of interview survey, JAMSTEC's answer is "the operation rate is higher than 99%."

As for Japan Meteorological Agency (JMA), operation rate or data missing rate is not compiled as a database. According to the Ministry of Internal Affairs and Communications, failure happened 107 times in three years (from 2010 to 2012) for 397 seismic intensity stations, including 95 times with short recovery (within 2 days). Data missing rate can be calculated by PF/PO as lower than 0.1%, where PF is the period of failure, and PO is the total period of observation multiplied by the number of stations. On the other hand, 148 times failure during same period happened for 287 multi-function seismic stations, including 112 times with short recovery within 2 days. There is no description about the actual missing period at more than 15 days failure. If we calculate the missing rate by using the average of actual missing period as 4 months for "more than 15 days," the result is lower than 1%.

At the National Research Institute for Earth Science and Disaster Resilience (NIED), failure rate is not determined because the definition of failure depends on how it is being used. Data missing rate is designed as lower than 5%, and mostly it is satisfied. Based on the Ministry of Internal Affairs and Communications, operation rate was more than 99% in the period from 2016 to 2018.

Table 4-(2)-② Number of failures and number of cases by missing period in seismic intensity meter measurement. (Unit: Case, %)

Category		2010	2011	2012	Amount
Number of failures		47 (100)	26 (100)	34 (100)	107 (100)
Items	3days or less	39 (83.0)	23 (88.5)	33 (97.1)	95 (88.8)
	3 ~ 8days	7 (14.9)	3 (11.5)	1 (2.9)	11 (10.3)
	8 ~ 15days	1 (2.1)	0 (0)	0 (0)	1 (0.9)

(Note) 1. According to the survey results of this ministry.
2. Disorders related to the Tohoku Pacific Ocean Earthquake and failures related to power supplies or communication lines that occur at the facilities of electric power companies or Nippon Telegraph and Telephone Corporation are excluded.
3. () shows the ratio to the number of failures.

Table 4-(2)-③ Number of failures and number of cases by missing period in multi-function seismograph measurement. (Unit: Case, %)

Category		2010	2011	2012	Amount
Number of failures		80 (100)	34 (100)	34 (100)	148 (100)
Items	3days or less	61 (75.0)	25 (76.5)	26 (76.5)	112 (75.7)
	3 ~ 8days	9 (11.3)	2 (5.9)	5 (14.7)	16 (10.8)
	8 ~ 15days	5 (6.3)	2 (5.9)	3 (8.8)	10 (6.8)
	15 ~days	5 (7.5)	5 (11.8)	0 (0)	10 (6.8)

(Note) 1. According to the survey results of this ministry.
2. Disorders related to the Tohoku Pacific Ocean Earthquake and failures related to power supplies or communication lines that occur at the facilities of electric power companies or Nippon Telegraph and Telephone Corporation are excluded.
3. () shows the ratio to the number of failures.

Figure 2.15 Data Missing Failure at JMA (by the Ministry of Internal Affairs and Communications

	2016		2017		2018	
	Target	Results	Target	Results	Target	Results
① Observation network utilization rate of 95% or more.	95%	99%	95%	99%	95%	99%
② There are no leaks of personal information, confidential information, or other information that was learned when the contract was fulfilled.	0	0	0	0	0	0
③ There are no personnel accidents due to inadequate safety management.	0	0	0	0	0	0

(Notes)
(Note 1) The operating rate of the observation network is calculated based on the presence or absence of records of seismic observation waveforms that are delivered from each observation point to our data center and archived. In addition, the data center of this institute regularly monitors the time when the waveform recording is missing due to network failure, equipment failure, etc. from the operating time of the observation equipment as the failure period.

Figure 2.16 Operation Rate of MOWLAS (by the Ministry of Internal Affairs and Communications

② Policy of operation and maintenance highly depends on main purpose (real-time performance or scientific accuracy) of the system.

Because the earthquake observation system operated by JMA is stated in the Act (Meteorological Service Act), its real-time performance for 24 hours a day, 365 days of operation and its prompt recovery from failure is the most important. Against that, for the JAMSTEC's earthquake observation system, whose role is to obtain scientific fundamental data of the whole Earth continuously and stably, real-time performance is not primarily a requirement of the system. MOWLAS operated by NIED is a multi-purpose earthquake monitoring system with intermediate characteristics depending on the purpose.

Though all observation system itself works for 24 hours a day, 365 days, the policy of operation and maintenance depends on the above characteristics of the system. This is so because JMA system is monitored 24 hours from the Tokyo central office, and JAMSTEC and NIED system are monitored by staff during normal working hours, not for 24 hours.

(Duties of the Director-General of the Japan Meteorological Agency)
Article 3 The Director-General of the Japan Meteorological Agency shall, in order to accomplish the purpose set forth in Article 1, endeavor to carry out the following:
(i) Establishing and maintaining observation networks concerning meteorological phenomena, earthquakes, and volcanic phenomena;
(ii) Establishing and maintaining central systems for forecasts and warnings of meteorological phenomena, earthquake ground motions, volcanic phenomena, tsunamis, and storm surges;
(iii) Establishing and maintaining systems to quickly exchange information concerning observations, forecasts, and warnings of meteorological phenomena, earthquake ground motions, and volcanic phenomena;
(iv) Establishing and maintaining systems to quickly exchange the results of observations of earthquakes (excluding earthquake ground motions);
(v) Ensuring integration of the methods of meteorological observations and the methods of announcing the results thereof;
(vi) Promoting the use in industry, transportation, and other social activities of the results of meteorological observations, meteorological forecasts and warnings, and the results of investigations and research concerning meteorological phenomena.

Figure 2.17 Duties of the Director-General of JMA as Stated in the Meteorological Service Act

③ Organization system for operation and maintenance reflects the scale of the system, necessity of real-time performance and required scientific accuracy of the system.

・JAMSTEC

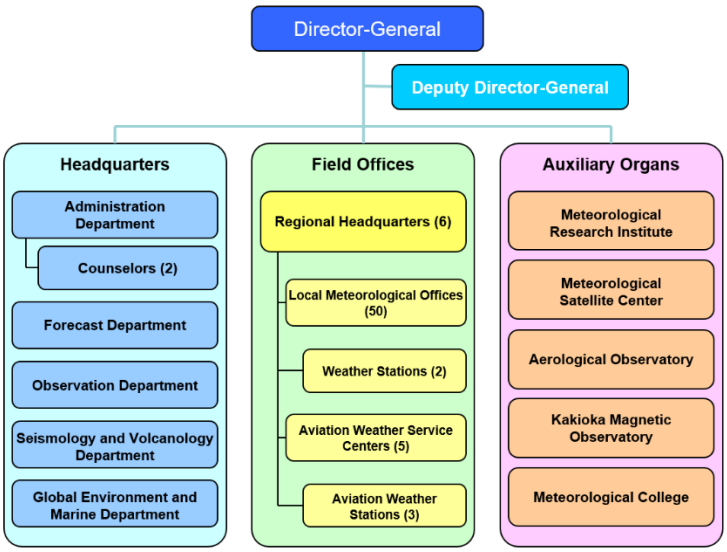
Since the scale of the observation system is relatively small and real-time performance is not required, the system is managed by three expertized researchers / staff.

・JMA

The Seismological and Volcanological Department is the main agency for operation and maintenance to keep real-time performance of the observation system. About 250 staff members are working in the Seismological and Volcanological Department and 250 staff members at the local level. The actual number of staff members involved in the operation / maintenance of the system as a group is around 20 in the department. A total of 5 teams consisting of 7 staff members in the department are assigned on night shift. In order to respond quickly to system failure, the central system is maintained by 24 hours "on call " contract.

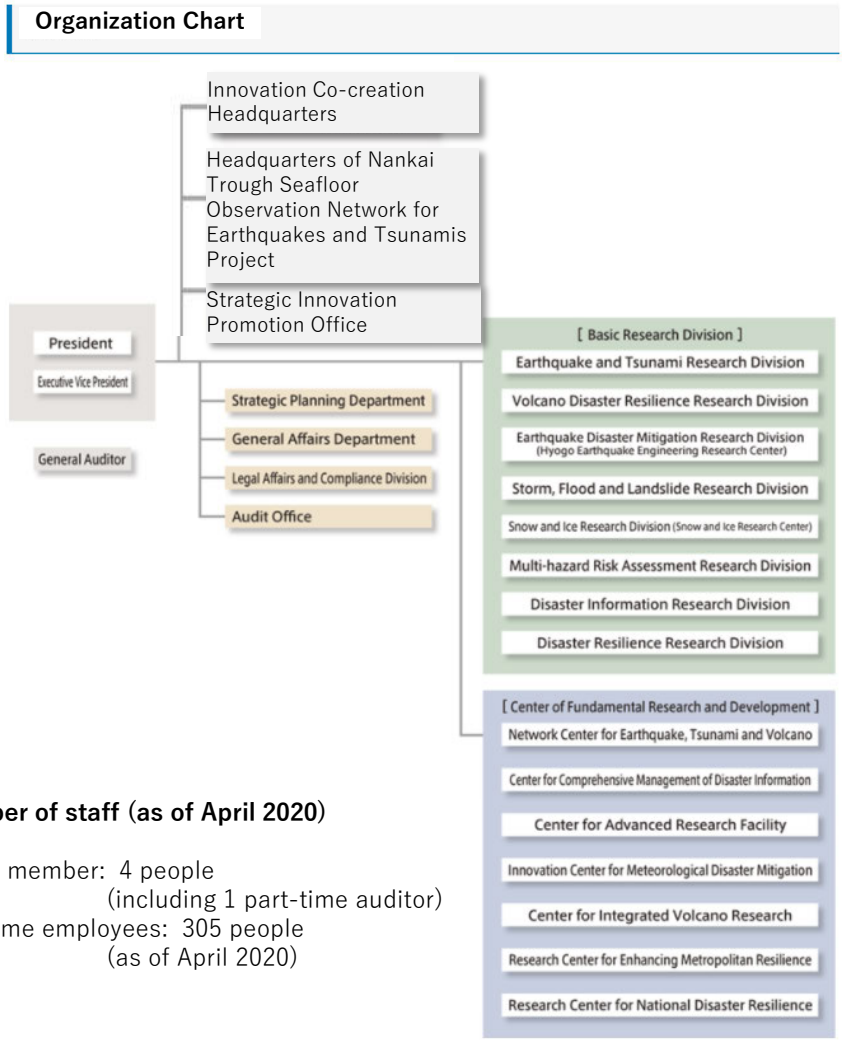
・NIED

MOWLAS is the biggest earthquake observation system in Japan, but real-time performance is less required than in the JMA system. Six laboratories in the Network Center for Earthquake, Tsunami and Volcanoes of NIED Tsukuba are responsible sections for operation and maintenance. In total, 26 staff members / researchers assigned to 6 laboratories manage 7 earthquake monitoring systems (K-net and Kik-net are managed by one laboratory) together with a subcontractor based on the annual contract for maintenance and management. According to a document of the Ministry of Internal Affairs and Communications, a total of 69 staff members from the subcontractor are involved in the maintenance / management of MOWLAS. Around 4.0~4.5 million USD is necessary for the outsourcing.



https://www.jma.go.jp/jma/kishou/intro/gyomu/index3.html

Figure 2.18 Organization Chart of JMA (Taken From JMA Homepage)



https://www.bosai.go.jp/introduction/organization.html

Figure 2.19 Organization Chart of NIED (Taken From NIED Homepage)

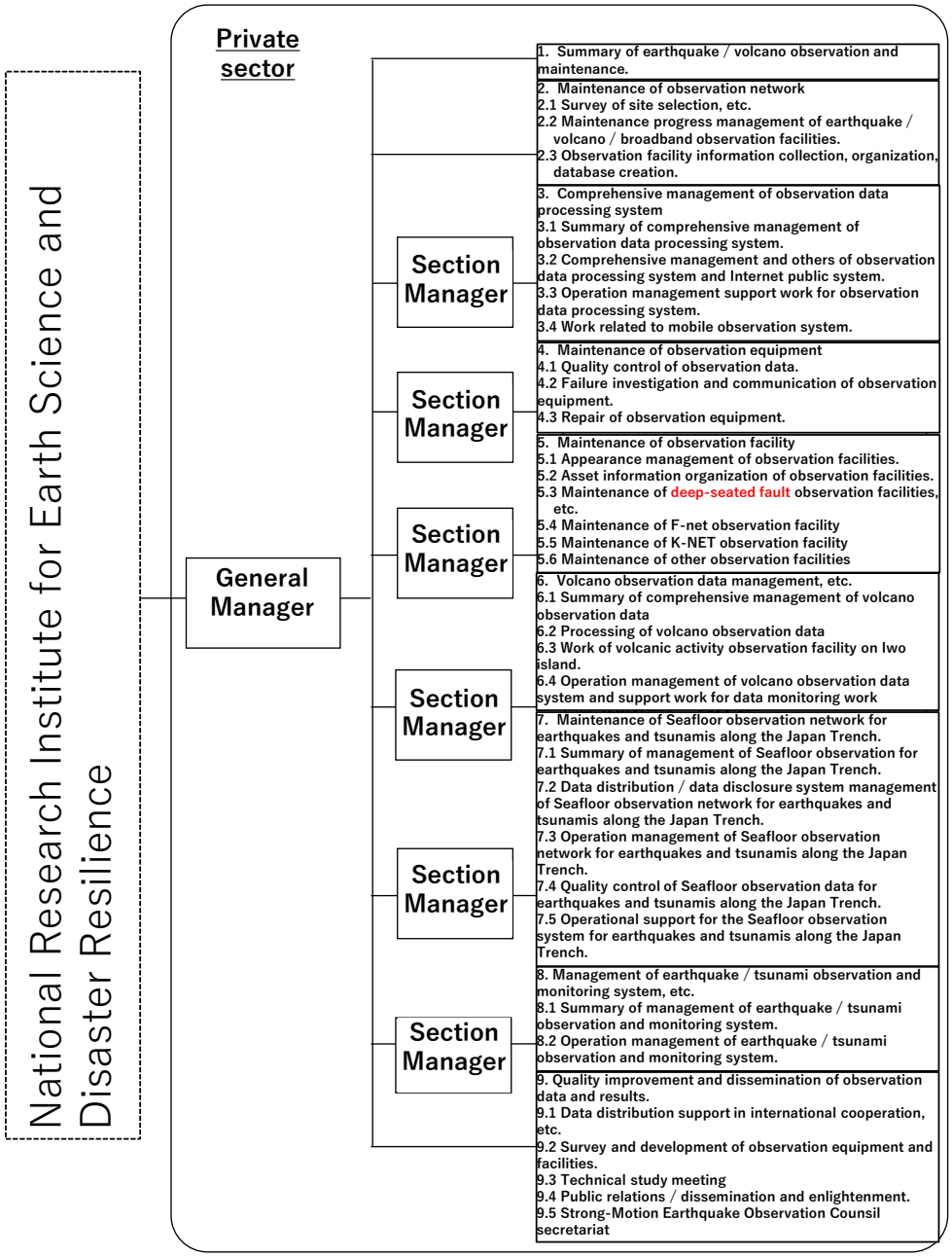


Figure 2.20 Organization Structure for MOWLAS Operation / Maintenance

(Unit: 1000 Yen)

	2016	2017	2018
Labor costs	371, 694	428, 958	439, 366
Operating expense	52, 104	38, 561	37, 329
Administrative expense	—	—	—
Total	444, 960	471, 960	471, 960

Figure 2.21 Outsourcing Cost for the Operation and Maintenance of MOWLAS (by the Ministry of Internal Affairs and Communications)

④ System failure is detected by monitoring remotely from the central system.

All of the observation system employ remote monitoring from the central system to detect system failure. JMA's a specifications show the requirements for the availability of remote monitoring function both at the central system and the station side equipment. In remote monitoring, important information are not only the waveform and seismic intensity data observed at the stations, but also the SOH (Status of Health) information by self-diagnosis function at each observation equipment to detect any abnormal conditions at the station.

SOH shows the status of sensor and recorder itself sent from recorder with observed waveform data. The content depends on the recorder, but usually includes supplied electrical voltage, error log for the system and communication line, status of GPS clock, empty space of local storage, mass position of the sensor, and internal temperature.

Abnormalities are judged by the SOH and the shape of obtained waveform.

To detect abnormalities by watching waveform, a drum record is one of the easy tools for detecting troubles. The drum record shows 30-minute waveform data from upper to lower, including 48 traces of 30 minutes of waveform, i.e., 24 hours of waveform monitoring in one figure.

At the broadband earthquake observation, it is sometimes very difficult to detect troubles by watching waveform. In such case, method-based on PSD (Power Spectrum Density) (McNamara, et al. (2004)), or comparing waveform with neighboring stations (Kimura, et al. (2015)) are proposed for performance confirmation.

As for the failure of communication line between stations and central system, this is detected by the system side and information is relayed automatically by e-mail, etc.

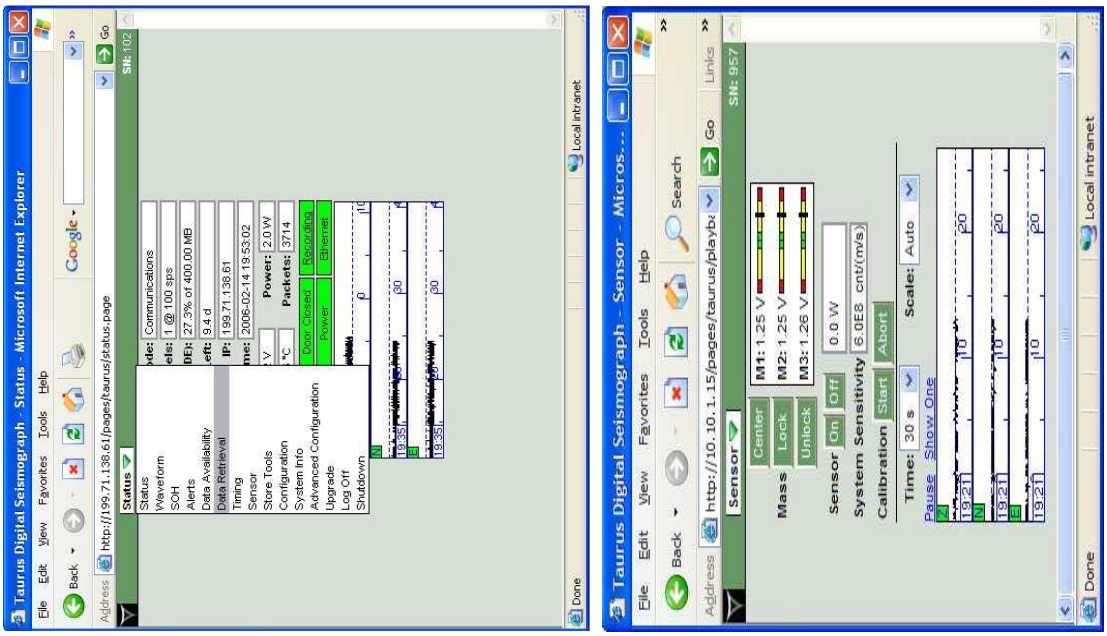


Figure 2.22 An Example of SOH Display on Web Browser by Taurus (Nanometrics)

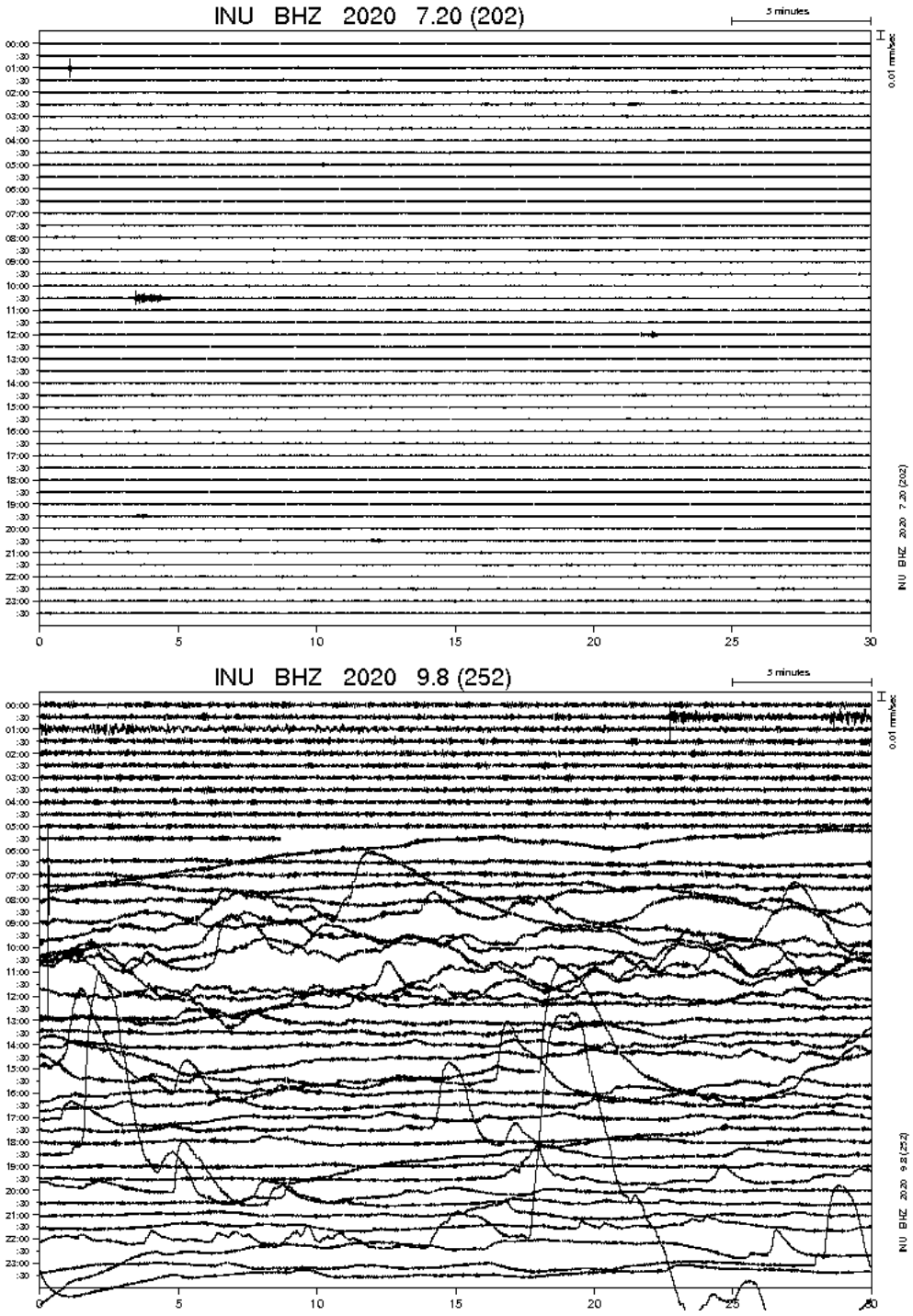


Figure 2.23 An Example of Detection by Drum Records (Upper: Normal; Lower: Trouble)

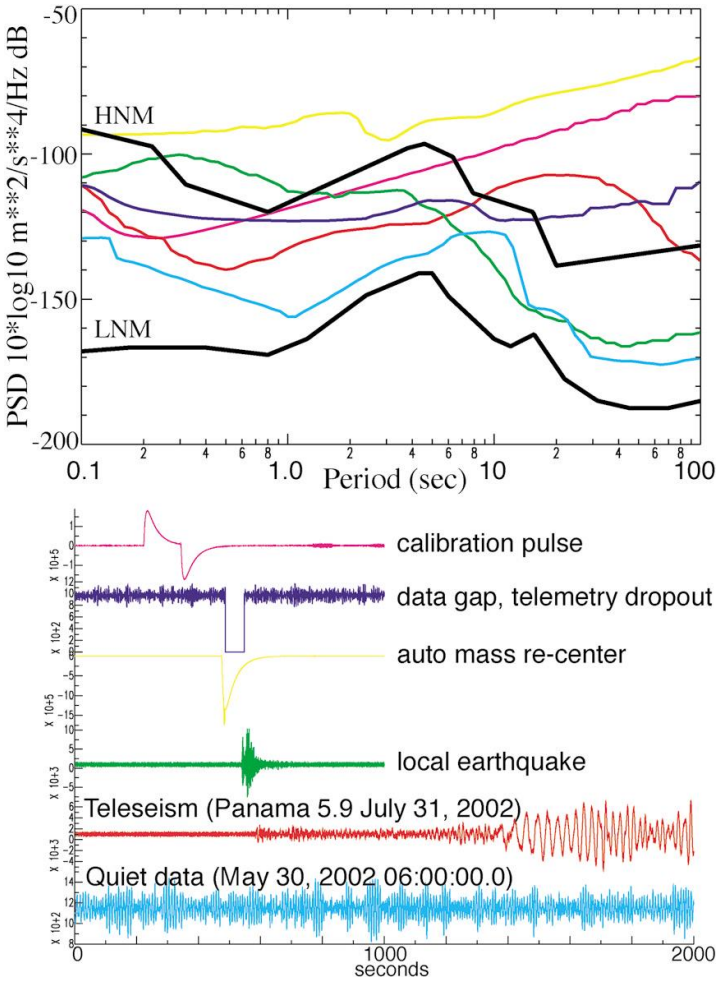


Figure 7. Time series and PSDs for recording system transients and earthquakes.

Figure 2.24 Judgement of PSD in Calm Condition
(Between Black Lines as HNM and LNM Means Normal)

⑤ Japanese observation system stands on the reliability of basic infrastructures such as communication system and power supply system.

In order to keep the function of the observation system by remote monitoring, basic infrastructures such as the communication system or the power supply system must be reliable and stable, especially for systems requiring real-time performance, such as those of JMA and MOWLAS.

If the communication line often disconnects, or the voltage of electric power is not stable or shuts down frequently, it is not only trouble for the observation, but it will also be very difficult to detect failure of the system. According to a document of the Ministry of Internal Affairs and Communications, missing data related to power supply have occurred three times, and once was related to communication system at JMA multi-function seismometer stations. However, those were not related to the infrastructure itself. A specification made by JMA related to EPOS procurement clearly states that the requirement for the reliability of communication line in terms of keeping its operation rate is more than 99.999%.

Many stations of JAMSTEC observation system are located at a country / region with insufficient infrastructure. Since real-time performance is not a primary function, a solar system is established for

areas with unstable power lines, and there is an effort to record continuously in a local storage on the assumption of frequent disconnection of communication lines.

2	Requirements related to operating rate	・The system operation rate shall be secured at ″99.999% or higher″ for the EPOS(*) backbone network, monitoring network, DB / recording network, terminal network, and other system server networks, and ″99.9% or higher″ for the test network. ・The system operation rate is the value excluding failure time, a situation in which the system is stopped, for example, when both systems of the cluster configuration are stopped. (Does not include halt condition during planned M/S conversion performed by the contractee.) ・The calculation method is to divide the failure time (minutes) by one year (365days x 24hours x 60minutes) as the failure rate, and subtract it from 100%. The failure times considered to be within the permissible range are ″5.3 minutes/year when the operating rate is 99.999%″ and ″526 minutes/year when the operating rate is 99.9%″. ・However, this permissible time (minutes) is a guideline for annual accumulation, and is not the maximum time that can be stopped continuously at one time.

* EPOS: Earthquake Phenomena Observation System

Figure 2.25 Specification Requirements Related to EPOS Procurement

⑥ **There is no integrated manual or guideline for system maintenance and failure detection, although manuals for other parts are organized. Staff members in charge of operation and maintenance are educated mainly through OJT(on-the-job training) and trained by suppliers of procured devices / systems.**

Though an operation and maintenance manual for each part comprising the observation system is provided by each supplier / manufacturer, no integrated manuals and guidelines have been established.

Workflow and technical skills are shared when operation and maintenance are done internally. Even operation and maintenance are done by outsourcing, since very few companies can undertake the operation and maintenance, and know-how and skills are shared inside the company.

According to a document of the Ministry of Internal Affairs and Communications, JMA established a rule in response to failure of seismic intensity observation system, shown below as “Operation Procedure for Instrumental Seismic Intensity Meter (2010/03/31) .”

(1) When meteorological offices confirm a failure that cannot be automatically reported (including a failure of communication equipment), they should promptly contact the Meteorological Observatory of each district and the Okinawa Meteorological Observatory (hereinafter referred to as the "center").
(2) If there is any doubt about the operation of the seismic intensity meter at the meteorological offices, report it to the center and ask for instructions.
(3) When information on power outages and line interruptions related to observation points and locations is obtained, the relevant meteorological offices will promptly report to the center.
(4) When the center confirms the occurrence and recovery of a failure, etc., it reports to the national center (Japan Meteorological Agency main office or Osaka District Meteorological Observatory).
(5) The center will endeavor to grasp the status of the equipment, etc. based on automatic notifications, etc. regarding failures from each observation point, and will promptly take measures for restoration.
(6) The local office will promptly try to recover from the failure according to the instructions from the center.
(7) If seismic intensity cannot be calculated due to a failure, it will be treated as a missing measurement. In case if the failure cannot be recovered by the measures of the above center or the local meteorological offices, the Japan Meteorological Agency will request the restoration work from the contractors of the district's meteorological observatory and the Okinawa Meteorological Observatory.

Figure 2.26 "Operation Procedure for Instrumental Seismic Intensity Meter" (Part Only)

NIED states the procedures and specifications of contract of operation and maintenance as shown below.

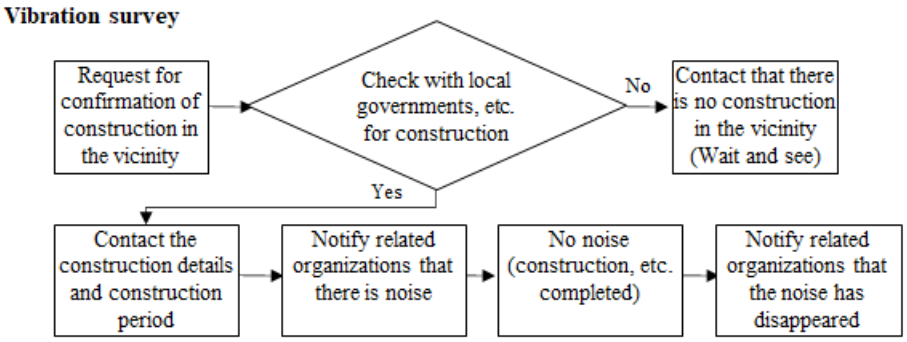


Figure 2.27 An Example of Investigation Procedure in Case of Abnormal Vibration

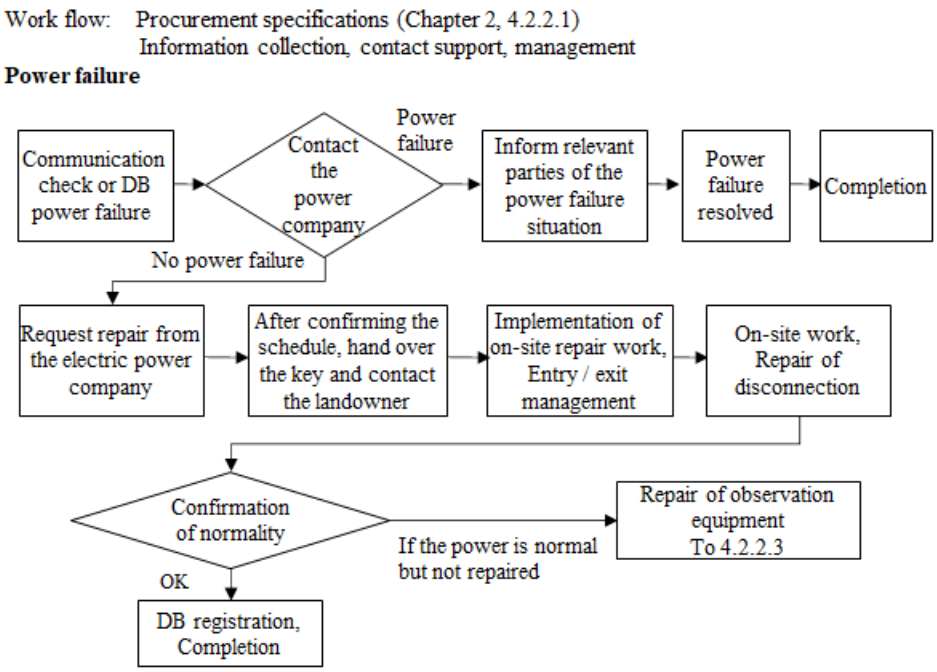


Figure 2.28 An Example of Check Flow in Case of Abnormal Power Line

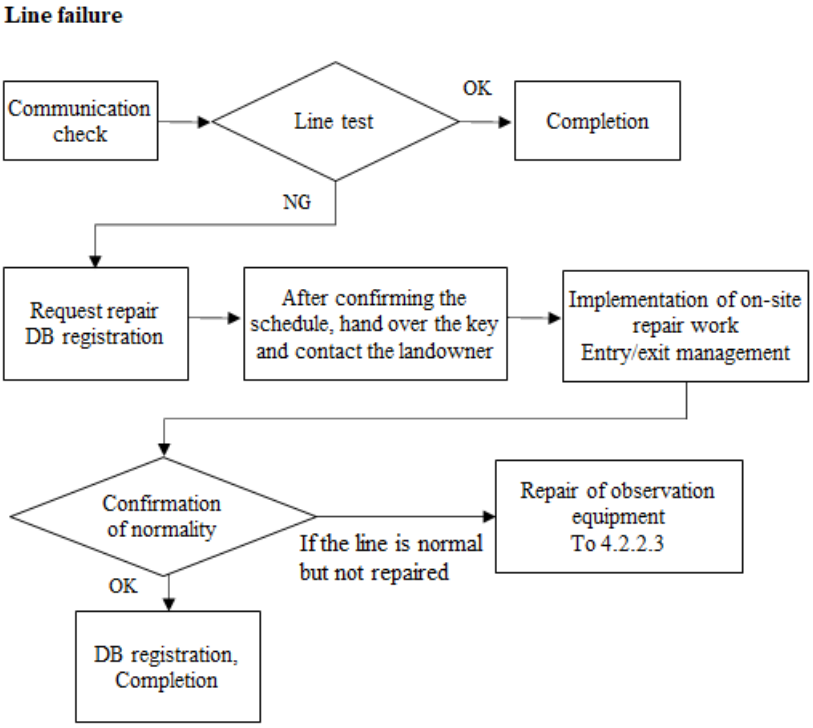


Figure 2.29 An Example of Check Flow for Communication Line

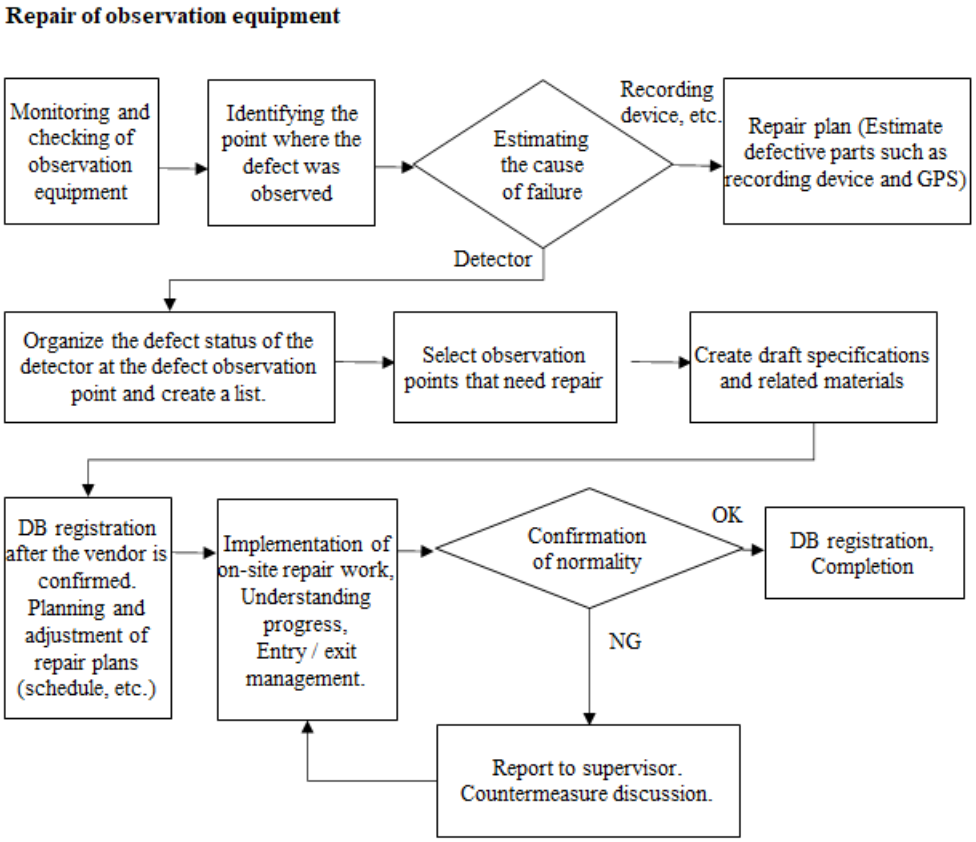


Figure 2.30 An Example of Failure Detection and Repair of Equipment

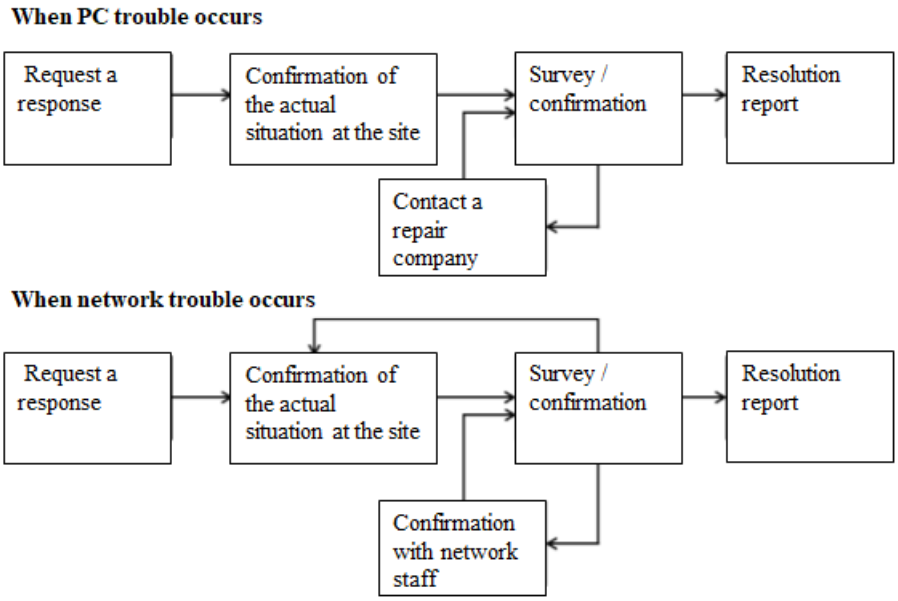


Figure 2.31 An Example of Response to Trouble in PC and Network

Failure of the system is detected by a strange waveform, SOH and missing packet including waveform / SOH. When failure is detected, firstly, we have to identify the problem source – if it is the communication line or the observation equipment. Investigation starts with the checking of the communication equipment (by error log, etc.) at the central system (receiving side), followed by an investigation of the communication line (by provider), then by checking of the communication equipment at the stations (by error log, etc.), and finally, by checking of the observation equipment at the stations. If remote login to the observation equipment is made available, we can identify the problem source (i.e., if it is the the observation equipment, or the sensor, or the power line, or the GPS, or the storage, etc.).

Check sheets for troubleshooting for MeSO-net (Metropolitan Seismic Observation Network) have been published (Kawakita,Sakai (2015)). The development of check sheets is very useful for effective response and quick recovery from trouble. The MeSO-net is a dense strong motion observation network which consists of 296 stations in the Tokyo metropolitan area with post-hole accelerometer. The network was developed by the University of Tokyo and transferred to NIED in 2017. By using the check sheets, time to recover from failure is shortened because it makes it easier to separate the troubled parts.

The check sheets assume that a missing packet is the trigger for using it. The first branch is, if logging in to router is possible or not. If logging in is possible, it means the communication line is alive and there is trouble with the observation equipment. Against that, if logging in is not possible, it means there is a possibly that there is trouble with the communication line. Two types of check sheets are ready for use depending on the first branch. They introduced a check sheet for recovery work at the station. It is also very helpful.

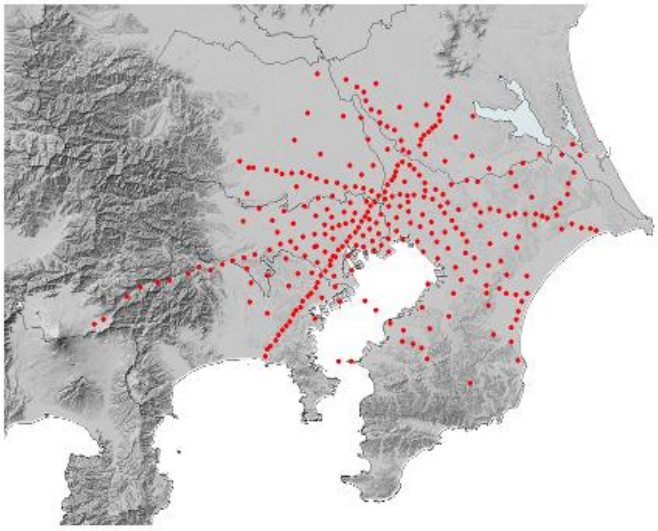


図1: MeSO-netの観測点分布

http://www.mesonet.bosai.go.jp/mrportal/about

Figure 2.32 Layout of MeSO-net Observation Stations

Appendix 1. Check sheet for when packet does not arrive and a device cannot be logged in to the router.

Cause investigation check sheet:
For device failure and when power failure log occurs

Slip number

Working hours stamping: From(hh: mm DD/ MM/YYYY) ~ to (hh: mm DD/ MM/YYYY)

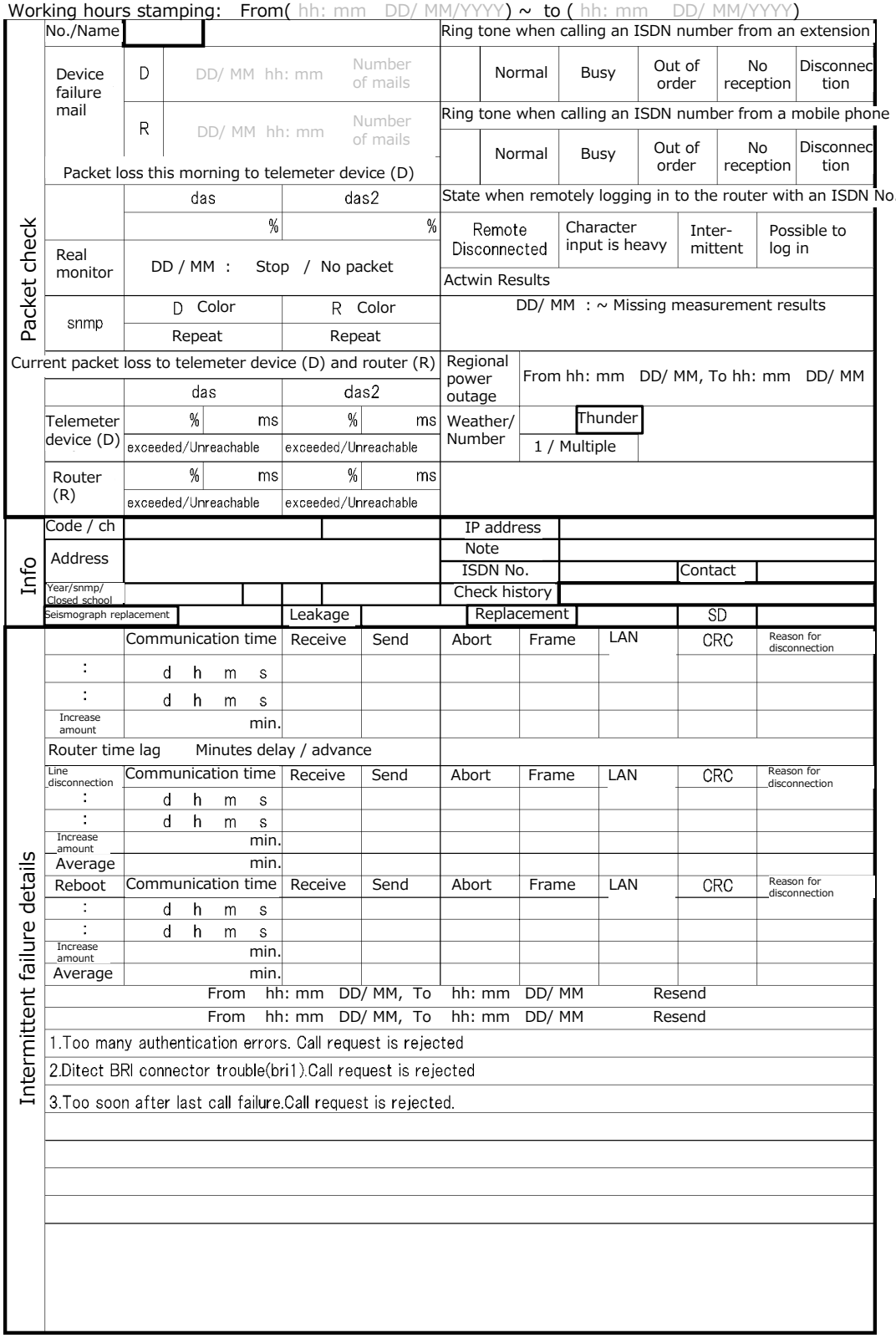


Figure 2.33 Check Sheet to Investigate Problems (In Case It Is Not Possible to Log in to the Router) (1)

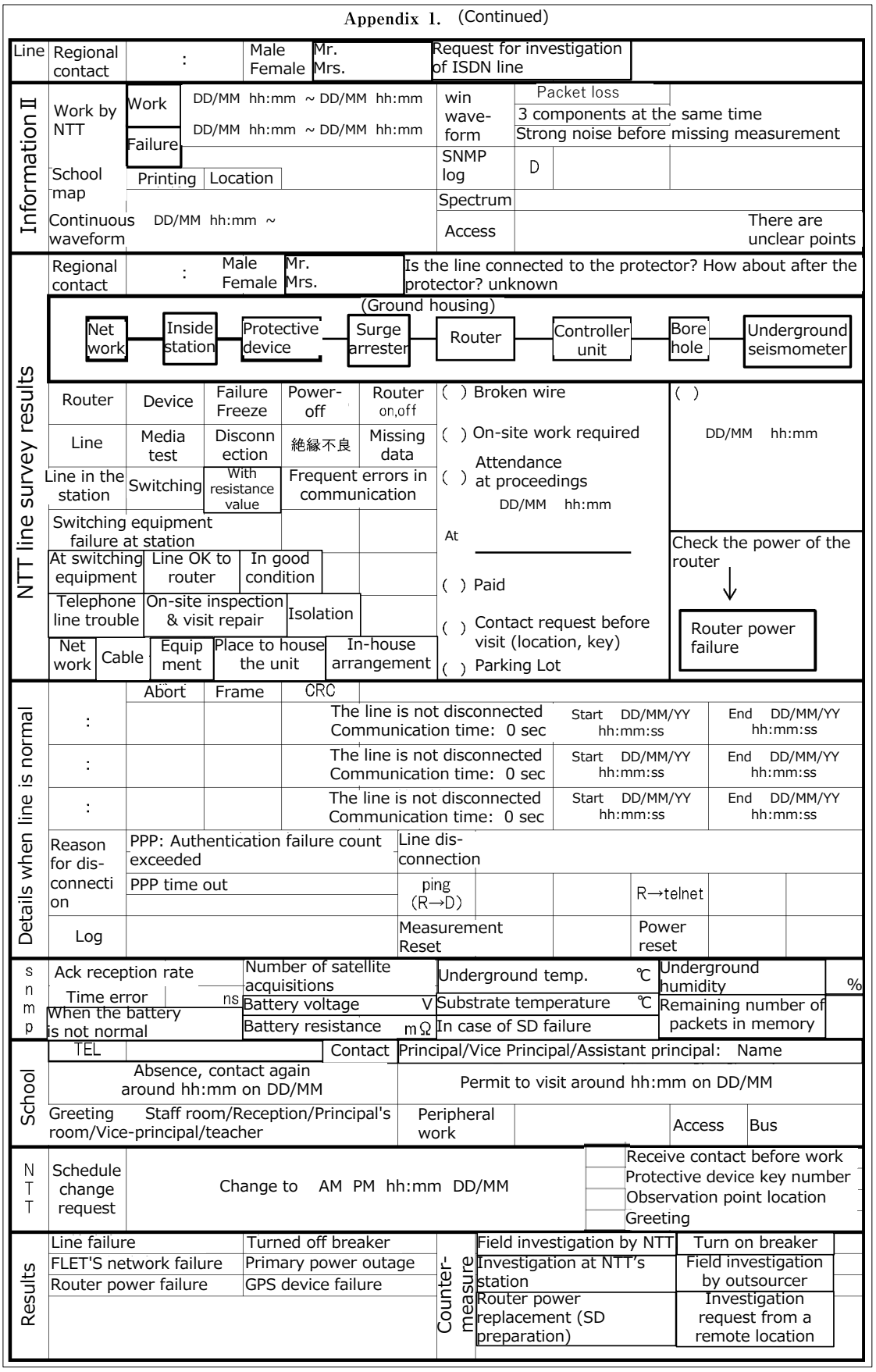


Figure 2.34 Check Sheet to Investigate Problems (In Case It Is Not Possible to Log in to the Router) (2)

Appendix 2. Check sheet for when packet does not arrive but a device can be logged in to the router.

Cause investigation check sheet:
For when packet does not arrive (Ping passed)

Slip number

Working hours stamping: From(hh: mm DD/ MM/YYYY) ~ to (hh: mm DD/ MM/YYYY)

Packet check

No./Name			Stop short-period observation	DD/ MM	Number of times		
Packet loss this morning to telemeter device (D)			Current packet loss to telemeter device (D) and router (R)				
	das	das2		das		das2	
	%	%	Telemeter device (D)	%	ms	%	ms
Real monitor	DD / MM : Stop / No packet			exceeded/Unreachable		exceeded/Unreachable	
			Router (R)	%	ms	%	ms
snmp	D Color	R Color		exceeded/Unreachable		exceeded/Unreachable	
	Repeat	Repeat	Actwin	DD/ MM : ~ Missing measurement			

Information

Code / ch		IP address	
Address		Note	
		ISDN No.	Contact
Year/snmp/ Closed school		Check history	
Seismograph replacement	Leakage	Replacement	SD

snmp

		Missing measurement :	After Measurement Reset :	After Power Reset :
Regular Polling: Controller Unit General	rgSystemStatus			
	Operational Status [0x21:MESURMENT]			
Report items at the time of TRAP: Controller Unit General	nrgCoMMStatus[172or173]			
	Controller Unit CANopen Master/Manager Status			
Regular Polling: Data transfer function	rdtAckReceiveRate			
	Ack Receive Rate [0~1000]			
Regular Polling: Information of GPS in the Controller Unit	rgtrNumSatellitesAvailable			
	Satellites Available[0~10]			
Regular Polling: UPS related items	ruPowerVaOutputDc			
	Connection to underground controller 【Thousands to tens of thousands(mW) 】			
	ruPowerValnput			
	Input to UPS 【Tens of thousands(mW) 】			
Regular Polling: Underground seismometer	rsTemperature			
	Underground temperature [0~10000/100(℃)]			
	rsHumidity			
	Underground temperature [0~10000/100(%)]			
	rsTimedevAverage			
	Time Error [(ns)]			
	rsPowerConsumption			
	Total power consumption 【Thousands(mW)】			
Report items at the time of TRAP: Equipment self-test results	nrsTcxoCenterValue(16-bit A / D control)			
	TCXO adjustment : Median【~about54000】			

Information II

WIN	3 components at the same time Packet loss Flat Before Measurement	weather		Thunder	
observation point Login	MeSOoperarion-try-start,Fail(1)	Spectrum			
Continuous waveform	From hh: mm DD/ MM, To hh: mm DD/ MM	sawtooth wave		Failure history	

Results	Capacitor Failure	Counter measure	Investigation request from a remote location	Seismograph Replacement
	Controller Unit Failure		Field investigation	
	Recovered by reset		Controller Unit Replacement	

Figure 2.35 Check Sheet to Investigate Problems (In Case It Is Possible to Log in to the Router)

Appendix 3. Data confirmation sheet for on-site work

Data confirmation sheet for on-site work

Slip number

Working hours stamping: From(hh: mm DD/ MM/YYYY) ~ to (hh: mm DD/ MM/YYYY)

Missing period : From(hh: mm DD/ MM/YYYY) ~ to (hh: mm DD/ MM/YYYY)

Observation point information

No./Name	
Code / ch/year	
Address	
IP address	
Phone No.	
snmp/ISDN	map report

Before on-site work

Snmp before replacing the seismograph :

Ack reception rate | Underground temp. ℃

Number of satellite acquisitions | Underground humidity %

Time error ns | Substrate temperature ℃

Battery voltage V

Real-time monitor

Noise

Failure history investigation

When Intermittent failure

Calling ISDN :

Normal Busy Out of order No reception Disconnection

Extension / Mobile phone

snmp: D Color Device failure / Repeat

Missing period ~ ~

Sudare / Sudare

snmp: R Color Device failure / Repeat

	Communication time	Receive	Send	Abort	Frame	LAN	CRC	Reason for disconnection
	d h m s							
	d h m s							
Increased amount	min.							

Router time lag Minutes delay / advance

Working Contents

Weather	Field worker		Field responder	Principal/Vice Principal/ Assistant principal
Real monitor	DD / MM : Nomal / No packet	Noise level	UD	NS / EW

Field Confirmation Items with Photo

GPS cable	Cable slack / Cable Tension / Touched a branch	Sticker	Door	Yes／No	Readable
GPS Antenna	Upper air / Open・Branch / Damaged		Inside	Yes／No	Readable
Pole	Inclined	serial number			
Overhead wires	Deflection / Tree branch	Equipment stickers			
A terminal box	Appearance / Key / Rust / Key hook	Battery	Leakage		
	Top plate deviation / The door cannot be opened or closed				
	The box is cracked / Branches around				
Flex Tube	Cut / Off				
Outdoor Housing	Wobbling/Tilting / Base / Hinge / Grass/Ivy/Insect				
	Door/Top plate / Rust / Painting / Cap/Screw / Obstacle				
Manhole	Embankment / Inundation / The upper and lower flanges cm				
	Dead leaves / Obstacle / concrete / lid				
JUMO	temperature ℃				
Breaker replacement	Yes／No				

Figure 2.36 Check Sheet to Confirm Recovery Work at Stations (1)

Appendix 3. (Continued)

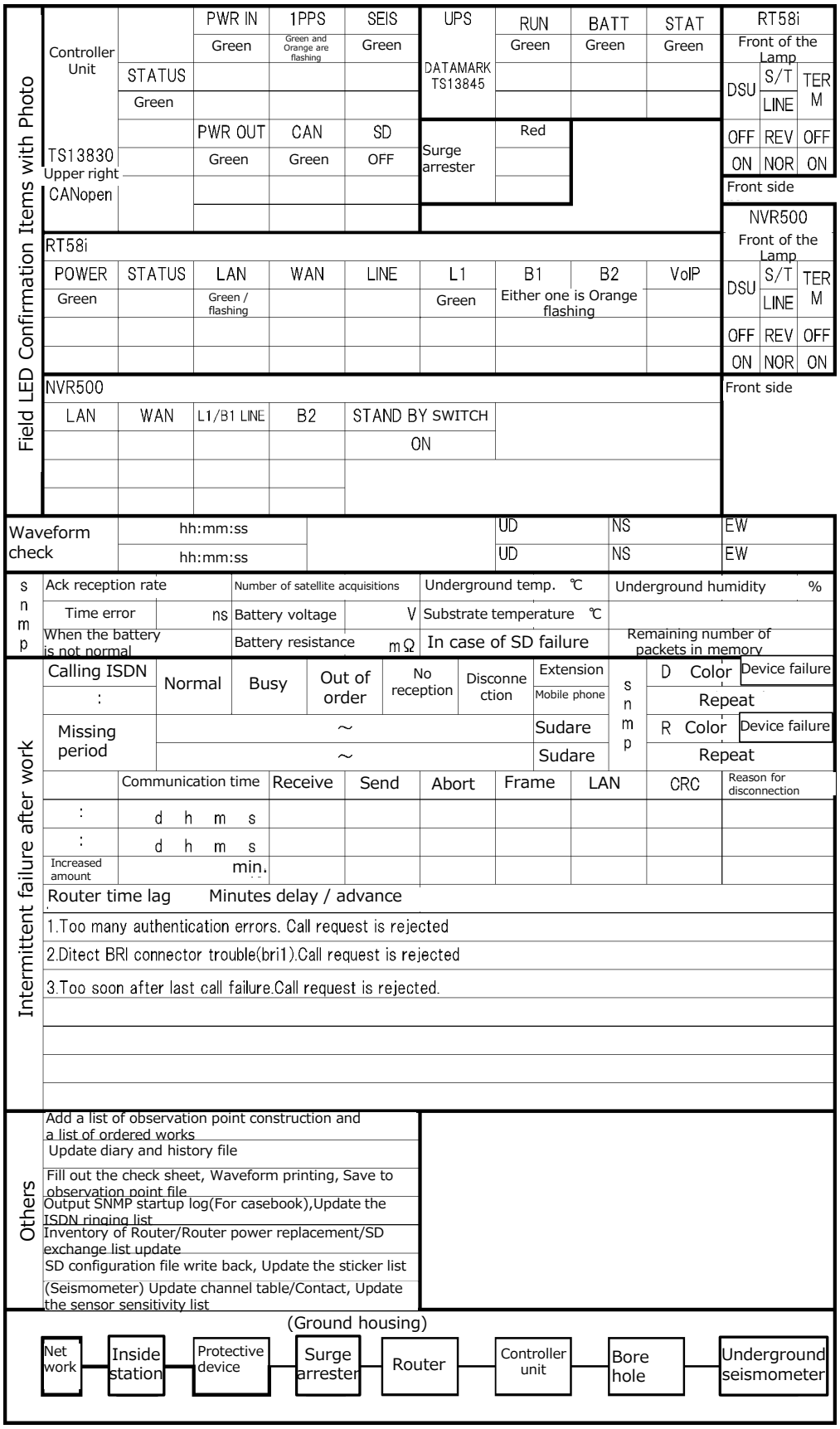


Figure 2.37 Check Sheet to Confirm Recovery Work at Stations (2)

Staff members are assumed to have basic knowledge and experience of earthquake observation because all earthquake observation systems are totally complicated. In general, staffs members are educated through OJT, though the training for operation and maintenance of each equipment is conducted by the supplier when the equipment is delivered. Integrated and practical manual or procedures for operation and maintenance are written for internal use by the responsible section. Individual manuals for operation and maintenance for each part are sufficient for the Japanese earthquake observation system.

Chapter 3 Analysis and Issues of Earthquake Observation System on Quality Management, Operation and Maintenance

3.1 Analysis

Collected data and information are analyzed for policy of operation, organization of observation system, stablility of operation, and quality management as detailed below.

3.1.1 Policy of operation

As previously described, the policy of operation depends on the main role of the observation system.

1） **Research-oriented system**

Its main role to provide observed data with scientific accuracy, continuousness, and completeness.

Though scientific accuracy and completeness (= no missing data) is indispensable to observed data, keeping real-time performance is necessary, but not the priority. In this case, the policy of operation is oriented toward keeping the best condition for observation and to save 100% of the data. The priority is to maintain a non-stop observation and to ensure that scientific, accurate data can be collected afterwards. If the data could not be transmitted to the data center in real-time, important matters to consider are the following: (1) to pay attention to suitable station layout and the surrounding conditions of the sensors; (2) to select high-quality equipment; (3) appropriate structure and construction of the sensor base; (4) to install sensors correctly, (5) to keep sufficient local storage space.

2） **Disaster management system**

Because the system must detect disaster or provide the necessary data on the situation of an ongoing disaster, keeping a real-time performance is the priority. In this case, an organization to perform 24-hour, 365 days of operation to prevent missing data is implemented. The operation policy is focused to prevent failure on all process of sensing earthquakes at the station, data transmission through the communication line, and processing at the data center. In addition, it is important to shorten recovering (data missing) period if failure would happen. Required accuracy is based on supporting disaster management activity. For example, Since JMA allows +/- 0.1 error on seismic intensity meter, a resolution of less than 0.1 is not necessary. As for magnitude and epicenter location, accurate values are not necessary for disaster management activity immediately after the earthquake occurrence, though precise values are indispensable for scientific research purpose thereafter.

3.1.2 Organization and Cost

Operating organization depends on the scale (number of stations) of the observation system. Table 3.1.1. shows a summary of the operating organizations of three earthquake observation systems in Japan. A total of 20 to 30 stations are managed by one person at JMA and NIED system. JAMSTEC system is special because most of the stations are scattered in several far-flung countries. However, as described earlier, it must be pointed out that 20 to 30 stations can be managed through a reliable infrastructure in Japan.

Table 3.1 Operating Organizations of Three Earthquake Observation Systems

	JMA (EPOS,etc.)	NIED (MOWLAS)	JAMSTEC (Pacific21)
Monitoring hours	24 hours	Business hours	Business hours
Number of stations	~700	~2100	20
Number of staffs	~20 + 7(night shift)*1)	26 + contractor 69	3
Stations/staff	~30*2)	~20	8*3)

(*1): Staff members on night shift are not dedicated to operation and maintenance, but their main role is to process the earthquake data.

(*2): Annual contract for system operation/maintenance is agreed with a company on a "24-hour on call" condition.

(*3): Since 1 of 3 staff members has another job, 8 = 20/2.5.

All systems shown above manage the observation system by remote monitoring from the central system. The cost for operation and maintenance of the observation system is not published, but according to the Ministry of Interior, the cost of 470 million JPY was paid for the outsourcing. In addition to the outsourcing cost, the cost for personnel expenses, communication line and power supply, land rental, and others may be paid. The cost can be estimated at 500 to 1000 thousands JPY per station.

3.1.3 Measures for Stable Operation of Earthquake Observation System

Earthquake observation system itself is required to function 24 hours for 365 days regardless of the purpose. In order to ensure stable operation, prevention of failure and quick recovery are necessary.

1) Prevention of failure

Keeping robustness and establishing redundancy for the causes of failures. Examples are the following:

(1) To procure reliable observation equipment, server, and communication equipment.

(2) To use reliable power supply and communication line, or to establish redundancy by multiplexing.

(3) To protect from failure due to lightning and cables from damage caused by insects / animals.

(4) To select a suitable place to install equipment (for example, higher than water level during a huge flood)

(5) To duplicate the server system.

(6) To conduct periodic inspection.

2) Quick recovery

In order to shorten the period of failure (missing data) as short as possible, identifying failure as early as possible and establishing recovery as quick as possible are required. Failure is detected by remote monitoring from the central system based on strange waveform / intensity data, no data transmission, and disconnection of communication line. Detected failure is analyzed to identify the source of failure using all obtained information. After the failure source is specified, it is either fixed or re-tuned.

The following measures are necessary for each items listed below:

(1) To detect failure earlier

1) To monitor for 24 hours

2) To improve monitoring and self-diagnosis function of the system such as sending SOH

3) To enhance monitoring capability / skills of staffs

(2) To find the source of failure and establish quick recovery

1) To select the equipment to easily to find failure sources (as many SOH information)

2) To create a standard procedure to find failure sources by using, for example, check sheets

3) To enhance response capability / skills of staffs.

4) To establish an emergency response organization system in the event of failure by, for example, securing a contract with a company to provide a 24-hour response service during emergency situations.

3.1.4 Measures for Quality Management

In order to keep the good quality of observation data, keeping a good observation condition, early detection of degrading quality and recovery are required.

1) Keeping a good observation condition

To keep a good observation condition, it is necessary to maintain stable functioning of the equipment, static circumstances, and quality of the observation facility including sensor base. Examples are as follows:

(1) To replace equipment before deterioration. Replacement interval should be 10 years for observation equipment, and 5 years for electric devices and computers.

(2) To prevent changes of surrounding circumstances at stations. Areas that affect the quality of observation data should be clarified.

(3) To avoid cause of damage to the equipment such as water intrusion, thunderstroke, and damage caused by insects.

(4) To keep stable electric power using a stabilized power supply or a solar power system.

2) Early detection of degrading quality and recovery

Degrading quality can be detected based on the strange shape of waveform or abnormal value of seismic intensity. However, for broadband seismic observation, it sometimes needs analysis using long-term wave record to find the lowering of quality. In the former case, one way to identify degrading quality is by looking at waveform on the drum record. On the other hand, in the latter case, since the data of broadband seismic observation are often affected by changing atmospheric pressure and temperature, deterioration of sensor base and observation shed are the causes of degrading quality. Calculation of PSD (Power Spectrum Density) of ambient noise can detect failure if the shape of waveform does not show any apparent abnormal figures (McNamara (2004)). Another way to identify degrading quality is by comparing the waveform of teleseismic events with those of neighboring stations (Kimura (2015)).

Station layout can worsen because of the changing surrounding circumstances or increasing stations, even if the layout used to be appropriate. For seismic intensity network, it can be observed that the obtained intensity cannot be used as a representative value in the area near the station (too big or too small) after the actual operation has started.

Obtained waveform and values should be checked periodically. Observation station can be moved to other location if necessary.

3.2 Tasks for Action in the Country

The purpose of BMKG's earthquake observation system is considered as part of disaster management. Therefore, real-time performance is the priority. On the other hand, since there is no other organization operating large earthquake observation system for the purpose of scientific research in Indonesia, BMKG is also required to provide complete / continuous data with scientific accuracy.

Table 3.2.1 shows the tasks for a stable operation of the system and for keeping the quality of obtained data.

Table 3.2 Tasks for a Stable Operation of the System and for Keeping the Quality of Obtained Data

Purpose	Issues	Measures
Stable operation	Prevention of failure	(1) To procure reliable observation equipment, server, and communication equipment.
		(2) To use reliable power supply and communication line, or to establish redundancy by multiplexing.
		(3) To protect failure by lightning and cable from damage caused by insects / animals.
		(4) To select a suitable place to install equipment (no water intrusion by flood, etc.).
		(5) To duplicate the server system.
		(6) To conduct periodic inspection.
	Early detection of failure	(1) To monitor for 24 hours.
		(2) To improve monitoring and self-diagnosis function such as sending SOH.
		(3) To enhance monitoring capability / skills of staff members.
	Finding cause of failure and establish quick recovery	(1) To select equipment to easily find failure sources (such as many SOH information).
		(2) To create a standard procedure to find failure sources by using check sheets, etc.
		(3) To enhance response capability / skills of staff members.
		(4) To establish an emergency response organization system in the event of failure with a related organization / company.
Quality management	Keeping a good observation condition	(1) To replace equipment before deterioration.
		(2) To prevent changes of surrounding circumstances at stations.
		(3) To avoid cause of damage to the equipment such as water intrusion, thunderstroke, and damage caused by insects.
		(4) To keep stable electric power using a stabilized power supply or a solar power system.
	Early detection of changing circumstances and recovery	(1) To detect abnormal waveform by drum recorder, etc.
		(2)To detect abnormal frequency response by PSD calculation of ambient noise.
		(3)To detect failure by comparing teleseismic waveform with that of the neighboring station.
		(4)To detect failure by comparing seismic intensity with that of the neighboring station.
		(5)To detect failure by spectrogram of ambient noise.

For the project activity in the country, confirming the current status of the above measures and extracting issues are conducted in the baseline survey. Based on the baseline survey results, work plan is created while considering the actual situation of the country, and realize effective and possible activities related to the issues.

Moreover, it is possible to conduct the baseline survey (as shown below) in advance because it can be done in Japan.

1) Investigation of actual quality of data observed through the current system

   In order to evaluate the actual quality, real observed waveform record should be analyzed, especially for broadband seismic observation. Therefore, at least one week of waveform record in calm condition and records of teleseismic events are requested to be provided. Analysis and evaluation can be done in Japan.

   For the strong motion data, two days of continuous wave recording between Monday and Friday, and another two days of recording on Saturday and Sunday are requested and will be analyzed for evaluation.

2) Survey of Detailed SOH Information

Though SOH information is indispensable for remote monitoring from the central system, details of SOH obtained from observation equipment depend on the manufacturer and the model. Contents, transmission timing and how to use SOH information are surveyed on mainly BMKG-owned equipment, and utilized for operation and maintenance in the country.

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APPENDIX 8-9

The Review on Disaster Prevention Information Transmission Disaster Prevention Education and Awareness Raising in Japan

The Review on Disaster Prevention Information Transmission, Disaster Prevention Education and Awareness Raising in Japan

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

September 2020

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
ADESS	Automated Data Editing and Switching System
C/P	Counterpart
CAO	Cabinet Office
DRR	Disaster Risk Reduction
EEW	Earthquake Early Warning
EPOS	Earthquake Phenomena Observation System
ETOS	Earthquake Tsunami Observation System
GEJE	Great East Japan Earthquake
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
JST	Japan Standard Time
L-ADESS	Local-Automated Data Editing and Switching System
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
NAVTEX	Navigation Telex
NHK	Japan Broadcasting Corporation
TEC-FORCE	Technical Emergency Control FORCE

Chapter 1 Introduction

1.1 Background

Japan has experienced several natural disasters in the past, and disaster prevention-related systems have been improved based on the lessons learned from previous disasters. In the Great East Japan Earthquake (hereinafter referred to as "GEJE") and tsunami that occurred in 2011, the existing disaster prevention systems were recognized to be insufficient and many lessons and challenges have remained. Utilizing this experience, disaster prevention-related organizations have strengthened their efforts such as installing new seismographs and tsunami meters, improving tsunami warnings, operating emergency warnings, and supporting disaster prevention education.

In Indonesia, the target of the Project, it has been criticized that tsunami warning was not issued and did not reach to citizens during the Central Sulawesi earthquake and tsunami, and Sunda Strait tsunami.

As for the disaster information transmission, it is generally recognized that receivers' capacity for understanding the information correctly is important as well as the technical aspect in the transmission process. Therefore, several experiences in Japan that have been improved from both the technical aspect and the educational and awareness-raising aspect after the GEJE can be useful knowledge for disaster prevention in Indonesia.

In this report, disaster information transmission mainly for earthquakes and tsunami disasters and the situation of disaster prevention education and awareness-raising implemented by Japan Meteorological Agency (hereinafter referred to as "JMA") are reviewed.

1.2 Objective of the Review

The objective of the Review is to pull together disaster prevention-related activities in Japan that have been improved based on the issues and lessons learned from the GEJE. The following items are analyzed in the Review.

(1) Current natural disaster warning system

(2) Updates of the meteorological information and disaster warning considering the perspectives of receivers

(3) Disaster prevention education and awareness

The result is expected to serve as a reference material to be utilized for raising the awareness of counterparts (hereinafter referred to as "C/Ps") regarding the issues of disaster information transmission and awareness-raising activities.

1.3 History of Large-Scale Natural Disasters in Japan

Japan is a country subject to frequent natural disasters such as earthquakes, tsunami, typhoons, torrential rains, heavy snowfalls due to topographical, geographical and meteorological conditions. Therefore, the country is exposed to disaster risks throughout the year. Major natural disasters in Japan are listed in Table 1.3.1.

In the history above, after the Typhoon Ise-wan in 1959, the Disaster Countermeasures Basic Act was enacted in 1961. In this laws, assignments of federal responsibilities have been indicated clearly, and cumulative and organized disaster-prevention structures, etc. have been developed. The Disaster Countermeasures Basic Act has been amended continuously based on lessons learned from several large-scale disasters. Recent amendments, done after the GEJE in 2011, were the enhancement of the measures concerning support activities mutually done by local government, measures for ensuring smooth and safe evacuation of residents, and the improvement of the protection of affected people.

Table 1.3.1 Major Natural Disasters in Japan

Date	Name	Affected Areas	No. of Dead and Missing
	Mikawa Earthquake	Aichi Pref.	2,036
	Typhoon Ida	Western Japan	3,756
	Nankai Earthquake	Western Japan	1,443
	Eruption of Mt. Asama	Around Mt. Asama	11
	Typhoon Kathleen	North of Tokai	1,930
	Fukui Earthquake	Fukui Plain and around it	3,769
	Typhoon Ione	From Shikoku to Tohoku	838
	Typhoon Jane	North of Shikoku	539
	Typhoon Ruth	All over Japan	943
	Tokachi Offshore Earthquake	Southern Hokkaido,Northern Tohoku	33
	Heavy Rain	Kyushu, Shikoku, Chugoku	1,013
	Nanki Heavy Rain	North of Tohoku	1,124
	Wind Hazard	Northern Japan, Kinki	670
	Typhoon Marie	All over Japan	1,761
	Isahaya Heavy Rain	Kyushu	722
	Eruption of Mt. Aso	Around Mt. Aso	12
	Typhoon Ida	East of Kinki	1,269
	Typhoon Vera	All over Japan	5,098
	The Great Chilean Earthquake-Induced Tsunami	Southern shore in Hokkaido, Sanriku shore, Shima shore	142
	The Heavy Snowfall in January 1963	Hokuriku,Sanin,Yamagata,Shiga,Gifu	231
	The 1964 Niigata Earthquake	Niigata, Akita, Yamagata	26
	Typhoon Shirley, Typhoon Trix, Typhoon Virginia	All over Japan	181
	Typhoon Heren, Typhoon Ida	Chubu, Kanto, Tohoku,	317
	The Heavy Rain in July 1967, Uetsu Heavy Rain	West of Chubu, South of Tohoku	256
	The 1968 Tokachi Offshore Earthquake	Aomori, Southern Hokkaido, Tohoku	52
	Typhoon Phyllis, Typhoon Rita, Typhoon Tess, The heavy rain in July 1972	All over Japan	447
	The 1974 Izu Peninsula Earthquake	Southern Izu Peninsula	30
	Typhoon Fran, Heavy Rain in September 1976	All over Japan	171
	Heavy Snowfall	Tohoku, Northern Kinki, Hokuriku	101
	The 1977 Eruption of Mt. Usu (~ Oct.1978)	Hokkaido	3
	The 1978 Izu-Oshima Inshore Earthquake	Izu Peninsula	25
	The 1978 Miyagi Earthquake	Miyagi	28
	Typhoon Tip	All over Japan	115
	Snow Disaster (~ Mar.1981)	Tohoku, Hokuriku	152
	The Heavy Rain Event in Jul. and Aug.1982, Typhoon Bess	All over Japan	439
	The 1983 Sea of Japan Earthquake	Akita, Aomori	104
	The Heavy Rain Event in July 1983	East of Sanin	117
	The 1983 Eruption of Miyakejima (~ Mar.1984)	Around Miyakejima	0
	Snow Disaster	Tohoku, Hokuriku	131
	The 1984 Western Nagano Prefecture Earthquake	Western Nagano	29
	The 1986 Eruption of Izu-Oshima	Izu-oshima	0
	The 1991 Eruption of Mt. Unzen (~ Jun.1995)	Nagasaki	44
	The 1993 Southwest-off Hokkaido Earthquake	Hokkaido	230
	The Heavy Rain Event in August 1993	All over Japan	79
	The Great Hanshin-Awaji Earthquake	Hyogo	6,437
	The 2000 Eruption of Mt. Usu (~ Jun.2001)	Hokkaido	0
	The 2000 Eruption of Miyakejima, Niijima-Kozushima Offshore Earthquake (~Mar.2005)	Tokyo	1

	Typhoon Tokage	All over Japan	98
	The Chuetsu Earthquake	Niigata	68
	The 2005 Heavy Snowfall Event (~ Mar.2006)	The Sea of Japan side	152
	The 2007 Chuetsu Offshore Earthquake	Niigata	15
	The 2008 Iwate-Miyagi Nairiku Earthquake	Tohoku	23
	Heavy Snowfall (~ Mar.2011)	The Sea of Japan side	131
	The Great East Japan Earthquake	Eastern Japan	22,288
	Typhoon Talas	Kinki, Shikoku	98
	Heavy Snowfall (~ Mar.2012)	The Sea of Japan side	133
	Heavy Snowfall (~ Mar.2013)	The Sea of Japan side	104
	Heavy Snowfall (~ Mar.2014)	From northern Japan to Kanto	95
	The Heavy Rain Event in August 2014	Hiroshima	77
	The 2014 Eruption of Mt. Ontake	Nagano, Gifu	63
	The 2016 Kumamoto Earthquake	Kyushu	273
	The Heavy Rain Event in July 2018	All over Japan	271
	The Hokkaido Eastern Iburi Earthquake	Hokkaido	43
	Typhoon Hagibis	Kanto, Tohoku	94

Source: "White Paper on Disaster Management 2020", Cabinet Office, Governemnt of Japan (Translated by JICA Expert Team)

1.4 Overview of the Great East Japan Earthquake

At 14:46 JST on March 11th, 2011, a massive earthquake occurred off the coast of Sanriku, which is located northeast of Japan's main island of Honshu, particularly N38.10°, E142.86°, 23.7 km depth. It has been proven that its magnitude is 9.0, the earthquake resulted from extensive fault ruptures on or near the boundary between the Pacific and North American tectonic plates, and the focal mechanism of the tremor indicates a reverse fault type with a pressure axis in the WNW-ESE direction. The Pacific coast of the Tohoku and Kanto areas were damaged by the earthquake motion and the tsunami. JMA named this earthquake the 2011 off the Pacific coast of Tohoku Earthquake. On April 1st, 2011, the Cabinet gave the collective name of the disaster "Great East Japan Earthquake." The earthquake induced an enormous tsunami, the maximum height of which is over 9.3 meters. The major waves hit the Pacific coast of the Tohoku and Kanto areas, which caused serious damage. Because of the earthquake and tsunami, Fukushima Daiichi nuclear power plant was damaged and the broad area around it was radioactively contaminated.

As a result of the quake, the tsunami and aftershocks, 16,278 people had died, 2,994 people were missing and 129,198 houses had completely collapsed.

Table 1.4.1 Basic Information on the Great East Japan Earthquake

Earthquake's Name	
Date	March/11/2011, 14:46(JST)
Epicenter	N38.10°, E142.86°
Depth [km]	23.7
Mw	9.0
Type	Megathrust earthquake
Mechanism	Reverse fault
PGA [cm/s^2]	2,933 (three-component synthesis)
Duration [s]	About 160
Number of Deaths	16,278
Number of Missing Persons	2,994
Number of Completely Collapsed Houses	129,198
Mainly Affected Areas	Eastern Japan, especially Miyagi, Iwate, Fukushima
Earthquake-Induced Tsunami Height [m]	Over 9.3

The GEJE occurred on March 11th, 2011. JMA issued earthquake early warnings calling for attention to strong tremors in the prefectures of Miyagi, Iwate, Fukushima, Akita and Yamagata as early as 8.6 seconds after the seismic wave was detected. The first tsunami warnings and advisories were issued at 14:49, about three minutes after the quake. JMA issued major tsunami warnings for coastal areas in the prefectures off Iwate, Miyagi, and Fukushima and tsunami warnings/advisories for other areas along the Pacific coast of Hokkaido, Honshu, Shikoku and Kyushu and the Ogasawara Islands. The warnings/advisories were upgraded several times, and the warning area was extended for several days. Additionally, JMA issued other related information, such as tsunami observation results and Northwest Pacific tsunami advisories until all warnings and advisories were lifted at 17:58 on March 13th.

On the other hand, JMA set up special web pages as a way to efficiently provide information to those who lived in affected areas.

JMA opened the emergency response headquarters at 14:46 on March 11th, 2011, immediately after the main shock, and strengthened its information collection functions.

Table 1.4.2 JMA's Actions in the Great East Japan Earthquake

Time	JMA's Actions
March 11th, 2011	
14:46 18.1s	The 2011 off the Pacific coast Tohoku Earthquake (GEJE) occurred
14:46 48.8s	Earthquake early warnings calling for attention to strong tremors for the prefectures of Miyagi, Iwate, Akita and Yamagata.
14:48	1st to 4th Advance announcements of the estimated seismic intensity
14:49	Advance announcement of the estimated hypocenter
	Tsunami warnings for coastal area in the prefectures of Iwate, Miyagi, and Fukushima. Tsunami warnings/advisories for other areas along the Pacific coast of Hokkaido, Honshu, Shikoku, and the Ogasawara Islands.
	Navigation Telex (NAVTEX)
	5th to 8th Advance announcements of the estimated seismic intensity
14:50	Earthquake and tsunami information for foreigners
	9th to 14th Advance announcements of the estimated seismic intensity
14:50-15:25	1st to 5th Tsunami information (the estimated tsunami arrival time and height, high tide time and the estimated tsunami arrival time at each place, observation result)
14:53-16:00	Earthquake information (hypocenter and seismic intensity, updating the notable factors of hypocenter)
14:55, 16:16	Earthquake and tsunami information for US military in Japan
14:56-16:11	Tsunami forecast
15:01-16:32	1st to 4th Northwest Pacific tsunami advisory
15:02, 15:25	Tsunami information for foreigners
15:14-16:08	Tsunami warning/advisory
	NAVTEX
15:14-17:00	6th to 22nd Tsunami information (the estimated tsunami arrival time and height, high tide time and estimated tsunami arrival time at each place, observation result)
15:45-18:14	Tsunami information for foreigners
16:30-22:53	Earthquake information (seismic activities, updating the notable factors of hypocenter)
17:15-23:25	23rd to 47th Tsunami information (observation result, the estimated tsunami arrival time and height, high tide time and the estimated tsunami arrival time at each place)
18:47-22:53	Tsunami warning/advisory
	NAVTEX
18:57-23:02	5th to 7th Northwest Pacific tsunami advisory
March 12th, 2011	
00:04-19:39	48th to 62nd Tsunami information (the estimated tsunami arrival time and height, high tide time and the estimated tsunami arrival time at each place, observation result)
00:20	Earthquake information (seismic activities)
01:11, 06:56	8th, 9th Northwest Pacific tsunami advisory

03:20-20:20	Tsunami warning/advisory
	NAVTEX
05:12-23:50	Earthquake information (seismic activities)
13:54, 20:26	Tsunami forecast
March 13th, 2011	
07:30	Tsunami advisory
07:38, 18:04	Tsunami forecast
08:02, 18:05	63rd, 64th Tsunami information (observation result)
09:10-18:50	Earthquake information (seismic activities and updating the notable factors of hypocenter)
17:58	Cleared All tsunami advisories
	NAVTEX
	Earthquake and tsunami information for foreigners
18:15	Earthquake and tsunami information and tsunami warning for US military in Japan

1.5 History of Tsunami Warning Services Before the Great East Japan Earthquake

The nationwide tsunami forecast in Japan began on December 2nd, 1949. The means of communication from the meteorological office began with individual transmission using public telephones, dedicated telephones, and telegraphs. With the start of operation of the simultaneous telephone transmission device in March 1961, transmission system has changed from the individual transmission method to simultaneous transmission. The transmission system has shortened the time required to transmit disaster prevention-related information and news media.

After April 1986, with the start of operation of the meteorological information broadcasting device, the telephone method was changed to the fax method. This change improved the accuracy of transmitted contents as well as shortened the time for transmission.

In September 1999, transmission device was updated from fax method to online system with the start of operation of the disaster prevention information-providing device that updated the weather information broadcasting device.

Weather information such as weather forecasts and weather / tsunami warnings began to be transmitted by data communication with the development of ADESS (Automated Data Editing and Switching System) in 1969. This upgrade dramatically improved the transmission time and accuracy of the transmission content.

In April 1994, in consideration of shortening the transmission time of the tsunami forecast to external related organizations and enhancing users' convenience, the tsunami forecast was announced through the emergency seismic satellite broadcast receiver using the geostationary meteorological satellite "Himawari" (finished in March 2009 with to the development of communication technology). Currently, the disaster prevention information provision system and ADESS are used for communication.

In addition, observation technology and information transmission technology have been improved in response to the lessons from large-scale disasters.

The categories and definitions of tsunami forecasts and the corresponding tsunami height ranges have also been updated to meet the requirement of the receivers of information, both the practitioners of disaster risk reduction (DRR) and citizens. The updating of expression is designed to properly inform about the risk of the tsunami corresponding to the perceptions of citizens and society. For example, if the estimated height is small, accurate information may adversely discourage people to evacuate in case the coastal areas have been protected by tsunami dyke in recent years. Citizens' misperceptions of the warning message have been verified to minimize ambiguity of expression as forecasting capacity permits.

The details on improvements after the GEJE will be discussed in succeeding chapters.

Table 1.5.1 Improvement of Tsunami Warning Services

Date	Contents of Improvement
Dec. 1949	• In case a strong-motion seismograph recorded an earthquake with seismic intensity 4-higher, 3-lower (recorded total amplitude of 2 centimeter within 2 minutes) and 2-lower within 2 minutes, the designated government office sent a telegram which included the occurrence time of earthquakes, seismic intensity, amplitude, etc. to the district / local meteorological observatory and the central meteorological observatory (currently the Japan Meteorological Agency) within 3 minutes. The tsunami judgment center issued the tsunami forecast within 15 minutes after the earthquake. • The first comprehensive test based on the "Tsunami Forecast Transmission Comprehensive Plan" was conducted. Each transmission agency communicated to the person in charge of issuing the warnings within around 10 minutes on average. In addition, an internal test of the meteorological observatory was conducted assuming the Sanriku Earthquake. Each tsunami judgment center completed the judgment of tsunami forecast within 12 to 13 minutes. • Tsunami warnings that existed in this period: “Major Tsunami,” “Weak Tsunami,” “No Tsunami Risk,” “Tsunami Canceled.”
Mar. 1952	Tokachi Offshore Earthquake • 1 to 4 meters tsunami was observed from Hokkaido to the Tohoku region. Some earthquake telegrams did not arrive at the Sapporo District Meteorological Observatory due to communication failure. The earthquake was expected as an inland earthquake and a "No Tsunami Risk" warning was issued.
Jan. 1957	• “Tsunami Risk” was newly established as the one of tsunami warnings in the case the observation data and sufficient data were not sufficiently collected to confirm the status of tsunami. • The tsunami height corresponding to "Weak Tsunami" was modified in order to change the explanation from "It is expected that there is no damage, but people need to beware of tsunami just in case" to "People need to beware of tsunami." • Modified the explanation of "No Tsunami Risk" from "There is no risk of tsunami" to "There is no risk of tsunami attack." This modification aimed to induce fear by putting the word "attack" • The preliminary tremors duration was added to the codes of earthquake report for the tsunami forecast, and it became possible to issue tsunami forecast within 20 minutes after the earthquake. • Tsunami warnings that existed in this period: “Major Tsunami,” “Weak Tsunami,” “Tsunami Risk,” “No Tsunami Risk,” “Tsunami Canceled.”
May 1960	The Great Chilean Earthquake-Induced Tsunami • This earthquake caused serious tsunami damage in Chile, the Hawaiian Islands, Japan, etc. It became clear that it was necessary to further strengthen the international cooperation system against the tsunami.
Mar. 1961	Since the operation of the simultaneous transmission device was started, the information transmission means from JMA shifted from individual transmission to simultaneous transmission method.
Mar. 1965	When the nationwide center issued a tsunami forecast, it was decided to inform the NHK headquarters about this.
Aug. 1967	• Since the height of the tsunami from the valley of a wave to the top of a wave, or the height from the normal tide level to the top of a wave was not clearly defined and has caused confusion in the operation of tsunami warnings, the height of tsunami was defined as “the height from the normal tide level to the top of a wave.” • The tsunami heights corresponding to "Major Tsunami," “Weak Tsunami” and “No Tsunami Risk” were modified.
Mar. 1969	The operation of ADESS was started.
Jun. 1971	ADESS branch line was installed for connecting to NHK (Japan Broadcasting Corporation).
Aug.	• The category of "No Tsunami Risk" was changed from a tsunami warning to a tsunami advisory in order to adjust the definition of tsunami advisory as stipulated in the Order for the Enforcement of Meteorological Service Act. • Tsunami warnings that existed in this period: “Major Tsunami,” “Weak Tsunami,” “Tsunami Risk.” Tsunami advisories that existed in this period: “No Tsunami Risk,” “Tsunami Canceled.”
Oct. 1973	A dedicated fax machine was installed between the site operation room of the Earthquake Division of the JMA and the office of the Social Affairs Department of NHK. When a tsunami warning due to a teleseism was issued and a felt earthquake was observed, "Notice" and "Information on earthquakes and tsunami" were transmitted.
Feb. 1977	• "Tsunami Risk" was abolished due to shortened time for collecting information. • Since “Weak” as part of the phrase “Weak Tsunami” was judged to be an inappropriate expression as a warning, “Weak Tsunami” was modified to “Tsunami.” • Tsunami forecasts for small tsunamis that did not cause damages on land and ships had been included under "No Tsunami Risk." However, due to the growing social interest in such tsunamis, in consideration of the safety of coastal recreation and coastal fishing facilities, "Tsunami Caution" was newly introduced. (This was separate from "No Tsunami Risk.") • Tsunami warnings that existed in this period: “Major Tsunami,” “Tsunami.” Tsunami advisories that existed in this period: “Tsunami Caution,” “Tsunami Warning Canceled,” “Tsunami Advisory Canceled.”
Jan. 1981	It became possible to issue earthquake information when the earthquake with seismic intensity 1-higher and the teleseism of M7-higher were recorded in Japan.
Jan. 1982	The operation of L-ADESS was started.

Apr. 1986	Since the operation of the meteorological information broadcasting device was started, the means of information transmission from the JMA shifted from telephone to fax system.
Aug. 1987	The operation of EPOS (Earthquake Phenomena Observation System) was started.
Mar.1990	The operation of Sendai ETOS (Earthquake Tsunami Observation System) was started.
Apr. 1995	• With the introduction of new telegrams, it has become possible to broadcast earthquake information and tsunami warnings on TV as breaking news. • It was decided that "No Tsunami Risk" was not issued in case there were no concerns about the damages caused by the tsunami, and this was announced in the earthquake information. In addition, when tsunami warnings were not issued, it was decided that "There is no concern of tsunami" advisory would be announced in the earthquake information.
Jul. 1993	The 1993 Southwest-off Hokkaido Earthquake • The tsunami caused enormous damage mainly on Okushiri Island. The Sapporo District Meteorological Observatory issued "Major Tsunami" to the coast of the Sea of Japan in Hokkaido 5 minutes after the earthquake. This experience promoted the development of an early detection network for tsunami and earthquakes.
Jul. 1994	As a provisional breaking news of seismic intensity, the announcement of the occurrence of a strong earthquake was started.
Sep.	The operation of an early detection network for tsunami and earthquakes, which was established after the 1993 Southwest-off Hokkaido Earthquake, was started in sequence. It improved the accuracy of the epicenter and tsunami forecast.
Jan. 1995	The Great Hanshin-Awaji Earthquake • The earthquake caused enormous damage mainly in Kobe City. The Osaka District Meteorological Observatory issued "No Tsunami Risk" 4 minutes after the earthquake.
Apr.	The operation of the 2nd generation EPOS was started.
Apr. 1996	• The physical observation of seismic intensity was abolished. • It became possible to measure seismic intensity 7. • The operation of a huge tsunami gauge was started. • Urban / rural seismographs was started to be utilized.
Nov. 1997	In addition to seismographs maintained by the JMA, the observation data of seismographs maintained by local governments was started to be utilized for seismic intensity information.
Apr. 1999	• Quantitative tsunami forecast was started. The tsunami forecast zone was subdivided into 18 to 66 zones. • The criteria for tsunami advisories and warnings were modified as follows. As a result of the modification, the overlap in the height range of each warning was improved, and it became easier for both the recipient and the sender of tsunami warnings to determine the specific response. ➢ Tsunami caution: Modified from “several tens of centimeters” to “20 centimeters or more and less than 1 meter.” ➢ Tsunami: Modified from “approximately 2 meters and several tens of centimeters in other area” to “1 meter or more and less than 3 meters.” ➢ Major tsunami: Modified from “3 meters and 1 meter in other area” to “3 meter or more.” ➢ If the tsunami height is estimated to be 20 cm or less and there is no risk of damage, it is announced as "sea level fluctuation information" instead of a tsunami advisory.
Sep.	• The operation of the device for providing the disaster prevention information, which was an updated version of the device for broadcasting weather information, was started. • Means of information transmission from the JMA shifted from fax method to online system.
Oct. 2003	The operation of the 3rd generation EPOS was started.
Dec. 2004	Indian Ocean Tsunami
Mar. 2005	• Pacific Tsunami Warning Center started operations and provided information such as the time of earthquake occurrence, location of epicenter, estimated time of tsunami arrival, expected tsunami height, etc. to the relevant countries when an earthquake of M6.5 or more occurred in the northwestern Pacific Ocean. • Provision of the information of tsunami monitoring in the Indian Ocean was started. It provided information such as the time of earthquake occurrence, the location of epicenter, the estimated time of tsunami arrival, the expected tsunami height, etc. to the relevant countries when an earthquake of M6.5 or more occurred in the Indian Ocean.
Oct. 2006	Utilizing the technology of Earthquake Early Warning system, it became possible to announce tsunami forecast at the fastest rate within 2 minutes after the occurrence of the earthquakes that had effective epicenter information for tsunami forecast.
Feb. 2007	Dissemination of tsunami advisories / warnings and the earthquake early warning by J-Alert was started.
Dec.	• “Tsunami forecast” was established as a category of tsunami warnings in the case that tsunami was not expected, sea level fluctuation of less than 0.2 meters was expected, and sea level fluctuation continued after the cancelation of tsunami advisory. (This was separated from “Tsunami Advisory.”) Due to the establishment of “Tsunami Forecast,” the definition of tsunami advisory was modified as follows: Tsunami Advisory: Modified from "Forecast to call on the public to beware of the presence and extent of tsunami" to "Forecast to call on the public to beware of the risk of disaster when a disaster occurs due to a tsunami." • Before 2007, when the tsunami attenuated and its height became lower than the standard specified in the tsunami warning, the warning was canceled at once even while tsunami with the height exceeding the

	standard specified in the tsunami advisory continued. However, it was pointed out that it was important to inform that the tsunami was continuing for the safety of aquaculture rafts and marine recreation. Therefore, instead of canceling the tsunami warning at once, it was decided to switch to the tsunami advisory first based on the tsunami height and gradually canceled the warning.
Mar. 2009	Operations of the earthquake and tsunami monitoring were consolidated into two centers, Tokyo and Osaka. The operation of Osaka EPOS was started.
Oct.	The operation of the 4th generation Tokyo EPOS was started.
Mar. 2011	The Great East Japan Earthquake

Source: JICA Expert Team edited in accordance with "History of Tsunami Warning Services in Japan" (Fujio KUSANO et al., 2011).

Chapter 2 Current Natural Disaster Warning System

This chapter articulates the current contents of tsunami warning information, Earthquake Early Warning (EEW), and Emergency Warning, by referring to JMA's website[1] and quoting information from it. Such warning information types underwent continuous upgrade in response to the improvement of observation and forecasting technology and lessons learned from past disasters, especially large-scale disasters including the GEJE and intense typhoons. It should be noted that these updates were based on the discussions of interdisciplinary working groups composed of government agencies, municipality, media and academia, which are the key stakeholders of DRR in Japan.

2.1 Tsunami Warning System

Through the GEJE in 2011, JMA left various issues for the future regarding the estimation of magnitude, switching and updating of tsunami warning. In this particular disaster, expected earthquake and tsunami announced as tsunami warning were lower than the actual. Based on the above experiences, JMA had been attempting to consider the improvement of tsunami warning by verifying the contents and timing of the issuance of tsunami warning. To achieve this objective, a study group which consisted of experts and related disaster prevention organizations was organized to improve the tsunami warning, and the group had been working on its improvement since. Specific recommendations for improvement were published in February 2012. Improvements in information transmission have been made based on the following policies:

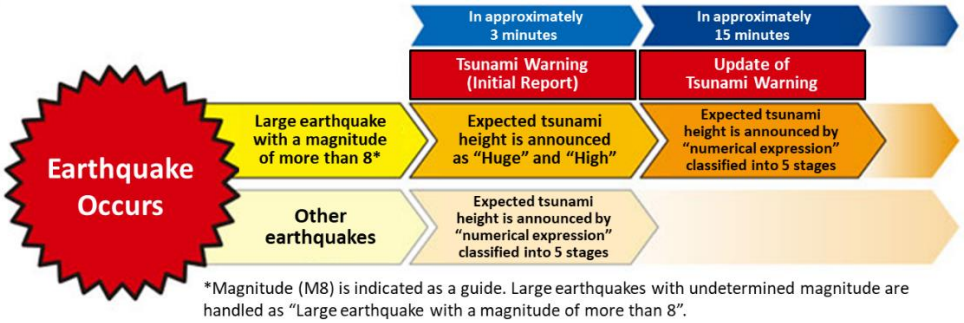
1) **Concise expression:** To make the information contents and expression concise and easy to understand from the information receivers' perspective.

2) **Expression indicating the actions to be taken:** To show not only tsunami height, but also disasters caused by tsunami and disaster prevention-related actions such as evacuation actions to be taken.

3) **Expression considering information accuracy and issuance timing:** The contents of tsunami warning and information are an effective combination of qualitative expressions and numerical values in consideration of the accuracy of the information and the timing of announcement.

4) **Expression showing important points in the information:** Important items of tsunami warnings and information are shown in the heading section, and when updating the warnings and information, a flag (identification mark) is attached so that important changes can be accurately conveyed.

Figure 2.1.1 shows the flow of tsunami warning issuance as a result of the improvement after the GEJE. JMA issues "Major Tsunami Warning," "Tsunami Warning," and "Tsunami Advisory" in accordance with tsunami height when a disaster is expected to occur due to the tsunami. Approximately three minutes after the earthquake, JMA expects the scale and location of the earthquake, and issues the first tsunami warning / advisory to the tsunami forecast areas[2].



Source: JMA (Translated by JICA Expert Team)

Figure 2.1.1 Issuance Flow of Tsunami Warning

[1] https://www.data.jma.go.jp/svd/eqev/data/tsunami/kaizen/index.html
[2] JMA divided the whole country into 66 areas for tsunami forecast.

Detailed contents of the improvements are specified in the following items:

2.1.1 Classification of Expected Tsunami Height

Tsunami warning is classified into "Tsunami Warning (Major Tsunami)," "Tsunami Warning (Tsunami)" and "Tsunami Advisory."[3] Since its classification is well known to citizens, JMA has not modified it after the GEJE.

Based on the results of a survey on the relationship between tsunami height and damages, one meter height was set as the issuance level of tsunami warning (tsunami), and three meters height was for tsunami warning (major tsunami). In addition, since the damage status becomes serious when the tsunami height reaches around five meters, it has been added to the boundary of expected tsunami height level. A tsunami height of 10 meters has also been added to the boundary, taking into consideration the stages of possible disaster response and the fact that the larger the expected height, the larger the error. The classification of expected tsunami height was set at eight stages. However, it has been simplified to five stages considering the errors in the issuance level of tsunami warning and expected tsunami height, possible disaster response stages, etc.

Table 2.1.1 Classification of Expected Tsunami Height of Tsunami Warnings

Types of Warning and Advisory	Classification of Expected Tsunami Height	
	After Improvement	Before Improvement
Tsunami Warning (Major Tsunami) "Major Tsunami Warning"	10 m ~	10 m ~
	5 m ~ 10 m	8 m
		6 m
		4 m
	3 m ~ 5 m	3 m
Tsunami Warning (Tsunami) "Tsunami Warning"	1 m ~ 3 m	2 m
		1 m
Tsunami Advisory	0.2 m ~ 1 m	0.5 m

Source: JMA (Translated by JICA Expert Team)

2.1.2 Information Statement on Tsunami Warning and Actual Tsunami Status

(1) Contents and Expression of Tsunami Warning Information

When a large earthquake occurs, the qualitative expression identified in Table 2.1.2 is used in the first tsunami warning for emergency announcement. While the estimation of the earthquake magnitude is uncertain, the qualitative expression can avoid troubles caused by underestimation of the earthquake scale. In the GEJE, there were cases in which people's evacuation was delayed because they misunderstood that tsunami would not go over the seawall when they heard "expected tsunami height of three meters," which was announced during the underestimation of the earthquake scale.

After the accuracy of the magnitude estimation becomes high, the expression of the expected tsunami height shifts from qualitative to numerical expression with a simple and single numerical value. For the numerical expression, the largest number in each stage has been used for the announcement to avoid the underestimation of tsunami height and to raise a sense of crisis.

[3]Tsunami advisory calls attention to people at the sea or near the coast. Tsunami warning calls for caution on land area. In case of major tsunami, it calls for strict caution on land area.

Table 2.1.2 Expression of Expected Tsunami Height

Types of Warning and Advisory	Classification of Expected Tsunami Height	Numerical Expression	Qualitative Expression
Tsunami Warning (Major Tsunami) "Major Tsunami Warning"	10 m ~	Over 10 m	Huge
	5 m ~ 10 m	10 m	
	3 m ~ 5 m	5 m	
Tsunami Warning (Tsunami) "Tsunami Warning"	1 m ~ 3 m	3 m	High
Tsunami Advisory	20 cm ~ 1 m	1 m	N/A

Source: JMA (Translated by JICA Expert Team)

(2) Contents and Expression of Tsunami Observation Results

1) Announcement of Low Height Tsunami Observation Results While High Height Tsunami is expected

In the GEJE, the first tsunami wave observation result was announced as 0.2 meters in the area where high height tsunami was expected. It was assumed that people who heard it understood the tsunami would be low, and this caused the delay of their evacuation from further waves. While observed tsunami height is lower than the lowest stage in the classification of expected tsunami height, there is a possibility that announcing a numerical value of observed tsunami height makes people feel relieved and causes the delay of evacuation.

Based on the lesson learned regarding the first tsunami wave, its arrival time and anaseism, or backwash, are announced. As for the maximum tsunami wave observation results, "Currently Observing" is announced to inform that a tsunami is arriving, while the observed tsunami height is low in the area where major tsunami warning and tsunami warning are issued.

Table 2.1.3 Announcement of the Largest Tsunami Wave Observed on the Coast

Status of Warning and Advisory	Expected Tsunami Height off the Coast	Contents of Information
Under Major Tsunami Warning	Height ＞ 1 m	Announce numerical value of observed tsunami height
	Height ≦ 1 m	Announce numerical value of observed tsunami height
Under Tsunami Warning	Height ≧ 0.2 m	Announce numerical value of observed tsunami height
	Height ＜ 0.2 m	Announce "Currently Observing"
Under Tsunami Advisory	All cases	Announce numerical value of observed tsunami height (in case the tsunami surge is considerably small, it is announced as "Slight")

Source: JMA (Translated by JICA Expert Team)

2) Announcement of Offshore Tsunami Observation Results

In the GEJE, the GPS wave gauge observed the arrival of tsunami, and the results were utilized for updating tsunami warnings. This shows that tsunami observation off the coast is functional.

JMA announces the observation time of the first wave of offshore tsunami, anaseism and backwash of tsunami, and the height and arrival time of observed maximum tsunami by that time. Moreover, expected information from the above observation is also announced.

Regarding the maximum tsunami wave observation results, "Currently Observing" or "Currently Investigating" is announced to inform that a tsunami is arriving, while the observed tsunami height is low in the area where major tsunami warning and tsunami warning are issued because of the same reason stated above.

Table 2.1.4 Announcement of the Largest Tsunami Wave Observed on the Coast

Status of Warning and Advisory	Expected Tsunami Height off the Coast	Contents of Information
Under Major Tsunami Warning	Height ＞ 3 m	Announce numerical value of observed offshore tsunami height and expected tsunami height on the coast.
	Height ≦ 3 m	Announce observed offshore tsunami height as "Currently Observing" and expected tsunami height on the coast as "Currently Investigating."
Under Tsunami Warning	Height ＞ 1 m	Announce numerical value of observed offshore tsunami height and expected tsunami height on the coast.
	Height ≦ 1 m	Announce observed offshore tsunami height as "Currently Observing" and expected tsunami height on the coast as "Currently Investigating."
Under Tsunami Advisory	All cases	Announce numerical value of observed offshore tsunami height and expected tsunami height on the coast.

Source: JMA (Translated by JICA Expert Team)

(3) Contents and Expression of Tsunami Forecasts

In case there is no risk of disasters caused by the tsunami after the earthquake, it is announced in tsunami forecasts. If tsunami is not expected, JMA announces it in the earthquake information.

Table 2.1.5 Contents of Tsunami Forecasts

Conditions of Issuance	Contents of Information
Sea level changes (less than 0.2 m) are expected	There is no need to worry about damages due to sea level changes that are expected to be less than 0.2 m at the highest points, and no special disaster prevention measures are required.
Sea level changes continue after the tsunami warning is released	Sea level changes due to tsunami have been observed and are likely to continue in the future. Therefore, sufficient care must be taken when entering the sea, fishing, and swimming.

Source: JMA (Translated by JICA Expert Team)

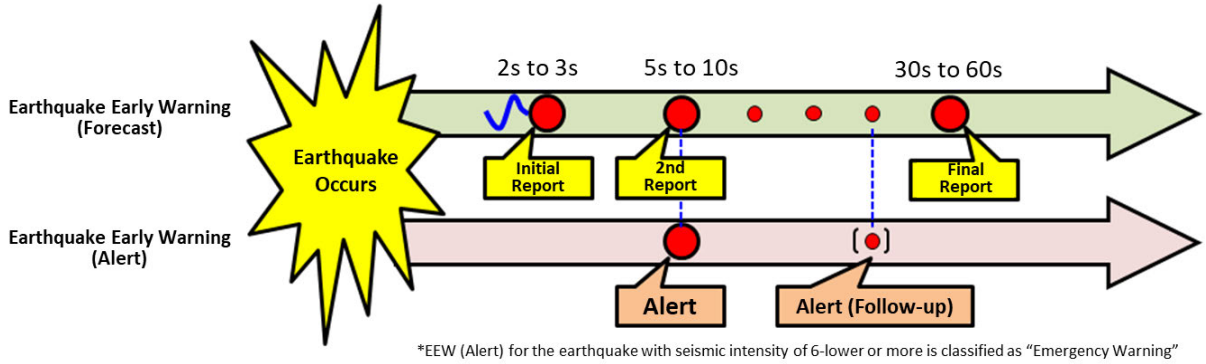
2.2 Earthquake Early Warning (EEW)

Earthquake Early Warning (EEW) is one of the early warnings that predicts the arrival time and seismic intensity of strong tremors immediately after the earthquake. Issuance of EEW is the duty of JMA as prescribed in Article 13 of the Meteorological Service Act. From October 1st, 2007, JMA started operating EEW for all residents in almost all areas except in some isolated island areas. EEW is classified as shown below.

Table 2.2.1 Classification of Earthquake Emergency Warning, Warning and Forecast

Classification	Name Used for Warning Issuance	Remarks
Seismic Motion Emergency Warning	Earthquake Early Warning (Alert) or Earthquake Early Warning	When a tremor with a maximum seismic intensity of 5-lower or more is expected, the warning is issued that an earthquake may cause a serious disaster in areas where a strong tremor is expected. In case the seismic intensity of 6-lower or more is expected, the warning is designated as emergency warning.
Seismic Motion Warning		
Seismic Motion Forecast	Earthquake Early Warning (Forecast)	When a maximum seismic intensity of 3 or more or a magnitude of 3.5 or more are expected, the warning is issued.

Source: JMA (Translated by JICA Expert Team)



Source: JMA (Translated by JICA Expert Team)

Figure 2.2.1 Issuance Flow of Earthquake Early Warning

According to Article 15 of the Meteorological Service Act, when JMA issues warnings for weather, geography, tsunami, storm surge, waves and floods, it immediately reports the information to the Metropolitan Police Department, Fire and Disaster Management Agency, Ministry of Land, Infrastructure, Transport and Tourism, Japan Coast Guard, local governments, Nippon Telegraph and Telephone East Corporation, Nippon Telegraph and Telephone West Corporation or NHK.

2.2.1 Earthquake Early Warning (Alert)

From October 1st, 2007, JMA has started operating EEW (Alert). Once JMA issues EEW (Alert), the warning is disseminated through TV, radio, mobile phone, administrative radio system for disaster prevention, etc. in the areas where an earthquake is expected. The issuance conditions and contents are described below.

(1) Issuance Criteria

JMA issues EEW (Alert) under the following situations: (1) when seismic waves are observed at two or more earthquake observation points; and (2) the maximum seismic intensity of 5-lower or more is expected. The reason for the first situation is to avoid a false report due to lightning strikes in and around the vicinity of the seismograph. For the second situation, it is necessary to be prepared for earthquake in advance. Serious damages begin to occur when seismic intensity reaches 5-lower or more.

(2) Contents of EEW (Alert)

The contents of the warning are as follows:

- Earthquake occurrence time, expected location of the earthquake (hypocenter), epicenter name
- Areas expected to be affected by strong tremors (with seismic intensity of 5-lower or more) and seismic intensity of 4 (the whole country is divided into about 200 areas)

Since the specific value of expected seismic intensity is accompanied by gaps of about ±1 and further reports have to be avoided as much as possible, JMA has decided not to announce the values, but instead expresses them as "strong tremors."

The reason why areas in which seismic intensity of 4-lower or more is expected are included in the warning is because there is a possibility that the seismic intensity may actually be 5 or less due to gaps in prediction. In addition, it may become 5 or less after sometime due to the fault motion. In case the expected seismic intensity of 3-lower is modified to 5-lower or more based on analysis after the issuance of EEW (Alert), JMA issues follow-up reports, which include information on the areas with newly expected seismic intensity of 5-lower or more and 4.

2.2.2 Earthquake Early Warning (Forecast)

JMA issues EEW (Forecast) several times (around five to ten times) within one minute after the

tremor is observed. The first issuance prioritizes rapidity, and the accuracy of the information provided subsequently is improved.

(1) Issuance Criteria

- In case the amplitude of P-waves or S-waves is 100 Gal or more at any seismic observation point; and
- In case the epicenter, magnitude, and predicted seismic intensity of each place are obtained and the magnitude is 3.5 or more, or the maximum predicted seismic intensity is 3 or more as a result of analyzing seismic waves observed through a seismograph.

(2) Contents of EEW (Forecast)

The contents of the warning are as follows:

- Earthquake occurrence time, expected location of the earthquake (hypocenter)
- Expected magnitude
- Expected maximum seismic intensity, in case it is 3 or less
- Areas to be affected by seismic intensity of 4 or more, expected seismic intensity, and arrival time of the strong tremors in case the maximum seismic intensity of 4 or more is expected

2.3 Emergency Warning and Weather Warning

2.3.1 Establishment of Emergency Warning

JMA issues weather warnings, advisories and early advisories to prevent and reduce disasters caused by heavy rains, storms and so on. The contents of information and issuance timing of these warnings and advisories are decided based on discussions made between JMA, local governments, national agencies, media and disaster-related agencies. JMA has been improving these warnings and their utilization.

Table 2.3.1 Classification of Weather Warnings

Types of warning	Categories
Emergency warning	Heavy rain, heavy snow, storm, snowstorm, storm surge, high waves
Warning	Heavy rain, flood, heavy snow, storm, snowstorm, storm surge, high waves
Advisory	Heavy rain, flood, heavy snow, storm, snowstorm, storm surge, high waves, heavy fog, thunderstorm, dry weather, avalanche, ice/snow accumulation, snowmelt, frost, low temperature
Early Advisory	Heavy rain, storm, heavy snow, high waves

Source: JMA (Translated by JICA Expert Team)

In the GEJE in 2011, there had been instances in which the major tsunami warning did not urge people to evacuate. When a typhoon occurred in the same year, JMA issued several warnings. However, JMA did not have the means to convey the high possibility of disaster occurrence which was different from normal disasters. Thus, JMA established "Emergency Warning" to convey a sense of crisis regarding the occurrence of disasters equivalent to a phenomenon with a level of intensity observed only once every few decades. The operation of Emergency Warning started on August 30th, 2013. The target disasters and issuance criteria are shown below.

Table 2.3.2 Criteria for Issuance of Emergency Warnings

Phenomenon	Criteria	
Heavy rain	Heavy rainfall with a level of intensity observed only once every few decades is predicted in association with a typhoon or similar. Or: Heavy rainfall is predicted in association with a typhoon expected to have a level of intensity observed only once every few decades or an extratropical cyclone with comparable intensity.	
Storm	A storm is predicted	In association with a typhoon expected to have a level of intensity observed only once every few decades or an extratropical cyclone with comparable intensity.
Storm surge	A storm surge is predicted	
High waves	High waves are predicted	
Snowstorm	A snowstorm is predicted in association with an extratropical cyclone expected to have a level of intensity observed only once every few decades.	
Heavy snow	Heavy snowfall with a level of intensity observed only once every few decades is predicted.	

Source: JMA

In regard to tsunami, volcanic eruptions and earthquakes, JMA maintained the system of warning nomenclature used until August 29th, 2013, and has issued the existing Major Tsunami Warnings, Volcanic Warnings (residential areas) and EEW incorporating the prediction of tremors measuring 6-lower or more on JMA's seismic intensity scale in the new classification of Emergency Warnings.

Table 2.3.3 Criteria for Issuance of Other Emergency Warnings

Phenomenon	Criteria
Earthquake	Seismic intensity of 6-lower or more is expected. (Earthquake Early Warnings incorporating prediction of tremors measuring 6-lower or more on JMA's seismic intensity scale are issued in the classification of Emergency Warnings.)
Tsunami	Tsunami height is expected to be greater than 3 meters. (Major Tsunami Warnings are issued in the classification of Emergency Warnings.)
Volcanic Eruptions	Eruption or possibility of eruption that may cause serious damage in residential areas and non-residential areas nearer to the crater (Volcanic Warning (Level 4 and 5) and Volcanic Warning (residential areas)* are issued in the classification of Emergency Warnings.)

Source: JMA

From July 7th, 2017, JMA has improved the area covered by the emergency warnings of heavy rain by utilizing the risk distribution technology. As a result, the system has been improved so that gradual announcements have been made, from advisory to warning, to sediment disaster warning information, and to emergency warning according to the increase in risk as indicated in the risk distribution. Instances in which emergency warnings were issued suddenly after the advisory have basically disappeared. However, emergency warnings caused by typhoons, etc. may switch from advisory to emergency warnings.

Emergency Warnings are disseminated to the public through municipalities and media such as TV and radio in the same way as the existing Warnings, Advisories and other bulletins. In addition, from 11:00 on November 19th, 2015, as with the EEW and tsunami warnings issued by JMA, the delivery of emergency warnings regarding weather and eruptions by "Emergency Area Mail" has been started.

In operating the Emergency Warnings, there have been cases in which the warning message was misleading and did not fully induce the evacuation behavior of people in the affected areas. For this reason, JMA has established a study group called "Method of conveying meteorological information for disaster reduction" composed of DRR-related agencies. The study group continuously validates the effectiveness of warning information to induce the necessary actions and improve the contents and messages based on the issues raised in the process of validation.

2.3.2 Improvement of Weather Warnings and Their Utilization

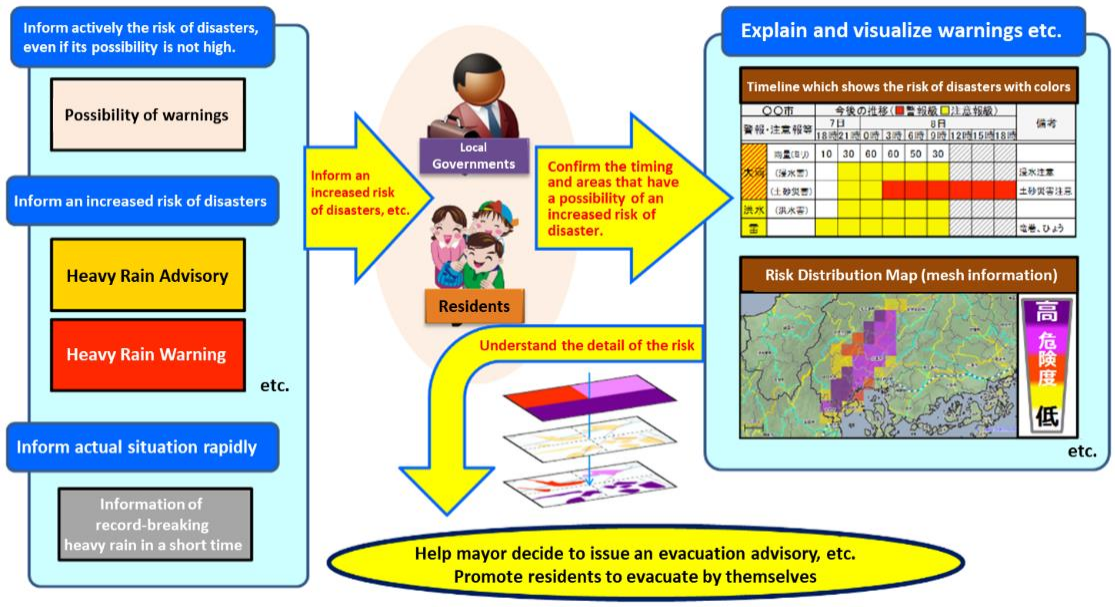
In recent years, damages due to torrential rain, typhoon and so on have occurred frequently, and rainfalls have been localized, centralized and severe. Therefore, JMA started the improvement of climate and disaster information from 2015. The basic policies on the improvement of climate and

disaster information are the following:

- To convey proactively the possibility of a phenomenon that has a great impact on society even if the possibility of its occurrence is low
- To provide information in an easy-to-understand manner so that citizens can easily understand the risks and urgency of the situation

Based on the above policy, JMA improved the weather warning and its utilization as shown below:

- Improvement of display of risk distribution map of heavy rain warning (sediment disaster)
- Acceleration of announcement of the highest rainfall ever recorded
- Providing time series with risk levels specified by different colors
- Announcement of early advisory (possibility of warning level)
- Providing distribution map of warning levels
- Heavy rain warning (flood damage) risk distribution map
- Flood warning risk distribution map
- Improvement of warning system in the areas targeted for heavy rain emergency warning announcement using risk distribution technology.



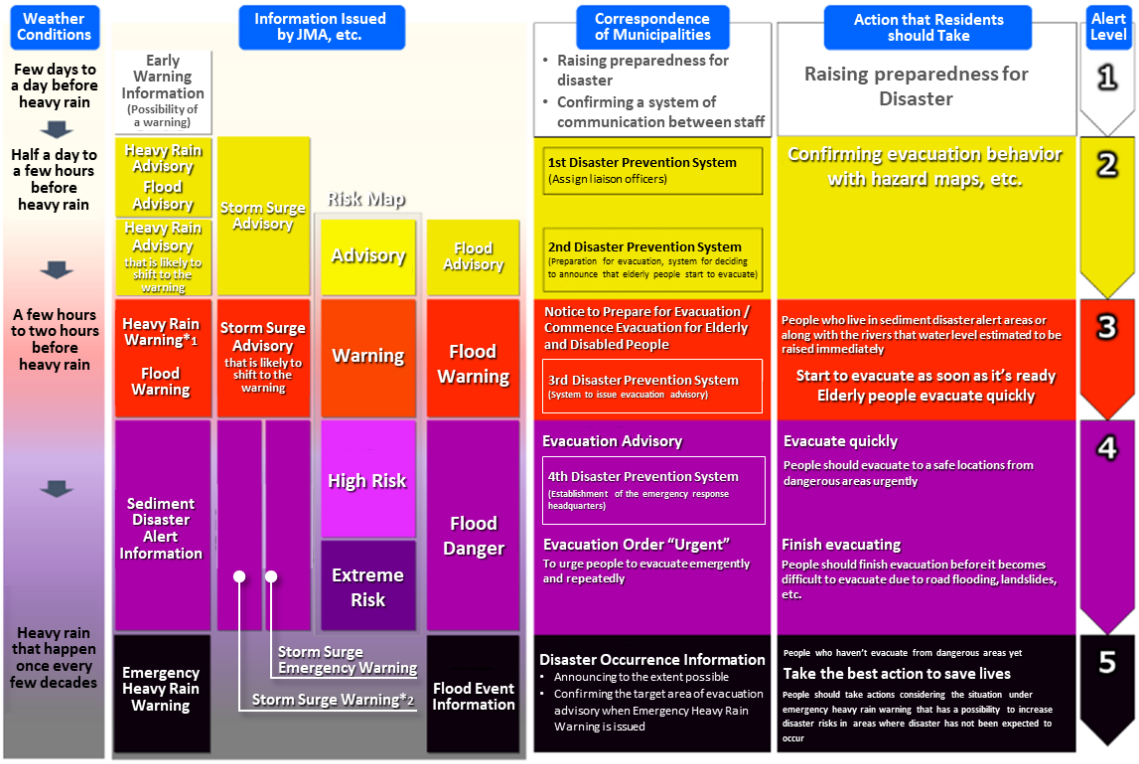
Source: JMA (Translated by JICA Expert Team)

Figure 2.3.1 Direction of Weather Warnings Aimed at by JMA

The Cabinet Office (hereinafter referred to as “CAO”) revised the "Guidelines for Evacuation Advisories, etc." in March 2019, and indicated that residents should take evacuation actions at their own discretion with the consciousness of "protecting their own lives."

CAO has indicated that disaster prevention information would be provided by clearly stating the five levels of caution so that residents can easily and intuitively understand the actions to be taken based on the disaster prevention information issued by local governments and JMA.

JMA has organized disaster prevention weather information, and its utilization methods are announced in stages according to risk level. The details are published on the JMA website.



*1 Advisories with a high possibility of shifting to a heavy rain warning during the night time to early morning are equivalent to alert level 3.
*2 Advisories with a high possibility of shifting to a storm surge warning in the situation that a storm warning has been issued are equivalent to alert level 4.

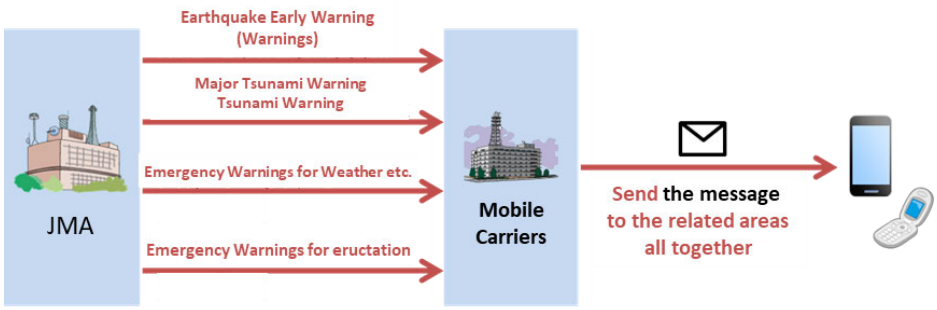
Source: JMA (Translated by JICA Expert Team)

Figure 2.3.2 Weather Warnings and Correspondence to be Taken

2.4 Emergency Area Mail

Emergency area mail is a free service provided by mobile phone carries. It provides information on disaster and evacuation from national and local governments through mobile phones in specific areas at the same time without being affected by line congestion. This service started in 2007 and the usage fee for carries was set. However, the usage fee has been abolished after the GEJE. Among the disaster prevention weather information announced by JMA, the following are the warnings distributed through the emergency area mail.

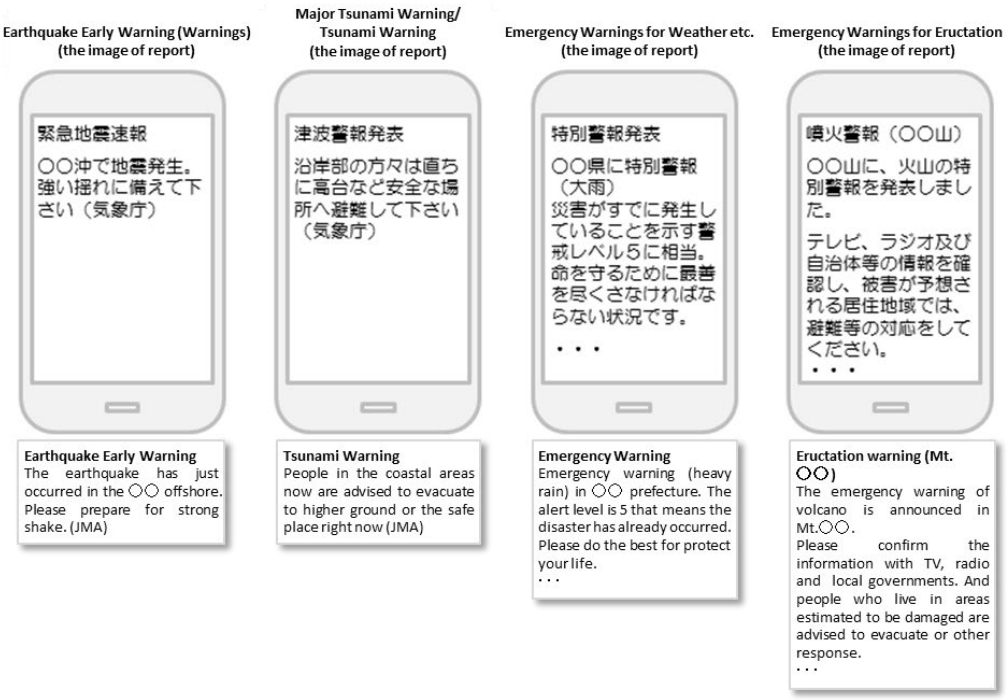
- Earthquake early warning
- Major tsunami warning and tsunami warning
- Emergency warning for weather (heavy rain, heavy snow, storm, snowstorm, storm surge, high waves)
- Emergency warning for eruption



Source: JMA (Translated by JICA Expert Team)

Figure 2.4.1 Dissemination Flow of Weather Warnings to the Public

Since July 9th, 2020, information on alert level and actions to be taken have been concluded in the emergency area mail.



Source: JMA (Translated by JICA Expert Team)

Figure 2.4.2 Template of Emergency Area Mail

Chapter 3 Updating the Meteorological Information and Disaster Warning Considering the Perspectives of Receivers

The previous chapter illustrated the current conditions of improved disaster information based on lessons from past disasters as well as the improvement of observation and forecasting technology. This chapter articulates the process of updating the warning messages, with particular focus on the viewpoint of the receiver of information and the methodology for raising the awareness of citizens when updating the warning messages.

One of the lessons of the GEJE tsunami evacuation was that the receivers of information, or the residents, underestimated the threat of the disaster, which caused inappropriate evacuation actions. The reasons for the underestimation are observed for both technical reasons and misconceptions of the receivers of information. Since the ultimate goal of tsunami warning is to save the lives of citizens, technical working groups including academia, civil servants, media and JMA have engaged in the improvement of warning message.

3.1 Survey of information receivers in the disaster-stricken areas regarding the updating of tsunami warning messages

3.1.1 Overview of the survey

Responding to devastating tsunami damage caused by the GEJE, JMA organized "Study group for improving tsunami warnings based on the damage caused by the 2011 off the Pacific coast of Tohoku Earthquake" from June to September 2011, and "Study panel for investigating tsunami warning issuance criteria and information text " from October 2011 to January 2012. The findings of the interdisciplinary study group were compiled in the report, "Improvement of tsunami early warning based on the tsunami damage caused by the 2011 off the Pacific coast of Tohoku Earthquake." Based on the report, this section focuses on the improvement of the message from the perspectives of receivers.

"Study group for improving tsunami warnings based on the damage caused by the 2011 off the Pacific coast of Tohoku Earthquake" and "Study panel for investigating tsunami warning issuance criteria and information text" – composed of various level of DRR stakeholders – were established.

3.1.2 Summary of the stakeholders' involvement in upgrading the tsunami warning

In order to understand the perception of the tsunami warning of the actual GEJE evacuees, JMA conducted interview surveys on the persons affected by the tsunami. The outline of the surveys is summarized below.

(1) Survey of tsunami-affected populations

The survey was conducted to understand the affected population who evacuated from the tsunami. Outline and items of the survey are shown below.

1. Objective of the survey
The survey was conducted to analyze the relation between tsunami evacuation actions and the disaster damage, and to compile a material for promoting the necessary evacuation countermeasures. (Joint survey of Cabinet Office in Japan, Fire and Disaster Management Agency, and JMA)
2. Target of the survey (Sample survey)
1) Participants of the survey
Citizens living in coastal areas in Iwate, Miyagi and Fukushima prefecture. (Iwate (391 persons), Miyagi (385 persons), Fukushima (94 persons))
2) Methodology of the survey
Surveyors visited temporary housing and evacuation sites and directly interviewed the

evacuees. (Surveyors visited the site with questionnaire and exchanged questions and answers after the respondents consented to the questionnaire.)
3) Timing of the survey
From beginning to end of July 2011
3. Items of the survey
1) Information about tsunami information and evacuation advisory
Q1. Did you see and hear about the tsunami information and evacuation advisory before you evacuated? If so, what was the source of information?
1. Large tsunami warning 2. Estimated tsunami height 3. First observed tsunami height
4. Evacuation advisory 5. Did not hear about the information
2) Source of information(measure)
Q2. How did you see and hear about the information?
1. From TV 2. From radio 3. From administrative disaster management wireless network
4. From TV and from radio installed in a car 5. From one-segment broadcast of mobile phone
6. From SMS of mobile phone 7. From municipality office car and/or official
8. From family or neighbors 9. From police car and/or official 10. From fire brigade car and/or official 11. Announcement from the facilities/building 12. Others

3) Influence of tsunami warning on the decision to evacuate
Q3. Did the tsunami warning affect your decision to evacuate?
1. The warning raised the awareness on the necessity to evacuate
2. The estimated height of tsunami did not impress upon the necessity to evacuate
3. The warning did not affect the actions
4. The warning had no affect because of immediate evacuation

4) Influence of estimated tsunami height on the decision to evacuate
Q4. What did you think after seeing and hearing about the estimated tsunami height?
1. Felt the necessity to evacuate 2.Did not feel the necessity to evacuate

5) Information on updated information
Q5. Before the arrival of the tsunami, the estimated tsunami height issued by JMA became higher than first estimated tsunami height. Did you see or hear about that information?
1. Yes 2.No

6) Reason for not hearing about the updated information
Q6. What was the reason why you did not see or hear about the updated estimated tsunami height?
1. Could not afford to listen to the information because of imminent evacuation
2. No information from municipality office and administrative disaster management wireless network
3. Could not watch/listen to TV and Radio due to blackout
4. Could not use mobile phone
5. Did not pay attention to the height of tsunami
6. Others

(2) Survey of citizens and DRR-related officials in areas where tsunami warning was issued

The survey was conducted targeting the areas where tsunami warning was issued and not regarded as heavily affected areas of tsunami. The outline and items of the survey are as shown below.

1. Objective of the survey

The survey was conducted to analyze the relations between tsunami evacuation actions and the disaster damage, and to compile a material for promoting the necessary evacuation countermeasures.

2. Targets of the survey (Sample survey)

Residents and DRR officers in the areas where the tsunami warning was issued (Hokkaido and Tokyo and the western part)

3. Contents of the survey

(1) Target：Citizen

1) Recognition of tsunami warning and evacuation advisory

Q1. Did you hear about the tsunami warning and evacuation advisory?

1. Yes/ 2. No

Q2. How did you learn about the tsunami warning?

1. From TV 2. From radio 3. From administrative disaster management wireless network
4. From TV and from radio installed in a car 5. From one-segment broadcast of mobile phone
6. From SMS of mobile phone 7. From municipality office or fire brigade car
8. From family or neighbors 9. From police or fire brigade official 10. Announcement from facilities/building 11. Others

2) Source of Information

Q3. Source of information about estimated tsunami height

Q4. Source of information about observed tsunami height

Q5. Source of information about evacuation advisory

1. From TV 2. From radio 3. From administrative disaster management wireless network
4. From TV and from radio installed in a car 5. From one-segment broadcast of mobile phone
6. From SMS of mobile phone 7. From municipality office or fire brigade car
8. From family or neighbors 9. From police or fire brigade official 10. Announcement from the facilities/building 11. Others

3) Influence of tsunami warning on the decision to evacuate

Q6. Did the tsunami warning affect your decision to evacuate?

1. The warning raised the awareness on the necessity to evacuate
2. The estimated height of tsunami did not impress upon the necessity to evacuate
3. The information was utilized to select where and how to evacuate
4. The height did not affect how to evacuate or did not know how to utilize the height for choosing the evacuation site and taking evacuation measures
5. The information did not particularly affect the action

Q7. Did the estimated tsunami height affect your decision to evacuate?

1. The warning raised the awareness on the necessity of evacuation
2. The estimated height of tsunami impressed that it was not necessary to evacuate
3. The information was utilized to select where and how to evacuate
4. The height did not affect how to evacuate or did not know how to utilize the height for choosing the evacuation site and taking evacuation measures
5. The information did not particularly affect the action

4) Updating of tsunami height

Q8. Did you know that tsunami warning and estimated tsunami height information was updated?

1. Yes 2.No

Q9. The reason for not knowing the renewal of tsunami warning and updating of tsunami height
1. Could not afford to listen to the information due to evacuation
2. No information from municipality office or could not hear the announcement
3. Could not use TV and radio
4. Could not use mobile phone
5. Did not pay attention to the height of tsunami
6. Others

5) Trigger for the evacuation and impression of tsunami warning
Q10. What was the trigger for the evacuation?
1. Because of strong tremors
2. Because of tsunami warning
3. Recommendation from municipal office, fire brigade, or police
4. Instruction from family members
5. Strong recommendation from neighbors
6. Because of actual tsunami observation
7. Based on past tsunami experience
8. Recommended by the company or colleagues
9. Do not remember

Q11. Impression of tsunami warning and estimated tsunami height
1. Tsunami warning of 1m 2. Tsunami warning of 2m 3. Large Tsunami warning of 3m 4. Large Tsunami warning of 4m 5. Large Tsunami warning of 6m 6. Large Tsunami warning of 8m 7. Large Tsunami warning of more than 10m
a. Does not feel too dangerous b. Feels dangerous c. Feels too dangerous

(2)Target: DRR-related officials
1) Tsunami warning/obtaining tsunami information/evacuation advisory
Q1. Could you obtain the information about the updated tsunami advisory and estimated tsunami height?
1. Could obtain all the information 2. Could not obtain some information 3. Could not obtain any information 4. Do not know

Q2. Did you advise on the evacuation after listening to the tsunami warning?
1. Issued evacuation advisory based on the tsunami warning
2. Issued evacuation advisory based on additional sources such as observed tsunami height
3. Immediately called for evacuation due to large tremor
4. Did not issue advisory for evacuation

Q3. Did the information about the estimated tsunami height affected the evacuation advisory?
1. The warning raised the awareness on the necessity of advising evacuation
2. The warning made me think that it was not necessary to evacuate
3. Informed the estimated tsunami height during the evacuation advisory
4. The warning changed the contents of evacuation advisory, place for evacuation, and ways of evacuation
5. Nothing affected the evacuation advisory

Q4. Did the information about observed tsunami height affect the evacuation advisory?
1. The information raised the awareness on the necessity of advising evacuation
2. The information made me think that it was not necessary to evacuate

3. Informed the observed tsunami height during the evacuation advisory
4. The information changed the contents of evacuation advisory, place for evacuation, and ways of evacuation
5. Nothing affected the evacuation advisory

3) Impression on the lifting of tsunami warning/impression of tsunami warning
Q5. How do you feel about the lifting of tsunami warning?
1. The timing was appropriate
2. It took a long time to lift the warning, but it was unavoidable.
3. The warning should have been lifted earlier

Q6. Impression on the tsunami warning and estimated tsunami height
1. Tsunami warning of 1m 2. Tsunami warning of 2m 3. Large Tsunami warning of 3m 4. Large Tsunami warning of 4m 5. Large Tsunami warning of 6m 6. Large Tsunami warning of 8m 7. Large Tsunami warning of more than 10m
a. Does not feel too dangerous b. Feels dangerous c. Feels too dangerous

(3) Online public comments on the proposed improvement of tsunami early warning

JMA shared the mid-term report of the study and the improvement of tsunami warning to various levels of stakeholders to receive the viewpoint of the receivers such as potential evacuees, public officials who will order evacuation in case of disaster, and so on. The outline of the public hearings is shown below.

(1) Mid-term report for "Study group for improving tsunami warnings based on the damage caused by the 2011 off the Pacific coast of Tohoku Earthquake" compiled on August 8th, 2011.
1) Collecting online opinions
51 persons replied (Duration：Aug. 8～ Sep.2)
2) Hearing opinions from prefectures
39 prefectures, 12 sub-prefectures (Hokkaido), 233 municipalities
3) Hearing opinions from broadcasting agencies
159 agencies
4) DRR-related government agencies
Central government: 11 agencies; Local government: 19 agencies

(2)Report on "Study panel for investigating tsunami warning issuance criteria and information text" compiled on December 16th, 2011.
1) Collecting online opinions
36 persons replied (Duration：Dec. 16～ Jan. 18)
2) Hearing opinions from prefectures
43 prefectures, 12 sub-prefectures (Hokkaido), 603 municipalities
3) Hearing opinions from broadcasting agencies
128 agencies
4) DRR-related government agencies
Central government: 20 agencies

3.1.3 Major findings of the survey

The series of surveys envisaged the perspectives of the receivers, such as affected evacuees, residents, public servants, and broadcasting agencies, from various backgrounds. The following section summarizes the major findings of each survey.

(1) Survey of tsunami-affected populations

As for the information about tsunami information and evacuation advisory, a notable finding is that approximately half of the evacuees did not hear about the tsunami warning or advisory. The percentage is lower than in other areas where tsunami advisory was issued. The possible reasons were due to blackout, or the tremor was too strong considering that the major source of information for evacuation was through administrative disaster management wireless network, while in other areas, the dominant source of information was TV.

It is remarkable that approximately 20% of the evacuees commented that the tsunami warning that included the estimated tsunami height made them think that there was no need to evacuate. Since the first tsunami height was underestimated, the issuance of underestimated information adversely affected the evacuation actions. The possible reasons for the underestimation were due to the height of breakwater, or the tsunami hazard map prepared by each municipality. The report of this study pointed out that the risk of underestimation of tsunami height should be minimized, and the necessity of awareness of citizens about the mechanism of tsunami warning should be increased.

The result of the survey also envisaged that the updated information on tsunami height did not reach more than half of the evacuees. Majority of the evacuees answered that either they could not afford to pay attention to the news during the evacuation, information devices such as TV, radio or mobile phone were unavailable because of blackouts and damaged communication networks.

(2) Survey of citizens and DRR-related official in areas where tsunami warning was issued

The items in this survey are similar to those in the first survey, but the represented areas of interviewees are different from the first one, in which the tsunami devastated the coastal lines and there were tremendous damages. As mentioned in the previous section, majority of the residents received tsunami warning from TV. It should be noted that even though the information from the TV was available, 44% of the residents did not know about the renewal of the tsunami warning. The residents' impression on the tsunami warning is another remarkable result. While only 13% of the residents answered that a large tsunami warning of 3m does not feel too dangerous, 47% of the residents answered that a tsunami warning of 2m does not feel too dangerous.

The survey conducted interviews with DRR-related officials in the same areas as the residents. The result of the survey indicates that the current tsunami warning includes sufficient information for them to take necessary actions. The notable difference between the residents was the perception of danger about the tsunami height. While 47% of residents answered that a tsunami height of 2m does not feel too dangerous, only 22% of DRR-related officials answered the same. Even though JMA has provided the information that there is a high risk of being washed by tsunami4 when the tsunami height reaches 0.2 or 0.3m, the risk is not widely recognized by the residents.

(3) Online public comments on the proposed improvement of tsunami early warning

As mentioned previously, JMA prepared the study report and called for comments from stakeholders. The remarkable feedbacks from the public, government officials, and broadcasting agencies are as follows. For each comment, JMA responded to their ideas, prospects of improvement and other necessary information.

1) Comments on mid-term report for "Study group for improving tsunami warnings based on the damage caused by the 2011 off the Pacific coast of Tohoku Earthquake" compiled on August 8, 2011

This section summarizes the comments on the abovementioned report, especially from the perspective of receivers of tsunami warning, since the comments included technical

[5] https://www.data.jma.go.jp/svd/eew/data/nc/shiryo/enkaku.html (Japanese)

improvements on the issuance of tsunami warning.

a) Timing of warning

- Promptness of issuance should be ensured
- The first announcement needs to be quick and accurate.

b) Estimation of tsunami arrival

- It is not recommended to lean too much on the safer side to the point that people do not believe the warning
- It is unavoidable to have the possibility of overestimation of the scale in the first announcement
- It is desirable to announce an estimated time of tsunami arrival the same as before

c) Contents of warning

- Naming of tsunami warning should be updated to urge the receivers to develop a sense of danger
- Dividing tsunami height into 5 stages is debatable (there were comments on the number of stages being appropriate / too little / too many)
- Threshold of large tsunami as being 3m in height is desirable to be continued considering that current disaster countermeasure holds the threshold
- Estimated height of tsunami on the first report should be presented with specific number
- Quoting the past damage may be difficult because tsunami is a low-frequency disaster
- Information about the first wave height is necessary
- Arrival of the first wave is the only necessary information at this period
- It is desirable that the contents are understandable for normal citizens
- It is desirable that the information is precise
- Using expressions to urge evacuation is desirable
- Necessary actions to be taken during the warning (i.e. evacuate to a place higher than the third floor of RC building) should be presented
- Meaning of the warning figure, such as intensity of the earthquake, should be more understandable

2) Comments on report for "Study panel for investigating tsunami warning issuance criteria and information text" compiled on December 16, 2011.

This section summarizes the comments on the abovementioned report especially from the perspective of receivers of tsunami warning, since the comments included technical improvement for the tsunami warning.

- Information should be concise and associate the actions
- Publicity activity on the relation of tsunami height and its damage to the residents are essential
- It should be clearly stated if the border of tsunami height such as 10m or 5m is more than or less than its actual height
- In order to avoid confusion, the naming of large tsunami warning should be unified
- Qualitative expression "potential of large tsunami" is not clear
- For large-scale earthquake with high uncertainty, it is important to express extraordinary situation by using qualitative expression

- Necessity of qualitative expression is questionable
- "Immediate evacuation" is acceptable, yet the timing should be examined for the earthquake occurring overseas
- Geographical areas to be alerted should be more specific / valid
- Even though only a small amount observed is expressed as qualitative, DRR agencies should be informed of the specific number
- Coordination between the issuance of tsunami warning and hazard map is essential
- Picture information is effective, yet at the same time being able to read the figure is essential
- Regular awareness and publicity activities are critical
- Information should neither be overestimated nor underestimated

3.2 Disseminate the meteorological information and disaster information to the public

JMA, in collaboration with DRR-related stakeholders, make continuous efforts to raise public awareness about disaster information by recognizing that the general public is the first responder of the disaster, and any misconception may cause unexpected human loss and damages. In Japan, contents of the warning have been updated based on learnings from previous large-scale disasters that resulted in human loss and damage. This section illustrates the examples of the process of updating the warning contents and methodology of raising the awareness of the public, who are the receivers of the disaster information.

3.2.1 Update of Tsunami Early Warning

(1) Background on the information update

As mentioned in the previous section, the result of the survey to improve tsunami early warning indicates that raising public awareness is critical considering the characteristic nature of tsunami, in which citizens often need to make self-evacuation decisions. The result also points out that the mechanism of tsunami early warning was not fully recognized by the people in tsunami-affected areas, and misleading tsunami warning might discourage evacuation.

Therefore, when tsunami warning was upgraded, JMA, in collaboration with DRR-related agencies, strived to raise the awareness of citizens about the updated tsunami warning and provide the necessary background knowledge to make them fully understand the contents of the warning.

(2) Materials for updating the tsunami warning message

1) Movie files on the tsunami warning

Explanations regarding the movie files on the updated tsunami warning are available on the website of JMA. One of the movies is published as government internet TV program. The main contents of the eleven minute-movie are shown below. The movie covers the points of the lessons learned from the damage caused to the GEJE in general and result of the survey mentioned in previous sections.

- **Background of the improvement:** The movie starts by giving a background of the improvement of tsunami warning, explaining the facts regarding the underestimation of the tsunami warning on the day of the GEJE. Explaining the current technical limitation that may cause the underestimation of tsunami height is effective to encourage citizens to evacuate to a higher place to be safer.
- **Contents of improved tsunami warning:** The next section shows the contents of the tsunami warning by explaining how JMA is observing the earthquake and how tsunami warning is issued. As mentioned in the previous chapter, new tsunami warning includes

qualitative information in the first warning. The movie explains the meaning of "gigantic" and "high" tsunami as extraordinary situation and mentions that the words will be used when the tsunami height has the potential to be equivalent to the one that occurred during the GEJE so that citizen can better imagine the situation. The movie also cites the reason for using qualitative expression that the current tsunami observation technology has the risk of underestimating the tsunami height in the event of a gigantic earthquake.

- **Timeline of improved tsunami warning:** The movies describes the step by step process for issuing the tsunami warning, including the timing of the updating information. The section clearly mentions that tsunami warning is issued on a qualitative basis for the first report, and the estimated height is issued after elaboration on the simulation. This explanation addresses the residents' low level of understanding of the tsunami warning update.

Source: Cabinet Office of Japan

Figure 3.2.1 Timeline of the Tsunami Warning

- **Estimated tsunami damage:** This section outlines the tsunami damage in a more understandable way for the citizens. For example, if a tsunami with a height of more than 3m arrives, a typical wooden house will be totally destroyed. Since tsunami is a low-frequency disaster, people cannot easily imagine the damage due to tsunami. This tendency was shown in the result of the survey, in which approximately 40% of the interviewed residents answered that a tsunami with a height of 2m does not feel too dangerous. The movie clearly explains that tsunami below the knee can wash people away and that people will not be able to stand still.
- **Qualitative expression of the first observed tsunami:** The movie explains the update of observed tsunami height, learning from the experience that the low level of first tsunami height eventually discouraged citizens to evacuate even though the first observation and maximum height of the tsunami are totally different. This update was based on comments from the public and the interviewees who answered that the first observed height made them think that it was not necessary to evacuate.
- **Actions to be taken**: To wrap up the movie, this section explains how people construed the tsunami warning, and the importance of self-evacuation and not underestimating the tsunami. The movie quoted an advice from student who was affected by a tsunami. The advice was, "When you evacuate 100 times, and the tsunami did not arrive 100 times, you should definitely evacuate 101 times."

2) Leaflet, poster

In order to raise awareness on the improved tsunami warning, JMA prepared a leaflet and a poster explaining the summary of the upgrade. The poster focuses on the most important information regarding the update by casting on-screen talents who were affected by the GEJE.

Source: JMA

Mar. 7, 2013
Tsunami warning will change
"Do not forget"
"We'd better know"
If the tsunami was issued as "Gigantic", this means state of emergency.
This expression is used when the height of tsunami is expected to be similar to the one that occurred in the GEJE. Please evacuate immediately.
Before the arrival of high tsunami, tsunami height is issued as "Under Observation"
This expression is used when there is a possibility that a higher tsunami is expected.
In order to protect lives, evacuate immediately!
If you feel a strong tremor or weak but slow and long tremor, evacuate immediately even though you did not listen to the warning.

Figure 3.2.2 Poster for Awareness-Raising on the Improved Tsunami Warning

Meanwhile, the leaflet covers more detailed information on the improved tsunami warning, explaining the mechanism of observations of tsunami so that people do not misunderstand the figures and numbers on the tsunami warning. This part mainly focuses on the following:

- **Information on tsunami observation**: This section explains how tsunami observation is utilized when issuing the estimated tsunami height and observed tsunami height. It emphasizes that the first observed tsunami height is not the maximum height of tsunami by explaining that tsunami arrives repeatedly, and the following tsunami can be higher than the first one, and that tsunami becomes higher when approaching the coast.
- **Tsunami warning/advisory**: This section explains the contents of tsunami warning and advisory focusing on the interpretation of the wordings used in the tsunami warning, including "Gigantic" and "Tsunami height," so that people do not underestimate the scale of tsunami. The leaflet explains the reason for using qualitative expression, mentioning its technical limitation to accurately estimate the tsunami height in the early stage.
- **Category of warning and actions to be taken**: The table in this section summarizes the matrix of estimated tsunami height (qualitative expression and numerical report), actions to be taken and estimated damage. Descriptions of actions to be taken emphasize on not to feel safe when reaching a certain evacuation point, but to evacuate as high as possible learning from the loss of human lives during the GEJE. In order to facilitate better understanding, the estimated damage includes a picture of past tsunami aftermath.
- **Tsunami hazard map and signboard**: For proper and smooth evacuation, the leaflet includes how to interpret the hazard map and the meaning of tsunami signboard installed in the coastal areas.

Figure 3.2.3 Leaflet for the Improved Tsunami Warning

3) Portal site for learners

JMA establishes the portal site for DRR education such as by compiling the links and educational materials usable for school teachers and DRR officials at the community or municipal levels. Detailed information on the site is introduced in the Appendix.

3.2.2 Introduction of Earthquake Early Warning

(1) Background of the information update

In 2007, the Diet of Japan passed an Act to amend a portion of Meteorological Service Act (2007 Law No.115), and the law came into effect in December 2007. The purpose of the amendment is to include JMA's mandate to forecast and warn about seismic movement and volcanic phenomena which occurred due to fault motion for public use.

Prior to the law's enactment, JMA started operating EEW in October 2007 after three years of conducting trial and preparation about awareness-raising for public launching[5]. Since the technology is newly established, JMA has strived to implement public relation activities in cooperation with related government agencies, educational institutes and media before and after the launch.

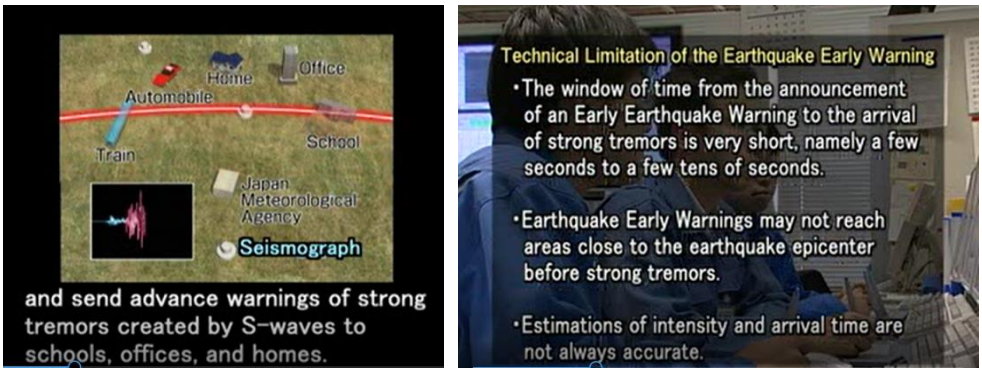
(2) Materials for introducing Earthquake Early Warning

1) Movie files on the Earthquake Early Warning

In 2010, JMA developed official PR movie on EEW available in Japanese, English, Chinese and Korean. The primary contents of the movie are as follows:

- Mechanism of earthquake observation and EEW
- Technical limitation of EEW
- Utilization of EEW (transportation, at home, workplace such as construction site, etc.)
- Devices that utilize EEW technology
- Actions to be taken when the EEW alert is activated (at home, at school/office, while driving, at store)

[5] https://www.data.jma.go.jp/svd/eew/data/nc/shiryo/enkaku.html (Japanese)



Source: JMA

Figure 3.2.4 Screenshots of the Movie about EEW (English version)

In addition, the Cabinet Office of Japan prepared a government internet TV program called "What to do if EEW is issued" in 2014.

2) Leaflet, poster

As for the leaflet on EEW, JMA has been updating its contents from the launching date as earthquake observation technology advances. The contents of the leaflet cover the contents of the movie and terminologies used such as "warning" and "forecast", preparation on a regular basis, and explanation of the warning sound. As mentioned in the previous section, in order to avoid panic and confusion immediately after the launching, JMA prepared the leaflet before launching the EEW. The figure below is the material used for awareness-raising before launching the EEW.

Source: JMA

Figure 3.2.5 Leaflet on EEW Issued in March 2018

Source: JMA

Figure 3.2.6 Leaflet on EEW Issued in July 2007

3) Awareness-Raising Activities

In March 2007, JMA established the Dissemination and PR promotion Headquarter composed of the members of general administration office, earthquake and volcano department management division[6]. The Headquarter is in charge of formulation of dissemination and PR plan and promotion, collaboration with related agencies, and control of the condition of information dissemination and PR activities.

After introducing the EEW, JMA regularly conducts questionnaire targeting thousands of residents and DRR-related agencies. The survey is designed to analyze which information is understood correctly by the residents and which needs improvement.

In addition, JMA has implemented awareness events in collaboration with educational institutes, municipalities and other DRR-related stakeholders.

Table 3.2.1 List of Major Awareness Events on EEW by JMA

- Feb. 14, 2018 Earthquake Early Warning Lecture in Osaka: 10th Anniversary of Earthquake Early Warning and the Future of Earthquake Early Warning
- November 24, 2016: "Earthquake Early Warning Symposium" - Major Earthquake Occurred! For the safety and security of commercial facilities
- October 15, 2014: "Earthquake Early Warning Lecture: Seven Years in Operation, and Way Forward"
- November 21, 2010: 2010 Earthquake Early Warning Lecture "Emergency Earthquake Warning! What will you do then? What do you do now?"
- December 1, 2009 Earthquake Early Warning Lecture: "I want to protect you and your loved ones"
- December 1, 2008 :Earthquake Early Warning 1st Anniversary Lecture
- July-Aug. 2007 :National Elementary and Junior High School "Emergency Earthquake Early Warning" Slogan Competition
- "Do you know!? Emergency Earthquake Early Warning" in Yaesu Underground Mall
- August 13-19, 2007: The 132nd Japan Meteorological Society of Japan Forum "Utilizing Emergency Warnings for Disaster Prevention"
- June 1 2007: 132nd Japan Meteorological Memorial Day Forum "Utilizing Earthquake Early Warning System for Disaster Prevention"

Source: JMA Website

3.2.3 Introduction of Special Early Warning

(1) Background of the information update

In the GEJE, JMA announced a large tsunami warning, but it was observed in some cases that the warning did not lead to the prompt evacuation of residents. In addition, in the case of heavy rain disasters caused by Typhoon No. 12 in 2011, JMA issued a warning against serious disasters, but there was no means to effectively communicate that the risk of disasters was extremely high, and that municipalities were at risk. It was not always tied to the timely and accurate announcement of evacuation advice/instructions and prompt evacuation actions by the residents themselves. To convey the Meteorological Agency's sense of crisis regarding disasters, JMA has launched the "Emergency Warning" in August 2013. . Emergency warning is issued during heavy rain, strong wind, storm surge, high-wave, heavy snow and snow storm. On top of the existing level of warning, JMA categorized earthquake, tsunami and volcano eruption under emergency warning without changing the naming.

[6] http://www.bousai.go.jp/jishin/eew/eew_top.html

(2) Materials for updating the emergency warning message

1) Annual report

As the emergency warning for climatological disaster has been updated learning from the damage caused by a large-scale disaster, JMA reported the progress in its annual report, "Climatological Works Now."

2) Movies

Explanation in the movie files about the emergency warning are available on the JMA website. One of the movies was published as government internet TV program. The main contents of the movie are shown below. The primary focus of the movie is to raise the awareness of residents by not underestimating the warning from JMA. This is based on past experience that not following the evacuation advisory increases the damages caused by the disaster.

- **Criteria for issuing the warning**: The section explicitly states that JMA issues emergency warning when the intensity is expected to occur once in several decades.
- **Timeline for how to respond**: The movie depicts the timeline of typhoon No.12 explaining how to respond to each stage of JMA's warning. It simulates the hypothesis of how JMA issued the warning if the emergency warning had been launched at that time of the typhoon.
- **Actions to be taken during the warning**: This section explains the actions to be taken during the warning by stating that emergency warning means taking immediate actions are necessary to protect lives. It emphasizes that preemptive evacuation is essential, and it recommends not to wait until the emergency warning is issued in case of heavy rain.
- **Criteria of emergency warning**: Since emergency warning targets earthquake, tsunami and volcanic eruption as well as meteorological disaster, this section explains the criteria of warning for each disaster.

3) Leaflet, poster

JMA prepared the leaflet explaining the introduction of emergency warning. The leaflet emphasizes that the issuance of emergency warning means unprecedented danger. It mentions well-known past events such as Ise-wan Typhoon and GEJE as examples of disasters that are equivalent to emergency warning so that everyone understands how imminent the situation is. The leaflet also describes the timeframe for issuing the emergency warning, the actions to be taken for each stage of the warning, and the criteria for emergency warning. The poster below explains the contents of mailing service for emergency warning in order not to misinterpret the contents of the mail.

Source: JMA

Figure 3.2.7 Leaflet and Poster for Emergency Warning

4) Awareness-Raising Activities

JMA has been continuously upgrading the educational materials for emergency warning, particularly after a large-scale meteorological disaster such as flooding, heavy rains and landslides has occurred, as Japan is exposed to severe disasters every year.

Since 2018, JMA has been holding a "Study group for improvement of conveying disaster management meteorological information and actions to be promoted." This study group was established in response to the lessons learned from the heavy rain disaster in 2018, in which the warning issued by JMA and evacuation order by municipality did not result to evacuation actions. How to convey the emergency warning message and raise awareness are among the challenges of the study group.

Various DRR related-agencies, including JMA, play essential roles in awareness-raising activities on disaster information to the public. Meteorological observatory offices under JMA and across Japan communicate and collaborate with local government, educational officials, and community-based DRR self-help groups who are the primary players of awareness-raising activities. Other DRR-related government agencies in Japan extend the awareness-raising activities on disaster information by utilizing their channels to cover as many populations as possible.

Appendix in this report illustrates the detailed example of activities conducted by the abovementioned agencies.

Chapter 4 Conclusion

JICA Expert Team emphasizes the following points as essential components for improving the disaster information especially during earthquakes and tsunami.

(1) Establishment of continuous feedback mechanism based on previous disaster experience

Regardless of the type of disaster, JMA has put an emphasis on collecting the lessons, challenges of disaster response related to the warning, aftermath of the disaster, and upgrading the warning at the maximum level of their available technology. For example, tsunami caused by Hokkaido – Nansei - Oki Earthquake raised the challenges of tsunami warning dissemination through administrative lines if the tsunami arrives less than five minutes after the triggering earthquake.

Experience from the GEJE demonstrates that disseminating accurate information from the sender does not ensure immediate and accurate evacuation actions of the receivers. The senders should consider the receivers' normalcy bias in the event of chaotic situations, knowledge about the hazard phenomena, and any other factors that may distort their decision to evacuate.

In order to understand the perceptions and level of understanding of the receivers of information, JMA has continuously conducted public surveys and questionnaires, especially for those affected by the disaster, to improve the contents of the warning. This action is based on the mission of JMA that it is devoted to saving the maximum number of human lives by providing proper information to the receivers of information.

(2) Consideration during blackouts or dysfunctional communication lines

An interview survey on the population affected by the tsunami during the GEJE shows that a certain number of evacuees could receive only limited information because of blackout or due to imminent needs for evacuation. The damage of communication lines is likely to occur in places where the damage of tsunami is also likely to be severe. Public comments pointed out the necessity of ensuring the source of information in case of blackout and cutting off of phone line services. Lessons from the GEJE indicate that even though JMA has updated the observed tsunami height and estimated tsunami height, not all receivers could receive the update due to imminent evacuation and blackout. The sender should assume the situation that receivers could not receive the all necessary information especially in the most affected areas where the warning information is most needed.

(3) Expression to urge citizens to evacuate

In the early stage of tsunami warning, there is a higher level of uncertainty due to current technical limitation. The result of the survey indicates that underestimation of the tsunami height discouraged some citizens to evacuate. In relation to the previous point, evacuees need to make a decision by themselves in case of blackout or damage of information dissemination facilities. This is the case for large-scale earthquakes that cause tsunami. Therefore, a clear warning to the evacuees, who are normal citizens and not specialists in disaster management, is essential.

(4) Awareness-raising of citizens about tsunami warning

The result of the survey presents that the risk of tsunami tends to be underestimated by the residents, and the mechanism of tsunami warning is not widely recognized by the residents. For example, the fact that estimated tsunami height is not recognized by a certain number of people may cause lost opportunity for obtaining more accurate information. The interpretation of the information in the warning message is also an issue, such as how one meter of tsunami is risky and the first observed tsunami height tends to be lower than the maximum height of tsunami. Educational activities for people to correctly associate the warning information issued by JMA and the necessity of evacuation are indispensable considering the cases of tsunami, because a precedent earthquake is likely to destroy the communication network, and it is possible that

earthquake arrival is less than five minutes in some areas. Given these situations, self-evacuation is the key to survival, and citizens cannot wait for instructions from their respective municipalities.

Case Studies on Disaster Prevention Education and Awareness Raising in Japan

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

September 2020

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

Preface

The case studies are compiled as part of the preliminary study for "Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination in Indonesia." The case studies are part of report, "The Review on Disaster Prevention Information Transmission, Disaster Prevention Education and Awareness Raising in Japan." One of the outputs of the Project is the preparation of awareness-raising materials regarding earthquake information and tsunami warning. The cases will be the reference for counterpart agencies of the Project in developing educational materials.

The objective of the case studies is to introduce awareness-raising activities implemented by Japan Meteorological Agency (JMA) and its branches, the Local Meteorological Observatories. The case studies will deepen the understanding of JMA's effort for collaboration and cooperation with DRR stakeholders at various levels including the educational staff, municipality officials and the local media so that receivers of information from JMA can make proper actions responding to each disaster.

The latter part of the case studies compile the awareness-raising portal sites operated by Japanese government agencies that implement DRR activities. Each agency addresses different fields in DRR and different populations in Japan. The efforts of related agencies contribute toward disseminating knowledge to protect the lives of citizens in Japan.

List of Activities by Japan Meteorological Agency and District / Local Meteorological Observatories

No.	Title of Activity	Responsible Agency
① **DRR Awareness-Raising Activities**		
Lecture to the Public		
1	Kinokuni Disaster Prevention Human Resource Development	Wakayama Local Meteorological Observatory
Lecture to DRR-related personnel		
2	Improvement of Regional Disaster Prevention Skills in Cooperation with Disaster Prevention Expert Organizations	Kobe Local Meteorological Observatory
Participation in DRR-related events		
3	Dissemination of Disaster Prevention Knowledge to Foreign People in Cooperation with Media Organizations	Wakayama Local Meteorological Observatory
② **DRR Educational Activities**		
DRR Education in Elementary, Junior High and High Schools		
4	Disaster Prevention Class in Cooperation with Prefectural Board of Education	Takamatsu Local Meteorological Observatory
Lectures for School Education Officials		
5	Round Table Conference Between Teachers Involved in School Education on DRR and the Meteorological Observatory Staff	Sapporo District Meteorological Observatory
Support for Developing Teaching Materials		
6	Earthquake Early Warning Response Training Kit	Tokyo District Meteorological Observatory
③ **Dissemination of DRR-Related Information Utilizing the Media**		
Utilization of Paper Media and Electronic Media		
7	Educational Activities Through the Website, "Disaster Prevention Education Support Portal"	Fukuoka District Meteorological Observatory

Title	**Kinokuni Disaster Prevention Human Resource Development**		
Location	Wakayama	**Period**	2008 ~
Responsible Agency	Wakayama Local Meteorological Observatory	**Cooperating Organization**	DRR-related organizations
Main Roles of the Meteorological Observatory Officials	• Dispatch Wakayama Local Meteorological Observatory staff to the training program, “Kinokuni Disaster Prevention Human Resource Development” as an instructor • Promote the utilization of DRR information provided by Wakayama Local Meteorological Observatory • Popularize weather-related knowledge		

Overview

The Wakayama Local Meteorological Observatory dispatched its staff to the training program, “Kinokuni Disaster Prevention Human Resource Development,” which was annually held by Wakayama Prefecture. Through this training program, the staff as an instructor promoted the usage of DRR information provided by the local meteorological observatory and popularized weather-related knowledge. The objective of this program was to develop the knowledge of local DRR leaders who would become key players in disaster prevention in local voluntary organizations and companies. Those who were active in local voluntary organizations and companies, or who wanted to take part in local activities, applied for this program. After the program, participants took an examination on disaster prevention.

Training programs were classified into three types as written below.

- **Countermeasures to Disasters:**
  Participants learned about various countermeasures to disasters.
- **Knowledge of Disaster Prevention:**
  The Wakayama Local Meteorological Observatory staff and science teachers of a school in Wakayama prefecture conducted lectures on DRR-related knowledge.
- **Responses to Disasters:**
  Participants learned about responses to disasters, such as mental health care at the time of disaster, and so on.

Contents of Activities

Countermeasures to Disasters

In this program, participants learned mainly four topics related to countermeasures to disasters. First, instructors taught countermeasures to disasters – centering on earthquakes and tsunamis – implemented by Wakayama Prefectural Government Office. Secondly, instructors explained the importance of seismic retrofitting of houses, the methods and support systems for seismic evaluation and retrofitting. Thirdly, participants learned the correct methods and knowledge in fixing furniture. Finally, instructors taught participants about improvement of self-help skills at home and co-help with neighborhood as a response to the Nankai Trough Earthquake, which was expected to occur in the near future.

The contents of "countermeasures to disasters" classes conducted in this training program are as follows:

- Countermeasures to disasters implemented by Wakayama Prefectural Government Office
- Methods and support systems for seismic retrofitting of houses
- Measures to prevent furniture from falling over
- Useful know-how about self-help and co-help to avoid damages caused by calamities

Knowledge of Disaster Prevention

Instructors mainly explained four topics in the program. Firstly, they taught about the mechanism of tsunami damage during the Great East Japan Earthquake and gave a tentative information about the Nankai Trough Earthquake. Secondly, participants learned about the history of tsunami that hit Wakayama Prefecture as revealed in the latest survey, and how to use this knowledge in the future. Thirdly, instructors explained about the history of disasters and city development, important lessons learned from the Great Hanshin-Awaji Earthquake, and the reconstruction of cities damaged by natural calamities. Finally, Wakayama Local Meteorological Observatory staff taught about the meteorological characteristics of Wakayama Prefecture and also provided DRR information.

The contents of classes related to acquiring knowledge about disaster prevention conducted in this training program are as follows:

- The mechanism of tsunami damage in the Great East Japan Earthquake and the contemporary information on the Nankai Trough Earthquake
- Tsunamis that hit Wakayama shore repeatedly
- City development for DRR and disaster prevention
- Meteorological characteristics of Wakayama prefecture and disaster-related information

Responses to Disasters

Instructors mainly explained four topics in the program. Firstly, participants learned about mental health care at the time of disaster from the staff of mental health care center. Secondly, instructors explained about the big issues concerning local evacuation measures, which were focused on people in need of special support at the time of disasters such as the elderly, infants, and so on. Participants walked around and checked the shelters and dangerous areas in order to provide evacuation support to these vulnerable people. Thirdly, a doctor taught about emergency medical responses at the time of disaster. Finally, participants learned about management of shelter through a workshop.

The contents of the classes on disaster response are as follows:

- Mental health care at the time of disaster
- Medical care at the time of disaster
- Support for evacuation of persons with special needs at the time of disaster
- Workshop on management of shelter

Title	**Improvement of Regional Disaster Prevention Skills in Cooperation with Disaster Prevention Expert Organization**		
Location	Hyogo	**Period**	2004 ~
Responsible Agency	Kobe Local Meteorological Observatory	**Cooperating Organization**	Private organizations
Main Roles of the Meteorological Observatory Officials	• Dispatch Kobe Local Meteorological Observatory staff to the training seminar, "Hyogo Disaster Management Leader Training Course" as an instructor • Teach about the mechanism of natural calamities in the seminar		

Overview

A staff of Kobe Local Meteorological Observatory conducted one of the disaster prevention classes in the seminar, named "Hyogo Disaster Management Leader Training Course," targeted for those who play an active role in voluntary disaster prevention organizations. This seminar was held in cooperation with Hyogo Prefecture Disaster Prevention Expert Organization in order to improve local disaster management skills by communicating on the spread and education on safety knowledge. In total, the seminar lasted 12 days. After the seminar, participants took an examination to receive qualification as disaster prevention experts.
Classes were classified into three types as shown below.

- **Classroom Lectures on Natural Disasters:**
  Participants learned about various scientific knowledge on disasters through classroom lectures.
- **Classroom Lectures on Disaster Prevention:**
  Participants learned about how to prepare for natural calamities and the actual examples of disaster prevention.
- **Practical Trainings and Workshops:**
  Participants mastered evacuation behaviors and developed a deep understanding of countermeasures to disasters based on their own experiences.

Contents of Activities

Classroom Lectures on Natural Disasters

Through classroom lectures on natural disasters, participants learned mainly four topics. Firstly, participants were taught by Kobe Local Meteorological Observatory staff about how wind and flood damage would happen. Secondly, a professor of Kobe University taught about flood damages and sediment disasters caused by heavy rain in recent years. Thirdly, participants learned how the Nankai Trough Earthquake and tsunami would occur. Finally, a university professor taught how near-field earthquakes were different from long-period earthquakes.

The contents of classroom lectures on natural disasters conducted in this training seminar are as follows:

- The mechanisms of wind and flood damage and how to respond to them
- Flood damages and sediment disasters caused by heavy rain
- The mechanisms of the Nankai Trough Earthquake and tsunami and the Yamasaki Fault-block earthquakes in Hyogo Prefecture
- The differences between near-field earthquakes and long-period earthquakes

Classroom Lectures on Disaster Prevention

Instructors mainly explained several topics during classroom lectures on disaster prevention. Participants gained useful knowledge to protect themselves from natural disasters. The instructors of classroom lectures were persons with in-depth knowledge of disaster management, such as university professors, government office staff, and so on.

The contents of classroom lectures on natural disasters conducted in this training seminar are as follows:

- Preparation for national and local disasters
- Local disaster prevention and initiatives
- Improvement of local disaster management using map
- Support for persons in need of assistance at the time of disaster
- Local disaster prevention and disaster medicine
- Local disaster management plan and practical activities and problems regarding local disaster prevention
- Information about disaster management
- Seismic retrofitting of buildings
- Preparedness for various scales of disasters
- Disaster volunteers
- Damage estimation and evacuation behavior in regional disaster management
- Local government's response to disasters
- What to expect from local disaster management leaders

Practical Trainings and Workshops

Participants mastered effective skills through hands-on experiences, which would be useful at the time of disaster. The themes of practical trainings and workshops were so many that participants could gain extensive knowledge about disaster management. In these trainings, participants practiced evacuation training, used drones and experienced shaking during an earthquake simulation. In addition, the instructors were experts in disaster prevention, so participants were able to deepen their knowledge and understanding of disaster prevention which was important.

The themes of practical training and workshops are written below:

- Experience in handling simple rescue tools
- How to tie a rope
- Smoke evacuation training
- Experience of earthquakes
- Tour of the strange warehouse
- Workshop on support system for damaged people
- Workshop on regional shelter management in order to improve disaster prevention skill
- Workshop on disaster management behavior
- Workshop on response to persons who cannot go back to their homes
- Disaster countermeasures in headquarters through mapping exercises conducted in local voluntary disaster prevention organizations
- General life-saving training

Title	**Spreading Disaster Prevention Knowledge to Foreign People in Cooperation with Media Organizations**		
Location	Wakayama	**Period**	November 2015~
Responsible Agency	Wakayama Local Meteorological Observatory	**Cooperating Organization**	Media organizations
Main Roles of the Meteorological Observatory Officials	• Explain to foreign people the important points for disaster prevention and the mechanisms of typhoon and earthquake during the disaster management event • Explain methods of getting information through media and what kind of information foreign people can obtain at the time of disaster by using the guideline		

Overview

Wakayama Local Meteorological Observatory dispatched its staff to the DRR event, named “Let’s Study BOSAI”, as an expert. This event, organized by NHK Wakayama and Wakayama International Exchange Center, was held annually for foreign people living in Wakayama prefecture to raise their awareness of disaster prevention. In this event, a staff of Wakayama Local Meteorological Observatory shared knowledge on disaster prevention.

- **Explanation About Wakayama Prefecture and Earthquake:**
  Expected tsunami arrival time in each region and the Nankai Trough Earthquake expected to occur were explained.
- **Explanation About Behavior to Protect Yourself:**
  How to prepare and act at the time of earthquake, typhoon and heavy rain were shown.
- **Methods to Evacuate and to Collect Disaster Information:**
  Several methods to obtain disaster information are introduced.

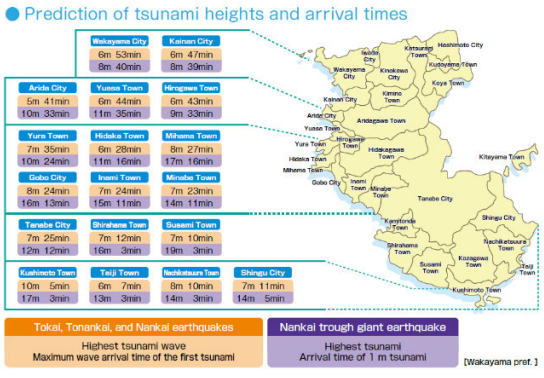
Contents of Activity

Explanation of Wakayama Prefecture and Earthquake

A staff of Wakayama Local Meteorological Observatory mainly explained about the Nankai Trough Earthquake – which was expected to occur in the near future – and the tsunami to foreign people who were living in Wakayama Prefecture. Among the contents of the explanation were the tsunami warnings/advisory issued by Japan Meteorological Agency when earthquakes would occur. In addition, the guideline showed the map of Wakayama prefecture, and the estimated tsunami arrival time and its height at each place considering the Nankai Trough Earthquake.

The main contents of the explanation related to Wakayama prefecture and the earthquake are as follows:

- Awareness-raising on tsunami damage
- Evacuation to higher places when tsunami happens
- Tsunami warnings / advisory issued by Japan Meteorological Agency
- Wakayama Prefecture map and the estimated tsunami arrival time and its height at each place
- Information on the Nankai Trough Earthquake
- The meaning of magnitude and seismic intensity



Explanation About Behavior to Protect Yourself

Using the Natural Disaster Safety Guideline, a staff of Wakayama Local Meteorological Observatory explained the important evacuation points using illustrations when a typhoon would be approaching, or when there was strong wind or heavy rain, and so on. Additionally, there was an explanation on warnings and advisories issued by Japan Meteorological Agency or local governments.

The Natural Disaster Safety Guide has been written in three languages: Japanese, English and Chinese.

Below are the precautions that need to be taken when evacuating during earthquake as written in the guideline:

- Go under a table or desk
- Keep the doors open
- Turn off fire when the shaking due to earthquake stops
- Do not go out immediately
- Stay away from the cliff
- Evacuate to a higher place and far from sea
- Stop your car at the left side of the street when an earthquake happens

The important evacuation points when a typhoon or heavy rain occurs are as follows:

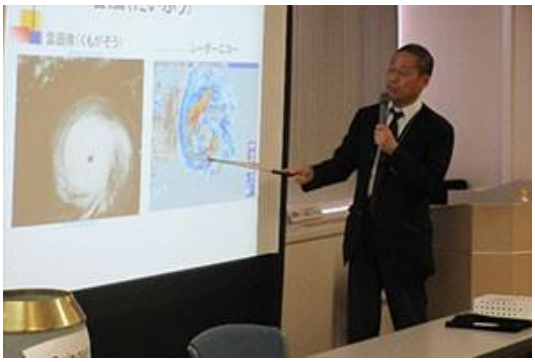
- Preparation before a typhoon or heavy rain arrives
- Behavior to protect yourself when there is strong wind or heavy rains
- Warnings and advisories

Methods to Evacuate and to Collect Disaster Information

Wakayama Local Meteorological Observatory staff taught foreign people what they needed to be careful of when seeking shelter and upon arriving at the shelter facility. An example includes “You should not use a motor vehicle when escaping from a tsunami,” etc. In addition, the staff taught about methods to collect the latest disaster information using electronic devices, in Japanese and in other foreign languages.

The main contents related to evacuation are as follows:

- Things to keep in mind when evacuating (e.g., Do not bring much luggage during evacuation.)
- What to do when going to a shelter (e.g., Register your name at the reception desk to inform staff that you have arrived at the shelter facility.)



The main contents explaining various methods to collect disaster information are listed below:

- Earthquake Early Warning is issued and disseminated through TV, radio or cell phone
- The latest information is broadcasted on TV
- People can obtain information from radio during a power outage because it runs on batteries
- Useful website managed by NHK Wakayama
- Useful applications that provide information Earthquake Early Warning, tsunami warning and so on (in English) for foreign people

Title	Disaster Prevention Class in Cooperation with Prefectural Board of Education		
Location	Kagawa	**Period**	2012 ~
Responsible Agency	Takamatsu Local Meteorological Observatory	**Cooperating Organization**	Educational Institutions
Main Roles of the Meteorological Observatory Officials	• Dispatch Takamatsu Local Meteorological Observatory staff to schools • Advise on school disaster prevention activities • Advise on school disaster prevention plan in teachers' training sessions		

Overview

Kagawa Prefectural Board of Education requested Takamatsu Local Meteorological Observatory to participate in the "School Disaster Prevention Advisor Project" and dispatched its staff members to kindergarten, elementary, junior high and high schools as instructors. The main objective of this project was to improve disaster prevention system and DRR education in each school. Among the activities conducted by the instructors included advising on improving the school disaster prevention plan and risk management manual, evacuation training in cooperation with school and parents, and so on. The school teachers received advice on making a disaster response manual.

The main topics of the activities are as follows:

- **Support for Evacuation Training and DRR Education**
  Instructors conducted disaster prevention classes and gave advice on evacuation training
- **Advice on Disaster Prevention Map**
  Instructors helped teachers and students in making a disaster prevention map
- **Advice on School Disaster Prevention Plan and Risk Management Manual in Teachers' Training Sessions**
  Instructors gave advice on improving the school disaster prevention plan and risk management manual

Contents of Activities

Support for Evacuation Training and Disaster Prevention Education

Takamatsu Local Meteorological Observatory staff mainly advised on evacuation training at school, utilizing earthquake early warning, strengthening cooperation between the school and local community, and so on. For instance, among the advices given included the necessity to review the school's announcement manual because it had been difficult to hear emergency announcements, and teaching school staff on how to fix furniture items.

One of the actual examples in this project is shown below:

Purpose of dispatching staff

- To advice on the contents of DRR class observation.

Timetable

- 8:20-8:30: School made an announcement about the meaning of disaster prevention education, advisors' profiles, and so on
- 8:45-11:05: Classroom lectures and hands-on activities for disaster prevention

Outputs

- Lower grades students understood evacuation behavior in the event of an earthquake
- Higher grades students understood the experiences of the Great Hanshin-Awaji Earthquake and how to use AED and stretcher.
- All students experienced evacuation training and firefighting training using water.

Advice About Disaster Prevention Map

Takamatsu Local Meteorological Observatory staff mainly provided coaching in making a concrete disaster prevention map, walked around and verified the evacuation routes in sight, and so on. The purposes of giving advice were to identify what the people needed to be careful of at the time of evacuation, and to estimate risks in order to improve the disaster prevention map.

One of actual examples in this project is shown below.

Purpose of dispatching staff

- To give advice to teachers and students' parents about the preparations needed in making a disaster prevention map
- To advice students on how to make a disaster map

Timetable

- The day before: The staff taught teachers how to make a concrete disaster prevention map
- 13:50-13:55(on the day): Introduction of advisors
- 13:55-14:50: Walked around and checked dangerous places, etc., on the map
- 14:50-15:45: Group work to make a disaster prevention map
- 15:45-15:50: Advice on how to improve on making a disaster prevention map

Outputs

- Teachers understood how to prepare maps and checklists for making a disaster prevention map.
- Students understood the dangerous places or useful places in the event of a disaster through making a disaster prevention map.

Advice About School Disaster Prevention Plan and Risk Management Manual in Teachers' Training Sessions

Takamatsu Local Meteorological Observatory staff advised teachers and / or the students' parents about school disaster prevention plan and risk management manual through the training sessions. Teachers confirmed that it was necessary to prepare BCP so that a small number of people could respond to a disaster in the absence of teachers, and so on.

One of actual examples of this project is shown below.

Purpose of dispatch

- To advise on school disaster prevention plan and risk management manual

Contents

- Estimated damage and shelters around the school
- The mechanism of school's playground liquefaction
- Advice about school disaster response manual
- Utilization and response to disaster information in the event of earthquake / tsunami in Kagawa Prefecture

Outputs

- A school was confirmed as a safer place in the event of disaster due to the good conditions of the school's location and its facilities.
- School playground was confirmed as liquefaction prone place.
- It was confirmed that clearly differentiating between local communities and the local government in dealing with the evacuees was important.
- The importance of understanding how to utilize earthquake early warning and criteria for earthquake warnings and advisories were confirmed.

Title	**Round table conference between teachers involved in school DRR education and officials from the Meteorological Observatory**		
Location	Hokkaido	**Period**	July 1st, 2013 ~
Responsible Agency	Sapporo District Meteorological Observatory	**Cooperating Organization**	Educational Institution
Main Roles of the Meteorological Observatory Officials	• Promotion of activity • Provision of staff office for the round table conference • Dispatching of staff to open class • Teaching material development • Development of record of the activity and sharing it on Sapporo District Meteorological Observatory's website.		

Overview

Sapporo District Meteorological Observatory started improving methodologies of disaster risk reduction (DRR) education in schools for promoting DRR education, with the aim to prevent and reduce the effects of natural disasters such as earthquakes, tsunami, etc. Sapporo District Meteorological Observatory included various opinions from educators in its improvement process through cooperation with educational institutions. Implemented activities were a follows.

- **Round Table Conference:**
  Meteorological observatory officials and educators had discussions regarding the methodologies of DRR education
- **Open Class at Elementary School:**
  Teachers and meteorological observatory officials conducted an open class based on the discussions in the round table conference at an elementary school in Sapporo.
- **Subcommittee Meeting:**
  During the open class, participants discussed challenges and the contents of future DRR education.

Contents of Activities

Round Table Conference

Sapporo District Meteorological Observatory organized a round table conference with educators in Sapporo to exchange opinions regarding issues, curriculums, etc., in DRR education. Sapporo District Meteorological Observatory officials were in charge of providing the staff office for the conference and facilitating the discussion. After the conference, Sapporo District Meteorological Observatory uploaded a video recording of the conference on its own website to share the discussion results with public.

In the conference, the following topics were considered:

- Consideration of promotion methods for further understanding of the importance of DRR education
- Consideration of issues in current DRR education
- Introduction of approaches to facilitate DRR education at schools
- Consideration of improvement of existing DRR education materials and promotion of its utilization
- Conducting open classes and exchanging opinions at model schools
- Other necessary issues to extend DRR education

Open Class at an Elementary School

Sapporo District Meteorological Observatory and members of round conference conducted an open class at a model elementary school on October 9th, 2013. The results of the round table conference had been reflected in its teaching plan. A total of 26 elementary school teachers in Sapporo participated in the class. Sapporo District Meteorological Observatory officials gave a lecture regarding the mechanism of natural phenomenon and the disaster caused by it. In addition, meteorological observatory officials provided support in the development of teaching materials.

The open class was conducted during a science class for 5th graders at a model elementary school. Teachers and Sapporo District Meteorological Observatory officials conducted lectures on "weather changes" from the perspective of DRR education as cited below:

- Introducing the movement and types of clouds
- Conducting an experiment to make children understand the mechanisms of cloud appearance
- Explaining how cumulonimbus appears (Meteorological Observatory officials gave a lecture)
- Summarizing actions to be taken when the cumulonimbus approaches.

Subcommittee Meeting

After the open class, the teacher who conducted the class, meteorological observatory officials and other participants joined the subcommittee meetings. In session 1, participants exchanged their opinions on the open class conducted. In session 2, the way of incorporating DRR perspective into the existing curriculums was considered. Meteorological Observatory officials recorded the two-session discussions.

Subcommittee meetings were conducted as shown below:

Session 1: Discussions on the Results of Open Class

- The teacher who conducted the open class explained the outline of the class discussion, including the teaching plan
- Exchange of opinions regarding the teaching plan (i.e., contents, teaching materials, time allocation, etc.)

Session 2: Discussions on DRR Education
Based on the existing curriculums, participants considered how to incorporate DRR perspective into the school education.
Participants formed three discussion groups and exchanged opinions.

Title	Earthquake Early Warning Response Training Kit		
Location	Tokyo	Period	April 2014 -
Responsible Agency	Tokyo District Meteorological Observatory	Cooperating Organization	Educational Institutions
Main Roles of the Meteorological Observatory Officials	• Develop teaching material, “Earthquake Early Warning Response Training Kit” in cooperation with Tokyo Metropolitan Board of Education • Distribute the training kit for free to every public school in Tokyo		

Overview

Tokyo District Meteorological Observatory developed teaching materials for each grade in kindergarten, elementary and junior high schools. The kit consisted of presentation materials that were used for pre-explanation of evacuation training as an example. The characteristic of the materials was that they were focused on earthquake early warning. Students learned about the system of earthquake early warning, actions to be taken to avoid damage caused by the earthquake when they hear the earthquake early warning, and so on. After creating the kit, Tokyo District Meteorological Observatory distributed it for free to every public school in Tokyo. The contents of the training kit are as follows:

- **Presentation Material for Kindergartens and Lower Grade Elementary School Students**
  The presentation materials included explanations on several actions to protect students from earthquakes and the earthquake early warning using a lot of illustrations.
- **Presentation Material for Middle and Higher Grade Elementary School Students**
  The presentation materials were added to the system of earthquake early warning as well as the seismic intensity scales in details to the kit targeted for lower-grade elementary school students.
- **Presentation Material for Junior High School Students**
  More scientific explanations about the earthquake and earthquake early warning were added to the presentation materials.

Contents of Activity

Presentation Material for Kindergarten and Lower Grade Elementary School Students

Tokyo District Meteorological Observatory developed a training kit for kindergarten and lower-grade elementary school students for their understanding of earthquake early warning and what to do when an earthquake occurs. Since the presentation material consisted of many pictures and illustrations, students could learn about earthquake early warning by sight. Additionally, there were some scripts in this kit so that the teachers could use it briefly.

The flow of the presentation is as follows:

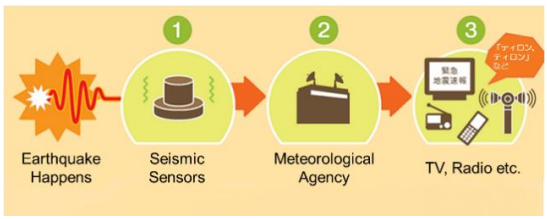
- Question for students about when an earthquake early warning is announced
- Some pictures which show the collapsed buildings when the Great Hanshin-Awaji Earthquake occurred to explain how dangerous earthquake is
- Question for students about what they should do when they hear the earthquake early warning
- An illustration explaining that students should go under the desks as soon as the earthquake early warning is announced
- Some illustrations to explain the four prohibitions when the students take shelter. The prohibitions were: Do not push someone, Do not run, Do not talk, and Do not go back.
- Conclusion

Presentation Material for Middle and Higher Grade Elementary School Students

Tokyo District Meteorological Observatory developed a training kit for middle and higher grade elementary school students as well as a training kit for lower grade elementary school students.

The contents added to the materials targeted for kindergarten and lower grades of elementary school students are the following:

- Some illustrations to explain the seismic intensity scales
- Some illustrations and a picture to show the system of the earthquake early warning
- Some illustrations to teach students about appropriate action to protect themselves during an earthquake when they are at home or en route to school



The flow of the presentation is as follows.

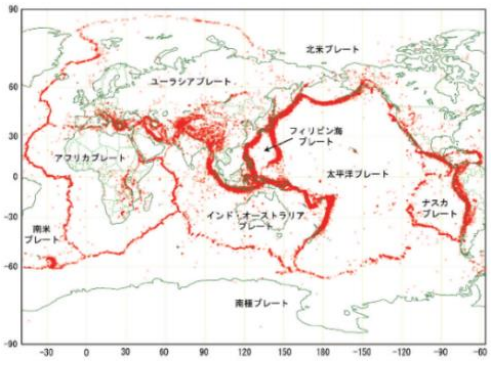
- Some pictures which show the collapsed buildings during the Great Hanshin-Awaji Earthquake to teach about fear of earthquakes
- Question about when an earthquake early warning is announced
- Many illustrations to show the expected damage by seismic intensity scales
- Some illustrations to teach about the system of earthquake early warning
- Some illustrations to explain how to avoid injuries during earthquakes.
- Some illustrations to teach about the four prohibitions when the students take shelter
- Conclusion

Presentation Material for Junior High School Students

For junior high school students, Tokyo District Meteorological Observatory developed a training kit that is more scientific and detailed than the training kit for elementary school students.

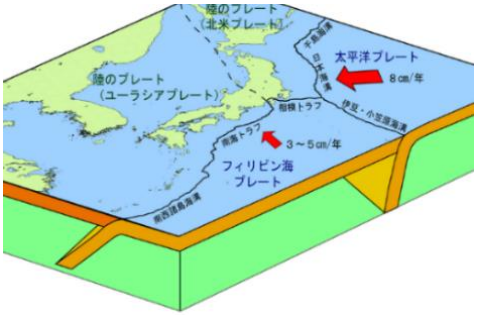
The contents added to the materials targeted for kindergarten to middle grades in elementary school are the following:

- The epicenters of which earthquakes have ever occurred
- Four plates near Japan and the reason why there are comparably many earthquakes happening in Japan
- Four ways to know when an earthquake early warning has been released: through TV, radio, cell phone, and disaster prevention administration wireless line



The flow of the presentation is as follows.

- Map to show the distribution of epicenters of which earthquakes have ever happened in the world and to show many earthquakes that have occurred in the past
- Illustration to teach about the four plates near Japan: Pacific Plate, Philippine Sea Plate, Eurasian Plate, and North American Plate, and to explain why there have been many earthquakes in Japan



- Some illustrations to show the system of earthquake early warning
- Some illustrations to show four ways to know when an earthquake early warning has been released
- Some illustrations to teach about how to take shelter
- Conclusion

Title	**Educational Activities Using the Website, "Disaster Prevention Education Support Portal"**		
Location	Fukuoka	**Period**	N/A
Responsible Agency	Fukuoka District Meteorological Observatory	**Cooperating Organization**	Educational Institution Disaster Prevention Institution Nongovernmental organization
Main Roles of the Meteorological Observatory Officials	• Develop teaching materials and share it on the website • Record Fukuoka District Meteorological Observatory's activities and share it on the website • Release guidelines for disaster prevention activities and share it on the website		

Overview

Fukuoka District Meteorological Observatory developed and released the contents on the website called "Disaster Prevention Education Support Portal." The information were useful to improve disaster prevention management and disaster prevention education at school. It included several contents related to evacuation trainings in the event of earthquake, tsunami and tornado, workshops on DRR, and so on. The main topics are as follows:

- **Teaching Materials for Disaster Prevention Class**
  The materials were developed to help teachers conduct disaster prevention class easily.
- **Guideline for Evacuation Training**
  The guideline showed the teachers how to manage evacuation training at school in detail.
- **Workshop for Disaster Prevention**
  There were some useful reference materials which explain how to implement the workshop on disaster prevention.

Contents of Activity

Teaching Materials for Disaster Prevention Class

Fukuoka District Meteorological Observatory developed teaching materials and released them on "Disaster Prevention Education Support Portal," which was named "10-minute class in disaster prevention," to help teachers teach their students about disasters and disaster prevention. The Meteorological Observatory thought that it was important for children to think and discuss about natural calamities and hazards in their hometown even for just 10 minutes. There was an example that showed the materials that were used in the last 10 minutes of science class at an elementary school.

The main materials released by the meteorological observatory are the following:

- Worksheet to use in disaster prevention class
- Reference documents and movies for students

The flow of an actual example of "10 minutes class of disaster prevention" is as follows:

- Divide students into several groups
- On an individual basis, think about what happens when a typhoon is approaching
- Discuss about it in each group
- Present what was discussed in groups
- Consider what to do to avoid damage caused by typhoon on an individual basis
- Discuss about it in each group
- Present what was discussed in each group
- Review from their teacher

Guideline for Evacuation Training

Fukuoka District Meteorological Observatory has been showing the guidelines for evacuation trainings to school officials through the “Disaster Prevention Education Support Portal.” That guidelines included reference materials to help teachers explain to students about the importance of evacuation trainings, how disaster early warning system was managed and so on. There were reference materials targeted for both elementary school students and junior high school students, and students could learn about disasters easily.

The main contents of disaster prevention education released by the Meteorological Observatory are the following:

- Guidelines for evacuation trainings in the event of earthquake and flooding
- Plan to implement evacuation trainings
- Teaching materials targeted for elementary school and junior high school students to explain about evacuation trainings
- Useful materials for conducting evacuation trainings, such as announcements, movies and so on

The flow showing an actual example of the evacuation training is as follows:

- Staff: Pre-explanation about evacuation training
- Staff: Play the sound of earthquake early warning
- Students: Take action to protect themselves, for instance, by crawling under desks
- Staff: Check situations and conduct a plan to escape from the disaster
- Students: Begin to take shelter
- Staff: Check students’ safety and conduct general review of the evacuation training
- Staff and students: Review the evacuation training in each class

Workshop for Disaster Prevention

Fukuoka District Meteorological Observatory has been showing to the public the manual for conducting workshop for disaster prevention targeted for children through its “Disaster Prevention Education Support Portal.” There were two types of workshops: one for flood and one for tsunami, and children could learn what to do when these disasters happen through the workshop.

The main materials developed by the meteorological observatory are as follows.

- Scenario of the workshop
- Explanation the role of group work
- Maps
- Lottery
- Weather information
- Worksheets

The flow of the workshop is as follows.

- Explain about disasters and disaster prevention to acquire basic knowledge of them
- Explain the rules of group work
- Decide on the situation, for instance, location, residence and family through lottery
- Get information about the weather and changing circumstances

- Discuss what to do to avoid disaster in this situation and share their thoughts with other group members
- Write down what they discussed on the worksheet
- Present what was discussed in the group

List of Activities by Central Government Agencies

No.	Title of Activity	Responsible Agency
1	Disaster Prevention Information	Cabinet Office, Government of Japan
2	Information about Disaster and Disaster Prevention	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
3	TEAM Disaster Management Japan	Cabinet Office, Government of Japan
4	MEXT × School Safety	Ministry of Education, Culture, Sports, Science and Technology (MEXT)
5	Disaster Prevention Education Portal	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
6	Disaster Prevention Education Support Portal Site	Tokyo District Meteorological Observatory
7	Disaster Prevention Guide	Prime Minister's Office
8	Disaster Prevention / Crisis Management e-College	Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications

Title of Portal Site	**Disaster Prevention Information**
Responsible Agency	**Cabinet Office, Government of Japan**
Roles and Responsibilities in DRR	The major roles of the Cabinet Office are as follows: • Establishment of the Central Disaster Management Council • Comprehensive Promotion of Disaster Countermeasures • Fostering International Cooperation in Disaster Reduction • Formulation of Master Plans Against Earthquakes, Tsunamis, Volcanic Eruptions, Large Floods and Others • Human Resource Development and Disaster Management Drills • Education and Enlightenment Activities • Disaster Response and Supporting Victims

Concept

As mentioned above, awareness-raising activities are one of the major roles of the Cabinet Office (CAO).
This website managed by the CAO introduces its roles in DRR, organization / budget / tax, disaster information, disaster countermeasure, publication and educational activities, DRR international cooperation and meeting / study session.

Among these activities, this summary sheet introduces the contents related to awareness-raising activities.

- Useful information
- Publication (DRR White Paper, DRR Magazine, DRR Lessons Learned, DRR Education, Pamphlet)
- Public Involvement (DRR Related Events, Regional DRR Plan, Volunteer, Corporate DRR activities, etc.)

Contents

Useful Information

CAO provides useful information to the public categorized into three groups, namely citizens, company & organization, and local government.

Major information provided by CAO to each stakeholder is shown below:

Citizens
- Assistance for disaster-affected people
- Useful APP and website
- Communal DRR Plan

Company & Organizations
- Evacuation site / temporary site operation guideline

Local Government
- Disaster Response (e.g., assistance, housing, notification from CAO, etc.)
- Planning (BCP, local DRR Plan, etc.)

Publication

CAO publishes White Paper, Magazine, DRR educational material, movie, and pamphlet for DRR awareness-raising.

The website provides information on the following publications prepared by CAO and related agencies.

- Annual DRR White Paper
- Quarterly PR Magazine, “Bousai,” about DRR and recent disasters
- DRR lessons learned from past major disaster (tsunami countermeasure, good practices of build back better)
- DRR educational materials
- DRR awareness-raising pamphlet (knowledge on disaster, community DRR activities for victims of disaster, etc.)

Public Involvement

CAO organizes various DRR events and promotes public involvement in DRR activities.

The website provides information on DRR events and activities which various stakeholders can participate in. The following are the major information related to public involvement.

- DRR volunteer-related information
- Corporate DRR
- Gender and DRR
- Various DRR events
  - ✓ DRR National Promotion Event
  - ✓ DRR Poster Award
  - ✓ Tsunami DRR Day
  - ✓ DRR Map Award
  - ✓ DRR Koshien (high school)
- National movement to mitigate the damage of disaster
  - ✓ DRR for everyone
  - ✓ DRR for kids, teachers
  - ✓ DRR simulator

Title of Portal Site	**Information About Disaster and Disaster Prevention**
Responsible Agency	**Ministry of Land, Infrastructure, Transport and Tourism (MLIT)**
Roles and Responsibilities in DRR	The MLIT plays key roles regarding comprehensive and systematic usage of land; development and maintenance of land; efficiently consolidating social capital; implementation of transportation policy; improvement of climate-related service; securement of safety and security at sea; implementation of disaster countermeasures, and so on.

Concept

The MLIT website introduces useful information and contents related to DRR. For example, in the disaster information, contents of MLIT's DRR plans and activities were covered on the website.

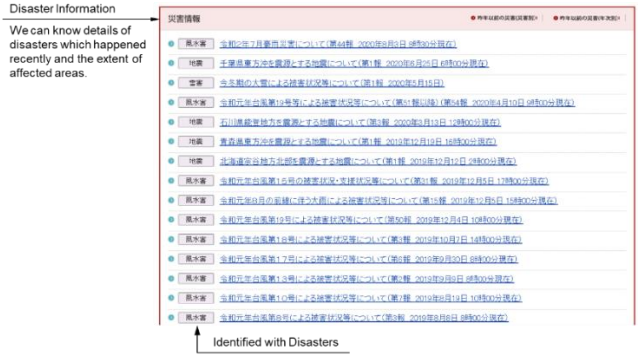
- **"Disaster Information"**: Contents which show the details on disasters and the extent of damage
- **"DRR Activities"**: Contents which explain MLIT's activities regarding DRR
- **"Technical Emergency Control FORCE's Activities at the Time of Large-Scale Disasters"**: Roles of Technical Emergency Control FORCE in case of large-scale disasters
- **"Support System for Local Governments"**: Explanation on MLIT's support system for local governments

Contents

Disaster Information

Official documents prepared by the MLIT articulates the disasters that recently occurred and the extent of damage in affected areas.

The section on disaster information accumulates the details of recent disasters. For instance, it informs when the disasters occurred, the affected areas, what the MLIT did during the disasters, and so on. Additionally, the website explains MLIT's support for disaster-affected populations.



DRR Activities

MLIT introduces DRR and disaster mitigation countermeasures, particularly meteorological disaster and sediment disaster.

The MLIT website introduces MLIT's activities for DRR such as preparation for earthquakes and floods, BCP, hazard maps, and so on.

The following information are introduced as MLIT's major roles in relation to DRR.

- MLIT's preparation for disasters
- MLIT's implementation of DRR
- Hazard maps
- Timeline of action plan for DRR
- Educational materials
- Operating plan for DRR
- BCP
- Disaster Prevention Center, established by the MLIT, that manages disaster information

Technical Emergency Control FORCE's Activities at the Time of Large-Scale Disasters

Disaster response activities of Technical Emergency Control FORCE (TEC-FORCE) operated by MLIT

MLIT dispatches TEC-FORCE to disaster-affected areas to support local governments in case local government staff cannot handle the response and recovery from large-scale disasters.

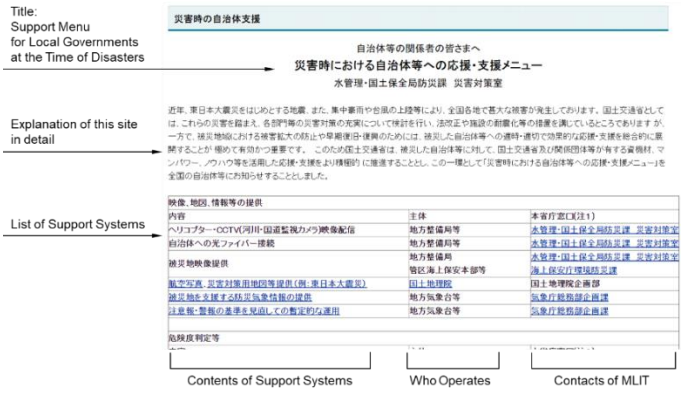
The website introduces TEC-FORCE's actual activities when assisting local government staff, with supporting text and pictures provided.

Support System for Local Governments

MLIT's support system for local governments are explained in detail.

Documents provide explanation to the staff on MLIT's support system for local governments.
Categories of materials are as follows:

- Videos targeting local government staff about how to treat flood damage
- MLIT's system to send out technical experts to support disaster recovery efforts
- How MLIT supports local governments when disasters occur
- Financial damage to government facilities related to civil engineering



Title of Portal Site	**TEAM Disaster Management Japan**
Responsible Agency	**Cabinet Office (CAO), Government of Japan**
Roles and Responsibilities in DRR	The major roles of the Cabinet Office are as follows: • Establishment of the Central Disaster Management Council • Comprehensive Promotion of Disaster Countermeasures • Fostering International Cooperation in Disaster Reduction • Formulation of Master Plans Against Earthquakes, Tsunamis, Volcanic Eruptions, Large Floods and Others • Human Resource Development and Disaster Management Drills • Education and Enlightenment Activities • Disaster Response and Supporting Victims

Concept

The website, called "TEAM Disaster Management Japan" operated by CAO, Government of Japan, introduces useful information and contents related to DRR. For example, the contents include the latest DRR activities, DRR education, relay column and other related sources of information.

- **"Relay Column"**: Introduction of personal experiences and ideas about RDD
- "**Learning Materials**": Materials for learning about various types of disasters
- "**DRR Event Information**": Reference to the latest DRR event information
- "**Reference Materials**": Materials to understand various types of disasters

Contents

Relay Column

Articles including personal experiences and ideas on DRR written by doctors, consultants, NGO workers and so on are introduced as columns.

Actual conditions of DRR activities in several disaster situations are shown in the articles. These information can be utilized as a knowledge source when people face disasters.

The articles include the following topics:

- The reason why the author began to implement DRR activities
- The most impressible experience
- Challenges for future DRR, etc.

Learning Materials

The website provides learning materials targeting elementary, secondary and high school teachers.

The contents provide information on the characteristics of disaster.
Students can learn about the mechanism of disasters by watching movies, and formulate their own ideas through group works using the available documents.

Three types of disaster educational materials on the following are found on the website:

- Earthquake
- Tsunami
- Typhoon

DRR Event Information

DRR events held all over Japan are listed. There are brief explanations on each event and links for more details.

The latest event information is shown and can be searched using specific keywords such as history, facilities, BCP, etc.
Additionally, information can be searched by area, which promotes people's participation in events held near the places where they live.

Reference Materials

Variety of reference materials regarding various disasters are stored in the portal site.

Readers can access the documents and watch movies to learn about DRR.
Reference materials prepared by Japanese government agencies, universities and experts are archived in the portal site.

Main categories of materials are as follows:

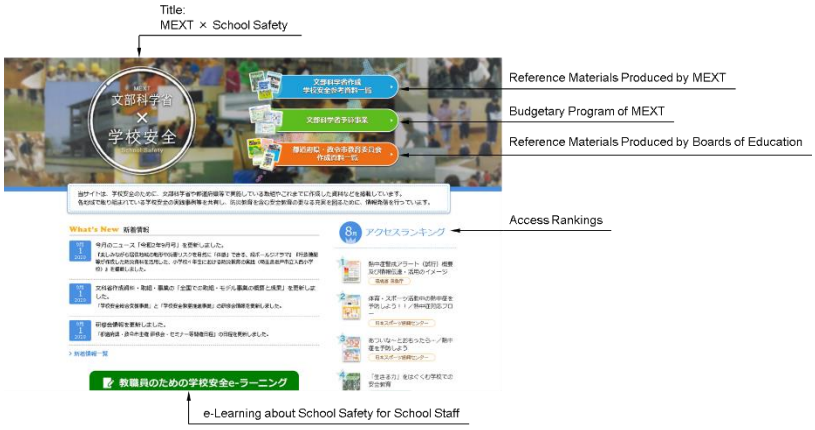
- Policy and system of the government
- Company and BCP
- Community
- History and lessons
- Facility and organization
- Products, services and information
- International education

Title of Portal Site	**MEXT × School Safety**
Responsible Agency	**Ministry of Education, Culture, Sports, Science and Technology (MEXT)**
Roles and Responsibilities in DRR	MEXT's roles in DRR include school safety; disaster prevention activities corresponding to students' developmental stages and regional characteristics; improving gaps between each region, each school or each school staff in relation to school safety; and construction of the implementation system for school safety in cooperation with families, local people and relevant organizations. MEXT plays key roles in activities to implement the following three tasks: enhancing safety management through organized activities and strengthening cooperation with each school; utilization of professional knowledge; and improving/upgrading equipment.

Concept

The main contents of this website are as follows:

- **"e-Learning about School Safety for School Staff"**: Online learning materials for teachers about school safety
- **"Reference Materials Produced by MEXT"**: MEXT's reference materials for school staff about school safety
- **"Reference Materials Produced by Boards of Education"**: Reference materials for school staff about school safety prepared by boards of education
- **"Information on Disaster Prevention Training Seminar"**: Theme, date, region of training seminar about school safety are listed.



Contents

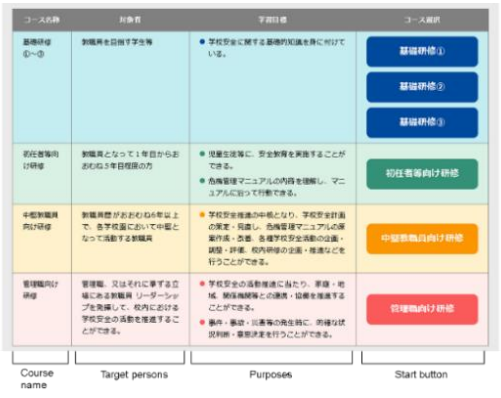
e-Learning about School Safety for School Staff

There are learning materials on the website for school staff to enable them to obtain credentials and acquire skills about school safety.

The website archives a variety of videos and documents for school staff to understand how to manage school safety. The e-learning materials are prepared for each grade level.

The flow of this e-learning is as follows.

1. Read the document and watch videos that explain about school safety.
2. Take the examination on the website to confirm understanding of the contents.
3. Obtain certificate after passing the examination.



Reference Materials Prepared by MEXT

The website archives reference materials made by MEXT to show the guidelines or reports on school safety.

The website archives the reading reference materials for education officers prepared by MEXT. These materials are useful not only to understand government guidelines and manuals about school safety, but also to learn about disasters.

The reference materials are classified into four types as follows:

- Guideline and plan of school safety
- Management of school facilities
- Mental healthcare of students
- Knowledge and evacuation action in case of earthquake

Reference Materials Prepared by Boards of Education

The portal site accumulates the reference materials prepared by the board of education in each prefecture and municipality.

The reference materials for school staff prepared by boards of education are archived in the portal site. Education officers can learn about school safety in other regions and utilize this information as their teaching materials.

The materials cover various contents including hazard safety, traffic safety, etc.

Information About Disaster Prevention Training Seminar

The information about disaster prevention training seminars conducted by boards of education for school staff.

Education officers can refer to the seminar themes and dates on this website.

The contents of the seminars are as follows:

- Safety management leadership seminar
- Safety management and risk management training workshop
- Practical training workshop on disaster prevention education
- Training workshop in response to accidents at school
- Regional disaster prevention workshop
- Life-saving training session

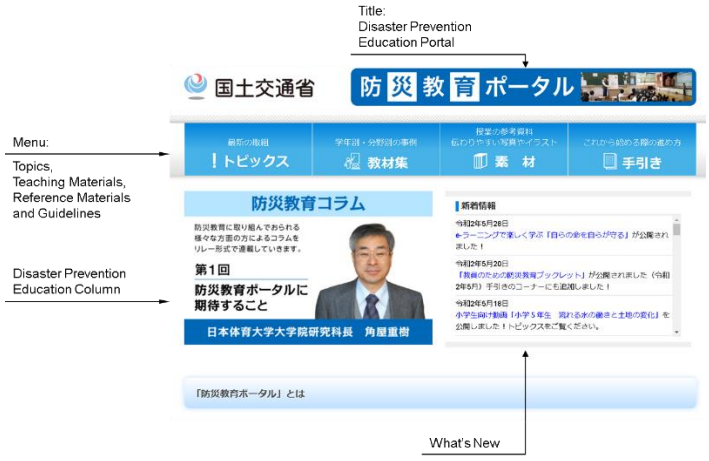
etc.

Title of Portal Site	**Disaster Prevention Education Portal**
Responsible Agency	**Ministry of Land, Infrastructure, Transport and Tourism (MLIT)**
Roles and Responsibilities in DRR	MLIT plays a key role regarding comprehensive and systematic usage of land, development and maintenance of land, efficient consolidation of social capital, implementation of transportation policy, improvement of climate-related service, securement of safety and security at sea, implementation of disaster countermeasures and other related activities.

Concept

This website introduces useful information and contents for those who are engaged in disaster prevention education, including teachers.
The website archives the latest activities of MLIT, examples of teaching materials for class, and examples of disaster prevention education.

- **"Topics"**: The latest activities
- **"Teaching Materials"**: Examples of teaching materials for each grade / field
- **"Reference Materials"**: Reference materials for classes and easy-to-understand photographs and illustrations
- **"Guidelines"**: Methodologies for disaster prevention education



Contents

Topics

Video and document materials for teachers and students are posted on the top page of the website.

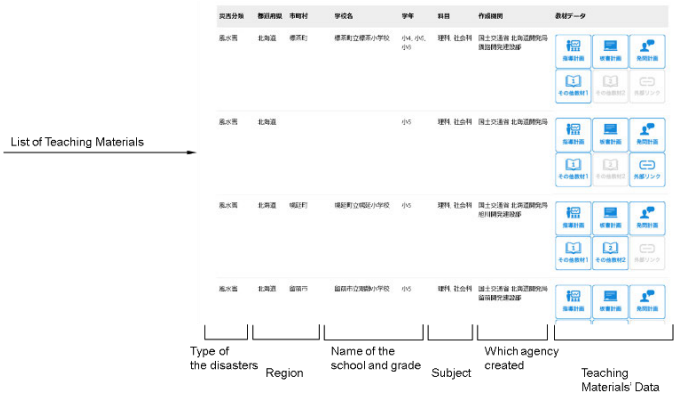
The website archives variety of videos and documents for teachers and students to learn about disasters and disaster prevention.

The movies include information on the characteristics of rivers to learn how to evacuate when flood occurs, and also the guidebook used when conducting flood emergency training at school.

Teaching Materials

Teaching materials used for classes are archived in downloadable format.

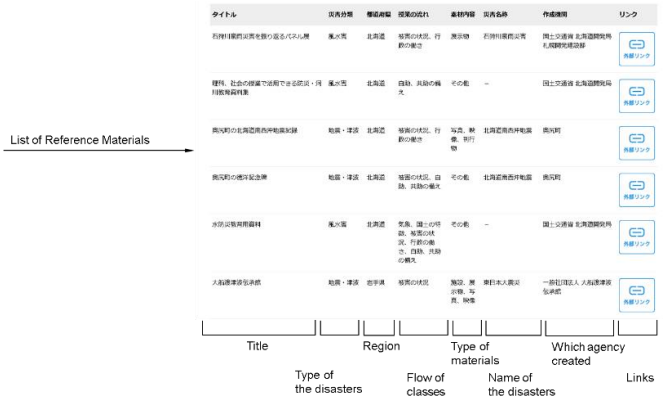
The website archives teaching materials for elementary school and junior high school prepared by MLIT's subsidiary organizations, local governments, NPO and other DRR-related agencies. The teaching materials are designed to help teachers in planning and conducting disaster prevention classes.



Reference Materials

Reference materials for classes, including third-party websites, are archived as useful links.

The useful reference materials for teachers prepared by MLIT's subsidiary organizations, local governments, and other related agencies are listed as links to help teachers in preparing disaster prevention lectures.



Guidelines

Guidebook, guideline, and other related materials usable as a guidance for disaster prevention education are achieved in downloadable format.

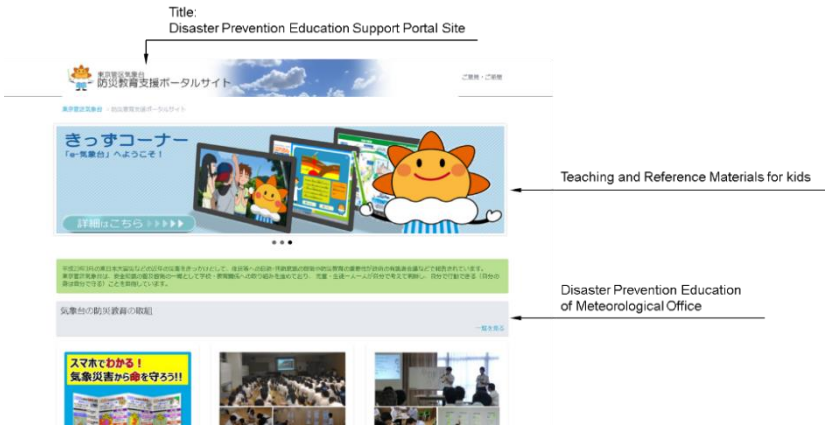
The section archives the guidelines on how to teach students about disasters and disaster prevention.
Users can search the materials by types of disaster and format of materials.

Title of Portal Site	**Disaster Prevention Education Support Portal Site**
Responsible Agency	**Tokyo District Meteorological Observatory, JMA (Tokyo Regional Headquarters)**
Roles and Responsibilities in DRR	JMA plays a vital role in natural disaster mitigation and prevention activities in the country through cooperation and coordination with relevant authorities, including the central government and individual local governments. JMA, as the sole national authority responsible for issuing weather / tsunami warnings and advisories, is required to provide reliable and timely information to governmental agencies and residents for the purpose of natural disaster prevention and mitigation.

Concept

The main contents of this website are shown below.

- **"Disaster Prevention Education of Tokyo Regional Headquarters, JMA"**: Useful leaflet and a report on disaster prevention education
- **"Teaching and Reference Materials about Disaster Prevention for Students"**: Documents and movies us for disaster prevention class
- **"Teaching and Reference Materials about Disaster Prevention for the Public"**: Documents about evacuation actions and links to various data announced by Japan Meteorological Agency(JMA)
- **"Cooperation with Japanese Red Cross Tokyo Metropolitan Chapter"**: Teaching material about disaster prevention created by Japan Red Cross



Contents

Disaster Prevention Education of Tokyo Reginal Headquarters, JMA

The Tokyo Regional Headquarters prepared useful leaflets about disaster prevention and report on the workshop for teachers and students.

The Tokyo Regional Headquarters prepared useful and portable leaflet about the utilization of disaster information announced by JMA.

Additionally, the website archives the reports on disaster prevention classes conducted by JMA staff. The contents of the class are about the actions to be taken during a heavy rain. Students and teachers can learn how to evacuate in extraordinary weather.

Teaching and Reference Materials About Disaster Prevention for Students

Teaching and reference materials explain about earthquake early warning and how to evacuate from rapid and heavy rain, thunder and tornado.

The portal site archives teaching and reference materials for disaster prevention class or evacuation trainings at school. The materials include presentation reference, movie, documents and workshop kit and other supplementary materials.

The site also archives reports on disaster prevention class using the teaching materials as follows:

- Draft guidance
- Pictures for blackboard display
- Explanatory material
- Worksheet

Teaching and Reference Materials About Disaster Prevention for the Public

Teaching and reference materials prepared by Tokyo Regional Headquarters for the public and links to weather information informed by JMA and regional hazard maps made by local governments.

Tokyo Regional Headquarters prepared lecture materials in order to support local disaster prevention leaders in explaining to the public how to evacuate in the event of disaster.

The website provides a list of the links to access weather information announced by JMA, or hazard maps prepared by each local government which indicate the estimated flood areas and street information.

Cooperation with Japanese Red Cross Tokyo Metropolitan Chapter

The contents introduce disaster prevention education initiatives in cooperation with Tokyo Regional Headquarters and Japanese Red Cross Tokyo Metropolitan Chapter.

JMA and Japanese Red Cross signed an agreement on the extension of disaster prevention education.

The website introduces actual examples of collaborations as part of the initiative.

The teaching materials targeted for elementary school students to high school students provide explanation on how to evacuate, the mechanism of disasters, etc. using a worksheet.

Title of Portal Site	**Disaster Prevention Guide**
Responsible Agency	**Prime Minister's Office**
Roles and Responsibilities in DRR	The Prime Minister's Office plays key roles in collecting disaster-related information from related agencies and the emergency actions taken by the government when natural disasters occur. Some of the information are disseminated via their various social media official accounts, including SNS services, website, etc. In addition, the prime minister's office is the venue of the emergency response headquarters and the central disaster management council.

Concept

The website of the Prime Minister's Office contains a guide, called "Disaster Prevention Guide," with information on disaster prevention. The prevention guide consists of the following contents:

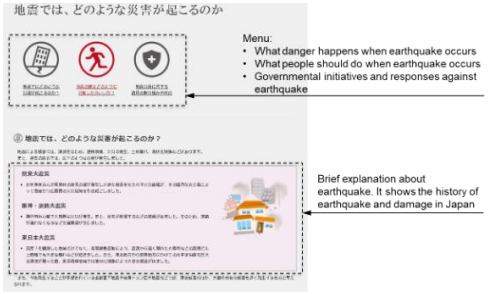
- **"Various Disasters and How to Behave to Protect Yourself"**: Reference information about various disasters, appropriate evacuation behavior when escaping from danger, and governmental initiatives about disaster management
- **"Preparation for Disasters"**: Reference materials about preparation for disasters
- **"Disaster Prevention Information and Warning Level"**: Reference materials about the roles of disaster prevention information and correspondence relation between disaster prevention information and warning level
- **"When and Where to Evacuate"**: Reference materials about evacuation information and how to evacuate based on each warning level

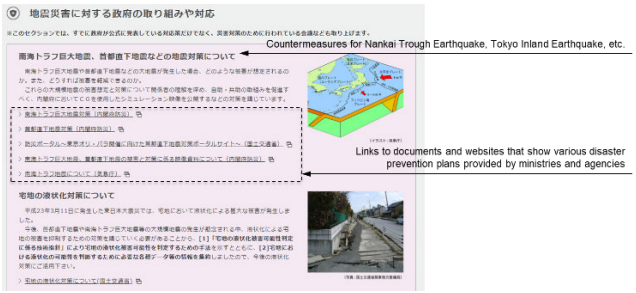
Contents

Various Disasters, How to Behave to Protect Yourself and Governmental Initiatives and Responses

There are reference materials about various disasters. They explain the estimated damage caused by each disaster and appropriate evacuation behavior so as not to get injured. Additionally, the reference materials show the implementation and response of the Japanese government to disaster prevention.

There are explanations about the characteristics, evacuation behavior and the governmental initiatives or activities implemented by other central government ministries and agencies responsible for each disaster.





Preparation for Disasters

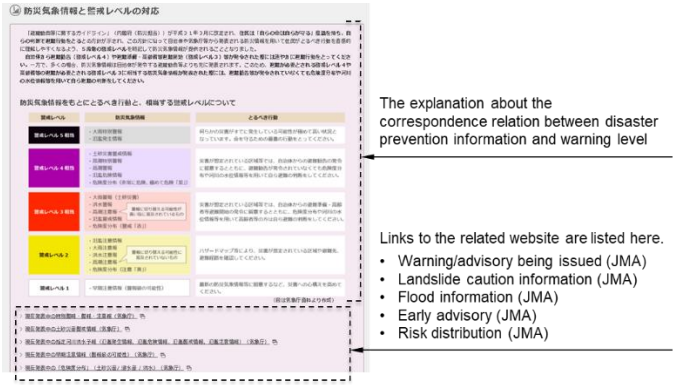
There are reference materials for the public about detailed disaster prevention. The contents are classified as follows: the place of furniture, preparation of food and beverage, contents of emergency bag, how to confirm safety, and evacuation shelter and route.

On this page, people can learn about preparation for disasters.
There are some brief explanations about DRR, and links to other related websites of central government ministries and agencies are listed to learn more information.
For example, the chapter with information on the place of furniture provides explanation on how to fix furniture items or where to locate. There is also a link to the website managed by the Fire and Disaster Management Agency on which the rollover of furniture is explained in detail.

Disaster Prevention Information and Warning Level

There are explanations about disaster prevention information and warning level and the links to other central government ministries and agencies.

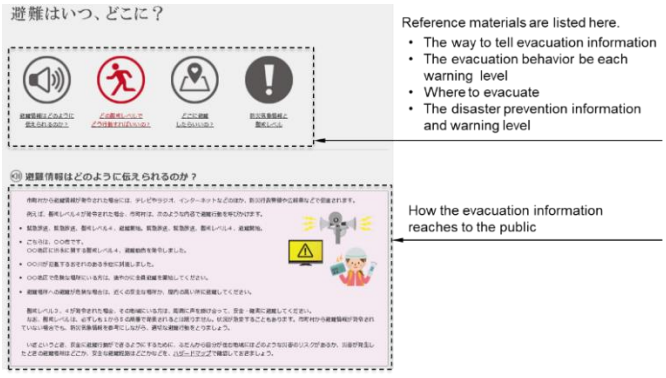
On this page, people can learn about disaster prevention information issued by Japan Meteorological Agency or local governments and the corresponding warning levels.
First, disaster prevention information is explained and how it is issued and reaches the people.
Next, there is brief explanation on the warning level containing information on identifying the danger level of disasters.
Finally, the correspondence relation between the disaster prevention information and the warning level is explained.



When and Where to Evacuate

There are explanations about knowing the timing of evacuation, place of evacuation shelters and links to the related websites managed by other central government ministries and agencies.

There are explanations intended for the public on evacuation behavior and links to related websites of other central government ministries and agencies to learn more about evacuation behavior.
An explanation on evacuation behavior by each warning level is provided so that people can know when to evacuate.
Next, there is an explanation about the place of evacuation shelter. The links to the website managed by other organizations showing where the shelters are located are listed along with the explanation.

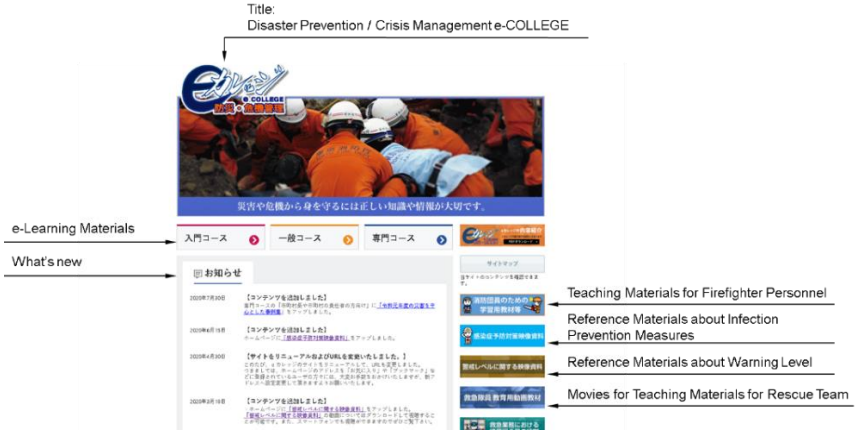


Title of Portal Site	**Disaster Prevention / Crisis Management e-College**
Responsible Agency	**Fire and Disaster Management Agency (FDMA), Ministry of Internal Affairs and Communications**
Roles and Responsibilities in DRR	Within a rapidly changing socio-economy and the consequently changing societies of communities, FDMA strategically and practically creates secure and safe communities through developing requisite laws and guidelines, and preparing vehicles and equipment in cooperation with Fire Service Institutes and local governments across the country. On the other hand, in the event of emergencies such as extraordinary natural disasters, FDMA grabs the big picture of the damage immediately, and at the same time, dispatches Emergency Fire Response Teams to disaster-hit areas in order to minimize the damage.

Concept

This portal site, named “Disaster Prevention / Crisis Management e-College,” is established to provide residents, firefighting personnel and local government officers a place where they can learn about disaster prevention and crisis management on the internet. The main contents of this website are shown below.

- **“e-Learning Materials by Targeted Persons”**: e-learning materials about disaster prevention and crisis management
- **“Teaching Materials for Firefighter Personnel”**: Movies and documents as teaching materials for firefighter personnel
- **“Teaching Materials for Rescue Team”**: Movies as teaching materials for ambulance attendants
- **“Activities of the Rescue Teams in the Time of Disasters”**: Documents which explain the reconstruction activities of the rescue teams during past disasters



Contents

e-Learning Materials by Targeted Persons

There are informative e-learning materials about disaster prevention and crisis management by targeted persons.

There are three e-learning courses on disaster prevention and crisis management: Beginner Course, General Course and Expert Course.
Targeted persons are children, general people and experts such as local government officers, firefighters, etc.
People can learn essential knowledge of disasters, volunteer activities and so on.

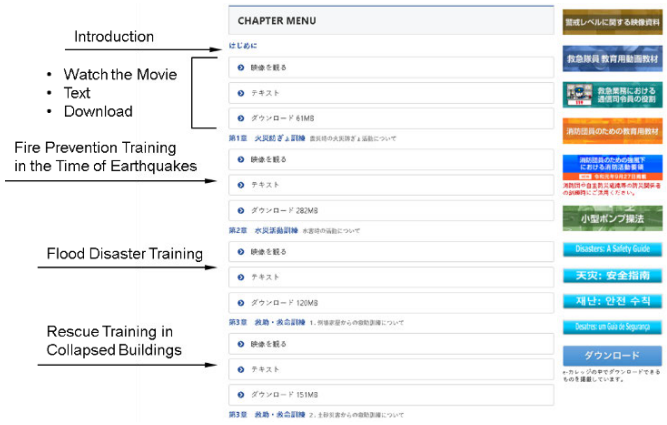
Teaching Materials for Firefighter Personnel

Documents and movies that explain firefighter activities and the way to use equipment for rescue intended for firefighter personnel are available.

The teaching materials for firefighter personnel are classified based on its activities and how to use rescue equipment.
The contents of the document about firefighter personnel activities are as follows:

- Present circumstances of firefighters
- System and organization of firefighters
- Role of firefighters in disaster prevention, and so on.

There are also movies and documents that explain how to use a particular kind of rescue equipment.

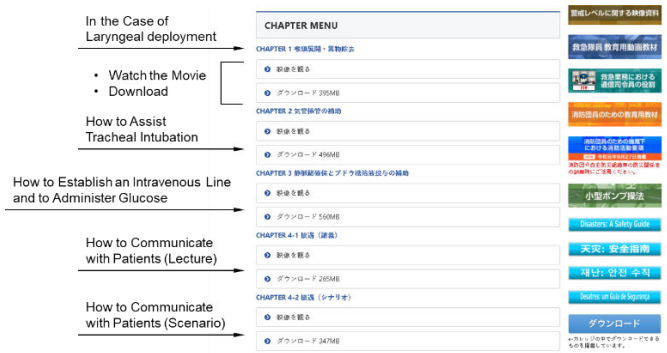


Teaching Materials for Rescue Team

There are movies for ambulance attendants to learn how to rescue injured people.

The flow and tips in each case are explained in the movies. The estimated cases are as follows:

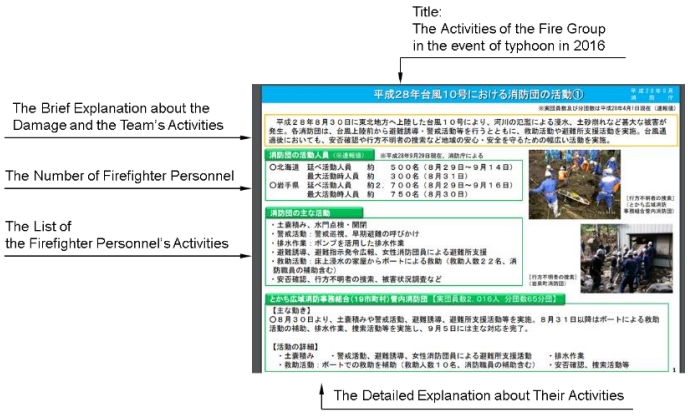
- Laryngeal deployment
- How to communicate with patients or those who are related to them
- How to establish an intravenous line
- How to administer glucose



Activities of the Rescue Teams at the Time of Disasters

The activities of various kinds of firefighter personnel at the time of disasters are shown with several supporting pictures and documents.

The activities of the three groups of firefighter personnel during past disasters are introduced here. The three groups are: Emergency Rescue Team, International Rescue Team and the fire company.
Their activities are explained with pictures listed in chronological order and relevant documents.
Their activities during the 2015 Nepal Earthquake are also shown in detail.



APPENDIX 8-10

The Review on Disaster Prevention Information Transmission from the Perspective of Residents in Indonesia

The Review on Disaster Prevention Information Transmission from the Perspective of Residents in Indonesia

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

September 2020

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
AIS-SAT	Satellite Automatic Identification System
App	Mobile Application Software
ASEAN	Association of Southeast Asian Nations
BASARNAS	National Search and Rescue Agency
BIG	Geospatial Information Agency
BMKG	Agency for Meteorology, Climatology and Geophysics
BNPB	National Disaster Management Agency
BPBD	Regional Disaster Management Agency
CCTV	Closed-Circuit Television
C/P	Counterparts
CVGHM/PVMBG	Center for Volcanology and Geological Hazard Mitigation
DRR	Disaster Risk Reduction
EQ	Earthquake
ESDM	Ministry of Energy and Mineral Resources
FB	Facebook
HQ	Headquarters
InaTEWS	Indonesia Tsunami Early Warning System
INST	Instagram
JICA	Japan International Cooperation Agency
M	Magnitude
MMI	Modified Mercalli Intensity
MoU	Memorandum of Understanding
PDT	Pacific Daylight Time
PMI	Indonesian Red Cross Society
PNS	Government Officer
POI	Point of Interest
POLRI	Police of the Republic of Indonesia
ROQ	Response On Earthquake
RRI	Radio Republik Indonesia
SAR	Search and Rescue
SCTV	Surya Citra Televisi
SKPD	Regional Work Units
SMS	Short Message Service
SNS	Social Networking Service
TNI	Indonesian Army
TV	Television
TW	Twitter

Abbreviation	English
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
VAR	Volcanic Activity Report
VONA	Volcano Observatory Notice for Aviation
WA	WhatsApp
WIB	Western Indonesian Standard Time
WITA	Central Indonesian Standard Time
WRS	Warning Receiver System

Chapter 1 Introduction

1.1 Background

The Project was designed to implement the baseline survey, where information and issues related to disaster prevention information transmission will be collected through questionnaires and interview surveys with Agency for Meteorology, Climatology and Geophysics (BMKG) as well as central and local disaster risk reduction (DRR)-related departments concerning disaster information transmission.

However, there have been criticisms by the public that tsunami warning was not issued and transmitted sufficiently during the Central Sulawesi earthquake and tsunami and the Sunda Strait tsunami. There are concerns that some related agencies might be reluctant to answer the questionnaires being afraid of such criticism, and that different people may have different perceptions regarding the issue of information transmission. It is widely recognized that the perception on disaster information transmission from the receivers' side is indispensable to ensure the effectiveness of the information as well as the senders' side regarding the accuracy of information.

Therefore, as a more objective method, the Project will carefully review the news on the day of the disaster occurrence, information on warnings and Social Networking Services (SNS) of disaster risk reduction-related agencies including BMKG. Information will also be gathered from the residents of the affected areas who received the information. It is essential to secure the amount of information related to raising the issues of disaster information transmission. Since these tasks involve enormous amounts of internet data and individual interviews regarding the Central Sulawesi earthquake and tsunami and Sunda Strait tsunami, the Project does not usually conduct such surveys as normal baseline surveys, but the Project assumes that information collection is valuable before launching the Project.

1.2 Objective of the Review

The objective of the review is to analyze the issues concerning disaster information transmission from the perspective of the resident side to utilize the activities of the Project, especially Outputs 3 and 4. The result is expected to be a reference material to raise the awareness of C/Ps regarding the issues of disaster information transmission and awareness-raising activities.

Chapter 2 Means of Conveying Information About EQ and Tsunami

Currently, earthquake and tsunami warning information issued by BMKG is transmitted to various stakeholders including media and DRR-related agencies. The Indonesian public receives information directly from BMKG through web services such as SNS and smart phone applications, and indirectly from media and their regencies / municipalities through administrative lines. This section summarizes the current means of earthquake and tsunami-related communication available to the public.

2.1 Information Management / Controlled by BMKG

Law No. 31 of 2009 concerning Meteorology, Climatology and Geophysics prescribes that the government has an obligation to provide information services related to weather, climate, and geophysics (Article 29), and this information service consists of routine information and early warning (Article 31). It clearly states that routine information includes earthquake information (Article 32), and the early warning includes tsunami early warning (Article 33). Under legal basis, BMKG provides information services on earthquake and tsunami through the following means of communication.

2.1.1 TV

Law No. 31/ 2009 regarding Meteorology, Climatology, and Geophysics prescribes the roles and responsibilities of the media related to disaster early warning (Article 34) as shown below.

(1) Public broadcasting institutions and mass media owned by the government and regional governments must provide an allocation of time or column space every day to disseminate public information in accordance with statutory provisions / law.

(2) Broadcasting institutions must provide time allocation to disseminate meteorological, climatological and geophysical early warning in accordance with statutory provisions/law.

In order to assure the provision of earthquake information and tsunami early warning, BMKG has installed Warning Receiver System (WRS) tools in 17 broadcasting institutions. However, only a few of them had responded and utilized the information relayed by BMKG. There were issues from the broadcasting institutions' side that the information from WRS included technical terms in geophysics, and it took some time for them to translate the terms to be understandable to the public.

There have been efforts of cooperation between TV and radio stations and BMKG through the use of BMKG's early warning communication modes such as: (1) Warning Receiver System/WRS, (2) fax, (3) e-mail, (4) SMS, and (5) BMKG website (www.bmkg.go.id). Those modes are expected to relay prompt, accurate, and understandable information to the public when disaster occurs.

Since June 2020, WRS NewGen tool has been installed in DRR-related organizations – including Regional Disaster Management Agency (BPBD) offices, broadcasting institutions, and related institutions that concluded MoU with BMKG – through data and information-sharing. This WRS New Generation could speed up information transmission and visualize real-time earthquake and tsunami information.

2.1.2 Radio

According to Law No. 31/ 2009 concerning Meteorology, Climatology, and Geophysics, Article 34 prescribes that, similar to television stations, radio broadcasting institutions are responsible for broadcasting disaster-related information as a priority. Radio Republik Indonesia (RRI) is a government radio network agency broadcasting all over Indonesia. RRI's local radio channels are covering regional information.

2.1.3 Social Networking Service (SNS)

BMKG operates major SNS accounts and pages as means of communicating to the public. In general, BMKG's SNS accounts are dominantly followed by the public as instant and reliable sources of information. The following are BMKG's three SNS accounts used for posting official

information related to earthquake and tsunami.

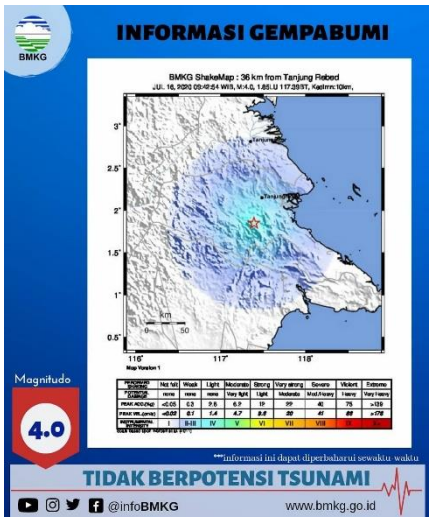
In general, the number of followers of each BMKG's official SNS account outnumbers those of other DRR-related agencies in Indonesia. Citizens in Indonesia rely on BMKG's official account as primary source of disaster-related information.

(1) Facebook Page

BMKG HQ and Geophysics Stations (UPTs) at regional level maintain Facebook pages. Only BMKG HQ posts up-to-date information on earthquakes and tsunami occurrences in Indonesia.

Table 2.1.1 Basic Information About BMKG's Facebook Page

Name of Facebook Page:
Info BMKG
(https://web.facebook.com/InfoBMKG)
Likes:1,108,881 people
Followers: 1,159,219 people (As of July 17, 2020)
Contents of Information:
- General information on BMKG
- Climate information/warning
- Earthquake and tsunami information and warnings issued by WRS



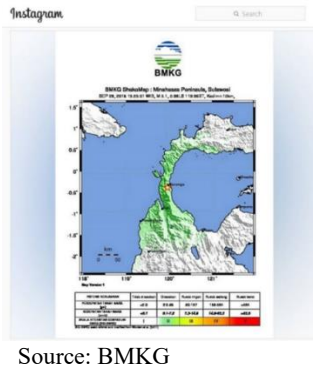
Source: BMKG

(2) Instagram

BMKG HQ has social media accounts such as Instagram, and Info BMKG posts up-to-date information on its Facebook page. The official account does not indicate the purpose or objective of the account. It provides various kinds of BMKG-related information not limited to weather and disaster information, but also includes workshops and events information.

Table 2.1.2 Basic Information About BMKG's Instagram Account

Name of Instagram Account:
Info BMKG (https://www.instagram.com/infobmkg/)
Followers: 3.56 million people (As of July 17, 2020)
Contents of Information:
- General information on BMKG
- Climate information/warning
- Earthquake and tsunami information and warnings. Figures from WRS.



Source: BMKG

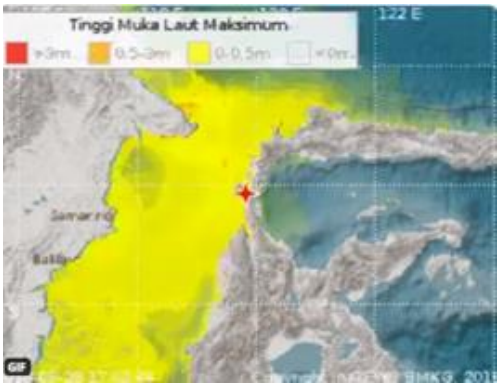
(3) Twitter

BMKG also handles a Twitter account called Info BMKG, same as its Facebook page and Instagram account. Among the SNS accounts managed by BMKG, its Twitter account has the largest number of followers, with more than five million. It has been observed that during the Central Sulawesi earthquake and tsunami, DRR-related agencies often retweeted from the BMKG official account and informed their followers to pay close attention. The information received

through Twitter was the fastest means of information dissemination for agencies that do not have a dedicated communication system, which includes the WRS installed in DRR-related agencies and media. During the Sunda Strait tsunami, since the InaTEWS did not issue a tsunami warning, the Twitter account gave an update on the situation accordingly. A detailed information will be described in Chapter 3 of this report.

Table 2.1.3 Basic Information About BMKG Twitter Account

Name of Twitter Account:
Info BMKG
(https://twitter.com/infoBMKG)
Followers: 5 million+ people (As of July 17, 2020)
Contents of Information:
- General information on BMKG
- Climate information/warning
- Earthquake and tsunami information and warning issued by WRS



Source: BMKG

2.1.4 Mobile Application Software (Apps)

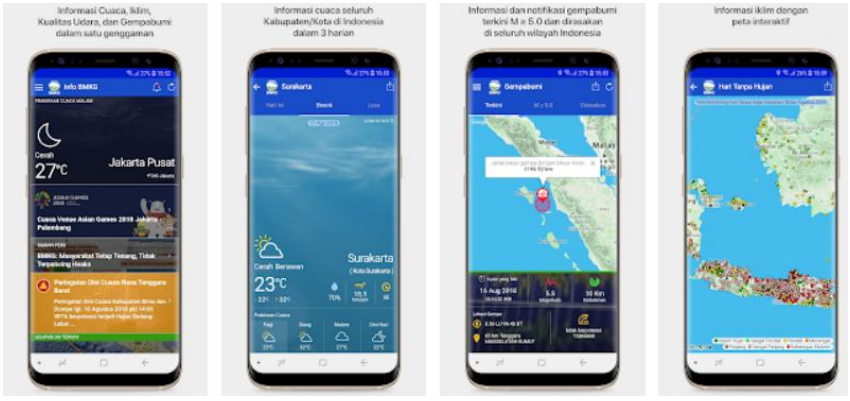
BMKG operates Mobile Application Software (apps) for disseminating climate and natural disaster information to the public. The apps contain maps to show the weather conditions and the location of natural disasters such as earthquake and tsunami.

The mobile apps released by BMKG are Info BMKG with more than five million downloads; WRS-BMKG with more than 100,000 downloads; and BMKG Real-Time Earthquakes with more than 10,000 downloads. An overview of the three mobile apps mentioned above are described below:

(1) Info BMKG

Info BMKG provides various information related to weather, climate, air quality and earthquake in Indonesia. Since Info BMKG has the largest number of downloads of all the apps discussed in this report, it is assumed to be the most popular app that delivers climate-related information.

Name of App: Info BMKG
Downloads: 5,000,000+ users
Contents of Information:
Weather forecast / Latest M ≥ 5.0 earthquake and tsunami information / Climate information / Air quality information especially in Sumatera and Kalimantan / Maritime weather (sea wave height) / Weather information around airports / Forest fires information / Early warning / BMKG press releases



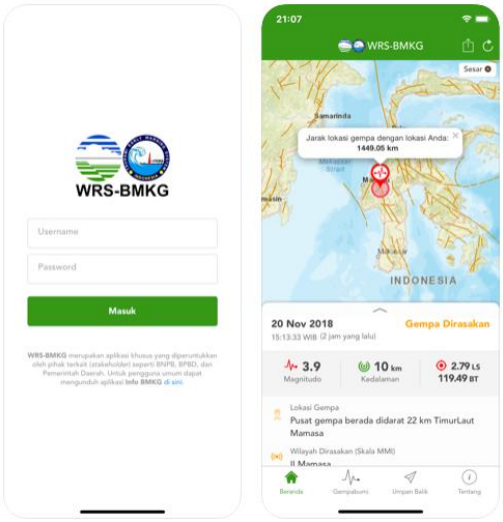
Source: Google Play (https://play.google.com/store/apps/details?id=com.Info_BMKG&hl=ja)

Figure 2.1.1 Basic Information on Info BKMG

(2) WRS-BMKG

WRS-BMKG provides information on earthquakes with a magnitude of more than 5.0, tsunami, and felt earthquake that occurred especially in Indonesian territory. This app has been provided for BMKG stakeholders such as BNPB, BPBD, local governments, radio media, TV media, Indonesian Army (TNI), Police of the Republic of Indonesia (POLRI), other ministries/state institutions and private parties, as WRS-BMKG is the easiest way for the stakeholders to receive information from the Indonesian Tsunami Warning System (InaTEWS).

Name of App: WRS-BMKG
Downloads: 100,000+ users
Contents of Information:
Shake map / Estimated tsunami arrival time / Estimated maximum sea level / Estimated warning level / List of 30 latest events for M ≥ 5.0 earthquake and tsunami / Tsunami early warning / Distance between the epicenter and user location / MMI information of the area that felt the earthquake / Suggestions and direction from BMKG / Age of earthquake occurrence / Voice notifications and pop-up alerts / BMKG press release / User feedback / Glossary



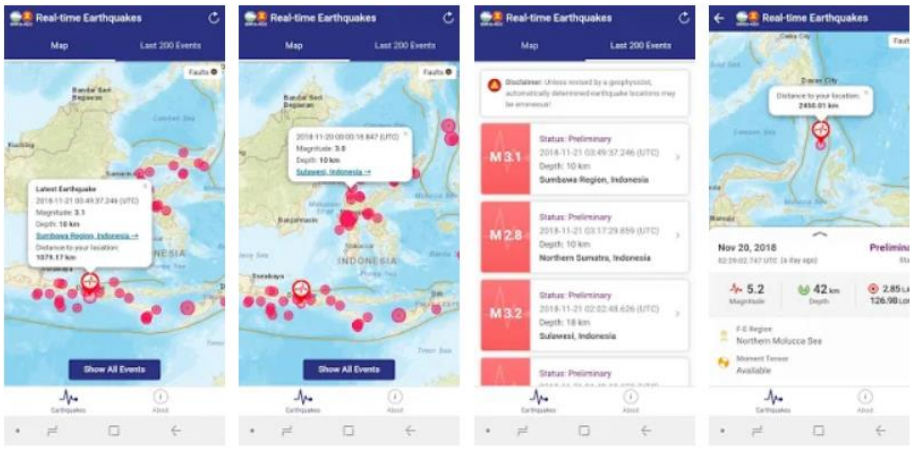
Source: Google Play (https://play.google.com/store/apps/details?id=id.bmkg.wrsbmkg&hl=ja)

Figure 2.1.2 Basic Information on WRS-BMKG

(3) BMKG Real-Time Earthquakes

BMKG Real-Time Earthquakes provides real-time information on all earthquakes that occur particularly in the territories of ASEAN countries. This app has been targeted to seismologists, students, or people who are interested in earthquakes, and is the easiest way to receive earthquake information from BMKG Indonesia.

Name of App: BMKG Real-Time Earthquakes
Downloads: 10,000+ users
Contents of Information:
Map of ASEAN countries / List of the last 200 earthquakes / Earthquake analysis / Moment tensor / Update on earthquake parameter / Distance between the epicenter and user location / Event age / Push notification



Source: Google Play (https://play.google.com/store/apps/details?id=id.bmkg.bmkgaeic&hl=ja)

Figure 2.1.3 Basic Information on BMKG Real-Time Earthquakes

2.2 Information Services on Earthquake and Tsunami Other Than BMKG

2.2.1 SNS Accounts of Disaster Risk Reduction-Related Agencies

Several DRR-related agencies other than BMKG operate major SNS accounts. The following are the information on SNS accounts owned by BNPB and BPBD. Since these two agencies provide several information regarding disasters, their SNS activities are introduced as typical examples below.

The number of followers of each SNS account is less compared to BMKG's SNS account. However, they are assumed to be helpful information sources for the public, since these two accounts contain different types of information from that of BMKG's.

BNPB/BPBD

BNPB has Facebook, Instagram and Twitter social media accounts. BNPB's Facebook page has the largest followers, with 1.8 million, and its Twitter and Instagram accounts have approximately 330,000 followers. Through SNS services, BNPB provides up-to-date information related to disasters with maps, epicenter points and so on. In addition, the information posted by BNPB contains impacts of earthquake and tsunami on humans, facilities, houses, infrastructures, etc.

Name of Facebook Page: BNPB_Indonesia

Followers: 323,945 users (As of August 18, 2020)

Contents of Information:
General information of BNPB/ Climate information and warning/ Earthquake and tsunami information and warning issued from WRS/ Information of disaster impacts such as number of deaths and missing persons, damaged houses, etc./ Status of people evacuation.

Source BNPB

Figure 2.2.1 Basic Information About BNPB's Twitter Page

Similar to BNPB, BPBD in some regions have their own SNS accounts as well and provide information particular to their respective regions. In Palu City, the capital of Central Sulawesi province, BPBD has its own Instagram account named "bpbd_kotapalu."

2.2.2 Mobile Application Softwares (Apps) for Earthquake and Tsunami

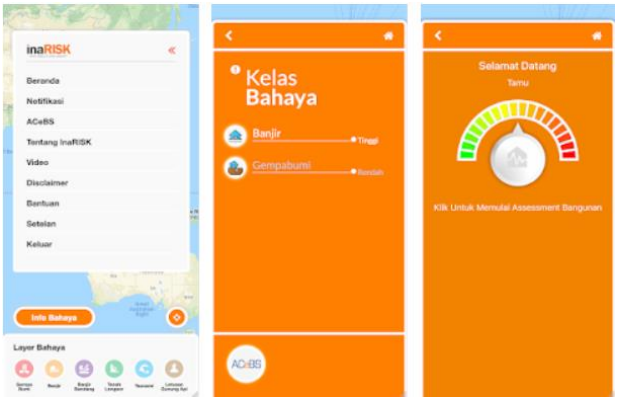
(1) BNPB

Mobile apps released by BNPB are: inaRISK Personal; inaRISK Mobile; InDRA BNPB; and I-Tangguh apps.

1) inaRISK Personal

The purpose of creating this app is to assess the risk level of a place. The application for Disaster Risk Assessment results can be utilized by citizens and is created to know the dangers of disaster and the efforts that people can do independently. This application uses the results of studies organized by BNPB together with the ministry / agencies and support disaster organizations in Indonesia.

Name of App: inaRISK Personal **Downloads**: 100,000+ users **Contents of Information**: Maps displaying disaster-related information (earthquakes, floods, flash floods, landslides, tsunami, volcanic eruptions) / Danger level of disasters / Building assessment



Source: Google Play

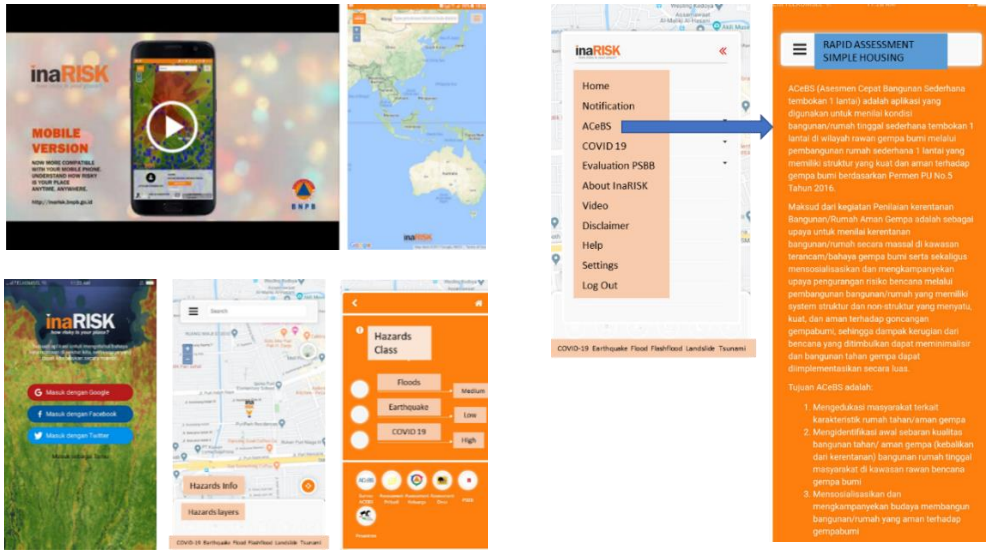
Figure 2.2.2 Basic Information on inaRISK Personal

2) inaRISK Mobile

The inaRISK Mobile is a portal that summarizes the result of disaster risk assessment using ArcGIS server as data services that describe disaster-prone areas, impacted population, potential physical loss (in Rp), economic potential loss (in Rp), and potential environmental damage (in ha). United Nations Development Programme (UNDP) has contributed to the establishment of inaRISK by providing data services which have been the essential data in inaRISK. The inaRISK is linked to disaster management plan which enables users to monitor the decline of disaster risk index.

The inaRISK also serves as a tool for monitoring the decline of disaster risk index as it is also linked to the realization of disaster risk reduction program implementation. This app has been updated on October 29, 2017 and has been installed by 10.000+ users.

Name of App: inaRISK Mobile **Downloads**: 10,000+ users **Contents of information**: Map / Infographics (flood, flash flood, extreme weather, extreme wave and abrasion, earthquake, land and forest fire, drought, volcanic eruptions, landslides, tsunamis, multi-hazards) / Hazards / Vulnerability / Capacity / Risk / Satellite / Terrain / Road / Hill shade / Population density / 250k rivers / Drainage basin



Source: Google Play

Figure 2.2.3 Basic Information on inaRISK Mobile

3) InDRA BNPB

InDRA BNPB contains three sections: home, disasters and weather. The home section summarizes disaster information including the number of catastrophic events, fatalities, damaged houses and facilities. The disasters section contains map, data on disasters including names of disasters, and the regencies/municipalities and provinces affected. Lastly, the weather section shows the weather situation including temperature, humidity, date and time.

Name of App: InDRA BNPB
Downloads: 5,000+ users
Contents of information:
Infographics (number of events, fatalities, damaged houses and facilities) / Disasters (map, names of disasters, regency/municipality and province) / Weather (temperature, humidity, date and time)

Source: Google Play

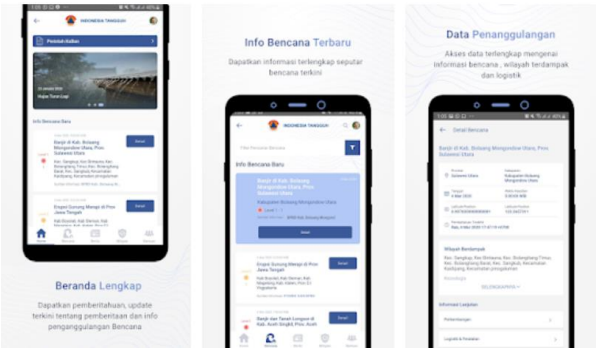
Figure 2.2.4 Basic Information on InDRA BNPB

4) I-Tangguh Apps

I-Tangguh app helps BNPB decision-makers to get updated news data on the handling status of disaster events conducted by BNPB. It consists of sections namely home, disasters, news, mitigation and help. The home section summarizes the latest disaster information such as date and time, name of disasters, location (regency/municipality, province), source of information and a detail button. When this button is touched, a detailed information will appear (province, regency, date, time of occurrence, latitude position, longitude position, latest update, affected areas, further information [progress, logistics & equipment, personnel, documentation, victims, internal discussions, impact of damage, and a download button showing "Download Executive Summary (PDF)"]). The disasters section has the same information as in the home section. The news section consists of news on disaster events. The mitigation section consists of explanations regarding EQs, tsunamis, volcanic eruptions, floods, landslides, tornados, droughts, forest and land fires. The help section contains information on application use, BNPB contact details, BPBD contact details and emergency contact details.

Name of App: I-Tangguh Apps
Downloads: 100,000+ users
Contents of Information:

Login & logout module / Provisional disaster data notification / Provisional disaster details data / Provisional disaster data report / Final disaster data / Final disaster details data / Final disaster data Report / Disaster reports and executive summary / Contact *Pusdalops* / Profile



Source: Google Play

Figure 2.2.5 Basic Information on I-Tangguh Apps

(2) National Search and Rescue Agency (BASARNAS)

1) Rescue 115 Basarnas

Rescue 115 Basarnas aims to allow users to quickly report tragedies and events in the surrounding areas through photos, videos and locations where disasters occur.

Name of App: Rescue 115 Basarnas
Downloads: 1,000+ users
Contents of Information:
Direct call button 115 / Camera function

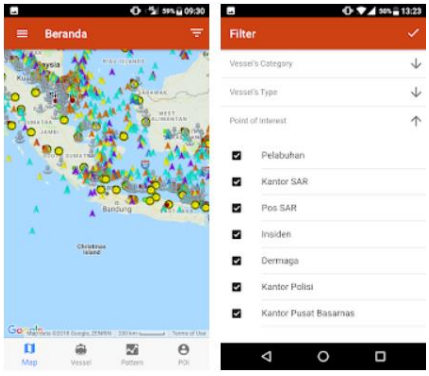
Source: Google Play

Figure 2.2.6 Basic Information on Rescue 115 Basarnas

2) IMSAR BASARNAS

IMSAR application is used by BASARNAS to monitor the activities of the Basarnas vessels and all vessels of various types that are spread in the Indonesia archipelago waters. This application consists of several sections namely map, vessel, pattern and point of interest (POI). The map section consists of a map with different dots and colors which show the spread of different vessels in Indonesia archipelago waters. The vessels section consists of information such as vessel category (AIS-SAT, Basarnas (AIS + LRIT), Basarnas Iridium), vessel type (cargo, fishing, tanker, military, hazard, passenger, h. speed craft, others) and POI (port, SAR office, Search and Rescue (SAR) posts, incidents, docks, post office, Basarnas headquarter). The pattern section consists of graphics.

Name of App: IMSAR BASARNAS
Downloads: 1,000+ users
Contents of Information:
Map (spread of vessels) / Vessel (vessel category, vessel type) / Pattern (graphics) / POI



Source: Google Play

Figure 2.2.7 Basic Information on IMSAR BASARNAS

(3) BPBD

In this research, eight mobile apps released by BPBD from several regions were collected. These apps provide disaster-related information specialized for each region. The basic information on the apps is shown in Table 2.2.1.

Table 2.2.1 Summary of Information on BPBD's Apps

Name of App	BPBD	Number of Downloads	Contents
Sistem Informasi Kebencanaan Kabupaten Magelang	Magelang Regency	1,000+	Map of disaster event within the last 90 days, infographics on the number of victims, location, chronology information.
BPBD Lebak	Lebak Regency	100+	Last disaster events (map of location, and related attribute information)
BPBD Kabupaten Pandeglang	Pandeglang Regency	100+	Map showing the location of the person who reported the disaster events, report form
Lapor Bencana Sleman	Sleman Regency	1,000+	Map showing the location of the person who reported the disaster events, report form
BPBD Karawang	Karawang Regency	10+	Gallery news and photos of disaster management activity
SiCEPAT	Tuban Regency	100+	Disaster report, disaster guides, weather info, news, disaster update info
BPBD Jawa Tengah	Central Java Province	100+	Disaster report
SiGAP	Sidoarjo Regency	1,000+	Disaster report, disaster guides, weather info, news, disaster update info

Information on "SiCEPAT," released by BPBD of Tuban Regency, and "SiGAP," released by BPBD of Sidoarjo Regency, are summarized below as typical examples. The two apps are targeted for regencies in East Java province.

1) SiCEPAT

SiCEPAT is used for reporting disaster management in Tuban Regency, East Java Province in order to realize disaster management quickly, precisely, effectively, and efficiently. This app was updated on August 15, 2019 and has been installed by 100+ users.

Name of App: SiCEPAT
Downloads: 100+ users
Contents of Information: Disaster report (emergency)/ Disaster guides/ Weather information/ News/ Disaster update information

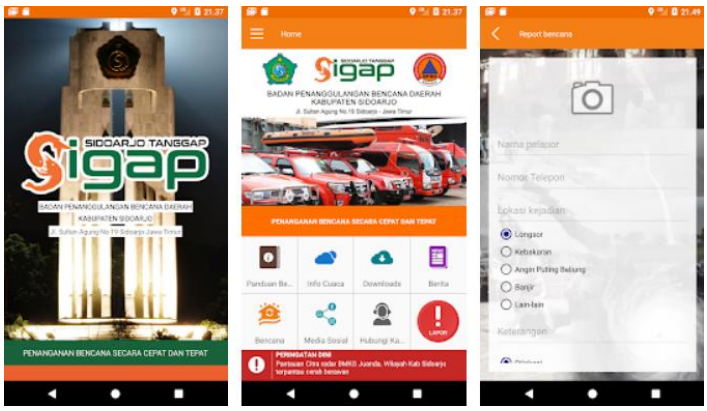
Source: Google Play

Figure 2.2.8 Basic Information on SiCEPAT

2) SiGAP

SiGAP is used for reporting disaster management in Sidoarjo Regency, East Java Province. The objectives and main contents of the app are the same as in SiCEPAT. This app was updated on May 29, 2020 and has been installed by 1,000+ users.

Name of App: SiGAP
Downloads: 1,000+ users
Contents of Information: Disaster report (emergency), Disaster guides, Weather information / News / Disaster update information.



Source: Google Play

Figure 2.2.9 Basic Information on SiGAP

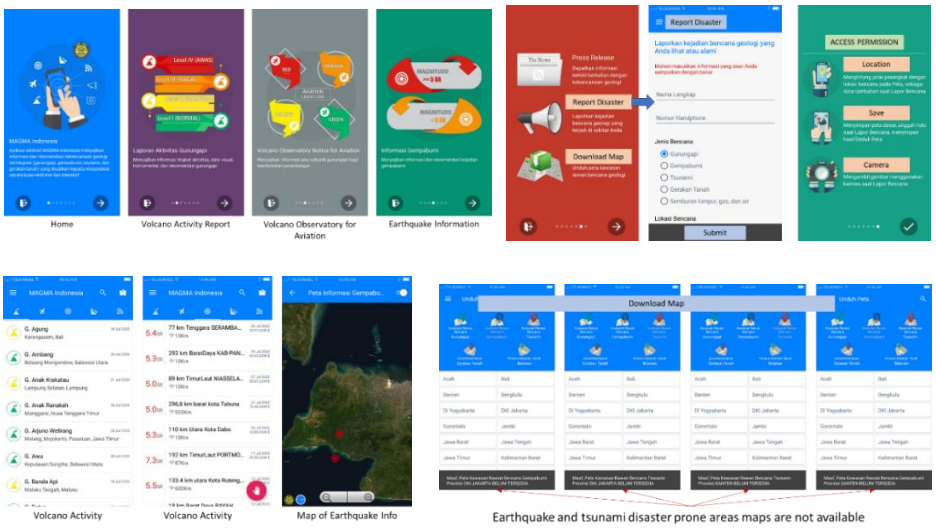
(4) Ministry of Energy and Mineral Resources (ESDM) / Center for Volcanology and Geological Hazard Mitigation (PVMBG)

ESDM, through PVMBG, has an application called MAGMA Indonesia that has been downloaded by more than 100,000 users.

1) MAGMA Indonesia

MAGMA Indonesia presents information and recommendations in quasi real time regarding geological disaster in Indonesia including volcano, land movement, earthquake and tsunami. This app is developed independently by government officers (PNS) development team at the under PVMBG, ESDN. MAGMA Indonesia was built to serve the people of Indonesia and the international community. MAGMA Indonesia is a newly developed breakthrough application developed by Indonesia within the context of geological disaster mitigation efforts. This app has been installed by more than 100,000 users.

Name of App: MAGMA Indonesia
Downloads: 100,000+ users
Contents of Information:
Information on Volcanic Activity (Volcanic Activity Report/VAR) / Information on Eruption/Volcanic Ash to Flight (Volcano Observatory Notice for Aviation/VONA) / Information on the overall volcanic activity level status / Information and response to earthquake/tsunami (Response on Earthquake-ROQ)



Source: Google Play

Figure 2.2.10 Basic Information on MAGMA Indonesia

(5) Private Sector

1) Info Gempa Bumi Terkini (Latest Earthquake Information)

This app is created by Bercoding Studio, an Indonesian android developer that has been active since 2015. Currently, the developer has 17 apps in its portfolio. Some important apps are Asma ul Husna - Meaning & Meaning (Audio), SOAL SIMULASI TES CAT CPNS TERBARU 2020, Doa Harian Anak dengan Suara, Game Edukasi Anak PAUD - TK Lengkap, Game Edukasi dan Lagu Anak Indonesia Offline, and Info Gempa Bumi Terkini. All of these apps have been installed more than 100,000 times.

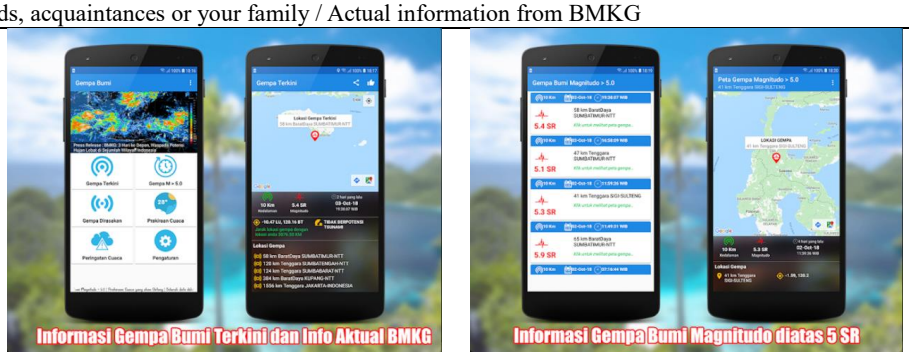
This Latest Earthquake Info application contains the latest earthquake information and estimates of weather conditions in all regions of Indonesia. With this earthquake application, users can directly find out information on the time, location, and region of the earthquake. Through this Earthquake Info application, BMKG can also find out the distance between the current earthquake information and the users' location information. Application of Info BMKG on the latest earthquake has been equipped with the tsunami warning alarm directly from BMKG.

The Latest Earthquake Info application is also equipped with a weather forecast feature to monitor the current weather and the next few days forecast based on the users' location.

All data displayed in the Latest Earthquake Info application is always up-to-date, so the information the user needs is delivered very fast and accurate according to BMKG data.

In essence, this app has the same function as the Info BMKG app.

Name of App: Info Gempa Bumi Terkini
Downloads: 100,000+ users
Contents of information:
Latest earthquake information / Information on earthquake with a magnitude above 5 on the Richter scale / Information on earthquake with a magnitude below 5 on the Richter scale / Indonesian weather forecast information / Indonesia weather forecast settings / Latest earthquake notification alarm reminders / Share it with friends, acquaintances or your family / Actual information from BMKG



Source: Google Play

Figure 2.2.11 Basic Information on Info Gempa Terkini

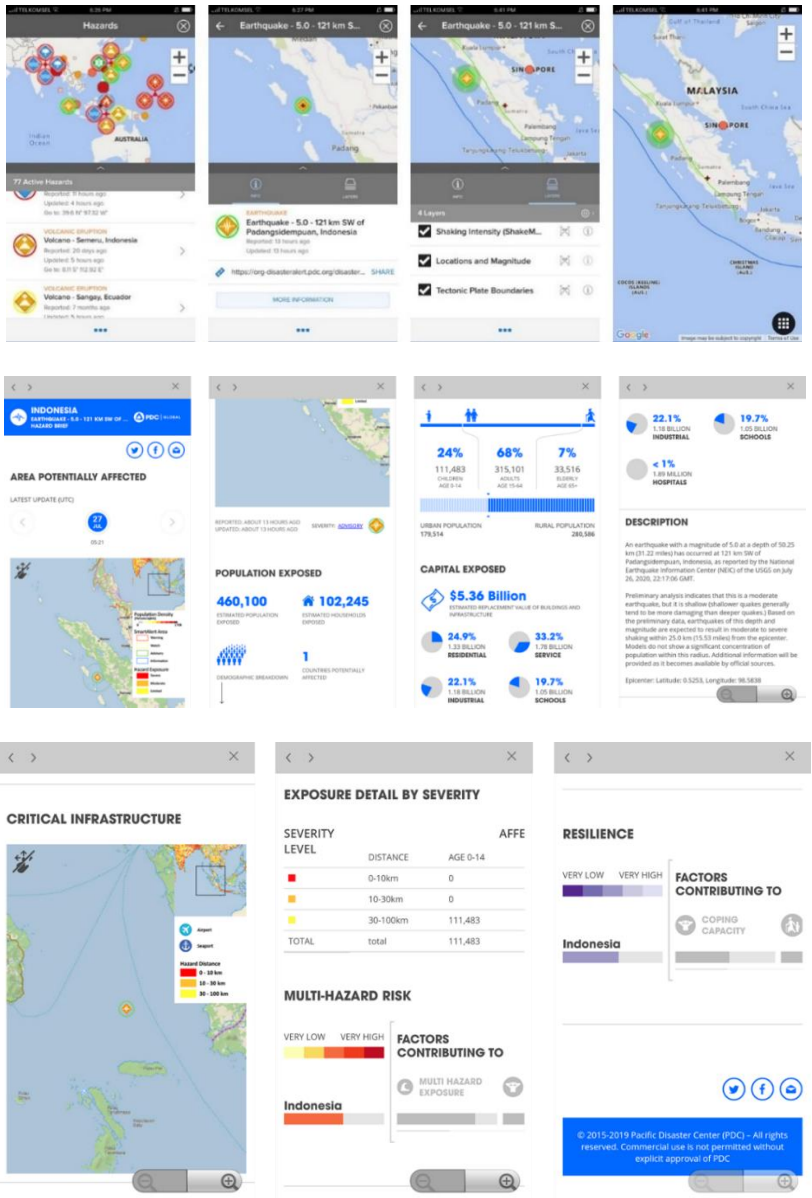
2) Disaster Alert

Disaster Alert is a free, mobile app that provides individuals, families, and their loved ones with the information they need to stay safe anywhere in the world. Built on Pacific Disaster Center's Disaster AWARE® platform, Disaster Alert™ offers near real-time updates about 18 different types of active hazards as they are unfolding around the globe.

With Disaster Alert, you can customize early warning alerts, view situational analysis reports, and access modeled hazard impacts for select hazards in a single, easy-to-use map interface. Disaster Alert's continuous stream of new information is automatically derived from only scientifically verified sources. When no official source is available, alerts are updated manually, presenting a small lag in time. Hazard updates provided with Disaster Alert include only active hazards. "Active Hazards" are part of a collection of recent incidents that have

been designated as potentially hazardous to people, property, or assets by Pacific Disaster Center.

Name of App: Disaster Alert
Downloads: 500,000+ users
Contents of Information:
Hurricanes (tropical cyclones / typhoons), earthquakes, tsunamis, volcanos, floods, wildfires. Also included for the U.S. only are tornados and winter storms. Marine hazards, storms, droughts, and manmade incidents. Also included for Hawaii only are high surf advisories, high winds, and flash floods. / Free, customizable hazard alerts based on location and severity, with automatic updates as each new advisory is released / Animated Layers (rainfall, clouds, winds, etc.) / Layers for tropical storm tracks and 20 other various incidents (including smaller earthquakes, etc.) / Improved navigation and user experience, including user preferences for look and feel / Support for select international languages (other languages are added over time) / Interactive map interface displaying 18 different types of active hazards / Situational analysis reports including modeled impact analyses for select hazards / Customizable background maps / Map overlays with population densities, global cloud coverage, and more



Source: Google Play

Figure 2.2.12 Basic Information on Disaster Alert

Chapter 3 Actual Conditions of Information Dissemination

3.1 Sunda Strait Tsunami 2018

3.1.1 Information Timeline

The timeline of Sunda Strait Tsunami illustrates the volcanic activities observed, tsunami arrival, and its coverage through SNS and TV. (Table 3.1.1) Since BMKG did not issue a tsunami arrival warning, media coverage mainly focuses on the damage and condition afterwards. PVMBG is responsible for volcanic observation and provides information on the volcanic activities that triggered tsunami.

The details on the contents of information are clarified in Section 3.1.2.

Table 3.1.1 Information Timeline for Sunda Strait Tsunami 2018

Date	Time (WITA)	Phenomenon/ BMKG Action	TV/Radio	SNS (Twitter(TW), Facebook(FB), Instagram(INST))	Reaction of People and Others
Dec. 21, 2018	07:00	**07:00 : BMKG Issued a High Wave Early Warning** BMKG issued a high wave early warning of 1.5 - 2.5-meter effective in the Sunda Strait waters region from 7:00 am on Dec. 22 to 7:00 am on Dec. 25.	BMKG posted the same information on its Twitter, Facebook and Instagram accounts at the same time.	**08:45 TW : BMKG Maritim** 1. Update on high wave early warning 2. Figure explaining the issued high wave early warning **08:45 FB : www.maritim.bmkg.go.id** 1. Update on high wave early warning 2. Figure explaining the issued high wave early warning **08:45 INST : info BMKG** 1. Update on high wave early warning 2. Figure explaining the issued high wave early warning	
	13:51	**13:51 : 1st Eruption of Mt. Anak Krakatau** On Dec. 21, 2018, Mt. Anak Krakatau erupted at 13:51 with the height of the ash column observed +/- 400 m from above the peak of +/- 738 m above sea level. The black color ash column was observed with a thick intensity heading toward the North. The status of Mr. Anak Krakatau was at Level II (Alert).		**17:22 WA : ESDM/PVBG** *ESDM/PVBG posted a message on its WhatsApp group, "MAGMA-VEN" 1. Information on the eruption of Mt. Anak Krakatau at 17:22 2. N/A	
Dec. 22, 2018			**00:01 TV : Metro TV** Metro TV reported the occurrence of tidal wave at Cilegon, Banten province and it was caused by the full moon phenomena.		
	20:56	**20:56 : Larger Eruption of Mt. Anak Krakatau** The eruption triggered a 64-hectare slope landslide at Mt. Anak Krakatau.			
	21:03	**21:03 : Frank Collapse on the Slope of Mt. Anak Krakatau** The frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung			
	21:27	**21:27 : Tidal Wave With a Height of 0.9 m** A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge. **21:30 : BMKG Received Reports of Public Panic in Banten and Lampung** BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water. **21:33 : Tidal Wave With a Height of 0.35 m** A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge. **21:35 : Tidal Wave With a Height of 0.36 m** A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge. **21:53 : Tidal Wave With a Height of 0.28 m** A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge.			
	22:30	**22:30 : BMKG Issued a Press Release**	**After 22:30 TV : TV One** TV One News reported that the head of BMKG, Ms. Dwikorita, held a press conference.	**22:37 TW : Info BMKG** 1. Earthquakes that could cause tsunami had not been recorded. High tides that occurred in Anyer beach and its vicinity were tidal waves due to full moon phenomenon, not a tsunami. 2. N/A **23:41 FB : www.bmkg.go.id** 1. A tsunami, which was not triggered by a tectonic earthquake, has hit Banten and Lampung Area 2. BMKG's press release **23:44 WA : BMKG** *A public relations officer of BMKG sent the message to the registered group members of "Early Warning for Media." 1. Tsunami at west coast of Banten was not triggered by an earthquake 2. N/A	

				23:58 FB : BNPB 1. No Tsunami in Anyer and South Lampung, only tidal wave caused by full moon. Emergency handling and data collection were still ongoing. 2. N/A	
				23:58 TW : BNPB Indonesia 1. No Tsunami in Anyer and South Lampung, only tidal wave. 2. N/A	
Dec. 23, 2018			**01:18 TV : iNews** iNews reported that tsunami hit Anyer and its surrounding vicinity.	**01:07 TW : Info BMKG** *To correct its previous posting at 22:37 (WIB), BMKG posted the following: 1. "Tidal waves due to a full moon phenomenon" was removed and revised to "what happened in Anyer and its surrounding vicinity was not a tsunami due to seismic activity earthquake". 2. N/A	BMKG modified and updated its posted information twice.
	01:30	**01:30 : BMKG Held a Press Conference** BMKG informed that a tsunami, which was not triggered by a tectonic earthquake, has occurred.		**01:31 FB : BNPB** 1. Information on the number of deaths and injured due to the tidal wave in Anyer and South Lampung and the status of emergency handling. 2. N/A	BMKG disseminated that a tsunami was caused by the activity of Mt. Anak Krakatau in Anyer and its vicinity.
			02:00 - TV : SCTV SCTV reported that tsunami waves hit Anyer, Banten, and Lampung on Saturday night, Dec. 22. According to BMKG, the tsunami was triggered by the volcanic activity of Mount Anak Krakatau. The reporter of SCTV reported the current situation at the evacuation center in Puskesmas Cinangka, Anyer.	**02:55 TW : Info BMKG** *BMKG posted to update information on previous posting at 01:07 (WIB) as below. 1. Tidal waves in Anyer and its surrounding vicinity was not a tsunami due to tectonic earthquake. However, it was suspected that the tsunami was caused by the activity of Mt. Anaka Karakatau after receiving data from Geological Agency. BMKG would do further verification regarding the phenomenon. 2. N/A	
			07:00 - TV : Kompas TV Kompas TV reported that BMKG had issued a high wave warning a day before the tsunami occurred. A total of 168 people had died, 430 houses were damaged, and 9 hotels were damaged.	**07:31 TW : infoBMKG** 1. Results of the press conference by BMKG: Tsunami in the western coast of Banten was not triggered by the earthquake. 2. N/A	
				08:36 TW : PVMBG-CVGHM 1. Contents of press release 2. Link to reference information	
		16:40 : BMKG Confirmed that the Epicenter was at Mt. Anak Krakatau BMKG confirmed that the epicenter was at Mt. Anak Krakatau. The ground shaking was equivalent to magnitude 3-4.			
Dec. 24, 2018				**11:40 TW : PVMBG-CVGHM** 1. Response to tsunami events 2. Link to reference information	
				20:19 FB : BNPB 1. Temporary data on the impact of the tsunami that hit the coast in Sunda Strait until Monday (24/12/2018) at 17:00 WIB 2. Photos of damaged areas	

【LEGEND】

- Phenomenon/ BMKG Action
- Main Phenomenon
- Time not Specified
- TV
- WhatsApp
- Twitter
- Instagram
- Facebook

(Posting Time) (SNS Type) : (Account Name)
1. Main information
2. Attached/quoted item

3.1.2 Contents of Information

(1) Information posted by BMKG

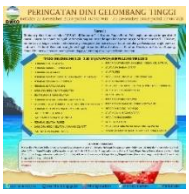
1) Twitter

BMKG posted an information on earthquake and issued a tsunami warning through its official Twitter account, "infoBMKG". During the Sunda Strait Tsunami, BMKG did not post details about the earthquakes and tsunami warning that includes information about the time, epicenter, magnitude, and potential of tsunami. Rather, BMKG posted information about a high tidal wave suspected as tsunami caused by a full moon phenomenon because BMKG did not record any earthquakes that can cause tsunamis. Later, BMKG posted the volcanic activity of Mt. Anak Krakatau as the reason for the tsunami in Sunda Strait. BMKG also posted that their preliminary conclusion needed clarification from Geological Agency/ESDM/PVMBG.

In another BMKG's official Twitter account, "BMKG Maritim," it also posted a figure about a high-wave early warning which took effect within the same timeline of Sunda Strait tsunami.

Posts via twitter were counted more than those on other social media platforms. Major posts and figures during the timeline of high-wave or tsunami occurrence are shown in Table 3.1.2. Since some posts have been deleted from BMKG's official account, the table below includes information obtained from web pages that posted screenshots of deleted posts taken by citizens.

Table 3.1.2 Major Posts on Twitter on Dec. 21-23, 2018

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
Dec 21	07:00	BMKG releases a high wave early warning	
	08:45	# Hello Maritime Friends! Update regarding high wave early warning with 1.5-2.5 meters height in the Sunda Strait water regions, which takes effect from Dec 22 at 07:00 AM to 25 Dec at 07:00 AM. #BMKG Maritim (Retweet:2, Quote Tweet: 0, Likes: 4)	
	13:51	First eruption of Mt. Anak Krakatau	
Dec 22	20:56	Big eruption of Mt. Anak Krakatau	
	21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung	
	21:27	A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge	
	21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water	
	21:33	A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge	
	21:35	A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge	
	21:53	A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge	
	22:30	BMKG issued a press release	
	22:37	# BMKG did not record any earthquake that can cause tsunami tonight. What happened in Anyer and its surrounding vicinity was not a tsunami, but a tidal wave. Especially tonight, there is a full moon phenomenon which causes high tides. Keep calm (emoji "cool") #BMKG (Retweets:3,122; Quote Tweets: 854; Likes: 1,919)	N/A
Dec 23	01:07	# BMKG did not record any earthquake that can cause tsunami tonight. What happened in Anyer and its surrounding vicinity was not a tsunami due to the seismic earthquake activity. Keep calm (revised emoji "sorry") #BMKG	N/A

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
		(Retweets:2.9K; Quote Tweets: 167; Likes: 2.8K)	
	01:30	BMKG held a press conference	
	02:55	# Tidal wave in Anyer and its surrounding vicinity is not a tsunami due to tectonic activity or earthquake. However, after receiving data from Geological Agency it was suspected that the tsunami was caused by the activity of Mt. Anak Krakatau. BMKG will do further verification regarding this phenomenon #BMKG (Retweets:6,489; Quote Tweets: 276; Likes: 3.4K)	N/A
	07:31	# A press conference by BMKG: Tsunami in the western coast of Banten was not triggered by the earthquake #BMKG (Retweets:8.1K; Quote Tweets: 492; Likes: 5K)	N/A
	16:40	BMKG confirmed the epicenter is at Mt. Anak Krakatau	

Note: JICA Expert Team translated posted texts from Indonesian language to English.

Source: JICA Expert Team

2) Facebook

BMKG posted the information on earthquake and tsunami via their official Facebook page, "www.bmkg.go.id (Info BMKG)," as Facebook is one of the most dominant social media sites in Indonesia. The contents of the information posted on Facebook basically contains similar information and posting time as its Twitter account. For example, BMKG Maritim posted an information about high wave early warning at 08:45am WIB.

Since Twitter only allows limited characters per post, information on the BMKG Facebook page post is more detailed. For example, BMKG posted a detailed content of its press release at 23:41pm WIB.

Table 3.1.3 Major Posts on Facebook on Dec. 21-23, 2018

Date	Posting Time (WIB)	Contents of Posts	
		Summary of Posted Information	Attached Figures
Dec 21	07:00	BMKG releases a high wave early warning	
	08:45	[www.maritim.bmkg.go.id] BMKG gives a 1.5-2.5 m high wave early warning in the Sunda Strait water regions, effective Dec 22 at 07:00 AM to Dec 25 at 07:00 AM. (Comments:7; Shares: 94; Likes: 105)	
	13:51	First eruption of Mt. Anak Krakatau	
Dec 22	20:56	Big eruption of Mt. Anak Krakatau	
	21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung	
	21:27	A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge	
	21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water	
	21:33	A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge	
	21:35	A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge	
	21:53	A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge	
	22:30	BMKG issued a press release	

Date	Posting Time (WIB)	Contents of Posts	
		Summary of Posted Information	Attached Figures
Dec 23	23:41	[www.bmkg.go.id] A tsunami, which was not triggered by a tectonic earthquake, has hit Banten and Lampung Area. The English translation has been attached to the original figure. (Comments:2; Shares: 14; Likes: 162)	
Dec 23	01:30	BMKG held a press conference	
	16:40	BMKG confirmed the epicenter is at Mt. Anak Krakatau	

Source: JICA Expert Team

3) Instagram and WA

On its official Instagram account, "Info BMKG," BMKG posted earthquake and tsunami information generated by InaTEWS. Instagram is another social media platform dominant among Indonesian people, and Instagram posts are often shared by other social media and messenger services.

The contents of the information posted on Instagram includes a figure and texts about high wave early warning, similar to what BMKG posted on its Twitter and Facebook accounts. In addition, the timing was also the same as that of its Twitter and Facebook account posts.

WhatsApp group was also popular and dominantly used to relay information in Indonesia. BMKG has maintained a WhatsApp group, "Early Warning for Media," which was dedicated to convey information to the media. Shortly after posting the press release, BMKG sent messages to its registered group at 23:44pm WIB.

Table 3.1.4 Major Posts on Instagram and WA on Dec. 21-23, 2018

Date	Posting Time (WIB)	Contents of Posts	
		Summary of Posted Information	Attached Figures
Dec 21	07:00	BMKG releases a high wave early warning	
	08:45	[INSTA] Update on high wave early warning of a 1.5-2.5 meters height in the Sunda Strait water regions, which takes effect from Dec 22 07:00 AM to Dec 25 07:00 AM. (Likes: 26,287)	
	13:51	First eruption of Mt. Anak Krakatau	
Dec 22	20:56	Larger eruption of Mt. Anak Krakatau	
	21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung	
	21:27	A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge	
	21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water	
	21:33	A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge	
	21:35	A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge	
	21:53	A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge	
	22:30	BMKG issued a press release	

Date	Posting Time (WIB)	Contents of Posts	
		Summary of Posted Information	Attached Figures
	23:44	[WA] A public relations officer of BMKG sent the message to the registered group members of "Early Warning for Media." The WA message declared that the tsunami on the west coast of Banten was not triggered by an earthquake.	
Dec 23	01:30	BMKG held a press conference	
	16:40	BMKG confirmed the epicenter is at Mt. Anak Krakatau	

Source: JICA Expert Team

(2) Information posted by other DRR agencies

1) ESDM (PVMBG)

ESDM/PVMBG posted the information related to volcanic activities through its official Twitter account, "PVMBG-CVGHM". Although the posting time was slightly slower, the information was crucial in regards to the clarification for the occurrence of Sunda Strait tsunami.

ESDM/PVMBG posted a message on its WhatsApp group, "MAGMA-VEN[1]".

The post at 17:22 WIB was the only and very important information regarding volcanic eruption of Mt. Anak Krakatau that was the causal factor for the Sunda Strait tsunami.

Table 3.1.5 Major Posts on Twitter and WA on Dec. 22-24, 2018

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
Dec 22	17:22	[WA] MAGMA-VEN Volcanic Eruption Notice There has been an eruption at Mt. Anak Krakatau, Lampung on December 22, 2018 at 17:22 with observable ash column height +/- 1.500 meters above the peak (+/- 1.838 m above sea level). Black ash column with thick intensity leaning north and east was observed. These eruptions are recorded in seismograms with maximum amplitude of 58 mm and duration of +/- 5 minutes and 21 seconds. The sound and vibration are felt in the Volcano Observatory (PGA) Post. Currently, Mt. Anak Krakatau is on the status of *Level II (Alert)* with the recommendation that people / tourists are not allowed to approach within 2 km of the crater. Data Source: KESDM, Geological Agency, PVMBG https://magma.vsi.esdm.go.id	N/A
	20:56	Big eruption of Mt. Anak Krakatau	
	21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung	
	21:27	A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge	
	21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal	

[1] https://magma.vsi.esdm.go.id

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
		sea water	
	21:33	A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge	
	21:35	A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge	
	21:53	A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge	
	22:30	BMKG issued a press release	
Dec 23	01:30	BMKG held a press conference	
	08:36	[TW] # Pers Release Activities of Mt. Anak Krakatau, Sunday, December 23, 2018. Referring to https://www.vsi.esdm.go.id/index.php/gunungapi/aktivitas-gunungapi/2445-pers-rilis-aktivitas-gunungapi-anak-krakatau-rabu-3-oktober-2018#PVMBG-CVGHM (Retweets:56; Quote Tweets: 4; Likes: 60)	N/A
	16:40	BMKG confirmed the epicenter is at Mt. Anak Krakatau	
Dec 24	11:40	[TW] # Response to tsunami events in the Sunda Strait, December 22, 2018. Referring to https://t.co/ZCnfJex0Pl?amp=1#PVMBG-CVGHM (Retweets:30; Quote Tweets: 4; Likes: 29)	N/A

Note: JICA Expert Team translated posted texts from Indonesian language to English.

Source: JICA Expert Team

2) BNPB

BNPB posted the status of emergency response and damages due to earthquake and tsunami through its official Twitter account, "BNPB Indonesia" and Facebook page, "BNPB".

In its press release posted on its Twitter and Facebook accounts within the same time period, BNPB summarized what happened in the affected areas and how the evacuation was carried out.

The later posts provided more detailed information about the damages and casualties, as well as the continuation of emergency handling.

Table 3.1.6 Major Posts on Twitter and Facebook on Dec. 22-24, 2018

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
Dec 22	20:56	Big eruption at Mt. Anak Krakatau	
	21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG's seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung	
	21:27	A tidal wave with a height of 0.9 meters was recorded at BIG's tide gauge	
	21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water	
	21:33	A tidal wave with a height of 0.35 meters was recorded at BIG's tide gauge	
	21:35	A tidal wave with a height of 0.36 meters was recorded at BIG's tide gauge	
	21:53	A tidal wave with a height of 0.28 meters was recorded at BIG's tide gauge	
	22:30	BMKG issued a press release	
	23:58	[FB] BNPB No tsunami in Anyer and South Lampung, only tidal wave. The people around Anyer Beach and South Lampung were shocked by the rising sea water that crashed into the buildings around the beach on 12/22//2018 at 21:30 WIB. The waves rose quite big and fast. This phenomenon is caused by a tidal wave. Especially when there is a full moon, the sea levels rise. BMKG has reported no major earthquakes that can generate tsunami, neither earthquakes around the Sunda Strait nor in the Indian Ocean. So, the current phenomenon is not a tsunami. There is no tsunami in Indonesian territory at this time. This tidal wave phenomenon also has nothing to do with the eruption of Mount Anak Krakatau. Since this morning, there was indeed an eruption, but it was only a small eruption that did not cause the rising of sea waves.	N/A

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
		Based on the results of tide data observations from the tide gauge of BMKG, some data are shown as follows: a. Tide gauge Serang was recorded at 21:27 WIB, with a height of 0.9 m b. Tide gauge Banten was recorded at 21:33 WIB, with a height of 0.35m c. Tide gauge Kota Agung Lampung was recorded at 21:35 WIB, with a height of 0.36 m d. Tide gauge Panjang Port was recorded at 21:53 WIB, with a height of 0.28 m BPBD, together with the TNI, Polri, Basarnas, SKPD and volunteers, are still handling it in the field. Evacuation was carried out in several places. Data collection and handling is still being carried out. We urge people to remain calm. Do not rely on misleading information. Temporarily avoid activities around the coast. Pay attention to the existing environmental conditions. Once again, there was no tsunami. What happened was a tidal wave around the coast. Sutopo Purwo Nugroho (Comments:27; Shares: 199; Likes: 132)	
	23:58	[TW] #No Tsunami in Anyer and South Lampung, only tidal wave. The people around Anyer Beach and South Lampung were shocked by the rising sea water that crashed into the buildings around the beach on....#BNPB Indonesia (Retweets:158; Quote Tweets: 13; Likes: 153)	N/A
Dec 23	01:30	BMKG held a press conference	
	01:31	[FB] Due to high wave impact, 3 people were killed and 21 were injured. Emergency handling of the impact of the high waves that hit Anyer beach in Pandeglang and South Lampung Regencies continues. The occurrence of high waves that hit settlements and hotels on the coast happened suddenly, causing casualties and damage. The tidal wave took place on 12/22/2018 at 21:30 WIB. Based on temporary data on the impact of tidal waves collected by BPBD on 12/23/2018 at 00:30 WIB, 3 people died, 21 people were injured and hospitalized, and more than 30 houses were severely damaged. Meanwhile, in Pandeglang District, 10 people were injured. Data collection is still being carried out. Nighttime and dark conditions mean that not all of the damage has been resolved. BPBD, together with the TNI, Polri, Basarnas, SKPD, volunteers and the community, takes care of the distribution of aids. Most of the tides that hit the coast have receded. There are still puddles and plenty of waste materials in the settlements. This tidal wave phenomenon was not caused by an earthquake that triggered a tsunami or the effect of the eruption of Mt. Anak Krakatau. Rather, it was due to the dynamics of the sea and the influence of the full moon. People are urged to remain calm. There was no tsunami. The various causes of tsunamis include earthquakes (generally earthquakes greater than 7 SR, with the epicenter at the sea with a depth of less than 20 km and in a subduction zone); underwater landslides; volcanic eruptions; and falling meteors in the sea. Handling and data collection are still being carried out. For further information, please contact: -Head of BPBD Kab. South Lampung, Ketut Sukerta, 081279211977 -Officer of BPBD Kab. Pandeglang, Deni, 08129536606 -BPBD Kab. Pandeglang, 081287849020 Sutopo Purwo Nugroho Head of Data Information and Public Relations Center of BNPB (Comments:13; Shares: 76; Likes: 129)	N/A
	16:40	BMKG confirmed that the epicenter is at Mt. Anak Krakatau	

Date	Posting Time (WIB)	Contents of Posts	
		Posted Text	Attached Figures
Dec 24	20:19	[FB] Temporary data on the impact of the tsunami that hit the coast in Sunda Strait until Monday (12/24/2018) at 17:00 WIB recorded that 373 people had died, 1,459 were injured, 128 were missing, and 5,665 were displaced. Physical losses due to the tsunami included damages to 681 houses, 69 hotels and villas, 420 boats, 60 shops, and dozens of vehicles. (Comments:13; Shares: 233; Likes: 249)	

Note: JICA Expert Team translated posted texts from Indonesian language to English.
Source: JICA Expert Team

(3) Dissemination of information by media

1) TV

BMKG and TV broadcasting companies have signed an MoU, in which the media will administer the dissemination of disaster warning from BMKG. According to the SOP, in the event of natural disasters, broadcasting companies receive information from BMKG through WRS and immediately broadcast a “stop press / breaking news”. Contents and timing vary depending on the company.

Major contents and timing of the press coverage in each TV broadcasting companies are as follows:

Table 3.1.7 Major Contents and Timing of TV broadcasting on Dec. 22-23, 2018

Broadcasting Time (WIB)	TV Company	Contents of Broadcasting	
		Summary of Information	Screenshot
Dec 22 00:01	Metro TV	Metro TV reported the occurrence of tidal wave at Cilegon, Banten Province. The news showed groups of people scattered outside of their houses and buildings. BMKG confirmed that the phenomenon was not a tsunami, but a high wave caused by the full moon. The news caption said: -BMKG reported that the tidal wave in Anyer was not a tsunami -BMKG reported that the high tidal wave was caused by the full moon phenomenon -BPBD recorded damages caused by high tidal waves in Anyer -BPBD, TNI (Indonesian Army), POLRI (Police of Rep. of Indonesia) handle the impacts brought by high tidal waves in Anyer	
20:56	Eruption of Mt. Anak Krakatau		
21:03	Frank collapse on the slope of Mt. Anak Krakatau was recorded by BMKG’s seismograph sensor at Cigeulis Pandeglang and sensors in Banten and Lampung		
21:27	A tidal wave with a height of 0.9 meters (tsunami) was recorded at BIG’s tide gauge		
21:30	BMKG received reports of public panic in Banten and Lampung due to abnormal tidal sea water		
21:33	A tidal wave with a height of 0.35 meters (tsunami) was recorded at BIG’s tide gauge		
21:35	A tidal wave with a height of 0.36 meters (tsunami) was recorded at BIG’s tide gauge		
21:53	A tidal wave with a height of 0.28 meters (tsunami) was recorded at BIG’s tide gauge		
22:30	BMKG issued a press release		
	tvOne	The head of BMKG, Ms. Dwikorita, held a press conference	

Broadcasting Time (WIB)	TV Company	Contents of Broadcasting	
		Summary of Information	Screenshot
Dec 23 01:18	iNews	Tsunami hit Anyer and its surrounding vicinity	
01:30	BMKG held a press conference		
02:00 – early morning	SCTV	https://www.youtube.com/watch?v=S30qcdeMEns Tsunami wave hit Anyer, Banten, and Lampung on Saturday night of Dec. 22. According to BMKG, the tsunami was triggered by the volcanic activity of Mount Anak Krakatau.	
	SCTV	The reporter of SCTV reported the current situation at the evacuation center in Puskesmas Cinangka, Anyer. He said that the center was hectic due to incoming evacuees after the tsunami or high wave hit Anyer and its surrounding vicinity. The team of BPBD and the Indonesian Red Cross Society (PMI) of Serang Regency helped during the evacuation. Initial reports said that 6 people had died, 5 were injured, and 9 were missing. One road in Bulakan was cut off. The evacuation process had been postponed due to bad weather in the location.	
07:00-noon	Kompas TV	https://www.youtube.com/watch?v=f9Gj2jdrAqw BMKG has issued a high wave warning a day before the tsunami. A total of 168 people had died, and 430 houses and 9 hotels had been damaged. One of the survivors was still looking for her family of 7 people, in which two members were found dead.	
16:40	BMKG confirmed that the epicenter is at Mt. Anak Krakatau		

Source: JICA Expert Team

2) Radio

The local consultant of JICA Experts Team has contacted RRI by electronic email and phone calls to search for the archives of RRI broadcasting transcripts. It was confirmed that no archives of broadcasting have been recorded during Sunda Strait Tsunami because RRI did not receive an official warning message from BMKG.

3.2 Central Sulawesi Earthquake and Tsunami 2018

3.2.1 Information Timeline

The information timeline of the Central Sulawesi earthquake and tsunami illustrates the time frame before the main shock at 18:02 on September 28 because of continuous pre-shock that led people to evacuate and caused blackouts in parts of Palu and Donggala, which were the areas most affected by the main shock (Table 3.2.1). The information on the timeline includes the interview results of

"Limitations and Challenges of Early Warning Systems" compiled by UNDRR[2].

It should be noted that the timeline of SNS posts only covered the foreshock at 15:00 WITA that caused blackouts in some areas and the main shock at 18:02 WITA. Several dozens of weak foreshocks and aftershocks were recorded on that day. If an earthquake is not intense and/or does not have the potential of causing tsunami, information will be posted only once, and the contents of the first post as the main shock will be the same.

BMKG posted almost all foreshocks and aftershocks through its Twitter, Facebook and Instagram accounts. Among these, Twitter posts are the most frequently and immediately re-posted. Due to the character limitation of posts in each SNS, contents of three SNS do not always coincide. Some posts on the SNS appeared to be manually typed and some explanations were added. According to an interview with the residents in Central Sulawesi Province, BMKG's mobile application issued a warning on September 28. However, the interviewee did not take a screenshot of the warning with a time stamp, so there is no evidence of what time people received information via BMKG's mobile application.

This survey relied on internet research to collect subjective information, such as information with the posting time, and time stamp of the TV news report. Because of the nature of SNS or internet media posts in which they can be easily deleted, the timeline information covers the information that JICA Expert Team could access as of July 2020.

Detailed contents of information are clarified in Section 3.2.2.

[2] Limitations and Challenges of Early Warning Systems Palu-Donggala Tsunami Case Study, September 28, 2018, UNDRR

Table 3.2.1 Information Timeline for Sulawesi Earthquake and Tsunami 2018

Date	Time (WITA)	Phenomenon/ BMKG Action	TV/Radio	SNS (Twitter(TW), Facebook(FB), Instagram(INST))	Reaction of People and Others
Sep. 28, 2018	15:00	**15:00 : Earthquake M 5.9** The first M5.9 earthquake was recorded by BMKG's seismometer station near Palu and Donggala (Epicenter: 8 km northwest of Donggala) ->Magnitude was modified to M6.1 afterwards **15:07 : DRR related agencies received SMS** Through WRS, BMKG sent SMS to DRR-related agencies :::: BMKG :::: BMKG :::: BMKG :::: TELAH TERJADI GEMPA BUMI DENGAN PARAMETER SEMENTARA SEBAGAI BERIKUT: Kekuatan : 5.9 SR Tanggal : 28-Sep-2018 Waktu Gempa : 14:00:00 WIB Lintang : 0.35 LS Bujur : 119.82 BT Kedalaman : 10 Km Lokasi: Minahassa Peninsula, Sulawesi Keterangan: 8 km BaratLaut DONGGALA-SULTENG 61 km BaratLaut PALU-SULTENG 105 km TimurLaut MAMUJUUTARA-SULBAR 115 km BaratLaut SIGI-SULTENG 1582 km TimurLaut JAKARTA-INDONESIA Informasi Tsunami : Gempa ini tidak berpotensi TSUNAMI :::: BMKG :::: BMKG :::: BMKG :::: Blackouts in some areas in Palu and Donggala, landline was functioning More than 20 foreshocks were recorded	BMKG posted on Twitter 3 minutes after the earthquake was recorded	**15:03/15:06 TW : infoBMKG** 3. Earthquake (M 5.9) at 15:00:00 (WITA) 4. Epicenter (location, depth)/ No tsunami potential 5. Epicenter location map Information was updated **15:21 TW : infoBMKG** 1. Earthquake (M 5.9) at 14:59:56 (WITA) 2. Epicenter (location, depth) 3. Shake map Posting on Facebook and Instagram was around 10 minutes later than the Twitter post **15:32 INST : infobmkg** 3. Earthquake (M 5.9) at 14:59:56 (WITA) 4. Epicenter (location, depth)/ No tsunami potential 5. Shake map **15:32 FB : www.bmkg.go.id (infoBMKG)** 1. Earthquake (M 5.9) at 14:59:56 (WITA) 2. Epicenter (location, depth)/ No tsunami potential 3. Shake map **16:25 INST : bmkgpalu.geof** 1. Earthquake (M 5.9) at 14:59:56 (WITA) 2. Epicenter (location, depth)/ No tsunami potential 3. Epicenter location map **16:49 TW : BNPB _Indonesia** 1. Earthquake (M 5.9) at 14:59:56 (WITA) 2. House damage 3. Photo of damaged houses **16:56 FB : BMKG Stasiun Geofisika Palu** 1. Aftershocks after Earthquake (M 5.9) 2. N/A 3. List of aftershocks **17:29-17:37 TW : BNPB Indonesia** 1. Earthquake (M 5.9) at 14:59:56 (WITA) 2. Information on epicenter, injured and number of deaths, house damages, emergency handling, etc. 3. N/A	Some people along the coastal areas at Donggala evacuated to hills judging from ground shake, unusual phenomenon of sea water surface, past record of tsunami as told by their parents, etc. Some people at Donggala community returned home knowing the foreshock would not cause the potential for tsunami (around 17:30).
	18:02	**18:02 : Earthquake M 7.7** Main M7.7 earthquake occurred in Central Sulawesi. (Epicenter 26-km north of Donggala) **18:04 : Blackout in Palu and Donggala** • Blackout in Palu and Donggala • Unstable Telkomsel phone line service (started around this time) • XL mobile carrier was still active			
	18:06	**18:06 : First Tsunami Arrival in Donggala** First tsunami arrival was recorded by CCTV in Donggala Regency, Wani 1 Village, Tanan Tovea Sub-District.			
	18:07	**18:07 : BMKG Issued a Tsunami Early** • BMKG established earthquake parameters and a tsunami early warning. • BMKG sent SMS • Tsunami Early Warning (PDT) 1 indicated that the highest potential wave would be 0.58 meter with an estimated time of arrival 20 minutes after the earthquake.	Breaking news started after BMKG sent SMS to DRR-related agencies **18:02 TV : tvOne** tvOne reported the occurrence of M7.7 earthquake. **18:08 TV : Metro TV** Stop Press	BMKG posted on Twitter at 18:07 (WITA), the same time as their actions **18:07/18:09 TW : infoBMKG** 1. Earthquake (M 7.7) at 18:02:44 (WITA) 2. Epicenter(location,depth)/Tsunami early warning 3. Tsunami warning distribution map	
	18:10 (-18:15)	**18:10-18:15 : Larger Tsunami Arrival**		**18:11 TW : BNPB Indonesia** 1. Earthquake (M 7.7) at 18:02:44 (WITA) 2. Epicenter (location, depth)/ Tsunami potential 3. N/A	

BMKG posted on Facebook and Instagram at the same time.

18:21 FB : www.bmkg.go.id (infoBMKG)
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. Tsunami potential
3. Table of tsunami warning level by targeted areas

18:21 INST : infobmkg
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. Epicenter(location,depth)/Tsunami early warning
3. Tsunami warning distribution map

18:32 TV : Kompas TV

Kompas TV reported the occurrence of earthquake and tsunami by quoting BMKG's information and phone call to BMKG officials. Kompas TV also called on the public to evacuate.

Several aftershocks were recorded

18:24 FB : www.bmkg.go.id (infoBMKG)
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. Epicenter(location,depth)/Tsunami early warning
3. Tsunami warning distribution map

18:30 TW : infoBMKG
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. Epicenter (location, depth)/ Tsunami potential
3. Table of tsunami warning level by targeted areas

Affected people in Palu contacted by using XL SIM card that was active during the blackout by phone and SNS (source: affected person in Palu)

18:36

18:36 : End of Tsunami Early Warning

BMKG JKT issued a tsunami early warning (PDT) 4 (ending of the tsunami warning)
BMKG Jakarta's decision to end the early warning was made after receiving a report of the sea level observation and tide gauge in Mamuju (±237 km from Palu) that recorded a 6-cm sea level rise at 18:27.

Breaking news started after BMKG JKT had issued PDT-4 at 18:36 (WITA)

18:35- Radio : RRI

RRI Palu office restarted broadcasting programs by using a generator. It broadcast situational updates in Palu by obtaining information from residents, Red Cross, etc.

18:36 TW : infoBMKG
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. End of tsunami early warning
3. Exclamation illustration image

18:40 TW : BNPB Indonesia
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. End of tsunami early warning
3. N/A

18:36 TV : tvOne

tvOne reported the issuance of tsunami warning and its ending and called on the public to remain vigilant and evacuate.

The telecommunications network of Telkomsel, a dominant SIM carrier in this area, was cut off.

18:42 FB : www.bmkg.go.id (infoBMKG)
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. End of tsunami early warning
3. Exclamation illustration image

18:42 INST : infobmkg
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. End of tsunami early warning
3. Exclamation illustration image

Several aftershocks were recorded

19:31 TW : BNPB Indonesia
1. All earthquakes occurred on 28th
2. N/A
3. Earthquake list on 28th

19:35 TW : infoBMKG
1. N/A
2. Message to urge people to get information through BMKG app
3. N/A

19:40 TW : BNPB Indonesia
1. Earthquake (M 7.7) at 18:02:44 (WITA)
2. End of tsunami early warning
3. Link to BNPB's Facebook page

20:40 TW : BNPB Indonesia
1. N/A
2. Access limitation to Palu area
3. Post from a private account of Mr. Sutopo Purwo Nugroho, former head of data information and public relations center of BNPB.

21:00

21:00 : Telecommunications Were Recovered

Telecommunications were recovered in some areas

*Head of BPBD Donggala received BMKG Bulletin via WhatsApp at 21:00.

21:01 TV : Metro TV

Metro TV showed an amateur video footage of tsunami hitting the area and reported that communication lines were cut off.

22:44 TV : Kompas TV

Kompas TV reported the occurrence of earthquake and tsunami through phone calls with BMKG officials.

23:21 FB : BNPB (infoBencanaBNPB)
1. N/A
2. Status of emergency handling
3. N/A

23:21-23:49 TW : BNPB Indonesia
3. N/A
4. Status of emergency handling
5. A link to the post on Facebook

BNPB posted on Facebook at 23:21 (WITA). At the same time, it posted a link on its Twitter account. After 23:29 (WITA), the contents of the Facebook post were posted part by part on BNPB's Twitter account.

【LEGEND】
- Phenomenon/ BMKG Action
- Main Phenomenon
- Time not Specified
- TV
- Radio
- Twitter
- Instagram
- Facebook

(Posting Time) (SNS Type) : (Account
3. Earthquakes subject to the post
4. Other information
5. Attached/quoted item

3.2.2 Contents of Information

(1) Information posted by BMKG

BMKG issued an earthquake information and tsunami early warning, both directly and indirectly, to the affected population though InaTEWS on September 28. Residents obtained information directly from BMKG via mobile phone application and SNS services, and received information indirectly from TV and radio stations that received warning information from BMKG via WRS. At this time, BPBD's tsunami siren did not function due to blackout and battery problems[3]. This section illustrates the information issued by each source and its timing.

1) Twitter

BMKG posted earthquake information and tsunami warning on its official Twitter account, "infoBMKG". BMKG posted figures about the earthquakes that included information on time, epicenter, magnitude, and potential of tsunami. Although BMKG posted the information through other social media platforms, its post via Twitter was delivered slightly faster than BMKG's other social media accounts. Major posts and figures during the foreshock and main shock are as follows:

Table 3.2.2 Major Posts on Twitter on Sept. 28, 2018

Posting Time (WITA)	Contents of Posts	
	Posted Text	Attached figures
15:00	M 5.9 earthquake occurred	
15:03	# Earthquake Mag:5.9, Sep 28, 2018, 14:00:00 WIB, Loc:0.35 SL,119.82 EL (8 km northwest of DONGGALA-CENTRAL SULAWESI), Depth:10 km, does not have potential to trigger tsunami #BMKG (Retweets:199; Quote Tweets: 14; Likes: 132)	
15:06	# Earthquake Mag:5.9, Sep 28, 2018, 14:00:00 WIB, Loc:0.35 SL,119.82 EL (8 km Northwest of DONGGALA-CENTRAL SULAWESI), Depth:10 km, does not have potential to trigger tsunami #BMKG (Retweets:80; Quote Tweets: 3; Likes: 87)	N/A
15:21	# Earthquake Mag:5.9, Sep 28, 2018, 13:59:56 (The epicenter was on land 61 km northward of Palu), A depth of10 km was felt (MMI) in III Palu, IV Donggala, II Poso (Retweets:72; Quote Tweet: 6; Likes: 49)	N/A
15:21	# Earthquake Mag:5.9, Sep 28, 2018, 13:59:56 WIB. Loc:0.35 SL, 119.82 EL (The epicenter was on land 61 km northward of Palu), Depth:10 km was felt (MMI) in III Palu, IV Donggala, II Poso (Retweets:94, Quote Tweets: 4, Likes: 76)	
18:02	M 7.7 earthquake occurred	
18:06	The first tsunami arrived	
18:07	BMKG issued a tsunami early warning	

[3] Interview survey result on the detailed planning survey of the Project

Posting Time (WITA)	Contents of Posts	
	Posted Text	Attached figures
18:07	#Tsunami Early Warning in CENTRAL SULAWESI,WEST SULAWESI, EQ Mag:7.7, Sep-28-18 17:02:44WIB, Loc:0.18LS,119.85BT, Depth:10 km (Retweets:7,177; Quote Tweets: 894; Likes: 3,523)	
18:09	# Earthquake Mag:7.7, Sep-28-18 17:02:44 WIB, Loc:0.18 SL,119.85 EL (27 km Northeast of DONGGALA-CENTRAL SULAWESI), Depth:10 km, has the potential to trigger tsunami to be passed on to the citizens (Retweets: 9,155; Quote Tweets: 996; Likes: 3,597)	N/A
18:10-18:15	Larger tsunami arrived	
18:30	#Tsunami Early Warning for the following areas: WEST SULAWESI, CENTRAL SULAWESI, EQ Mag:7.7, Sep-28-18 17:02:44 WIB, Loc:0.18 SL, 119.85 EL (27 km Northeast of DONGGALA-CENTRAL SULAWESI), Depth:10 km (Retweets:1,703; Quote Tweets: 148; Likes: 645)	
18:36	BMKG lifted the tsunami early warning	
18:36	TSUNAMI early #Warning triggered by Mag:7.7 EQ on Sep-28-18 17:02:45 WIB, has ended #BMKG (Retweets: 4,066; Quote Tweets: 342; Likes: 2,576)	
19:35	BMKG urged citizens to get information from BMKG's official application and not to believe in hoax information from other sources. (Retweets: 675; Quote Tweets: 21; Likes: 706)	N/A

Note: JICA Expert Team translated posted texts from Indonesian language to English.

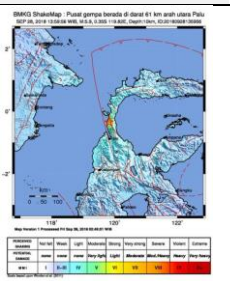
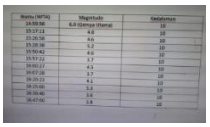
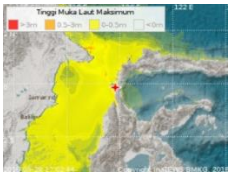
Source: JICA Expert Team

2) Facebook

BMKG posts information on earthquake and tsunami via its official Facebook page, "www.bmkg.go.id (Info BMKG)," as Facebook is one of the most dominant social media sites in Indonesia. Contents of the information posted via Facebook is basically similar to the Twitter post. Since Twitter has character limitation per post, information on the Facebook page post is more detailed. In addition, if the latest information has been updated, BMKG also updated the details of its post contents.

For example, when a large pre-shock occurred at 3pm WITA, BMKG posted the first information at 3:32pm WITA and updated the details on 4:21pm WITA. Changes in the initial post were made under the account name of the Head of Earthquake and Tsunami Center, which included an update on the magnitude of the earthquake and recorded seismic activity.

Table 3.2.3 Major Posts on Facebook on Sept. 28, 2018

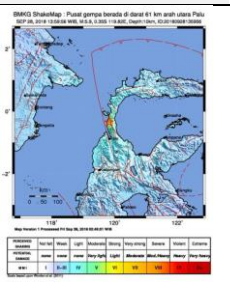
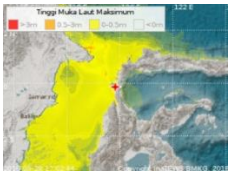
Posting Time (WITA)	Contents of Posts	
	Summary of Posted Information	Attached Figures
15:00	M 5.9 earthquake occurred	
15:32	[www.bmkg.go.id] On September 28, 2018 at 14.00.00 WIB, Donggala Regency area was shaken by a tectonic earthquake. M 5.9 was updated to M 6.0. Modeling results showed that the earthquake did not have potential to trigger tsunami. In addition, the information of epicenter location, hypocenter depth of the earthquake, results of the analysis of the source mechanism, the impact of the damage and aftershocks were posted. (Comments:141; Shares: 389; Likes: 831)	
16:56	[BMKG Stasiun Geofisika Palu] Aftershocks which occurred after the main 6.0 EQ (14:59:56 WITA) were posted in table format. (Comments:4; Shares: 1; Likes: 28)	
18:02	M 7.7 earthquake occurred	
18:06	The first tsunami arrived	
18:07	BMKG issued a tsunami early warning	
18:10-18:15	A larger tsunami arrived	
18:21	[www.bmkg.go.id] Areas could potentially get hit by the tsunami based on modeling were posted in table format. (Comments: 196; Shares: 2,785; Likes: 3,882)	
18:24	[www.bmkg.go.id] Parameters of the M 7.7 earthquake, including intensity, date, time, latitude, longitude, longitude depth and location, were posted. In addition, tsunami potentials that occurred due to the earthquake were shown in table and figure formats. (Comments: 175; Shares: 714; Likes: 1.645)	
18:36	BMKG lifted the tsunami early warning	
18:42	[www.bmkg.go.id] End of tsunami early warning caused by the M 7.7 earthquake was posted. (Comments: 616; Shares: 1,061; Likes: 2,772)	

Source: JICA Expert Team

3) Instagram

Through its official Instagram account, “Info BMKG,” BMKG posts earthquake and tsunami information generated by InaTEWS. Instagram is another dominant social media platform among the Indonesian people, and Instagram posts are often shared on other social media and messenger services. The contents of the information posted on Instagram include figures and texts generated by InaTEWS, similar to Twitter and Facebook posts, but with a slight time lag compared to these social media sites.

Table 3.2.4 Major Posts on Instagram on Sept. 28, 2018

Posting Time (WITA)	Contents of Posts	
	Summary of Posted Information	Attached Figures
15:00	M 5.9 earthquake occurred	
15:32	On September 28, 2018, at 14.00.00 WIB, Donggala Regency area was shaken by a tectonic earthquake. M 5.9 was updated to M 6.0. Modeling results showed that the earthquake did not have potential to trigger tsunami. In addition, the information of epicenter location, hypocenter depth of the earthquake, results of the analysis of the source mechanism, the impact of the damage and aftershocks were posted. (Likes: 5,517)	
16:25	【Posting under the account name "bmkgpalu.geof"】 Parameters of the M 5.9 earthquake including intensity, date, time, latitude, longitude, longitude depth and location were posted. (Likes: 113)	
18:02	M 7.7 Earthquake occurred	
18:06	The first tsunami arrived	
18:07	BMKG issued a tsunami early warning	
18:10-18:15	A larger tsunami arrived	
18:21	Areas that could potentially get hit by the tsunami based on modeling were posted in table format. (Likes: 32,442)	
	Areas that could potentially get hit by the tsunami based on modeling were posted in figure format. (Likes: 13,534)	
	Parameters of the M 7.7 earthquake including intensity, date, time, latitude, longitude, longitude depth and location were posted. In addition, tsunami potentials that occurred due to the earthquake were shown in table and figure formats. (Likes: 22,929)	
18:36	BMKG lifted the tsunami early warning	
18:42	End of tsunami early warning caused by the M 7.7 earthquake was posted. (Likes: 33,693)	

Source: JICA Expert Team

(2) Information posted by other DRR agencies

1) BNPB

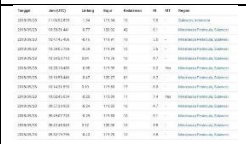
BNBP mainly posted the status of emergency response and damages caused by the

earthquake and tsunami on its official Twitter account, "BNPB_Indonesia." On its Facebook page, "BNPB", it posted a press release that reported the summary of M7.7 earthquake information as well as tsunami and emergency responses. The same information was also shared on its Twitter account. Sometimes, posts on Twitter included a link to the original Facebook post.

In addition to BNPB's official Twitter account, a personal social media account of Mr. Sutopo Purwo Nugroho, former head of data information and public relations center of BNPB, is another useful information source for citizens due to his frequent posting. BNPB would sometimes quote information from the said account and attach it to its posts.

Table 3.2.5 Major Posts on Twitter and Facebook on Sept. 28, 2018

Posting Time (WITA)	Contents of Posts	
	Posted Text	Attached Figures
15:00	M 5.9 earthquake occurred	
16:49	Several houses were reported to have been damaged by the M 5.9 earthquake. The epicenter of the earthquake on land came from the Palu fault, so that the tremors were intense. Data collection is still being carried out. (Retweets:14; Likes: 5)	
17:29	One person died, 10 people were injured and houses were damaged due to the M6 earthquake in Donggala. The impact of the M6 earthquake centered on land at shallow depths shook Donggala, Central Sulawesi. BMKG: https://facebook.com/HumasBNPB/post (Retweets:35; Quote Tweets: 4; Likes: 19)	N/A
17:34	1) The impact of M6 earthquake centered on land at a shallow depth shook in Donggala, Central Sulawesi. # Earthquake (Retweets:15; Quote Tweets: 1; Likes: 5)	N/A
17:34	2) On Friday, September 28, 2018 at 14:00 WIB, BMKG has downgraded the earthquake magnitude from M5.9 to M6 with the epicenter 2 km north of Donggala City at a depth of 10 km. # Earthquake (Retweets:14; Quote Tweet: 1, Likes: 10)	N/A
17:35	3) The earthquake originated from the Palu Koro fault. Based on map analysis, the EQ tremors were reportedly felt at Donggala IV MMI, Palu III MMI, Poso II MMI). The earthquake does not have the potential to trigger tsunami. #Earthquake (Retweets:15; Likes: 9)	N/A
17:35	4) BNPB command center has confirmed the impact of the earthquake to BPBD of Donggala Regency. The earthquake was felt in the areas of Donggala Regency, Palu Municipality & Parigi Moutong. In general, the earthquake was felt with moderate intensity for 2-10 seconds. The earthquake was felt several times due to aftershocks # Earthquake (Retweets:14; Likes:14)	N/A
17:36	5) The earthquake was felt very hard in Sirenja District, Donggala Regency because it was close to the epicenter. Some houses collapsed and were damaged by the earthquake. People panicked and ran out of their houses. # Earthquake (Retweets:17; Likes:10)	N/A
17:36	6) Based on the preliminary data from BNPB of Donggala Regency, one person died, 10 were injured and dozens of houses were damaged. The victims were struck by falling debris. # Earthquake (Retweets:9; Quote Tweets: 1; Likes: 8)	N/A
17:37	7) Evacuation activities are being conducted by officers. Data collection and emergency handling are still being carried out. Most people are still outside of their houses. Aftershocks still occur frequently. (Retweets:10; Likes:11)	N/A
18:02	M 7.7 earthquake occurred	
18:06	The first tsunami arrived	

18:07	BMKG issued a tsunami early warning	
18:10-18:15	A larger tsunami arrived	
18:11	# Earthquake Mag:7.7 , Sep-28-18 17:02:44 WIB, Loc:0.18 LS,119.85 BT (27 km Northeast of DONGGALA-CENTRAL SULAWESI), Depth:10 km, has potential to trigger tsunami to be reached to the citizens #BMKG (Retweets:184; Quote Tweets: 24; Likes: 68)	N/A
18:36	BMKG lifted the tsunami early warning	
18:40	BMKG has ended its TSUNAMI early # Warning caused by Mag:7.7 EQ, Date: Sep-28-18 17:02:45 WIB (Retweets:38; Quote Tweets: 1; Likes: 18)	N/A
19:31	The following table shows the series of earthquakes occurring today, Friday, September-28-2018. The earthquake is predominantly felt in the Sulawesi region. Source: @Infomitigasi (Retweets:33; Likes: 25)	
19:40	A MAGNITUDE 7.7 EARTHQUAKE OCCURRED, AND THE TSUNAMI EARLY WARNING WAS ONCE AGAIN ACTIVATED BUT HAS ENDED. The M 7.7 earthquake with an epicenter of 10 km at 27 km Northeast of Donggala, Central Sulawesi on... https://facebook.com/HumasBNPB/post (Retweets:50; Quote Tweets: 3; Likes: 29)	N/A
20:40	You are hereby informed that, according to Notam Number H0737/18, Mutiara Sis Al Jufri Airport, Palu is closed from September 28, 2018 at 19:26 WITA until the estimated date of September 29, 2018 at 19.20 WITA due to the earthquake. (Quoted a post from the personal account of Mr. Sutopo Purwo Nugroho) (Retweets: 48; Quote Tweets: 4; Likes: 27)	
23:21*	Detailed information on M7.7 earthquake and tsunami and the status of emergency handling were posted. (Press Release) (Comments: 33; Shares: 232; Likes: 353)	N/A
23:21	*TSUNAMI HIT PALU BEACH, EMERGENCY HANDLING IS CONTINUOUSLY BEING CONDUCTED* An earthquake with a magnitude of 7.7, which was later updated by BMKG to a magnitude of 7.4, has shaken Palu and ... https://facebook.com/26513468690518 (Retweets:89; Quote Tweets: 3; Likes: 53)	N/A
23:29	1) A 7.7 magnitude earthquake, which was downgraded by BMKG to a 7.4 magnitude, shook Palu and Donggala, Central Sulawesi on 9/28/2018 at 17.02 WIB #Earthquake (Retweets:163; Quote Tweets: 5; Likes: 113)	N/A
23:31	2) The epicenter was at a depth of 10 km, 27 km off the coast of northeast of Donggala, Central Sulawesi. The earthquake has the potential to trigger tsunami. BMKG has activated a tsunami early warning with the status of Alert (high potential tsunami of 0.5–3 meters) on the western coast of Donggala, #Earthquake (Retweets:116; Quote Tweets: 2; Likes: 78)	N/A
23:31	3) Warning status (high tsunami potential of less than 0.5 meters) on the northern coast of Donggala, northern Mamuju and western Palu City. BMKG ended the tsunami early warning on 9/28/2018 at 18.36 WIB #Earthquake (Retweets:121; Quote Tweets: 1; Likes: 91)	N/A
23:33	4) Based on BMKG information, a tsunami struck the bay. The BNPB Command Center also confirmed to BPBD that a tsunami had hit Talise beach in Palu City and the beach in Donggala. #Earthquake (Retweets:86; Quote Tweets: 3; Likes: 34)	N/A
23:33	5) Some video footages of tsunamis in Palu and Donggala documented by the public and distributed on social media are true. The tsunami caused fatalities. In the interim report, there were several victims who died as a result of falling buildings. #Earthquake (Retweets:490; Quote Tweets: 30; Likes: 409)	N/A
23:34	6) The tsunami also hit several settlements and buildings on the beach. The amount of causalities and impacts are still being verified. #Earthquake (Retweets:85; Quote Tweets: 3; Likes: 30)	N/A
23:34	7) BPBD officers, TNI, Police, Basarnas, Regional Work Unit, and volunteers conduct evacuations and help victims. Injured victims are	N/A

	handled by health workers. Emergency treatment continues. #Earthquake (Retweets:71; Likes: 25)	
23:35	8) The power outages caused the communication network in Donggala and surrounding areas to be inoperable because the PLN electricity supply was cut off. There are 276 base stations that cannot be used. #Earthquake (Retweets: 85; Likes: 31)	N/A
23:42	9) Communications operators continue efforts to restore electricity supply during the emergency. The Ministry of Communication and Information has taken steps to restore the damaged communication network. #Earthquake (Retweets: 58; Likes: 24)	N/A
23:44	10) The BNPB chief and fellow officials leave for Palu tonight via Makassar, proceeding to their destinations (Palu & Donggala) by helicopter. This is due to the Mutiara Al Al Jufri Airport Palu being closed on 9/28/2018 at 19.26 WITA until 9/29/2018 at 19.20 WITA. #Earthquake (Retweets: 53; Quote Tweets: 1; Likes: 26)	N/A
23:46	11) Meanwhile, the BNPB Rapid Response Team has also moved toward Donggala via Balikpapan. From Balikpapan, BNPB Rapid Response Team flew to Donggala using a water bombing helicopter in Balikpapan. The team brought satellite communications equipment and other necessary equipment. (Retweets:53; Quote Tweet: 1, Likes: 17)	N/A
23:47	12) TNI will mobilize troops to assist in handling the impacts of the earthquake and tsunami in Palu City and Donggala. The TNI moved 7 SSKs from Yonkes, Yonzipur, Yonif and Yonzikon using 2 C-130 Hercules aircraft. #Earthquake (Retweets: 58; Quote Tweets: 2; Likes: 24)	N/A
23:48	13) Using Herculer aircraft, Basarnas will be able to move the equipment alongside 30 personnel to the affected zone. The National Police will also be mobilizing specific equipment to assist the emergency response support team. #Earthquake (Retweets: 47; Likes: 24)	N/A
23:49	14) Reporting through the regions is paralyzed which, in turn, is affecting the coordination of relief to the affected places. Power outages have also left Palu and Donggala in complete darkness as the aftershocks continue unabated. #Earthquake (Retweets: 65; Quote Tweets: 4; Likes: 28)	N/A

Note: JICA Expert Team translated posted texts from Indonesian language to English.

*BNPB posted on Facebook at 23:21 (WITA). At the same time, it also posted a link on its Twitter account. After 23:29 (WITA), contents of the Facebook post were posted part by part on BNPB's Twitter account.

Source: JICA Expert Team

(3) Information by media

1) TV

As mentioned in previous sections, BMKG and TV broadcasting companies signed an MoU, in which TV companies will be broadcasting the disaster warning information received from BMKG. In the event of disasters, TV broadcasting companies receive the information via WRS and broadcast the information as a "stop press". Contents and timing of the broadcast warning vary depending on the company. Major contents and timing of the press coverage of each TV broadcasting company are as follows[4].

Table 3.2.6 Major Contents and Timing of TV Broadcasting on Sept. 28, 2018

Broadcasting Time (WITA)	TV Company	Contents of Broadcasting	
		Summary of Information	Screen Shoot
15:00	M 5.9 earthquake occurred		
18:02	M 7.7 earthquake occurred		

[4] Broadcast news reports by TV stations introduced in this section are retrieved from their respective YouTube official sites, on which the news aired on September 28 still remain in their archives.

18:02-18:36	tvOne	A reporter mentioned that an earthquake occurred several minutes ago, but the shaking lasted only 2 seconds.	
18:06	The first tsunami arrived		
18:07	BMKG issued a tsunami early warning		
18:10-18:15	A larger tsunami arrived		
18:32	Kompas TV	Kompas TV reported the occurrence of earthquake and tsunami by quoting information from BMKG. After which, the TV station called a BNKG official to ask several questions regarding the status of potential tsunami and tsunami warning. In addition, the station called on the public to evacuate to an open field and not return to their homes until conditions had been stabilized. People were also and advised to avoid buildings that were either lightly, moderately or severely damaged.	
18:36	BMKG lifted the tsunami early warning		
18:36	tvOne	tvOne reported that it had received confirmation from BNPB regarding the earthquake, and the station was confirming the validity of the videos broadcasted on its breaking news. tvOne also mentioned that BMKG had announced that a 7.7 magnitude earthquake had occurred 10 km below sea level and that BMKG had issued a tsunami warning, but the activation warning had been declared over, or revoked shortly after the earthquake occurred. The station called on the public to remain vigilant and evacuate to places far from the coast and to the fields in anticipation of the occurrence of aftershocks.	
21:01	Metro TV	Metro TV showed an amateur video footage of a tsunami sweeping behind and around Palu Grand Mall. It also reported that the communication line had been interrupted and the station was not able to contact the local government.	
22:44	Kompas TV	Kompas TV reported the occurrence of earthquake and tsunami through a phone call with BMKG officials.	

Source: JICA Expert Team

2) Radio

JICA Expert Team confirmed that during the Central Sulawesi earthquake and tsunami, national radio broadcasting agency RRI Palu office continued its broadcasting even during a blackout in Palu. Since RRI did not archive its radio broadcast in 2018, a local consultant from JICA Expert Team conducted an interview with the RRI Palu office to obtain information on the contents and timing of its radio broadcast.

In the aftermath of the earthquake and tsunami, only one local radio station, RRI Palu – a local station of a national radio broadcasting institution – remained active. Other radio

stations had stopped operating due to earthquake and blackout. According to interviews with RRI Palu officials, their office resumed operations 30 minutes after the occurrence of the earthquake despite the blackout by utilizing the generator. During this period, two channels were available to the residents. One is a news program directly from RRI headquarters in Jakarta that broadcasts general news, including information from BMKG. Another news program is broadcasted by RRI Palu officials. RRI Palu has updated the information on the damage, number of victims, and situational response update by obtaining information from local authorities and stakeholders such as Indonesian Red Cross Society.

Chapter 4 Information Source Utilized for Residents' Evacuation During the Sulawesi Earthquake and Tsunami in 2018

This chapter explores on the sources of information that residents in Palu rely on when an earthquake occurs. A survey on various means by which residents received information during the Central Sulawesi earthquake and tsunami was conducted.

4.1 Information Sources and Contents

This chapter explores on the sources of information that residents in Palu rely on when an earthquake occurs. A survey on various means by which residents received information during the Central Sulawesi earthquake and tsunami was conducted.

4.1.1 Objective of the Survey

The objective of the survey is to illustrate the evacuation actions of the people in Palu affected by the disaster, their sources of information, and the devices used to obtain information regarding earthquake and tsunami. The survey data will be utilized to investigate the information dissemination at the residential level and the awareness-raising materials to be prepared for the Project.

4.1.2 Methodology of the Questionnaire Survey on Residents

(1) Background

According to the detailed plan formulation study of the Project and the survey results related to information transmission during the Central Sulawesi earthquake and tsunami, power and telephone lines were cut off in Palu City about 2 minutes after the main shock at 18:02 on September 28. It has been confirmed that the only one siren that was installed in Palu City was not functioning. Under the above circumstances, JICA Expert Team will investigate the information that was utilized to decide on the evacuation of residents, and the type of media that residents used to obtain information before and after the restoration of electricity.

(2) Survey contents

For the residents of Palu City, the means of obtaining information on disaster risk reduction were based on the large foreshock at 15:00 on September 28, and the decisive factor for evacuation behavior during the main shock at 18:02. Th survey is designed to confirm the information received, type of media, and the residents' sources of information. The following are the items in the survey questionnaire that JICA Expert Team conducted on the disaster-affected population in Palu.

1.Respondent's Identity

Name of respondent ・Age・Sex・Phone number・Sub-district in Palu・Occupation

2. General Information on Information Dissemination
Q1. In your resident location, how did you receive the disaster information?
(E.g. Through a siren, TOA from the village office, police office, walkie talkie from the police, area SMS, village office, head of community / community leader)
Q2. What is your SIM carrier?
(Telcomsel, XL, Tri, Indosat Ooredoo, others)

3. Earthquake (EQ)
Q1. Where were you when the EQ at 3pm on September 28 hit Palu?
Q2. Did you evacuate somewhere (hill, evacuation point) after the earthquake at 3pm?
Q3. Where were you when the EQ at 6pm on September 28 hit Palu?

Q4. Did you evacuate somewhere (hill, evacuation point) after the earthquake at 6pm?
Q5. What kind of information did you get about the earthquake before the blackout?
From whom: e.g.. friend, head of the village, neighbor, colleague, government
Means of obtaining information: WhatsApp, SMS, TV, radio, apps, SNS, advice from others, self-evacuation
Q6. If you evacuated, what made you decide to evacuate?
From whom: e.g. friend, head of the village, neighbor, colleague, government
Q7. Why did you choose to go to your place of evacuation?
Means of obtaining information: WhatsApp, SMS, TV, Radio, APP, SNS, advice from others, self-evacuation

4. Tsunami
Q1. How did you learn about the occurrence of tsunami?
From whom: e.g. friend, head of the village, neighbor, colleague, government
Means of getting information: WhatsApp, SMS, TV, Radio, APP, SNS, advice from others, self-evacuation
Q2. During the blackout and the cutting off of telecommunication networks, how did you get updates on the situation?
From whom: e.g. friend, head of the village, neighbor, colleague, government, police, military, village office
Means of getting information: WhatsApp, phone call, SMS, TV, Radio, APP, SNS, others

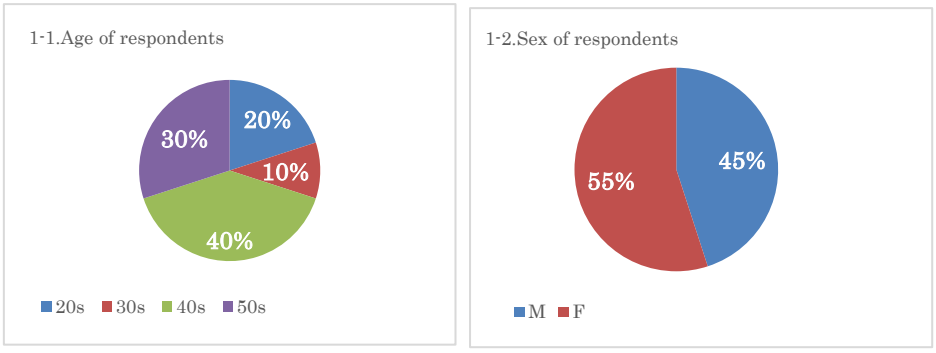
(3) Survey method

Considering the current situation, JICA Expert Team conducted a simple online questionnaire to the citizens of Palu City as a means for obtaining disaster information and as a source of information in the event of a disaster. Respondents who gave useful answers to supplement the timeline of this survey or how to grasp the current situation, such as through communication with the government, were also interviewed by a local consultant living in Palu City. Since this survey only covers the preliminary interview, the number of respondents had been limited to 20 persons.

4.1.3 Results and Major Findings of the Survey

(1) Respondents' identity

The graphs below illustrate the distribution of age and gender of the survey respondents.



Source: JICA Expert Team

Figure 4.1.1 Age and Sex Distribution of Respondents

(2) General Information on Information Dissemination

This section is designed to understand the source of disaster information not limited to earthquake and tsunami under normal conditions.

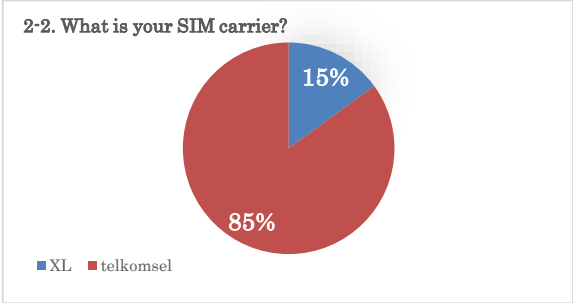
2-1) Sources of disaster information in normal situations

Thirteen out of 20 respondents answered that they did not receive disaster information or sensed the disaster by themselves. Only a limited number of respondents answered that they received information from an administrative source, including SMS from BMKG, walkie talkie from police and through siren.

2-2) SIM Card information

In Palu, shortly after the earthquake, the mobile phone network provided by Telcomsel – the most dominant SIM card carrier in Indonesia –was cut off. The communication network took several hours to recover and remained unstable for certain period of time[5]. Meanwhile, it was confirmed that the mobile phone line provided by XL was active for several hours after the earthquake even though the network connectivity was unstable.

According to a follow-up interview with a respondent who was an XL user, she could check Facebook and send SMS to communicate with her family members. In the aftermath of the tsunami, evacuees who used XL lent their SIM cards to Telcomsel users to communicate with their families and obtain information.



Source: JICA Expert Team

Figure 4.1.2 SIM Card Carrier Usage of Respondents

(3) Earthquake Information and Evacuation Actions

Tsunami-affected respondents were asked a series of questions about their actions during the major foreshock and the main shock at 6 pm.

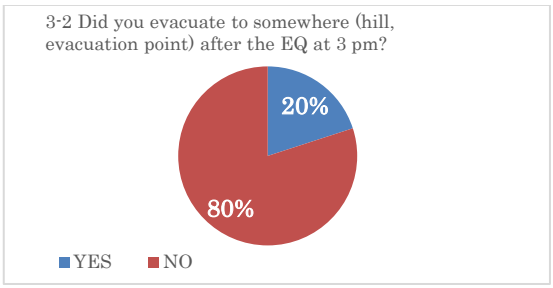
3-1) Location of respondents when an EQ hit Palu on September 28 at 3 pm

Eight respondents answered that they were staying at home, and six others were in their offices. Majority of the respondents were staying inside buildings, while a few replied that they were inside a car or out in the streets.

3-2) Evacuation situation during the earthquake at 3pm

According to the report, "Limitations and Challenges of Early Warning Systems" by UNDRR, part of Palu City and Donggala Regency experienced blackout due to damages caused by the earthquake that occurred at 3 pm and the largest foreshock on September 28. Since the earthquake was strong enough to damage infrastructure including electricity, a number of respondents evacuated for fear of potential tsunami.

[5] Results of the interview with a tsunami-affected person in Palu.



Source: JICA Expert Team

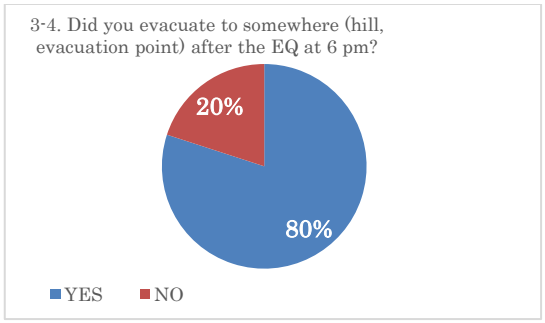
Figure 4.1.3 Percentage of Respondents Who Evacuated During the Foreshock at 3 p.m.

3-3) Location of respondents when an EQ hit Palu on September 28 at 6 pm

When the main shock hit Palu City, 12 out of 20 respondents stayed at home, the remaining 7 of them were outside either on the street or inside a car, and one was in the office.

3-4) Evacuation Situation

Because the intensity of the earthquake was much larger than the foreshock, 80 percent of the respondents evacuated after the occurence of the main shock at 6 p.m.

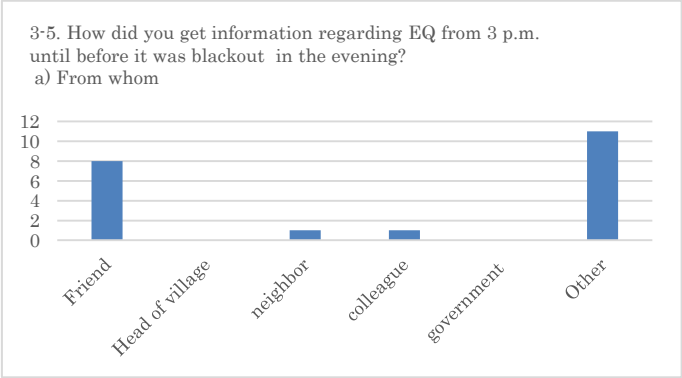


Source: JICA Expert Team

Figure 4.1.4 Percentage of Respondents Who Evacuated During the Main Shock at 6 p.m.

3-5) Sources of information regarding evacuation action

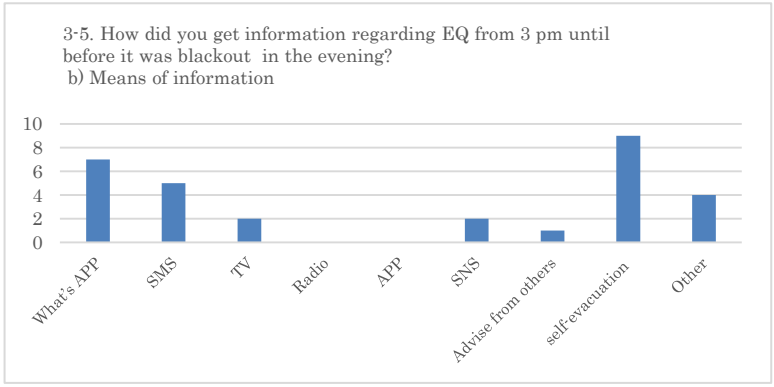
Figure 4.1.5 indicates the sources of information that respondents utilized during the major foreshock until the mainshock before the blackout. The breakdown for those who answered "Other" are: no information, sensing the earthquake, and from the internet. The result shows that residents in Palu relied on personal relationships when obtaining information rather than through administrative sources of information.



Source: JICA Expert Team

Figure 4.1.5 Sources of Information Before the Blackout Caused by Main Shock on September 28

Figure 4.1.6 indicates the means of information that respondents utilized during the major foreshock until the mainshock before the blackout. The breakdown for those who answered "Other" are: through telephone, through internet, and did not receive information. The figure illustrates that respondents relied on mobile phone communication using WhatsApp, SMS, SNS and phone calls. Those who answered "self-evacuation" were considered to be reminded of the previous tsunami incident in Central Sulawesi or Sumatra earthquake and tsunami in 2004[6].



Source: JICA Expert Team

Figure 4.1.6 Means of Obtaining Information Before the Blackout Caused by Main Shock on September 28

3-6) Evacuation recommendations

Regarding the question about who urged them to evacuate, 14 out of 16 respondents answered self-evacuation, and the remaining two said that they received advice from a family member and from a neighbor, respectively. The result indicates that residents in Palu has a culture of self-assistance as well as mutual assistance as shown in the results of the previous questions.

3-7) Means of obtaining information to determine the factors for evacuation

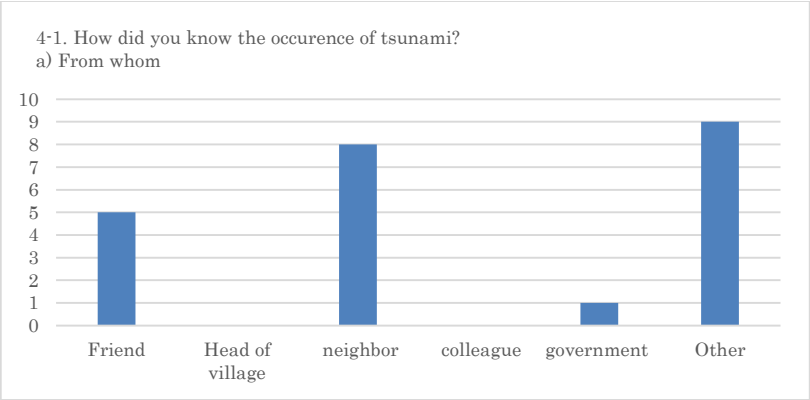
For the previous question, one respondent answered that local residents provided information about the tsunami arrival, and another respondent said that a family member recommended him to evacuate.

(4) Tsunami Information and Evacuation Actions

4-1) Sources of Information on Tsunami Arrival

Figure 4.1.7 illustrates from whom the respondents received information about the tsunami arrival. Majority of the respondents answered that they received information from their friends or neighbors. The breakdown for those who answered "Other" is as follows: three persons answered other people; and the rest answered self-evacuation; through media; upon hearing the screams; and from a family member. In general, the respondents received the information from their community.

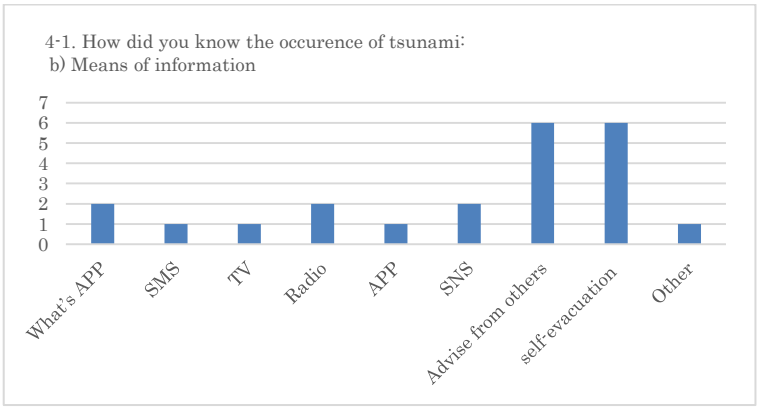
[6] One of the respondents commented during the follow-up interview that she knew of a possibility of tsunami based on experience during the Sumatra earthquake and tsunami in 2004 and evacuated without any hesitation.



Source: JICA Expert Team

Figure 4.1.7 Sources of Information on Tsunami Arrival

Figure 4.1.8 indicates the means of relaying information on the occurrence of tsunami that the respondents received. Comparing it to the means of obtaining information during the earthquake, the means of acquiring information on tsunami arrival are varied, as there are limitations in communication during the earthquake due to damaged network lines.

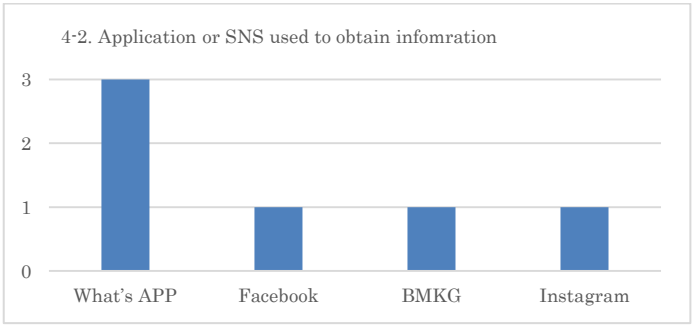


Source: JICA Expert Team

Figure 4.1.8 Means of Relaying Information About Tsunami Arrival

4-2) Means of obtaining information regarding tsunami evacuation

Due to the damage caused by the earthquake and the imminent situation, only a limited number of respondents used mobile application or SNS to acquire information regarding tsunami evacuation. Notably, chat application tool "WhatsApp" was mostly used among the apps. This implies that respondents received the information from friends / family / colleagues whom they regularly communicated with.

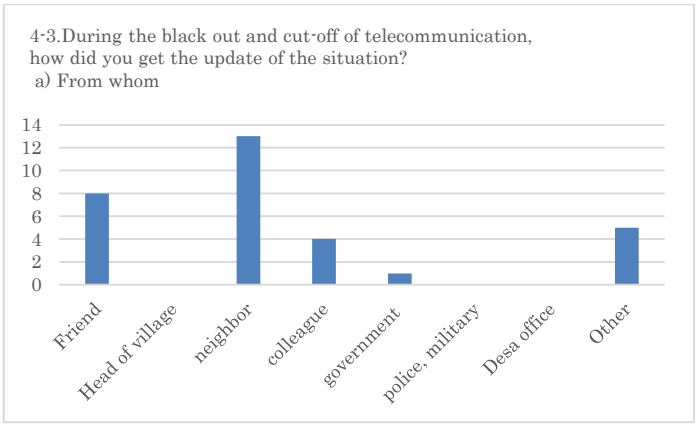


Source: JICA Expert Team

Figure 4.1.9 Means of Obtaining Information Regarding Tsunami Evacuation

4-3) Sources of information during a blackout

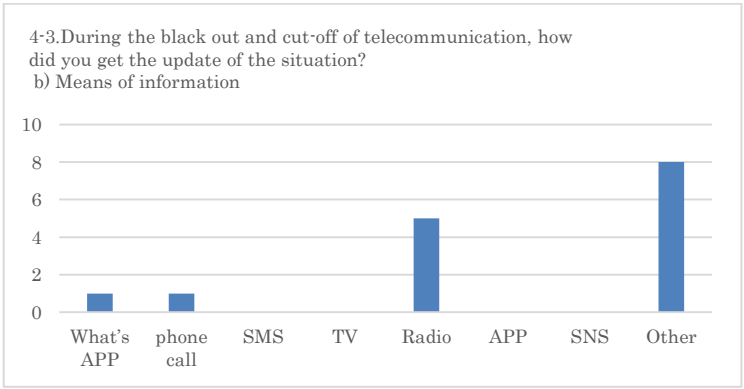
Figure 4.1.10 illustrates the sources of information regarding updates on disaster situation under a limited communication condition. The results indicates that the respondents largely relied on their personal relationships with regard to obtaining information, and only one person answered that he received information from the government. This tendency toward reliance on self-help and mutual help persisted for the duration of the disaster period.



Source: JICA Expert Team

Figure 4.1.10 Sources of Tsunami Information During the Blackout

Figure 4.1.11 illustrates the means of getting information on the updated situation during the blackout. The results indicated that those using the XL mobile SIM could obtain information online, while the rest obtained information from the radio and through other people.



Source: JICA Expert Team

Figure 4.1.11 Means of Obtaining Tsunami Information During the Blackout

Chapter 5 Conclusion

The following items are the major findings of the survey that are indicative for the implementation of the Project to develop awareness-raising materials for DRR-related agencies and the general public.

(1) BMKG's Position as a Dominant Disaster Information Provider

The survey on the available SNS and mobile application indicates that the number of SNS followers and downloads of BMKG app outnumbered those of other social media accounts of DRR-related agencies in Indonesia. Even though – legally speaking – BMKG's mandate is not to directly disseminate information to the public, the actual situation is that millions of Indonesian people are relying on direct information from BMKG which they can receive through their mobile phones.

It is plausible that direct information from BMKG through SNS and mobile application is obtained faster than other sources, including information from other DRR agencies and the media. The result of the timeline survey on the Central earthquake and tsunami illustrated that Twitter posts from BMKG is the fastest way to relay information to the public. It is recommended that the Project activities assumes that the information from BMKG will be directly delivered to the public and they will utilize the information to take appropriate response action to an upcoming disaster.

(2) Usage of SNS Communication as a Means of Disaster Information Dissemination

One of the remarkable findings of the survey is that Indonesian people, including government officials and citizens, utilize WhatsApp, messenger application and SNS such as Facebook, Twitter and Instagram for obtaining information and communicating about disaster information dissemination.

Literature survey and online survey results indicate that government officials create communications groups to share disaster information. The result of the interview survey indicates that residents utilized WhatsApp to obtain information on earthquake and tsunami arrival which occurred on September 28, 2018.

In addition, residents utilized SNS such as Facebook, Twitter and Instagram that are generally used to communicate with others to obtain disaster information and share the information with others through SNS. The result indicates that SNS and app are the efficient means for awareness-raising as well as information dissemination tools. It is desirable that the format of awareness-raising material for the public are deliverable and sharable via message app and SNS.

(3) Unavailability of Disaster Information from Local Government

The results of interview survey to the residents in Palu indicate that respondents did not receive early warning and evacuation information from the government, including BPBD and the village office, even though disaster information is designated to be delivered through administrative line. Only one respondent answered that he received information about the earthquake and tsunami through walkie talkie from the police. During the detailed project formulation survey, the JICA Study Team confirmed that police and military have dedicated wireless communications that are resistant to telephone line cut offs as emergency communication networks.

As for the main shock, the blackout and cutting off of telecommunication services were the main reasons for the unavailability of the disaster information to be delivered through administrative line. However, the survey result also indicates that residents do not usually receive disaster information from local government in general. This situation is a challenge for the Project to establish a robust administrative communication through administrative line. Since the current InaTEWS guideline does not clearly differentiate the role of each administrative line of local governments, it is recommended to define and assume the role of each level and communicate the necessary information for each level of administrative line. This will contribute to function of local governments as early warning dissemination agencies in the long run.

(4) Strong Culture of Self-Evacuation and Mutual Assistance Within the Community

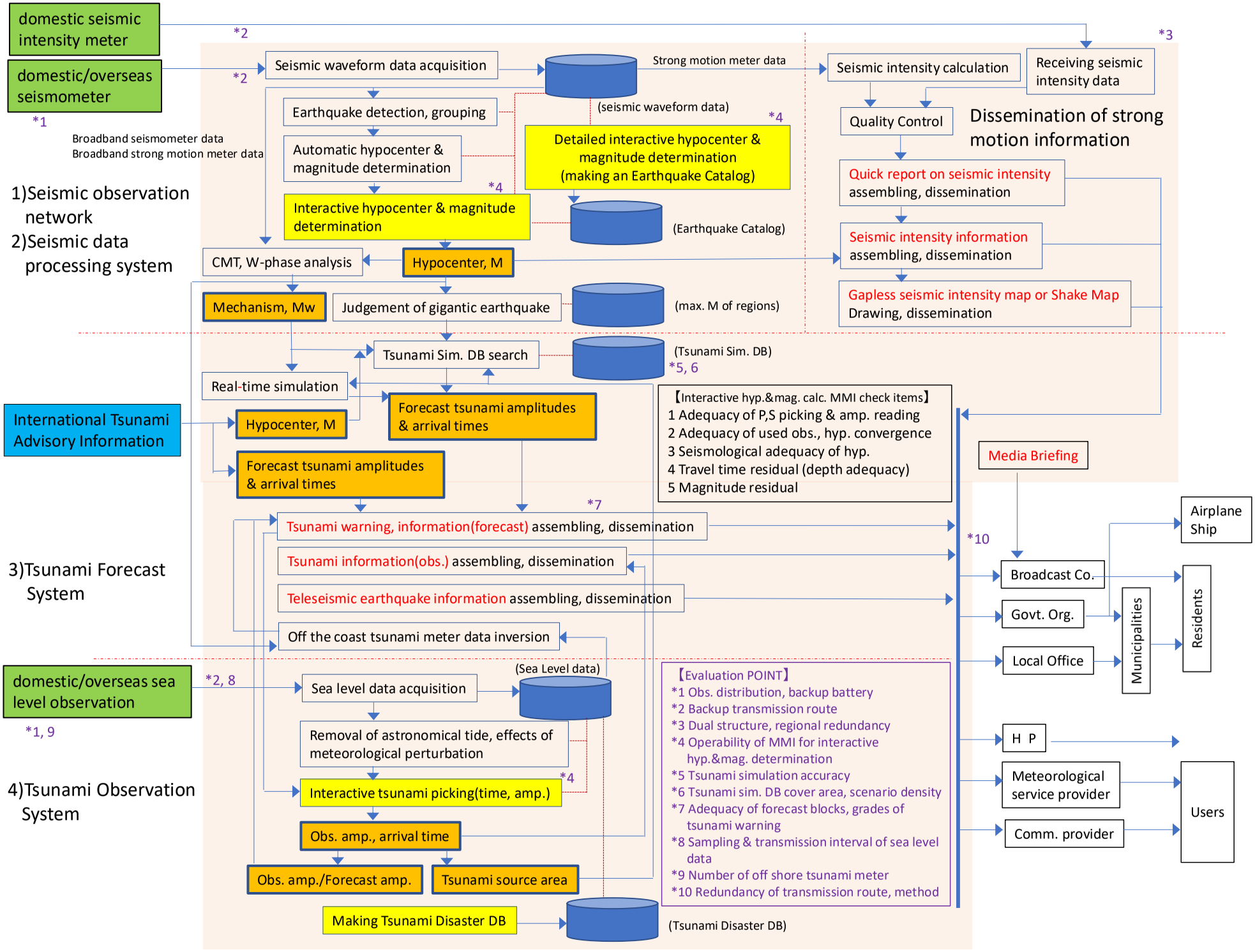
The result of the interview survey clearly envisions that residents in Palu have a clear understanding of the importance of prior self-evacuation. Even though tsunami warning information was not issued in Palu, 80 percent of residents voluntarily evacuated. The result indicates that residents understood the possibility of tsunami arrival after a strong earthquake.

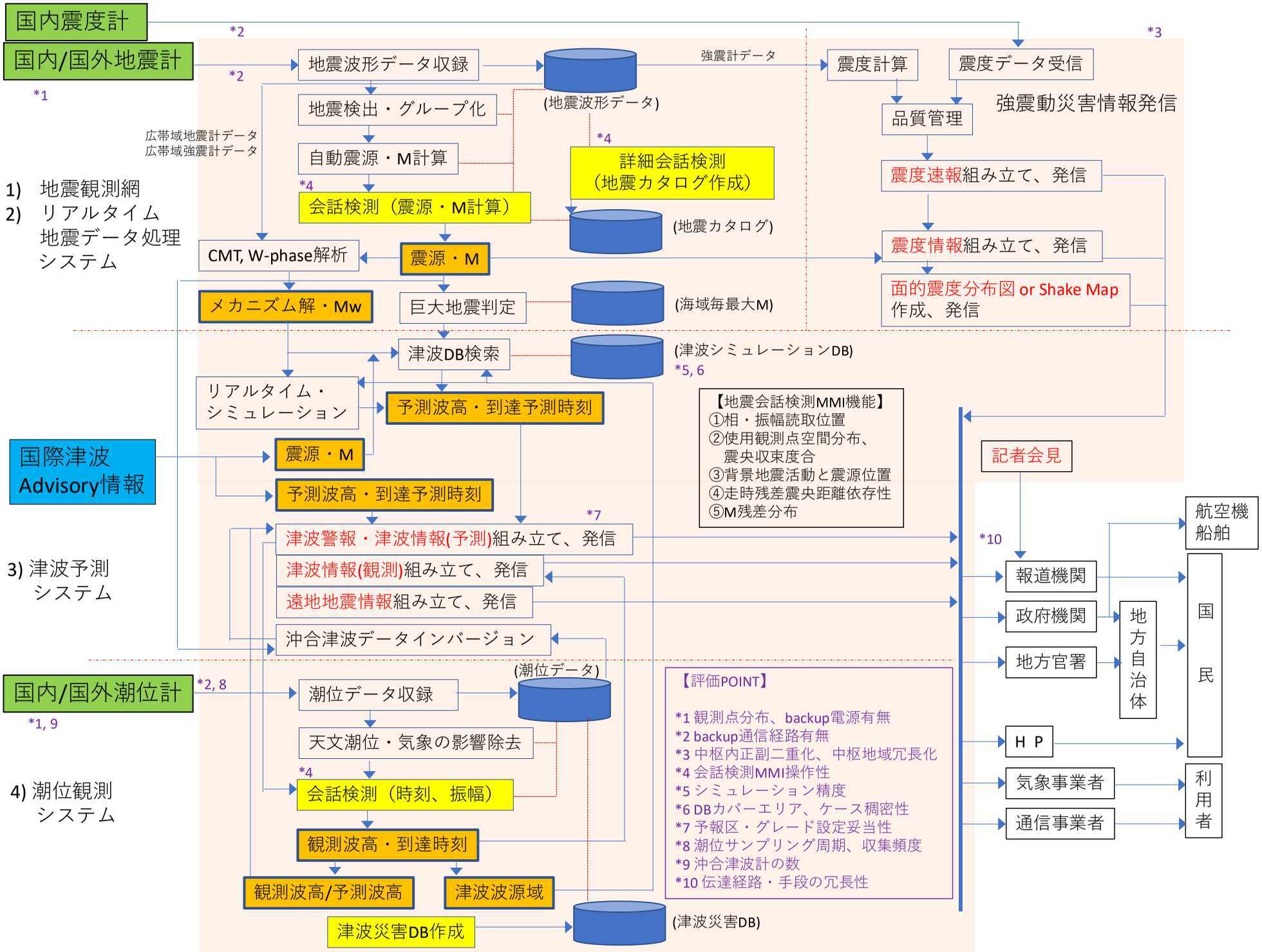
In addition, respondents of the survey received the information on earthquake and tsunami from their friends and neighbors as primary sources of information. Strong social ties and mutual assistance are beneficial for information dissemination and evacuation actions within the community.

The result indicates that the decisive factor for most of the people to evacuate is the advice or information within their community. Therefore, information from BMKG which can reach the public is desirable to be simple and understandable to facilitate proper evacuation actions.

APPENDIX 8-11

Aimed Picture of Earthquake and Tsunami Analysis and Warning Dissemination System


domestic seismic intensity meter
domestic/overseas seismometer
*1
Broadband seismometer data
Broadband strong motion meter data
1)Seismic observation network
2)Seismic data processing system
*2
*2
Seismic waveform data acquisition
Strong motion meter data
(seismic waveform data)
Earthquake detection, grouping
Automatic hypocenter & magnitude determination
*4
Detailed interactive hypocenter & magnitude determination (making an Earthquake Catalog)
*4
Interactive hypocenter & magnitude determination
(Earthquake Catalog)
CMT, W-phase analysis
Hypocenter, M
Mechanism, Mw
Judgement of gigantic earthquake
(max. M of regions)
*3
Seismic intensity calculation
Receiving seismic intensity data
Quality Control
Dissemination of strong motion information
Quick report on seismic intensity assembling, dissemination
Seismic intensity information assembling, dissemination
Gapless seismic intensity map or Shake Map Drawing, dissemination
Tsunami Sim. DB search
(Tsunami Sim. DB)
*5, 6
Real-time simulation
International Tsunami Advisory Information
Hypocenter, M
Forecast tsunami amplitudes & arrival times
Forecast tsunami amplitudes & arrival times
【Interactive hyp.&mag. calc. MMI check items】
1 Adequacy of P,S picking & amp. reading
2 Adequacy of used obs., hyp. convergence
3 Seismological adequacy of hyp.
4 Travel time residual (depth adequacy)
5 Magnitude residual
Media Briefing
3)Tsunami Forecast System
*7
Tsunami warning, information(forecast) assembling, dissemination
Tsunami information(obs.) assembling, dissemination
Teleseismic earthquake information assembling, dissemination
Off the coast tsunami meter data inversion
*10
Airplane
Ship
Broadcast Co.
Govt. Org.
Local Office
Municipalities
Residents
domestic/overseas sea level observation
*1, 9
*2, 8
Sea level data acquisition
(Sea Level data)
Removal of astronomical tide, effects of meteorological perturbation
4)Tsunami Observation System
*4
Interactive tsunami picking(time, amp.)
Obs. amp., arrival time
Obs. amp./Forecast amp.
Tsunami source area
Making Tsunami Disaster DB
(Tsunami Disaster DB)
【Evaluation POINT】
*1 Obs. distribution, backup battery
*2 Backup transmission route
*3 Dual structure, regional redundancy
*4 Operability of MMI for interactive hyp.&mag. determination
*5 Tsunami simulation accuracy
*6 Tsunami sim. DB cover area, scenario density
*7 Adequacy of forecast blocks, grades of tsunami warning
*8 Sampling & transmission interval of sea level data
*9 Number of off shore tsunami meter
*10 Redundancy of transmission route, method
H P
Meteorological service provider
Comm. provider
Users


国内震度計
国内/国外地震計
*1
*2
*2
地震波形データ収録
(地震波形データ)
強震計データ
地震検出・グループ化
広帯域地震計データ
広帯域強震計データ
自動震源・M計算
*4
会話検出（震源・M計算）
*4
詳細会話検出
（地震カタログ作成）
(地震カタログ)
CMT, W-phase解析
震源・M
メカニズム解・Mw
巨大地震判定
(海域毎最大M)
津波DB検索
(津波シミュレーションDB)
*5, 6
リアルタイム・
シミュレーション
予測波高・到達予測時刻
震源・M
予測波高・到達予測時刻
*7
津波警報・津波情報(予測)組み立て、発信
津波情報(観測)組み立て、発信
遠地地震情報組み立て、発信
沖合津波データインバージョン
国際津波
Advisory情報
国内/国外潮位計
*1, 9
*2, 8
潮位データ収録
(潮位データ)
天文潮位・気象の影響除去
*4
会話検出（時刻、振幅）
観測波高・到達時刻
観測波高/予測波高
津波波源域
津波災害DB作成
(津波災害DB)
震度計算
震度データ受信
*3
強震動災害情報発信
品質管理
震度速報組み立て、発信
震度情報組み立て、発信
面的震度分布図 or Shake Map
作成、発信
【地震会話検測MMI機能】
①相・振幅読取位置
②使用観測点空間分布、
震央収束度合
③背景地震活動と震源位置
④走時残差震央距離依存性
⑤M残差分布
記者会見
*10
報道機関
政府機関
地方官署
地方自治体
航空機
船舶
国民
H P
気象事業者
通信事業者
利用者
【評価POINT】
*1 観測点分布、backup電源有無
*2 backup通信経路有無
*3 中枢内正副二重化、中枢地域冗長化
*4 会話検測MMI操作性
*5 シミュレーション精度
*6 DBカバーエリア、ケース稠密性
*7 予報区・グレード設定妥当性
*8 潮位サンプリング周期、収集頻度
*9 沖合津波計の数
*10 伝達経路・手段の冗長性
1) 地震観測網
2) リアルタイム
地震データ処理
システム
3) 津波予測
システム
4) 潮位観測
システム

Explanation of the "Aimed Picture of Earthquake and Tsunami Analysis and Warning Dissemination System" Made by JMBSC

This material is intended to share the aimed picture of earthquake and tsunami analysis and warning dissemination system between the supporter and countries to be supported, and to discuss on items to be integrated together, standing on the common basis, as part of "Project for Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination of BMKG, Indonesia" (2020-2022). As a final goal of the system, EPOS (Earthquake Phenomena Observation System) of JMA (Japan Meteorological Agency) is envisaged. To create this material, we referred to the corresponding material in meteorology made by JICA (Japan International Cooperation Agency). In this material, processing functions composed of system and data flows in between are depicted.

The system consists of 1) earthquake observation network, 2) real-time earthquake data processing system, 3) tsunami forecast system, and 4) tsunami observation system (Kamigaichi (2015)). Tsunami warning is to enable evacuation in advance of tsunami arrival from coastal areas at risk by disseminating warning depending on the estimated tsunami amplitude based on seismic wave analysis, which propagates much faster than tsunami wave originating from seismic fault. For local tsunami, promptness of tsunami warning dissemination must be assured, but there exists a trade-off between promptness and accuracy. For this reason, tsunami warning is disseminated not only once, but updated several times with improved accuracy by using late arriving data and analysis, including sea level data. Some tsunamis are generated by sources other than earthquake (underwater eruption, ocean bottom landslide, mountain collapse of island volcano, etc.), and in such cases, it is difficult to predict tsunami generation and its amplitude beforehand of the arrival. However, it is possible to detect tsunami as soon as possible (presumably by off the coast tsunami meter), and to disseminate warnings to coasts where tsunami has not arrived yet. In this case, system components 3) and 4) play important roles.

A strong motion is another disaster brought by an earthquake. In this material, a function to disseminate strong motion information (corresponding to JMA's seismic intensity information) is also included, considering that in some countries like Indonesia, strong motion disaster is also a big issue. However, warning disseminated beforehand of the strong motion arrival (i.e., JMA's Earthquake Early Warning) is excluded because of its implementation difficulty in developing countries.

The right part of the figure denotes strong motion, and the uppermost part to above "Tsunami DB Search," below "Tsunami DB Search" to above "Sea Level Data Acquisition," and below "Sea level

Data Acquisition" of the left half of the figure denote 1) + 2), 3) and 4), respectively.

Note that evaluation points for each processing unit are described to enable total performance evaluation of the system in an analogue manner, in addition to an evaluation based on existence / non-existence of processing units. Details of the MMI (Man-Machine-Interface) functions of interactive procedure for seismic record reading, as well as hypocenter and magnitude determination – which are key issues for prompt and unerring warning dissemination – are also described.

Details of each constituent of the system are described below, along with the streamlining of data and processing functions.

【Details of processing functions】

〇Tsunami Warning Dissemination 1) Seismic Observation Network and 2) Real-Time Seismic Data Processing System

・Domestic / Overseas Seismometer Network

To estimate tsunami amplitude, determination of hypocenter location and magnitude is essential.

To estimate hypocenter (the starting point of underground rupture) location, the arrival times of seismic waves (P and S waves) are used. For precise picking of the arrival times, a short-period velocity type seismometer (or broadband seismometer with high-pass filtered waveform data) is suitable.

On the other hand, maximum amplitude of seismic waveform data is usually used for magnitude estimation. Especially for prompt magnitude estimation of an earthquake occurring in a local distance, strong motion meter data – which does not saturate even for a near and large earthquake from which seismic wave arrives at observatories soon after the occurrence – is suitable (i.e., JMA's method).

Broadband seismometer (or broadband strong motion meter) is suitable for CMT (Centroid Moment Tensor) or W-phase analysis as described below. CMT analysis gives Mw, which is suitable for an estimation of tsunamigenic potential even for a gigantic earthquake, but a longer seismic waveform data than conventional magnitude calculation is necessary. The analysis itself takes a longer time, so it is often the case that CMT analysis is not in time for the first warning issuance that must be prompt. However, for a magnitude estimation of teleseismic earthquake, for which it is allowed to take some time, CMT analysis is generally used.

Usage of seismometers of each type for seismic products applied for online information is as follows.

	Short period velocity type	Strong motion meter	Broadband seismometer
Hypocenter location	○	△	(○ : high-pass filtered)
Magnitude (Up : size, Down : distance)	○ (small) (near)	○ (middle - large) (near - middle)	○ (middle - large : Mw) (middle - distant)
Mechanism solution (First motion polarity)	○		
Mechanism solution (CMT, W-phase)			○ (broadband strong motion meter has lower S/N, but waveform data is available from nearer distance)
Strong motion index		○	

The required condition for deploying short-period velocity type seismometer is not so severe. In contrast, broadband seismometer is sensitive to temperature or atmospheric pressure change, and a careful setting for observation vault is required. A strong motion meter must be installed firmly to a stiff base that can withstand a strong shaking.

All these data should be sampled at more than 100Hz with more than 16bits resolution / dynamic range, and should be transmitted to a processing center in real-time. For CMT analysis, sampling at 20Hz is sufficient for broadband seismometer, but if it is used for precise picking of seismic phase arrival time after high-pass filtering, 100Hz is necessary.

For data transmission, it is desirable to use fixed broadband communication line (e.g. IP-VPN). As for transmission protocols, a) to enable flexible transmission route and to make data loss minimum, socket or application on TCP, or b) to make transmission delay minimum, RTP on UDP are desirable.

In case of main route outage after a strong shaking due to a large earthquake, it is desirable to promptly switch data transmission route to a backup route (e.g., fixed broadband to internet route via mobile phone communication network) (*2).

In case of emergency in each region, it is also desirable to equip observatory with a backup battery – whose capacity is as long as the average power outage time – to enable uninterrupted observation even after a large earthquake (*1).

Distribution of seismometers (*1) is ideal when they surround an epicenter from all directions. To make network configuration as close to ideal as possible, it is necessary to design a network so that the maximum azimuth (angle measured from epicenter to seismometer) gap is minimized. In general, hypocenter location accuracy gets worse for earthquakes occurring outside of the network. Especially in oceanic areas under restriction due to land distribution, network configuration close to straight line must be avoided.

Seismometer density (*1) should be dense enough so that seismic wave arrival times (for P and S) and maximum amplitudes from at least 10 observatories are assured within a time frame for prompt dissemination of the first tsunami warning, considering the time required for tsunami forecast and warning statement assembling. This critical time can be estimated from the S wave propagation velocity of the region.

If there is no remarkable seismicity in the country, and only tsunami from a distant sea affects the country, it is unnecessary to build domestic seismic network. Global seismic network (e.g., IRIS (Incorporated Research Institutions for Seismology)) data, which is open through the internet, or CTBTO (Comprehensive Test Ban Treaty Organization) seismic network data via NDC (National Data Center) of the country (if the institute is authorized as a responsible institute for tsunami warning dissemination) are available for hypocenter and magnitude calculation. Or, as described below,

hypocenter and magnitude information provided by Tsunami Advisory Center or Tsunami Service Provider is also available in some regions.

Nevertheless, for countries where tsunami disaster generated by earthquakes occurring in and around the country is expected, domestic seismic network is necessary because of a short time before the tsunami arrival.

Standard procedure for domestic observatory maintenance (regular and in case of emergency) must be prepared.

・Processing Center (whole cream-colored area)

To enable prompt tsunami warning dissemination even in the event of processing system failure, the system should have dual structure in a single center (*3). Moreover, two centers should be settled in case one center totally collapses due to sudden disaster. Two centers should be remote enough from each other to avoid simultaneous collapse (regional redundancy) (*3). Standard procedures to maintain and improve prompt tsunami warning dissemination ability, to promptly recognize a collapse of another center, and to enable smooth handover of the emergent duty, must be developed.

・Seismic waveform data acquisition, earthquake detection and grouping

Seismic waveform data is continuously recorded on HD (Hard Disc) in a cyclic manner. Seismic wave detection is conducted in real-time based on this continuously recorded waveform data. Usually, by detecting that STA/LTA (short-time average / long-time average of the squared amplitude of waveform data) value has exceeded a threshold, a seismic wave arrival is automatically recognized. To avoid false detection by noise contamination, “grouping” is usually used. In “grouping,” sub-areas are established to cover the entire country, so that several seismic observatories are involved in all sub-areas. When a seismic wave is detected at observatories with more than a pre-determined number in a pre-determined time period in one group, it is recognized that an earthquake has indeed occurred.

Due to the volume limit of HD, only a finite period is allowed to keep continuous seismic waveform data on HD. Therefore, it is effective to extract seismic waveform data to store only for observatories at which seismic waves are detected (+ alpha), and for a finite time period around the seismic wave detection time. This database can be used for detailed analysis (e.g., making a seismic catalog as described below) and for a long-term storage on external medium. It is also effective to store continuous seismic waveform data for designated observatories irrespective of seismic wave detection for a long-term monitoring of seismicity of a specific region.

・Automatic hypocenter and magnitude determination

Hypocenter and magnitude are automatically calculated by using seismic wave detection times (usually regarded as P wave), and maximum amplitudes are automatically measured within a certain

time window from detection time. In an advanced system, a method to improve accuracy of seismic wave detection time by applying mathematical model around the detection time by STA/LTA method, or to improve hypocenter determination accuracy by using not only P but also S wave which is detected by applying mathematical model around presumed S arrival time, deduced from preliminary hypocenter location and origin time by using only P, are used (e.g., EPOS of JMA).

In the hypocenter determination process, instead of global average velocity model, seismic wave velocity local structure model suitable for the region – developed by applying scientific results such as explosion seismology experiments or hypocenter and structure simultaneous estimation – should be used to improve accuracy.

In the magnitude determination process, it is desirable to adopt a magnitude calculation formula using strong motion meter data which does not saturate even for near and large earthquakes, and to match local seismic wave decay characteristic to improve accuracy and promptness. ML, which is usually incorporated in a seismic wave processing system, is defined in a local distance, but applicable only to regions where seismic wave decay characteristic is similar to that in Southern California. mb, mB and Ms are defined only in a teleseismic distance and are inferior in promptness for calculation. Mwp formula is developed assuming a usage of simple teleseismic waveform which is not so much affected by a local structure, and should be regarded as an auxiliary of magnitude formula defined in a local distance.

・Interactive hypocenter and magnitude determination

Considering the great social impact of tsunami warning, false warning or warning with poor accuracy must be avoided. For this reason, it is essential to check the automatic seismic picking results or automatically determined hypocenter and magnitude and, if necessary, to correct them manually in an interactive manner. Thus, checked and corrected hypocenter and magnitude are transferred to 3) tsunami forecast system as inputs. This interactive process greatly controls the total time for the warning dissemination, so the operability of MMI (*4) is a key issue for prompt and proper warning dissemination.

Items to be checked using the interactive tool are as follows:

1) Adequacy of automatic arrival time pickings for P and S, and maximum amplitude readings

Display seismic waveform data with automatically picked P and S arrival times and maximum amplitude times. Theoretical P and S arrival times calculated from automatically determined hypocenter and origin time are also overlayed for reference. These arrival times and maximum amplitude times are corrected manually if necessary.

2) Adequacy of seismic observatories distribution used for hypocenter determination and convergence of hypocenter calculation

Check the adequacy of seismic observatories distribution by showing calculated hypocenter

location and used observatory locations on the map. By drawing circles centered at used observatories and whose radius denotes theoretical epicentral distance, convergence of hypocenter calculation can be checked. (Concentration of circles at one point denotes good convergence.)

3) Seismological adequacy of calculated hypocenter

Plot the hypocenter location on the map and vertical cross section with the seismicity of the region overlayed. For this purpose, seismological catalog is very important.

4) Adequacy of hypocenter depth

Plot travel time residuals (difference between theoretical and picked arrival times) as a function of epicentral distance to check if there is a linear trend (epicentral distance dependence of the residuals). If the calculated depth is too shallow or too deep, a linear trend remains.

5) Magnitude residuals distribution

Plot magnitude residuals frequency distribution and exclude outliers if necessary.

After passing these manual check and correction, a final hypocenter and magnitude information is transferred to the tsunami forecast process.

・Detailed interactive hypocenter and magnitude determination (making a seismological catalog)

Detailed interactive hypocenter and magnitude determination (making a seismological catalog) is usually done by applying the abovementioned interactive tools to stored seismic waveform data in an off-line manner. Through this process, adequacy of hypocenter and magnitude determined in an emergent operation is scrutinized, and it leads to an improvement of quality of emergent products by accumulating know-how on an optimal choice of observatories depending on hypocenter location, or on proper picking of P and S waves considering their waveform characteristics. Moreover, the following are expected in making a seismological catalog:

・Quantitative commentary on an outlook of seismic activity by statistical analyses based on the seismological catalog can be made.

・Analysis of seismic fault activity and geometries of seismic faults, and region coverage setting of assumed seismic fault to be included in tsunami simulation database (described below) can be done with higher reliability.

・Seismological catalog is a very important basis for seismological studies in the country and in the world.

It is desirable that mechanism solution, as well as seismic intensity distribution brought by the earthquake, are listed also in the seismological catalog tied to the hypocenter and magnitude information. For an estimation of earthquake mechanism, CMT analysis based on broadband seismometer's waveform data is applied for middle to large earthquakes. For small earthquakes whose waveform data is below the noise level of broadband seismometer, an analysis based on the first motion polarity distribution (UP/DOWN) of P wave is applied. Underground stress distribution,

which is a cause of earthquake, can be estimated from earthquake mechanism solutions and is valuable for studies on tectonics of the region, analysis on the relation with surface traces of active faults, and proper setting of seismic fault geometries in the tsunami simulation database.

・Judging of gigantic earthquake

Magnitude value saturation is inevitable as far as maximum amplitude of a finite period is used (e.g., JMA magnitude that uses maximum amplitude with period of up to 6 seconds saturates over M8). When a saturated magnitude value is used in the tsunami forecast process, tsunami amplitudes are underestimated and cause serious problems in disaster mitigation. At this moment, there is no method to estimate magnitude correctly for gigantic earthquake whose magnitude is near 9 in 3 to 5 minutes. However, some techniques have been developed to recognize the possibility of magnitude underestimation in 3 to 5 minutes (already adopted by JMA). In case a possibility of magnitude underestimation is recognized by using such techniques, maximum magnitude value supposed in the area, which should be analyzed by authorized research institutes or universities, is used for tsunami warning instead of calculated magnitude. For this purpose, seismological catalog is very important. It is necessary to inform the public and organizations relevant to disaster mitigation of this policy prior to the operation implementation.

・CMT, W-phase analysis

In countries where earthquakes occurring near coasts cause disastrous tsunami, it is essential to disseminate the first tsunami warning as soon as possible, and time-consuming CMT and W-phase analysis cannot be used for the first warning. However, it is very important to revise previous warnings with updated warnings with higher accuracy based on the earthquake mechanism (fault geometry) and Mw evaluated by CMT and W-phase analysis. These analyses can reduce an uncertainty of mechanism on which an assumption must be set in the first warning. These analysis techniques are already adopted by institutes responsible for tsunami warning dissemination in several countries (including JMA), and it is very important to transfer know-hows (how to incorporate state-of-the-art techniques in the actual tsunami warning operations) of these institutes to developing countries.

○Tsunami Warning Dissemination 3) Tsunami Forecast System

・Tsunami Simulation Database Search

To realize prompt dissemination of the first warning with reliable accuracy, Tsunami Simulation DB (Database) method is adopted in several institutes responsible for tsunami warning dissemination. In this method, tsunami propagation simulations are conducted for many different scenarios considering the earthquake mechanism to be assumed in each region, so that tsunamigenic oceanic areas are entirely covered (*6) and calculated results are stored as a database. In case of earthquake

occurrence, the most appropriate case is retrieved from the database based on the emergently determined hypocenter and magnitude. The contents of database are: hypocenter, magnitude (assumed mechanism), forecast tsunami amplitude, and arrival time for each forecast point (+ simulated tsunami waveform).

Tsunami propagation simulation technique has been already established, and necessary programs are open and free of charge, so almost no barrier exists for an introduction. However, precise bathymetry data with a certain spatial resolution is necessary to conduct reliable tsunami propagation simulation. There would be a difference in the availability of such data depending on the countries. Disastrous tsunami is generated from an earthquake with M>7 in general. Spatial extent of tsunami source (nearly equal to seismic fault length) is about several tens of km for M=7. It is desirable to set as many as 20 calculation grids in the tsunami source area, and this means that data mesh size of about 1km (1 arc minute to 30 arc seconds) is desirable (*5). When a coarse mesh is used for simulation, accuracy deteriorates in a shallow sea area (where tsunami wave length becomes shorter). In this case, Green's law is usually applied to a simulated result at a calculation grid off the coast, and converted to a tsunami amplitude at a coast (*5). If more accurate and finer bathymetry data is available, "nesting" technique can be applied to calculate tsunami amplitude directly at a coast depending on computer availability (*5).

Only a finite number of simulated results can be stored in a finite volume of DB (*6), and there would be no exact case in DB to match emergently determined hypocenter and magnitude completely. So, a logical approach to retrieve the most appropriate case from a finite number of candidate scenario is necessary (e.g., JMA's). It is desirable to retrieve the worst case while uncertainty is left in the estimation of tsunami source spatial extent considering a high fatality of tsunami disaster. If a restriction on tsunami source spatial extent is given from 4) tsunami observation system, forecast tsunami amplitude and arrival time with less uncertainty can be applied to update previous tsunami warnings.

・Real-time tsunami propagation simulation

After earthquake mechanism solution and Mw are calculated by CMT or W-phase analysis (and / or a reliable tsunami source spatial extent is given), reliable real-time tsunami propagation can be conducted. Depending on the results, it is possible to update tsunami warning for near earthquake, or to disseminate the first tsunami warning for distant earthquake.

・International Tsunami Advisory Information

In some oceanic areas (Pacific Ocean, Indian Ocean, Caribbean Sea, and NE Atlantic Ocean and Mediterranean Sea), international tsunami advisory information is available and is provided by organizations authorized by the ICG (Intergovernmental Coordination Group) of the region. For

countries that are operating tsunami simulation database for distant earthquakes, hypocenter and magnitude value contained in the international information can be used as a key to retrieve the DB without needing to conduct hypocenter and magnitude calculation by themselves. A country without a DB can use forecast tsunami amplitude and arrival time at a point in its country contained in the international information.

・Off the coast tsunami meter data inversion

The initial amplitude distribution of tsunami source can be estimated by inversion technique based on tsunami waveform data observed at off the coast tsunami meters without an estimation of seismic fault parameters. By using the estimated initial amplitude distribution of tsunami source as an initial condition, tsunami amplitudes and arrival times along the coast can be forecasted by usual tsunami propagation simulation (JMA has already incorporated this technique in the operation). In this method, higher accuracy is expected than conventional seismological method because all uncertainties on the tsunami source can be removed. However, this method can be effectively applied only in a limited area where tsunami meters (pressure sensor or sea level height observation by GPS) are densely deployed (*9) so that the area is enclosed by them (including deployment inside the area), and these data must be transmitted to the processing center in real-time. Moreover, it takes some time for a pressure sensor type data to show a peak after the earthquake occurrence even it is deployed inside of the tsunami source, so this technique cannot be used for the first warning dissemination. This processing is triggered by the input of hypocenter and magnitude determination or manually.

・Tsunami Warning and Tsunami Information (Forecast)

Tsunami warning and tsunami information to supplement the warning are disseminated based on the forecasted tsunami amplitudes and arrival times. It is desirable that warning is categorized into a few grades (*7), by which residents can grasp the severity of tsunami disaster easily based on the forecast maximum tsunami amplitude. In Japan, three grades (Advisory : 0.2-1.0m; Warning : 1.0-3.0m; Major Warning : Over 3m) are adopted. Criterion of tsunami warning should be determined based on the survey of the relation between tsunami amplitude and tsunami disaster in the past, but the criterion used in an adjacent country where coastal usage situation is similar can also be applied. It is desirable to make tsunami inundation hazard maps corresponding to each tsunami warning grade in advance to inform the public well and to utilize the information to designated areas where residents should evacuate in case of emergency (in Japan, municipalities have the responsibility).

It is appropriate to disseminate tsunami warning to “forecast block” (*7) which has finite length along the coast, not to respective points on the coast (Japan has 66 tsunami forecast blocks). Forecast blocks should be settled through consultations between authorized organization of tsunami warning and municipalities, which are the primary units for disaster mitigation action; through sea

distribution; similarity of tsunami behavior; and accuracy of tsunami forecast.

Tsunami warning and information statement should have a pre-determined format (e.g., XML format), so that the relevant contents distributed to recipient organizations can be extracted easily by automatic computer processing.

In case (observed tsunami amplitude)/(forecast tsunami amplitude) ratio (which is given from 4)) is larger than a threshold, tsunami warning is upgraded and / or tsunami information on forecast amplitude is revised based on a statistical processing of these ratios. In case the ratio is smaller than a threshold, including no tsunami observation, the warning is downgraded or canceled.

・Tsunami Information (Observation)

Inform public of actually observed tsunami amplitudes and arrival times in a proper timing. This is to inform public of up-to-date tsunami situation, and to urge hesitant residents to evacuate by announcing that a disastrous tsunami has already arrived.

・Teleseismic Earthquake Information

In case confirmation of the safety of foreign nationals is necessary, or there is a possibility of tsunami warning dissemination with the occurrence of large earthquakes abroad, teleseismic earthquake information is disseminated to notify the public of the hypocenter, magnitude and outlook on the possibility of tsunami warning dissemination in the country.

○Tsunami Warning Dissemination 4) Tsunami Observation System

・Domestic / Overseas Tide Gauge (Sea Level Observation)

It is desirable that at least one sea level observation devise is deployed in each tsunami forecast block (domestic) (*1). To evaluate the influence of tsunami, at least several numbers of foreign sea level observation data should be monitored along the tsunami propagation path, from the hypocenter of overseas earthquake to the country. (*1). As for domestic sea level observation, it is desirable to have a backup battery and a backup transmission route, the same as seismic observation, in case of power failure and communication link outage due to strong motion (*1, *2). Foreign sea level observation data, which is collected by DCP (Data Collection Platform) function of geostationary satellite and circulated via WMO/GTS (World Meteorological Organization/Global Telecommunication System) circuit, is available. To improve the accuracy of tsunami warning, it is desirable that off the coast tsunami meters are deployed so that oceanic areas of interest are surrounded by them, or that valid tsunami warning dissemination is enabled even for tsunamis originating from sources other than earthquakes (*9).

Sea level observation device is versatile and can be applied not only in tsunami monitoring, but also in tidal observation and high tide monitoring. For the purpose of tsunami monitoring, it is

desirable to set a sampling interval of around 1 second and collection interval of around 1 second (at least 1 minute), especially for domestic sea level observation, because short period component is involved in near-distance tsunami data, and real-time monitoring is essential (*8). If earthquake observation and sea level monitoring are conducted by different organizations they should cooperate with each other to enable real-time sea level monitoring at the responsible organization of tsunami warning dissemination.

・Acquisition of sea level observation data

Sea level observation data is continuously recorded on HD in a cyclic manner, similar to seismic waveform data. Due to the volume limit of HD, only a finite period is allowed to keep continuous sea level observation data for all observatories on HD. Therefore, it is effective to extract sea level observation data to store only for observatories at which tsunamis are detected, and for a finite time period around the tsunami detection time. This database can be used for a making the tsunami disaster database (described below), and for long-term storage on external medium.

・Removal of astronomical tide and the effects of meteorological perturbation

Sea level changes not only due to tsunami, but also due to tidal force from the sun and moon and meteorological perturbation such as atmospheric pressure and sea surface wind change. For a precise picking of tsunami wave, these noises should be removed regularly. Tide is a periodic phenomenon, and its effect can be removed by subtraction of tidal component, which is predictable by analyzing the past sea level data. Effects of meteorological perturbation can be removed by obtaining numerical model forecast results (high tide) from authorized meteorological observation / forecast organizations.

・Interactive tsunami picking (time and amplitude)

This process is triggered by the first tsunami warning dissemination or manually after the recognition of tsunami generation, with the possibility that it originated from another source (e.g., island volcano eruption) other than an earthquake. Tsunami arrival time and up-to-date maximum amplitude and its time are picked by using MMI for each observatory on the console where sea level data time series is shown. Picked amplitudes and times are transferred to the tsunami information (observation) process in 3) in a proper time interval. Spatial extent of tsunami source can be estimated by using inverse refraction diagram and tsunami arrival times, and the result is transferred to the tsunami simulation DB search process to reduce the uncertainty on the spatial extent of tsunami source. Moreover, (observed amplitude)/(forecast amplitude) ratios are updated from time to time, and they are statistically processed and transferred to tsunami warning and information (forecast) process in 3) for the decision-making on upgrading or downgrading/cancellation of the warning. All these processes continue until sea level data fluctuations at all observatories decay below tsunami warning criterion

level.

・Making a Tsunami Disaster Database

It is very important to make a tsunami disaster database in which the following information are synthesized: earthquake source parameters (hypocenter, magnitude, mechanism solution, Mw, etc.)(if the origin is other than an earthquake, its analysis results); tsunami data; scrutinized tsunami amplitudes and arrival times; contents of disseminated warnings and information; results of on-site survey on damages, inundations and tsunami traces. The merits of making a tsunami disaster database are as follows:

1 Through the scrutinization of tsunami records, knowledge on the characteristic of tsunami wave for each observatory is accumulated and the picking skill can be improved.

2 Enables comments on the outlook of tsunami (duration, etc.) in case a tsunami of similar scale is generated in the same area.

3 Enables improvement of tsunami simulation technique through comparison of observed and simulated tsunami waveforms. Tsunami simulation DB can be improved by additions of scenarios, or by a sophisticated DB search logic.

○Dissemination of Strong Motion Information

Strong motion index (e.g., seismic intensity), which has a good correlation with damages, is calculated based on strong motion meter waveform data. It is very important to promptly disseminate strong motion information in which strong motion indices are contained, especially for governmental organizations and municipalities, to notify on the possibility of severe damage soon after an earthquake occurrence, and to make them ready for on-site survey, traffic control or rescue operation depending on the strong motion index value on each site. This is the triggering information to set up the emergency system of the country. When this information is announced to the public, the meaning of strong motion index and its relation to damages must be well known in advance.

・Domestic Seismic Intensity Meter

Sensing unit is the same as that of strong motion meter. The seismic intensity meter calculates the strong motion index in real-time in the processing unit at the site, and the index value is transmitted to the processing center via communication link (*2) in case its value exceeds a threshold. Waveform data does not have to be transmitted in real-time, and high-speed transmission link in not necessary. However, waveform data should be retrieved via communication link in response to the request from the processing center. Seismic intensity meter, similar to a strong motion meter, must be deployed firmly on a stiff base. It is desirable to have a backup battery and a backup transmission route, the same as for a strong motion meter (*1).

It is desirable to deploy at least one seismic intensity meter in a jurisdiction of a municipality, because municipality is a primary unit of on-site survey or rescue operation (*1).

・Seismic Intensity Calculation, Seismic Intensity Data Receiving, and Quality Control

There are two ways to calculate seismic intensity: one is to calculate at the site, and the other is to calculate at the processing center by using strong motion waveform data transmitted from the site in real-time. A similar technique on earthquake detection and "grouping" as described above is applied to seismic intensity data to avoid false dissemination (quality control).

・Quick Report on Seismic Intensity

In Japan, a quick report on seismic intensity is disseminated within 1.5 to 2 minutes after the earthquake occurrence. This is to report the maximum seismic intensity in each area (about 1/3 to 1/4 of one prefecture) to promptly notify regarding the overview of a disaster before the hypocenter and magnitude determination.

・Seismic Intensity Information

This is to notify seismic intensity distribution in each municipality as well as the hypocenter and magnitude of the earthquake.

・Gapless Seismic Intensity Map Information or Shake Map

Gapless seismic intensity map is calculated based on the seismic intensity observations by interpolating them spatially, taking into account the amplification in the surface layer. This is done in order to estimate spatially fine seismic intensities even at sites without seismic intensity meter deployment. This is valid for the specification of the area to concentrate resources for on-site survey or rescue. JMA's gapless seismic intensity map uses only observations, and prediction based on hypocenter and magnitude is not used. It is very important to utilize boring research results or analysis on correlation between surface layer amplification and geography to improve accuracy of surface layer amplification setting. On the other hand, shake map is calculated only through prediction from hypocenter and magnitude. By combining these, improvement of map accuracy can be expected.

Strong motion meter data is useful for disaster mitigation planning as shown below, as well as for real-time seismic intensity (strong motion index) information.

1 Detailed source process analysis

Dislocation amount on each subsection of the fault and rupture propagation chronology can be analyzed by using strong motion waveform data. Similar analysis is possible by using broadband seismometer waveform data, but since shorter period (= shorter wave length) component is used for

strong motion meter, an analysis with finer spatial resolution is realized. An area on the seismic fault with large dislocation amount is called “asperity,” which radiates stronger energy than other areas. This analysis result can contribute to the making of a realistic hazard map because asperity is considered to be conserved in a geological time scale (in a high probability, it radiates strong energy in the next earthquake again).

2 Analysis of surface layer amplification

Surface layer amplification coefficients for several period band can be estimated by a comparison of strong motion waveform data with that deployed on a stiff surface or at a depth of engineering bed rock. By using estimated precise surface layer amplification distribution, a strong motion distribution – in case of assumed seismic fault moves – can be estimated with higher accuracy.

3 Development of strong motion prediction formula

By a regression analysis between observed strong motion maximum amplitudes and the distance from seismic fault and magnitude, prediction formula for maximum strong motion amplitude from assumed seismic fault can be developed. This formula enables damage evaluation with higher accuracy.

4 Application for earthquake-resistant design

By utilizing observed strong motion meter data as an input for the shaking simulation of a structure, an earthquake-resistant design can be made more realistically.

【Supplement : Comparison of EPOS and SeiscomP3】

EPOS is a computer system developed by JMA to conduct earthquake and tsunami observation and warning dissemination operation, and corresponds to synthesized system with functions 2), 3), 4) and for strong motion information dissemination specified in this material. At present, this system is installed only in JMA.

SeiscomP3 is a computer system developed by GFZ of Germany to process seismic waveform data automatically, and corresponds to the function 2) specified in this material. GFZ is actively promoting this system to be installed in many institutes in the world. Presently, SeiscomP3 is being operated in BMKG in Indonesia and VMGD in Vanuatu, etc. Note that the system corresponding to 3) tsunami forecast system in BMKG is called "TOAST," which is different from SeiscomP3, and forecasts tsunami amplitude and arrival time by using hypocenter and magnitude provided by SeiscomP3.

The table below compares 2) real-time seismic data processing system functions which are common both in EPOS and SeiscomP3.

Note:) The writer of this material has no experience in the handling of SeiscomP3 at this moment. The comparison here was done by reading documents available on the internet. For a more reliable description, obtaining firsthand information from the operational staff or actual handling of the computer system are necessary.

	EPOS	SeiscomP3
Seismic wave detection	STA/LTA	STA/LTA
Automatic arrival time picking method	AR model + AIC minimization	STA/LTA exceeding a threshold
Velocity structure for hypocenter determination	JMA2001 (Average velocity model in and around Japan)	Global average model
M formula	Mjma, Mw (seismic wave decay characteristics in and around Japan is reflected)	ML, mb, mB, Ms, Mwp (see text)
MMI for Interactive picking and hyp. & M determination	Top priority of designing is to enable unerring and prompt operation, so that vital issues can be checked by minimal action (see text for detail).	For general purpose. Designing is researcher-oriented (confirmation is necessary).
Automatic mechanism analysis	CMT, W-phase (broadband strong motion meter is also used)	(unknown)
Judging of gigantic earthquake	○	×

JMBSC 資料（津波警報・震度情報発出システム図）補足説明

本資料は、「途上国における地震津波観測・警報発出に関わる目標像」につき、支援者側と被支援者側で認識を共有し、共通の基盤に立って改善すべき点を議論することを目的に、インドネシア国「地震・津波観測及び情報発信能力向上プロジェクト」(2020-2022)の 2020 年度国内業務の一環として作成したものである。最終目標像として気象庁の地震津波観測・警報発出システム(EPOS)を念頭に置き、JICA 殿作成の「途上国気象局の期待される最終目標」図を参考にしつつ、システムを構成する処理機能及びそれらの間のデータの流れを整理した。

津波警報発出システムに必要な構成要素を大きく分けて、1)地震観測網、2)リアルタイム地震データ処理システム、3)津波予測システム、4)潮位観測システムと整理した（Kamigaichi(2015)）。津波警報とは、津波発生原因の大半を占める地震に伴う津波の規模・到達時刻を、地震に伴って発生し、津波よりも伝搬速度が 1〜2 桁早い地震波を解析することにより定量的に予測し、津波の到達前に発表することによって事前の避難を可能とするものである。近地津波の場合、警報発出の迅速性は確保されなければならないが、迅速性と精度の間にはトレードオフが存在する。そのため、津波警報の発表は 1 回限りではなく、時間経過とともに得られるデータや解析結果（潮位観測も含む）に基づき精度を向上させながら複数回更新されるものである。地震以外の原因（海底火山噴火、海底地すべり、海域の火山の山体崩壊等）により発生する津波の規模を定量的に予測することは困難であるが、発生した津波を（沖合津波計等により）可能な限り早期に検知し、到達前の海岸域に対して警報を発出することは可能であり、その場合、構成要素 4)及び 3)が重要となる。

地震に伴う災害としては、津波のほかに強震動災害がある。本図では、インドネシアのように内陸で発生する地震に対する強震動災害に係る情報発信が求められる国もあることに鑑み、日本の震度情報に対応する情報発信に関する機能も含めた。ただし、日本の緊急地震速報のような、強震動に対する警報発出については、途上国で実現するのは極めて困難と考えられることから除外した。

図の右上部分が強震動関連、図の左側の最上部から「津波 DB 検索」より上が上述の 1 及び 2、「津波 DB 検索」から「潮位データ収録」より上までが 3、以下が 4 に対応する。

なお、本図では最終目標像を示したが、「中間的目標」については、一部処理機能の省略という 0or1 の記述だけでなく、各処理機能の「出来」をアナログ的に示す必要もあると考え、各処理機能を評価するにあたってポイントとなる事項も記述した。また、津波警報の迅速かつ的確な発出の鍵となる地震会話検測 MMI(Man-Machine-Interface)に求められる詳細機

能についても記述した。

以下に、構成要素毎に、処理機能の詳細をデータの流れに沿って説明する。

【処理機能の詳細】

○津波警報等発出 1)地震観測網及び 2)リアルタイム地震データ処理システム

・国内/国外地震計

津波の規模の予測には、震源位置と地震の規模（マグニチュード：以下「M」）の推定が必須である。

震源（地下の岩盤の破壊現象である地震の発生した場所。より厳密に言えば、破壊開始点）位置の推定には地震波（P 波及び S 波）の観測点への到着時刻を用いる。到着時刻の精度の高い読み取り（以下、「検測」）のためには、短周期地震計（ないしは広帯域地震計データに High-pass Filter を施したもの）が適している。

一方、M の推定には、波形データの最大振幅値が用いられることが多いが、特に近地地震に対する速やかな M 計算のためには、地震波がすぐに届く震源近傍での大きな揺れに対しても振り切れない強震計が適している（気象庁方式）。

また、後述の CMT 解析や W-Phase 解析には、広帯域地震計ないしは広帯域強震計が適している。CMT 解析は、巨大地震に対しても飽和せず（後述）、精度の高いマグニチュードである Mw の計算が可能であるが、通常の M 計算よりも長時間の波形データが必要なことと、解析自体にも時間を要するため、近地地震に対する津波警報第一報には間に合わないことが多い。しかし、比較的時間的余裕のある遠地地震の M 推定には Mw(CMT 解析)が用いられることが一般的になっている。

地震計タイプ毎の、オンライン情報に反映される主なプロダクトへの利用は以下のとおり。

	短周期速度型	強震計	広帯域地震計
震源位置	○	△	（○：highpass filter 波形）
マグニチュード	○（小地震） （近距離）	○（中～大地震） （近～中距離）	○（中～大地震：Mw） （中～遠距離）
メカニズム解 （初動極性）	○		
メカニズム解 （CMT, W-phase 解）			○（広帯域強震計は S/N は低いがより近距離から波形利用可能）
震度（強震動指標）		○	

短周期地震計は設置環境条件が比較的緩いが、広帯域地震計は温度・気圧変化の影響を受けやすいため観測施設に工夫が必要であり、強震計は大きな揺れに対しても良好な観測継続が必要なため、頑強な地震計台への固定が必要である。

いずれの波形データも、100Hz サンプリング以上、16bit 以上の分解能・ダイナミックレ

ンジで処理中枢にリアルタイム伝送される必要がある（広帯域地震計については、CMT 解析目的であれば 20Hz で十分であるが、波形データに High-pass Filter を施して P,S 波の到着時刻の読み取りに使用する場合には 100Hz 必要）。

データ伝送のための通信回線は、IP-VPN 等の固定ブロードバンドが望ましい。また、通信プロトコルは、柔軟な経路選択を可能とし、データ亡失を最小とするために TCP 上のソケットやアプリ通信とするか、遅延時間を最小とするために UDP 上の RTP とすることが望ましい。

データ伝送のための通信回線は、大きな揺れによって回線が不通となる可能性を考慮して、主経路のほか、主経路断線時には速やかに backup 経路（固定ブロードバンドに対して携帯電話網経由インターネット通信路等）が確保されることが望ましい(*2)。

また、特に震源近傍で大きな揺れに見舞われると停電となり、観測の継続が困難となる可能性があるため、当該国の停電復旧までに要する平均的な時間を考慮した容量の backup 電源が用意されることが望ましい(*1)。

観測点の分布(*1)は、対象とする領域を取り囲むような配置が理想的であるが、できるだけ方位角ギャップ（震央(震源の地表投影)から震源計算に使用する観測点を見た場合の方位角の差の最大値）が小さくなるように配置する必要がある。一般に、観測網の外側で発生する地震ほど震源決定精度は悪化する。特に島しょ部においては、観測点の配置が直線的にならないよう工夫が求められる。

観測点の密度(*1)は、津波警報発出までの猶予時間から逆算して、後段の津波予測～警報発出に要する時間を差し引いても十分な時間内に、概ね 10 点以上の地震波到着時刻(P 及び S 波)と最大振幅の検測値が確保できる必要がある（S 波の伝搬速度から推算可能）。

当該国内に顕著な地震活動が認められず、もっぱら遠方の地震に伴う津波を想定すればよい国については、自国内に地震観測網を構築する必要はなく、全球的に展開され、インターネット経由で公開されている IRIS 観測点や、国内津波警報発出機関としてオーソライズされた機関であれば、CTBTO の地震観測網のデータが各国 National Data Center 経由で利用可能である。ないしは、後述のとおり、領域によっては大洋全域を対象に提供される Tsunami Advisory Center ないしは Tsunami Service Provider からの震源・M 値を用いることもできる。

しかし、当該国の近傍で発生する地震によって津波災害が想定される国については、津波来襲までの時間的余裕がないため、自国内に地震観測網を構築する必要がある。

国内観測点については、観測点の維持・保守管理のための定期及び障害時の手順が定まっている必要がある。

・処理中枢（薄クリーム色枠全体）

処理中枢の計算機システムは、片系に障害が発生した場合にも迅速な津波警報発出を可能とするため、正副二重系構成となっていることが望ましい(*3)。また、ひとつの中枢が突発災害等により業務継続不能となる可能性を考慮して、同時に壊滅することがない程度に

離れた地域二か所に整備されることが望ましい（地域冗長性）(*3)。その場合、両中枢における迅速な警報発出能力の維持向上や、片側が業務継続不能に陥った場合の相互認知や円滑な業務移行のための手順が定まっている必要がある。

・地震波形データ収録、地震検出・グループ化

地震波形データは HD 上にサイクリックに連続収録される。その連続地震波形データに対して、地震波検出処理がリアルタイムで連続的に行われる。通常、STA/LAT 比（波形データの二乗振幅値の短時間平均/長時間平均）が設定値を越えたことをもって「地震波検出」とするが、ノイズによる誤検出を避けるため、対象領域をすべてカバーするようにサブエリアを適当数設定し（「グループ化」）、各サブエリア内に存在する観測点のうち一定数以上の観測点で、一定時間以内に「地震波検出」となった場合に限って本当に地震が発生したものとみなすのが一般的である。

全チャネルのデータを HD 上に保持できる時間は HD 容量から限界があるので、後述の地震カタログ作成等詳細解析及び外部記憶媒体での長期保存のために、地震波検出の時刻前後一定時間内の、地震波が検出された観測点（＋α）のデータのみ切り出して保存するのが有効である。また、特定領域の代表的観測点については、長期的な地震活動監視のため、地震波検出の有無にかかわらず連続的に波形データを保存するのも有効である。

・自動震源・M 計算

前段の地震波検出が成立した観測点の地震波検出時刻データ（通常 P 波とみなされる）と、同時刻から一定時間内の最大振幅値（自動読み取り）を用いて、震源・M が自動計算される。進んだ技術としては、単純に STA/LAT が一定値を越えた時刻ではなく、その時刻周辺の波形データに数学モデルを適用して P 波到着時刻の精度を向上させる方法や、一度 P 波到着時刻だけで計算した震源位置を元に、理論的に予測される S 波到着時刻付近に数学モデルを適用して精度の高い S 波到着時刻の自動読み取りを行い、P 及び S 波両方の到着時刻データを用いて震源の決定精度を向上させる方法もある（気象庁で使用中）。

この場合、震源決定に使用する地震波速度構造（走時表）は、全球平均的なものではなく、当該地域における爆破地震学実験や、震源と地震波速度構造の同時インバージョン等の成果を踏まえ、当該地域に適合したものを使用することにより、震源決定精度の向上を図るべきである。

また、マグニチュード計算式についても、近地で発生する大きな地震に対しても振り切れない強震波形データを用いた、かつ当該地域の地震波減衰特性に適合した式を用いることが、精度向上及び計算の迅速性を確保するうえで望ましい。地震波形データ処理ツールに一般的に組み込まれている ML は、近距離で定義されているが南カリフォルニア地域の地震波減衰特性と同じ地域にしか適用できない。mb, mB, Ms は遠距離でしか定義されていないため、迅速性という点で劣り、Mwp も、本来浅部の不均質性の影響をあまり受けない遠地

地震波形の使用を前提として作成された式であるため、これらは近地定義の M 式の補足という位置づけが妥当である。

・会話検測（震源・M 計算）

津波警報の社会的重大性を鑑みれば、精度の悪化や誤報は避けなければならない。そのため、上段の自動検測及びその結果を用いた自動震源・M 計算結果を人間がチェックし、必要に応じて再検測、震源・M 再計算を行い、後段の津波予測システムに引き渡す必要がある。この人間が介在する部分が警報発出までの作業の中で律速段階となるため、チェック及び再検測・再計算に用いる会話検測ツールの Man-Machine-Interface の操作性(*4)が迅速かつ的確な警報発出の鍵となる。

同ツールでチェックすべき事項は次のとおり。

① P,S 波到着時刻及び最大振幅の検測結果の妥当性：波形時系列に、自動検測による到着時刻及び最大振幅出現時刻を重ねて表示する。自動震源（及び地震発生時刻）から計算される理論 P,S 波到着時刻もあわせて表示し、その画面上で到着時刻及び最大振幅の手動検測（修正）が可能な操作性を有する必要がある。

② 震源計算に使用した観測点の分布の妥当性及び震源決定の収束具合：地図上に、決定された震源位置と、計算に使用された観測点分布を表示し、適切な分布で観測点が選択されているか確認する。また、各観測点から、理論震央距離円を描画し、それらの円がほぼ一点（震央）で収束しているか確認する。

③ 自動震源位置の地震学的妥当性：このために重要なのは「地震カタログ」である。地震カタログから背景地震活動を描画し（描画した地震活動図を画像データとして保存しておけば十分）、それに自動震源位置を重ねて描画することにより、地震学的な妥当性を確認する。

④ 震源の深さの妥当性：走時残差（観測された到着時刻と、理論的に計算される地震波到着との差）を震央距離の関数として描画し、残差の震央距離依存性が残っていないか確認する。

⑤ M 計算のばらつき具合：M 残差分布を確認し、必要に応じて異常値を除外する。

これらのチェック・修正を経て、津波警報等に用いる震源・M が決定される。

・詳細会話検測（地震カタログ作成）

上記会話検測ツールを、オフライン的に過去の地震波形データに適用して実施するのが一般的。このプロセスを通じて、職員が緊急的に決定した震源・M の妥当性につき分析が行われ、震源位置に応じた最適な観測点選択の方法や、P,S 波の波形の特徴に注意した適切な検測位置等のノウハウが蓄積され、緊急時のプロダクトの質の向上につながる。それ以外にも、地震カタログを作成する効果としては、地域毎の過去の地震活動の特徴が定量的に分析可能となることにより、当該地域で地震活動が発生した場合の今後の推移予測に関する解

説が可能になることや、活断層の活動度・断層形状の分析や後述の津波シミュレーションDB でカバーすべき領域の設定がより高い信頼度で可能となること、さらには自国及び世界の地震学研究のための基礎資料となることが挙げられる。

なお、本地震カタログには、後述の震度（強震動指標）分布とともに、メカニズム解（発震機構解）が震源・M と紐づけて掲載されることが望ましい。メカニズム解の計算には、中規模以上の地震であれば広帯域地震計波形データを用いた CMT 解析が用いられ、広帯域地震計データがノイズレベル以下となるような小規模な地震に対しては P 波初動極性の読み取り結果(UP/DOWN)に基づく初動極性解析が用いられる。メカニズム解からは、地震の原因となった地下の応力状態が推定できるため、当該地域のテクトニクスの分析、活断層走向との関係分析や、海域であれば津波シミュレーションデータベース作成の際に仮定すべき断層形状の設定に活用できる。

・巨大地震判定

地震波形中の最大振幅を用いたマグニチュード計算では、必ずある M 値以上で飽和が生じる。例えば、気象庁マグニチュード Mjma は M8 よりも大きな範囲で飽和する。飽和した M 値を用いて後段の津波予測を行うと過小評価となり、防災上問題である。現状、M8 を大きく超える地震のマグニチュードを 3〜5 分といった短時間で精度よく決定できる手法は存在しないが、3〜5 分で決定された M 値が過小評価となっている可能性を覚知する手法は存在する（気象庁で用いている手法等)。そうした手法を用いて過小評価の可能性を覚知できた場合は、計算された M 値ではなく、当該海域で地震学的に想定される最大 M 値（当該国の政府研究機関・大学等で分析される必要有。そのための基礎資料としても地震カタログは重要）で差し替えて津波警報を行う（そうした手順を踏むことを、予め防災関係機関や一般住民に周知しておく必要がある)。

・CMT, W-Phase 解析

CMT, W-phase analysis

海岸線の近くで大きな地震により津波が発生する国では、津波警報の第一報をできるだけ迅速に発出する必要があるため、解析に時間を要する CMT 解析や W-Phase 解析は第一報では使えない。しかし、CMT 解析や W-Phase 解析で得られるメカニズム解（断層形状）及び Mw の結果に応じて、すでに発出された津波警報をより精度の高いものに更新することは重要である（第一報ではメカニズム解についてはある仮定を置く必要があったが、その不確定性が取り除かれる)。標記解析手法はすでに実用化され、様々な国の津波警報機関（気象庁を含む）の津波警報作業に取り込まれており、最新技術をいかに津波警報の実作業に取り込むかというノウハウの伝授が重要である。

〇津波警報等発出 3)津波予測システム

・津波 DB 検索

迅速な津波警報（第一報）発表と、予測精度の確保を同時に満たすために、あらかじめ津波を発生される可能性のある海域を網羅(*6)するよう、各海域の地震のメカニズム解を考慮した断層モデルによる地殻変動を初期値とした津波伝搬シミュレーションを実施し、その結果を DB として保管しておき、大きな地震発生時には震源・M を検索キーとして同 DB から最も適切なケースを引き出す方法が多くの津波警報発出機関で採用されている。DB の内容は、震源・M（及びメカニズム解）毎の、各予測点での津波予測波高・到達予測時刻（及びシミュレートされた津波波形データそのもの）である。

津波伝搬シミュレーション技術はすでに確立されており、計算に必要なソフトウェア群も無償で公開されているため、導入にあたっての障害はほとんど存在しない。ただし、シミュレーションの実行には一定分解能以上の正確な水深分布データが必要であり、特に途上国の場合、その品質やカバー領域には差が大きいと思われる。被害を生じるような津波はおおむね M>7 の地震により発生するが、その波源域の広がりは数十 km であり、その中に 20 点程度の計算メッシュが確保されることが望ましいので、シミュレーション計算に用いる水深データのメッシュ間隔としては 1km 程度(1 arc minute～30 arc second)は確保されることが望ましい(*5)。粗い計算メッシュによる計算結果は、水深の浅くなる（そのため津波の波長が短くなる）沿岸域で精度が悪化するため、やや沖合に設定した予測点での結果に、Green の定理を適用して沿岸での値に換算する方法がとられることが多い(*5)。より詳細かつ正確な計算メッシュが用意できる場合は、計算機の能力に応じて、Nesting という手法を用いて沿岸までの計算も可能となる(*5)。

DB で保管できるシナリオ数は高々有限個(*6)であるため、実際の震源位置・M に完全に一致するシナリオは一般的には存在しない。そのため、有限個のシナリオ候補の中から最適なシナリオを選択するロジックが必要であり、気象庁ではそのノウハウを有している。また、津波波源の広がりに不確定性が残っている間は、津波災害の高い致死率を考慮すると、あり得るすべてのシナリオの中での最悪の状況（予測波高最大）を考慮する必要があるが、後段の潮位観測システムから提供される津波波源域の広がりが絞り込まれれば、より不確定性を減じた予測波高・到達予測時刻が津波警報の更新に活用できる。

・リアルタイム・シミュレーション

CMT、W-Phase 解析によりメカニズム解・Mw が得られた後（さらには、津波波源域が絞り込まれた後）であれば、リアルタイムで実行する津波伝搬シミュレーションの結果に応じて、近地地震に対する津波警報の更新、ないしは遠地地震に対する津波警報第一報の発表が可能である。

・国際津波 Advisory 情報

大洋域（太平洋、インド洋、カリブ海、北東大西洋及び地中海）によっては、同大洋全域を

対象として、各 ICG によりオーソライズされた機関から発出される標記情報が利用可能である。遠地地震に対する津波伝搬シミュレーション DB を運用する国であれば、自ら遠地震源・M 決定を行わずとも、標記情報に含まれる震源・M を検索キーとして DB を検索することが可能であり、DB を有しない国の場合は、標記情報に含まれる当該国の予測点での予測波高・到達予測時刻を利用可能である。

・沖合津波データインバージョン

地震の断層モデルまで戻ることなく、沖合の津波計で捉えられた津波波形から初期津波波源の空間分布を逆解析（インバージョン）により推定し、それを初期値とした津波伝搬シミュレーションにより沿岸の津波波形を予測（予測波高・到達予測時刻）することができる（気象庁はすでに業務に導入済）。津波波源に関するすべての不確定性が除かれるため、地震学的手法よりも精度が高い。ただし、津波発生が予想される海域を取り囲む（内部も含む）ように、ある程度の空間密度で津波計（水圧式 or 海面上下変動直接観測方式）が配置(*9)され、リアルタイムでデータがモニターできていなければならないため、適用できる海域は限られる。また、水圧式の津波計（ケーブル方式、DART-buoy）の場合、それが震源直上に配置されている場合であっても、地震発生から水圧の変化がピークを迎えるまでに時間を要するため、津波警報の第一報には間に合わない。前段の震源・M 計算結果ないしは手動により起動される。

・津波警報・津波情報（予測）

前段の予測波高・到達予測時刻に基づき、津波警報及び予測内容の詳細を補足する津波情報（予測）を発出する。警報は、予想される被害の程度に応じて、複数段階のグレード(*7)という、利用者が瞬時に災害の程度を想起できる表現で発表されるのが望ましい（日本の場合、予想される最大波高に応じて、0.2-1.0m：津波注意報、1.0-3.0m：津波警報、3.0m 超：大津波警報の３段階）。グレードの基準は、その国の過去の津波災害で観測された津波波高と被害程度との関係調査結果に基づくことが望ましいが、同様の海岸利用状況の周辺国における基準を流用することも可能である。各グレードの上限津波波高に対応する詳細な津波浸水予測ハザードマップを予め作成・周知（日本の場合、地方自治体がその責任を持つ）し、津波警報が発表された場合の避難を要する領域として防災行動と連動させることが望ましい。

また、津波警報は、沿岸地点毎ではなく、一定の広がりで海岸線を区切った「予報区」(*7)毎に発表するのが適当である（日本の場合、66 予報区）。予報区の設定にあたっては、防災対応の基本単位である行政区分、海岸線が面する海域、津波挙動の均一性、津波予測精度を考慮し、地方自治体等防災関係機関と協議のうえ設定される必要がある。

津波警報や津波情報に限らず防災情報は原則、自由文形式ではなく、定型化されている必要があり、計算機による自動処理により受領機関に関係のある警報内容の抽出が容易なフ

ォーマット（XML 形式等）で提供されることが望ましい。

後段の津波観測システムから提供される観測波高/予測波高が、許容値よりも大きかった場合は、その比の統計処理結果に基づき、津波警報の切り上げ、ないしは予測波高の更新発表を行う。また、その比が設定値よりも小さい（津波が観測されない場合も含む）場合には、津波警報の切り下げ、ないしは解除を行う。

・津波情報（観測）

後段の津波観測システムから提供される観測波高・到達時刻を適時に伝える。これは、発生した津波の実況をきめ細かく住民に知らせるという意味と、すでに到達したという事実を伝えることで、未だ避難を逡巡している住民の避難を促す意味がある。

・遠地地震情報

海外で発生した大きな地震について、当該地域に自国住民が居住して安否確認が必要となる場合や、その地震によって自国に津波警報が発表される可能性がある場合には、当該地震についての震源・M や、自国への津波の影響の有無を自国民に知らせるために発表する。

〇津波警報等発出 4)潮位観測システム

・国内/国外潮位計

警報発出の対象となる海岸線には、可能な限り 1 予報区に 1 箇所以上の潮位計（国内）が配置されていることが望ましい(*1)。また、遠地で発生した津波について、自国への影響の程度・有無を判断するため、自国までの途中海域の最低でも複数点の潮位計データがモニターできていることが望ましい(*1)。国内分については、近傍の大きな地震に伴う強震動によって停電ないしは通信回線断の可能性があるため、地震観測点と同様、backup 電源確保及び backup 通信回線への切り替えが可能であることが望ましい(*1,*2)。国外の潮位計データについては、静止気象衛星の DCP 機能を用いて収集され、WMO/GTS 回線上で国際的に流通しているものが利用可能である。精度の高い津波警報の発出や、地震以外の原因によって発生する津波について有効な津波警報を発出するため、当該海域を取り囲むように、ないしはその背後の沿岸の沖合に、沖合津波計が整備されることが望ましい(*9)。

潮位計は潮汐観測や高潮監視等、津波観測・監視以外の目的にも活用できる多目的施設であるが、津波観測・監視の目的では、近地で発生する津波には短周期成分が多く含まれること、及びリアルタイムでの監視が重要であることから、特に国内潮位計についてはサンプリング周期は 1 秒程度、収集頻度もできればサンプリング周期と同じ、最低でも 1 分以内であることが望ましい(*8)。国内で、津波警報発出責任機関以外の機関で潮位観測が実施されている場合は、両機関の緊密な連携により、津波警報発出責任機関での潮位計データのリアルタイムモニタリングが必要である。

・潮位データ収録

地震計データと同様、潮位データは HD 上にサイクリックに連続収録される。全チャネルのデータを HD 上に保持できる時間は HD 容量から限界があるので、後段の津波災害 DB 作成等詳細解析及び外部記憶媒体での長期保存のために、津波観測開始の一定時間前から津波による潮位変動が収まるまでのデータのみ切り出して保存するのが有効である。

・天文潮位・気象の影響除去

潮位は、天体による潮汐力や、気象（気圧及び海面風速）の影響を受けて変動するため、正確な津波の検測のためには、これらの影響を定常的に除去することが望ましい。潮汐は規則的な現象であり、観測点毎の過去の潮位データの解析から、潮汐力による周期的変化の特性を把握し、未来の潮位データに対して潮汐変動成分の除去を行うことができる。また、当該国の気象観測・予報責任機関（部署）から、気象数値予報モデルの計算結果（高潮予測）として、気象の影響成分の除去を行うことができる。

・会話検測（時刻・振幅）

前段の津波警報第一報発表により、ないしは火山島での噴火発生等、地震以外の原因によって津波が発生した可能性を覚知した場合は手動により起動される。

潮位データ時系列表示画面を監視し、MMI を用いて(*4)、画面上で潮位観測点毎の津波到着時刻、現時点までの津波の最大波高及びその検出時刻を検測する。検測された観測波高・到達時刻は、3)の津波情報（観測）処理に随時提供される。また、第一波の到達時刻から津波逆伝搬図を用いて津波波源域の広がりを特定し、3)の津波 DB 検索処理に提供するとともに、観測波高/予測波高を随時更新して、その比の分布を統計処理して 3)の津波警報・津波情報（予測）処理に提供する。

この処理は、すべての潮位観測点で潮位データ変動が警報等発表基準を下回るまで継続される。

・津波災害 DB 作成

津波の事例（実際津波が観測された or 津波警報等を発表した事例）毎に、その原因となった地震の諸元（震源・M、メカニズム解・Mw 等）（地震以外が原因の場合はその分析結果）、潮位データ、津波観測波高・到達時刻の精密な最終検測結果、発表した警報・情報の内容、現地における被害や浸水状況・津波の痕跡の調査結果等を総合的にとりまとめ、津波被害 DB として作成することは重要である。このプロセスを通じて、観測点毎に特徴のある潮位データ変化の特性把握と次回以降の検測精度の向上、今後同様の海域で同様の規模の地震が発生した場合の津波の推移予測・解説、予測された津波波形と実際に観測された津波波形との比較分析による、津波シミュレーション手法そのものの改善や、同 DB で用意すべきシナリオ追加や検索手法の改善に繋げることができる。

〇強震動情報発出

強震動による被害の程度と相関の良い指標値（震度等）を強震計データから計算し、その最大値に応じて速やかに情報として発出することは、特に政府機関や地方自治体にとって、大きな強震動災害が発生した可能性を速やかに覚知させ、指標値に応じた被害調査・交通制限や救助活動のための体制、国としての被災地支援体制を緊急に立ち上げるためのトリガとなるため防災上非常に有効である。一般住民に対して発表する場合には、事前に指標値と強震動被害の程度・様相の関係につき十分な周知が必要である。

・国内震度計

受感部としては強震計であり、観測点現地処理部においてリアルタイムで強震動の指標値を計算し、それが一定値を超えた場合に中枢に処理結果を通信回線経由(*2)で報じる（波形データ伝送はリアルタイムである必要はないので、通信回線容量は小さくて済む。ただし、中枢からの要求信号に応じて波形データを伝送する機能は必要)。強震計と同様、頑強な地震計台に固定される必要がある。Backup 電源や backup 通信回線も強震計と同様に求められる(*1)。

観測点分布(*1)は、各地方自治体単位で最低 1 点は確保されることが望ましい（被害調査や救援活動実施の基本単位は地方自治体であるため)。

・震度計算、震度データ受信、品質管理

震度計算は、現地での震度計処理部で行われる方式と、リアルタイムで伝送される強震計の波形データから中枢においてリアルタイムで算出される方式がある。誤報回避の目的で、両者とも、前述の地震検出・グループ化と同様の「本当の地震か否か」の判定処理（品質管理）が行われる。

・震度速報

日本でいえば、一つの県を数分割した程度の広がり毎の、最大震度のみを速やかに報じる情報で、地震発生から 1.5～2 分で発表される。震源・M 決定よりも前に発表するのは、強震動災害の概要をとにかく迅速に伝えるのが目的。

・震度情報

会話検測によって確定した震源・M と、それに紐づけられた地方自治体毎の震度をまとめて情報にしたもの。

・面的震度分布図 or Shake Map

震度計や強震計の配置されていない場所も含めて、震度の面的分布を推定して報じるこ

とにより、強震動災害の程度やその広がりを面的に詳細に報じるもの。重点的に被害調査・救援活動を行うべき領域の特定に有効。気象庁では、震源・M を用いた予測値は用いず、観測された震度のみから地表面の揺れやすさの違いも考慮して面的に連続な内挿を行っている。この場合、地盤増幅度の見積もりが分布図の精度を大きく左右するため、ボーリング等地盤調査や、地盤増幅度と地形との相関分析等を活用することが重要である。一方 Shake Map では、震源・M 値からの面的な予測値により作成される。両者を組み合わせることにより、より精度の高い情報とできる可能性がある。

強震計の波形データは、上述のリアルタイム情報としての震度（強震動指標）として利用されるほか、波形データそのものに以下のような利用価値がある。

① 詳細震源過程解析

仮定した断層面の各小領域におけるずれ量や、破壊伝搬の時間的推移が解析できる。広帯域地震計（及び広帯域強震計）によっても同様の解析が可能であるが、強震計データは広帯域地震計データよりも短周期（短波長）成分を用いるため、より空間分解能の高い解析が可能となる。特に、ずれ量の大きい領域は「アスペリティ」と呼ばれ、次の地震時にも再び強震動源となる可能性が高いため、被害想定（ハザードマップ等）を行ううえで重要な資料となる。

② 表層地盤の増幅特性解析

固い地盤上（ないしは工学的基盤の深さ）に設置された強震計の波形との比較により、各設置地点周辺の周期帯別の地盤増幅度が解析できる。これにより、仮定した想定断層がずれ動いた場合の地表における強震動による被害の程度が高精度で想定可能となる。

③ 強震動予測式の開発

別途解析された震源断層からの距離、マグニチュードと、実際に観測された強震動最大振幅の間の統計的解析により、ある断層を仮定した場合の、地点毎の強震動の強さを予測する式が作成できる。これにより、精度の高い被害想定が可能となる。

④ 耐震設計への活用

強震動時の構造物の挙動を解析する際の入力データとすることで、より現実的な耐震設計が可能となる。

【補足：EPOS と SeiscomP3 の比較】

EPOS(Earthquake Phenomena Observation System)とは、気象庁が地震津波監視・警報等発出のために開発した計算機システムであり、資料 2),3),4)及び強震動情報発出機能を統合した地震津波総合処理システムである。気象庁以外への導入実績はない。

SeiscomP3 は、独 GFZ が開発した地震データ自動処理システムで、資料の 2)に対応する。GFZ は同システムの世界拡散を精力的に図っており、現在インドネシア BMKG や、ヴァヌアツ VMGD 等で運用実績がある。なお、BMKG における 3)に対応するシステムは TOAST と呼ばれ、SeiscomP3 で計算される震源・M をオンラインで受け取って津波波高・到達時刻を予測する、SeiscomP3 とは別システムである。

以下に両者に共通する 2)リアルタイム地震データ処理システムについての比較を行う。

注）SeiscomP3 について、筆者は直接操作した経験がないため、同システムに関して web 上で入手可能な資料を基に記述した。より正確な記述のためには、稼働中の機関職員への聴取及び実際の操作が必要となる。

	EPOS	SeiscomP3
地震波検出法	STA/LTA	STA/LTA
自動到達時刻検測	AR モデル+AIC 最小化時刻	STA/LTA 閾値超時刻
震源計算速度構造	JMA2001 （日本周辺の平均的モデル）	全球平均モデル
M 計算式	Mjma（気象庁 M）,Mw （日本周辺の地震波減衰特性反映式）	ML, mb, mB, Ms, Mwp （本文中説明参照）
会話検測 MMI	緊急作業の正確かつ迅速化を最優先に、必要なチェックが最小限の操作で可能なように設計（本文中説明参照）。	汎用的。研究者の発想。 （詳細要調査）
メカニズム自動解析	CMT, W-phase （広帯域強震計も使用）	（不明）
巨大地震判定	○	×

APPENDIX 8-12

The Study on Technologies and Functions of Seismic Observation Equipment for Quality Management in Maintenance in Japan

The Study on Technologies and Functions of Seismic Observation Equipment for Quality Management in Maintenance in Japan

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

November 2021

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
BMKG	Meteorological, Climatological, and Geophysical Agency (Indonesian: Badan Meteorologi, Klimatologi, dan Geofisika)
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
NIED	National Research Institute for Earth Science and Disaster Resilience
SOH	State of Health

Chapter 1 Introduction

1.1 Background

JICA has started the technical cooperation project with BMKG of Indonesia as counterpart. BMKG has been conducting seismic observations in 100 stations located in various islands of Indonesia. However, the operation rate of the equipment at these stations is just about 60-80% and the observation quality is not high. This project consists of 4 outputs, and the following three items are the results of Output 1.

1-1 Investigate and analyze the current maintenance and management system of seismic observation and communication equipment, and identify problems.

1-2 Develop guidelines and manuals to standardize the maintenance procedures of the equipment.

1-3 Provide on-the-job training on the maintenance and replacement of seismic and communication equipment.

In preparation for the above activities, a survey on the current situation of maintenance and management of seismic observation systems in Japan was carried out at three institutes: National Research Institute for Earth Science and Disaster Resilience (NIED), Japan Meteorological Agency (JMA) and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In addition to this, JET had decided to conduct a survey on the maintenance and management of seismic equipment and systems from the viewpoint of the manufacturers of seismometers.

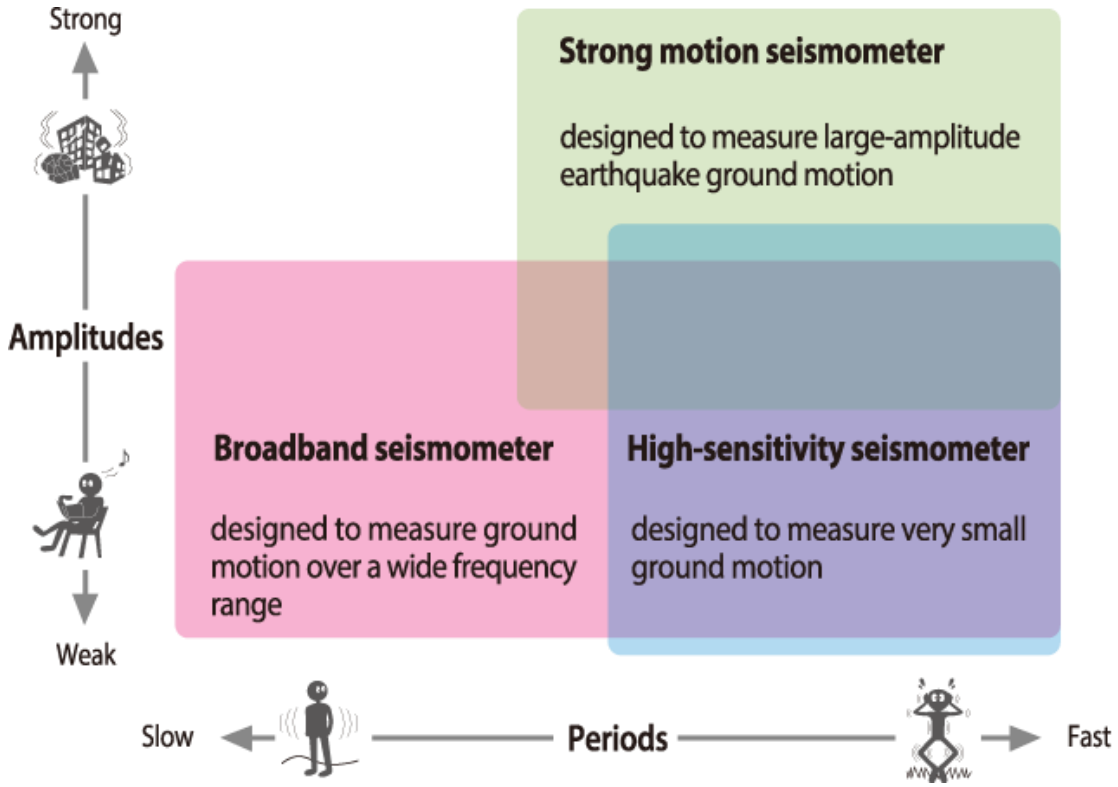
1.2 Objective of the Study

The current seismic equipment has been developed to maintain the quality of the observation data under poor natural environment and observation conditions. In order to learn about the functions of the equipment and the know-how on the technology, JET conducted an interview survey with the manufacturers who develop and sell the equipment, and investigate and analyze the technology on the equipment side and the innovations during the development that support the efficiency of the maintenance of the seismic observation system.

Chapter 2 Data Collection and Interview Survey

Earthquake observation equipment is of three types in accordance with the purpose of observation (see figure 2-1). This study focused on broadband seismometers and strong-motion seismometers, which are the subject of this project. Firstly, JET conducted a desktop survey on the equipment and characteristics of each of the two types of manufacturers, dividing them into two groups: distributors in Japan who provide products developed by overseas manufacturers and equipment manufacturers who develop and provide seismic observation equipment.

Secondly, JET conducted an interview survey with 4 companies to determine their efforts to improve the quality and efficiency of maintenance management from the manufacturers' perspective.



Source: NIED website[1]

Figure 2-1 Types of seismometers

[1] https://www.mowlas.bosai.go.jp/mowlas/?LANG=en

2.1 Interview Survey

2.1.1 Background Information

Japanese earthquake observation institutes are provided with seismometers from distributors of imported equipment or domestic manufacturers who researched on and developed these equipment. A desktop survey was carried out on the major manufacturers and distributors of seismometers with focus on the strong-motion and broad-band types supplied to the Japan Meteorological Agency and research institutes.

For more detailed information, “Appendix A. Datasheet of Seismographs” can be checked.

(1) Japanese Distributors of Imported Equipment

1) OYO Seismic Instrumentation Corp.

Address: Saitama-shi, Saitama Prefecture, Japan

Business outline[2]:

- ✓ Import and sales of seismometers
- ✓ Installation, maintenance and inspection of seismometers
- ✓ Development and sales of measuring instruments for earthquake engineering
- ✓ Design and construction of seismometer networks
- ✓ Topographical and geological survey for seismometer networks
- ✓ Development and sales of seismic protection equipment

Source: OYO Seismic Instrumentation Corp. website[3]

Figure 2-2 Broadband seismometers (left: STS-2.5 STRECKEISEN, right: MBB, Metrozet)

[2] http://www.oyosi.co.jp/Kaisya.htm

[3] http://www.oyosi.co.jp/ProductTop.htm

2) Clovertech Inc.

Address: Musashino-shi, Tokyo, Japan

Business outline[4]:

- ✓ Manufacture of electronic and electrical equipment for measurement, and sales of associated software
- ✓ Manufacture of computers and related equipment, and sales of associated software
- ✓ Manufacture of various sensors, and sales of associated software

Source: Clovertech Inc. website[5]

Figure 2-3 Broadband seismometer (Trillium360, Nanometrics)

Source: Clovertech Inc. website[6]

Figure 2-4 Broad-band seismometers (LE-3Dlite MkIII, Lennartz)

[4] http://www.clovertech.co.jp/company.html

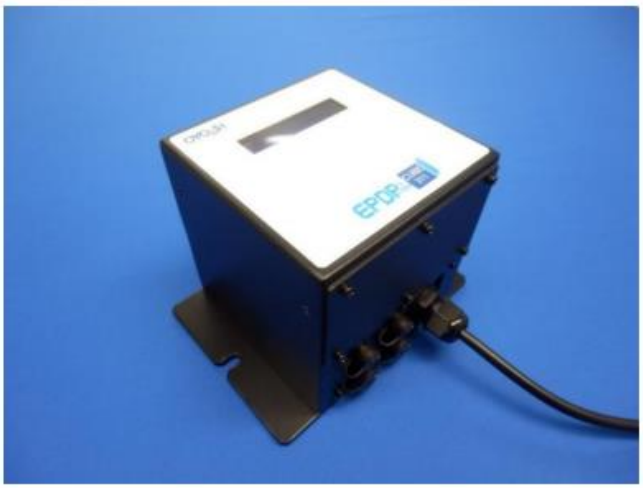
[5] http://www.clovertech.co.jp/products-360v.html

[6] http://www.clovertech.co.jp/products-le3dlmk3.html

(2) Japanese Domestic Manufacturers

1) OYO Seismic Instrumentation Corp.

Business outline: As noted above.



Source: OYO Seismic Instrumentation Corp. website[7]

Figure 2-5 Strong-motion seismometer (EPDP-CUBE 311)

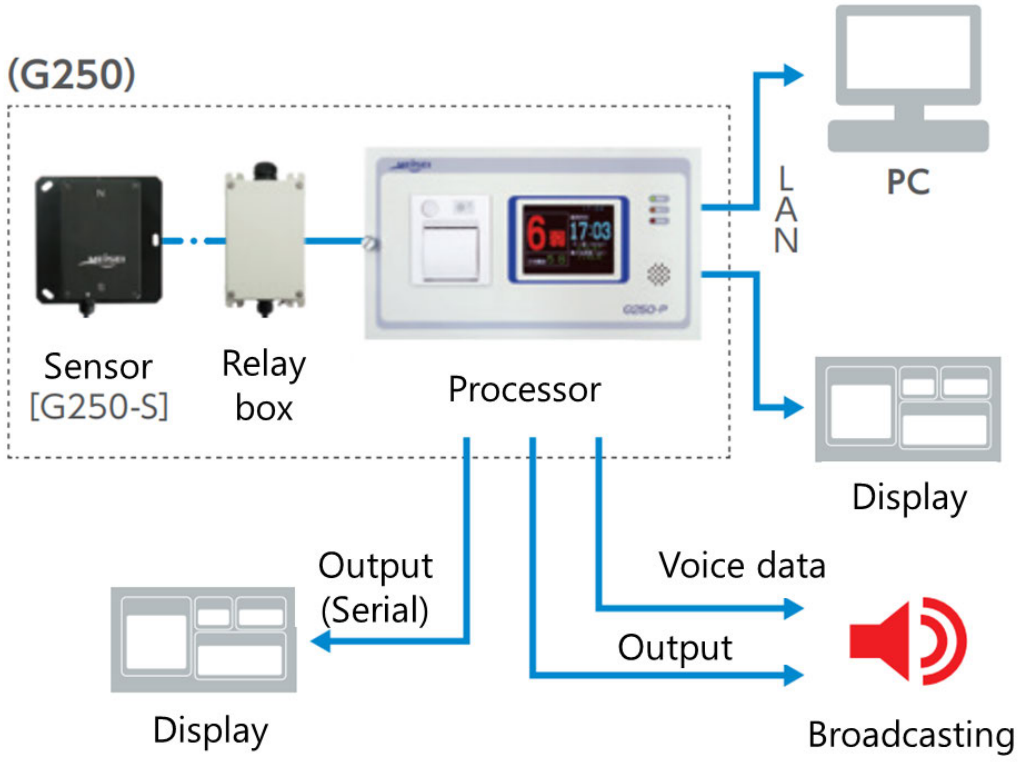
[7] http://www.oyosi.co.jp/ProA0000-EPDP.htm

2) Meisei Electric Co., Ltd.

Address: Isezaki-shi Gunma Prefecture, Japan

Business outline[8]:

- ✓ Manufacture and sales of communication, electronic, electric measuring, information processing machines and other electric and electronic instruments, machineries and parts
- ✓ Manufacture and sales of physical and chemical equipment, precision equipment and others not listed above
- ✓ Manufacture and sales of computer software



Source: Meisei Electric Co., Ltd. website[9]

Figure 2-6 Strong-motion seismometer (G250)

[8] https://www.meisei.co.jp/aboutus/outline

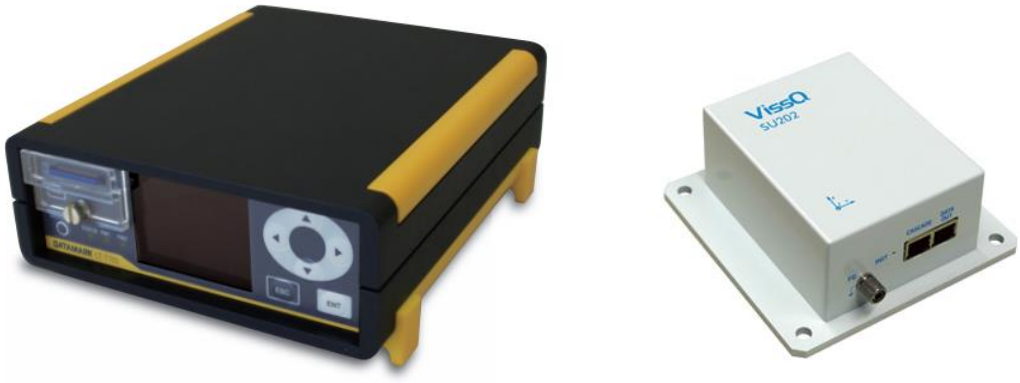
[9] https://www.meisei.co.jp/products/earthq/earthq_earthq/p2023

3) Hakusan Corporation

Address: Fuchu-shi, Tokyo, Japan

Business outline[10]:

- ✓ Development and sales of seismic observation network systems and earthquake disaster prevention systems
- ✓ Development and sales of disaster risk reduction systems and building damage evaluation support systems
- ✓ Manufacture and sales of precision slitters and peripheral equipment/systems



Source: Hakusan Corporation website[11]

Figure 2-7 Strong-motion seismometers (left: LT-7700, right: SU202)

4) Takamisawa Cybernetics Co., Ltd.

Address: Nakano-ku, Tokyo, Japan

Business outline[12]:

- ✓ Development and sales of transportation equipment
- ✓ Development and sales of mechatronics equipment
- ✓ Development and sales of specific system/machine

[10] https://www.hakusan.co.jp/english/company/

[11] https://www.hakusan.co.jp/products/keisoku/lt7700.html

[12] https://www.tacy.co.jp/en/corporate/company/business/

Source: Takamisawa Cybernetics Co., Ltd. website[13]

Figure 2-8 Strong-motion seismometer (STR-420)

5) Mitutoyo Corporation

Address: Kawasaki-shi, Kanagawa Prefecture, Japan

Business outline[14]: Manufacture and sales of precision measuring instruments

Source：Mitutoyo Corporation website[15]

Figure 2-9 Strong-motion seismometers (left: JEP-4A3, JEP-8A3, right: 831-118R)

[13] https://www.tacy.co.jp/products/tokki/str/str420/

[14] https://www.mitutoyo.co.jp/eng/corporate/outline/index.html

[15] https://www.mitutoyo.co.jp/products/jishin

2.1.2 Outline of the Interview Survey

Interview survey was carried out on equipment manufacturers and distributors (two international and three Japanese companies) who have installed seismic equipment in Japanese observation agencies, such as JMA and NIED.

(1) Target companies

The survey covered the following companies:

Distributors of imported seismograph (2 companies)

- ✓ OYO Seismic Instrumentation Corp.
- ✓ Clovertech Inc.

Agencies and manufacturers of seismic equipment in Japan (3 companies)

- ✓ OYO Seismic Instrumentation Corp.
- ✓ Meisei Electric Co., Ltd.
- ✓ Hakusan Corporation

(2) Survey method

Basically, JET conducted interviews and requested documents. In consideration of the COVID-19 situation, JET avoided face-to-face interviews and collected information by web conference interviews or follow-up interviews after receiving the answered questionnaires by e-mail.

(3) Survey items

- ✓ Concept of the product, performance and characteristics of the device
- ✓ Direction of technical development
- ✓ Recommendations to users to ensure quality
- ✓ Frequency of updating equipment
- ✓ Recommended operating methods for stable maintenance and management
- ✓ Methods for the rapid detection of failures
- ✓ Recommended daily inspections
- ✓ Manuals and guidelines for maintenance and management

2.2 Results and Analysis of the Survey

2.2.1 Results of the Interview Survey

Table 3.1 lists the results of the questionnaire survey on domestic manufacturers and distributors of earthquake observation equipment.

Details of the interview results are described in Appendix B-2.

Table 2-1 Summary of results of questionnaire survey

	OYO Seismic Instrumentation Corp.	Clovertech Inc.	Meisei Electric Co., Ltd.	Hakusan Corporation
Manufacturer or distributor	Manufacturer and distributor	Distributor	Manufacturer	Manufacturer
Concept of the product, performance and characteristics of the device	• It is important to keep it running (i.e., maintenance free) • Monthly checks are important.	• Prompt response to customer problem calls to minimize missing measurements.	• Improved environmental resistance, lower power consumption, simplified and common equipment configuration (reduced risk of failure), longer product life • Important to understand the status of instruments by software	• Transmitting error information is important
Direction of technical development	• It is improvement in accordance with renewal device.	• Combining existing equipment and customizing instrumentation in accordance with customer requirements.	• Same as above.	• Versatile sensor networks and low-cost equipment • ACT protocol being developed to retain data for several weeks and to cope with malfunctions
Recommendations to users to ensure quality	• Maintenance plans need to be developed and implemented from the delivery stage. However, our company thinks that it is difficult for the customer to realize this.	• Online checks as appropriate.	• Improvement of site conditions. • Daily check of the equipment • Improvement of power supply and communication line • Periodic maintenance • Exchange consumables periodically.	• **<u>It is important not to expect a high-quality communication line in operation.</u>**
Frequency of updating equipment	• 7 years after manufacture is recommended. However, updating after 7 years without maintenance will pose some difficulties. • Planned renewal depends on the customer.	• The service life of the product is approximately 5 to 10 years. • There is no set renewal period as it is highly dependent on the installation environment and usage.	• Server: 5 to 6 years • Battery: To be recommended by manufacturer (e.g., 3 years) • Seismometers: 10 years. If it is difficult to update, the company allows to exchange parts periodically.	• 7 years after manufacture is recommended.
Recommended operating methods for stable maintenance and management	• Maintenance policy, such as considering site conditions, should be created. • Fault detection should be provided by the manufacturer with a remote recognition function. • As ageing is inevitable, regular checks are important. • Periodic chucking is carried out in Japan by the manufacturer.	• The sensors that the company provides are pre-installed with hardware functions for **<u>remote monitoring of the measurement status</u>**.	• Conduct of inspection once every 1 or 2 years is recommended.	• Identify faults by monitoring sensor tests, observation loggers, etc. • Monitor consumables and media
Methods for the rapid detection of failures	• Training regarding maintenance is important.	• Same as above. • **Early detection of faults is recommended.**	• **<u>Add a feature of health check.</u>** • **<u>Add a detection of failure in server and daily check regarding transmission</u>.**	• Check ageing or recovery data by using SNMP protocol. • Requirement for recovery speed depends on customer (e.g., business hours, 24 hours, 365 days)
Recommended daily inspections	• Not involved in doing daily inspection • Customer order maintenance is done separately.	• Same as above. • **The equipment that the company as an importer offers has its own specific measurement built-in status monitoring function.**	• **<u>Monitor seismometers by using health check.</u>** • Site check (Wiring, overgrowth of trees in case of solar supply, rubbish, deterioration due to rain and wind)	• Monitor status remotely. • Periodically conduct a self-test of sensors. • Periodic inspection depends on customer
Manuals and guidelines for maintenance and management	• Each customer commissions a consultant. • The company provides user manual including troubleshooting.	• Not provided. • **Each customer commissions a consultant.**	• The company provides user manual.	• The company provides product manuals, quick start guide, and troubleshoot manual. • Confirmation is needed regarding other manuals which the company provides to customers.

Other opinions: To provide equipment overseas

- ✓ Supplying equipment overseas need training. It is not enough to just provide documents.
- ✓ International products have different concepts, design ideas and performance requirements. For example, the guaranteed operating temperature is set at -20°C to 70°C. For products delivered in Japan, the range is often -5°C to 50°C.
- ✓ In many cases, no test result sheets are attached to confirm that the required specifications are met.
- ✓ In many cases, local requirements (such as lightning protection and instantaneous power failure protection) are not included in the required specifications. It is important to build an observation system based on these requirements.

2.2.2 Trend Analysis

With regard to the list of questionnaire survey results shown in Table 3-1, the common contents of the answers of each company have been grouped and are shown in the table below.

Although the individual responses to most of the questions differ, a certain trend can be seen when the responses are grouped into categories. A summary of the responses to each question is given below.

Table 2-2 Grouped and classified questionnaire survey results

Company	Clovertech Inc.	OYO Seismic Instrumentation Corp.	Meisei Electric Co., Ltd.	Hakusan Corporation
1. Concept of the product, performance and characteristics of the device	Stability	Stability	Stability	Stability
2. Direction of technical development	Stability	Stability	Stability	Stability
3. Recommendation to users to ensure quality	Maintenance	Maintenance	Maintenance	Maintenance
4. Frequency of updating the equipment	5-10 years	5-10 years	5-10 years	5-10 years
5. Recommended operating methods for stable maintenance and management	Remote Periodic	Remote Periodic	Periodic	Remote
6. Methods for the rapid detection of failures	Self-check	Maintenance training	Self-check	Self-check
7. Recommended daily inspections	Remote Self-check	—	Remote Self-check	Remote Self-check
8. Manuals and guidelines for maintenance and management	Not provided Commissioned to Consultant	Not provided Commissioned to Consultant	Not provided	Not provided Commissioned to Consultant

1. Concept of the product, performance and characteristics of the device
   Stability: Minimum failure, maintenance-free, monitoring status

2. Direction of technical development
   Stability: Enhanced durability, simplification and generalization

3. Recommendations to users to ensure quality

Maintenance: Enhanced maintenance

4. Frequency of updating the equipment
5-10 years: 5-10 or 7 or 10 years

5. Recommended operating methods for stable maintenance and management
Remote: Detection of failure or status of measurement equipment remotely
Periodic: Periodic inspection of whole system

6. Methods for the rapid detection of failures
Self-check: Self-check feature **Maintenance training**: Maintenance training for staffs

7. Recommended daily inspections
Remote: Remote monitoring
Self-check: Self-check feature.

8. Manuals and guidelines for maintenance and management
Not provided: User manual is provided but operation manual is not provided.
Commission to Consultant: Customers commission the making of operation manual to consultants.

(1) Concept of the product, performance, and characteristics of the device

What all the companies have in common is the basic policy not to add new functions or to refine the accuracy of measurement, but to ensure the continuation of stable observation.

The following items were extracted from the results of interviews regarding “Concept of the product, performance and characteristics of the device”. These items can be classified in the category of "stability".

- ✓ Minimum failure
- ✓ Maintenance-free
- ✓ Enhanced durability
- ✓ Countermeasure for unstable power supply

(2) Direction of technical development

What all the companies have in common is not the development of new functions, but rather the improvement of stability related to the continuation of observations and the extension of the service life of the measurement equipment.

The following items were extracted from the results of interviews regarding “Direction of technical development”. These items can be classified in the category of "stability".

- ✓ Increased durability
- ✓ Simplification
- ✓ Generalization
- ✓ Long-term data retention (in case of network downtime)

(3) Recommendations to users to ensure quality

All the companies who provided the seismic measurement equipment requested the users to establish a maintenance system.

The following items were extracted from the results of interviews regarding “Recommendations to users to ensure quality”. These items can be classified in the category of "stability".

- ✓ Maintenance plans are made and implemented from the delivery stage.
- ✓ I don't feel that customers are very understanding
- ✓ Improvement of power supply and communication infrastructure
- ✓ Regular maintenance
- ✓ Regular replacement of consumables
- ✓ No expectation of high-quality communication lines during operation

(4) Frequency of updating the equipment

All the companies have set the frequency of renewal of delivered equipment between 5 and 10 years. In some cases, the frequency is set for a fixed number of years, such as 7 or 10 years, and in other cases, it is set for a range of 5 to 10 years. On the other hand, some respondents stressed the lack of understanding of the users to the planned renewal. Individually, the responses are listed below, placing these in the [5~10 years] category.

- ✓ The range of 5~10 years is set because it depends heavily on the environment and operation of the installation site.
- ✓ 7 years after manufacture is recommended, but maintenance must also be carried out regularly.
- ✓ Planned renewal depends on the supplier.
- ✓ 5 to 6 years for servers and the manufacturer's recommendation for batteries (regular replacement for 3 years)

(5) Recommended operating methods for stable maintenance and management

All the companies point out the need for regular maintenance. It is worth noting that three companies recommend remote monitoring, while the remaining one, taking into account the overall description, suggests the establishment of a similar management system.

The following items were extracted from the results of interviews regarding “Recommended operating methods for stable maintenance and management”. These items can be classified in the category of "remote" and " periodic inspection".

- ✓ Hardware functionality is built in for remote monitoring
- ✓ Proposed maintenance policy
- ✓ Delivered with the feature that the manufacturer can remotely recognize fault detection
- ✓ Periodic chucking by the manufacturer is carried out in Japan
- ✓ Remote monitoring includes sensor tests and observation loggers to identify faults

(6) Methods for the rapid detection of failures

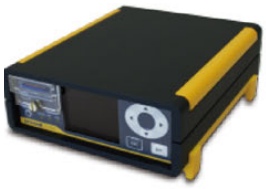
All the companies pointed out the necessity of daily inspections, but three of the four recommended self-checks or health checks, in which the measuring equipment itself transmits test signals to indicate its own health and deterioration.

For one company, maintenance training is also emphasized. The following items were extracted from the results of interviews regarding “Methods for the rapid detection of failures”. These items can be classified in the category of "remote" and " maintenance training ".

- ✓ Built-in hardware features for remote monitoring
- ✓ Maintenance training is important.
- ✓ Health check function added to the instrument.

- ✓ Added functions of daily inspection such as failure report and communication check by server
- ✓ Checking changes over time and error recovery by SNMP communication
- ✓ The speed of recovery depends on the customer (during business hours, 24 hours a day, 365 days a year, etc.)

The LT-7700 was chosen as the data logger that could solve the problem. The LT-7700 is usually used in telemeter mode, but in this case, the power-saving features of the logger mode are useful: AE has high frequency, but very small vibration phenomenon, and the LT-7700 can record the sensor signal for a long time as a continuous record with a sampling rate of up to 1000 Hz. The LT-7700 is capable of recording sensor signals at sampling rates of up to 1000 Hz for long periods of time. In response to a request from the Earth Science Research Institute, our company provided a firmware extension to enable the execution of user scripts and a service to support the installation of IoT devices. The system of observation points and the design of the activity monitoring were done by the Institute of Geosciences themselves, and the following system was built in just one month after the conceptualization.



LT-7700

Source：Hakusan Corporation website[16]

Figure 2-10 One case of the self-check feature

(7) Recommended daily inspections

While all the companies point out the need for remote monitoring, three out of the four recommend self-check, health-check and self-test systems in which the measuring equipment itself transmits test signals and information on its own health and deterioration.

The following items were extracted from the results of interviews regarding “Recommended daily inspections”. These items can be classified in the category of "remote" and " self-check ".

- ✓ Built-in hardware functions for remote monitoring
- ✓ Imported equipment has its own monitoring function.
- ✓ Maintenance is ordered separately by the observatory.
- ✓ Monitoring of instrument health checks
- ✓ Checking the local environment (wiring, dust, rain, wind)
- ✓ Remote condition monitoring via packets
- ✓ Regular self-testing of sensors

(8) Manuals and guidelines for maintenance and management

Each company provides a manual for the handling of the supplied measuring equipment and an explanation of the error codes. However, manufacturers do not provide manuals for daily inspection and maintenance. These manuals are prepared by the supplier or by a consultant according to the system established by each measuring institute.

The following items were extracted from the results of interviews regarding “Manuals and guidelines for maintenance and management”. All of the 4 companies can be included in the categories of "not provided" and "consultancy". In addition, there is one company that

[16] https://www.hakusan.co.jp/solution/casestudy/jgi.html

participates in the creation of manuals for the system on a separate-order basis.

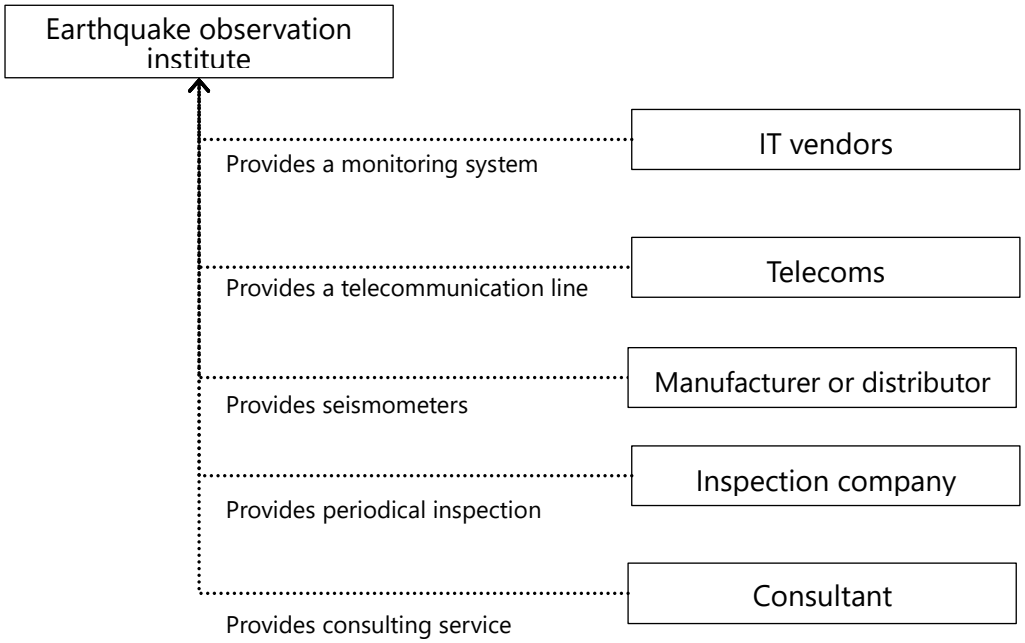
- ✓ It provides a user manual (instruction manual). Response to abnormal values is included.
- ✓ Provide standard product manuals, quick-start manuals, error code explanations, etc.
- ✓ System-specific manuals provided to customers are deliverables, so individual requests are required for verification.
- ✓ Maintenance manuals are commissioned by the respective institutions to consultancy companies.

Note: Arrangement between earthquake observation institutes and the private companies

The arrangements between the institutes and the private companies in Japan are described as follows:

- ✓ The development and operation of the monitoring system is outsourced to IT vendors (system integrators).
- ✓ Communication lines are provided by telecommunication companies (e.g., NTT). JMA rarely prepares special lines.
- ✓ The procurement and installation of seismometers are outsourced to manufacturers.
- ✓ JMA carries out daily inspections.
- ✓ Periodic inspections are outsourced to specialist inspection companies.
- ✓ In the event of a breakdown, JMA contracts with the manufacturer for emergency response.
- ✓ To provide operational and efficiency, support for maintenance and management is outsourced to consultants.

*Manufacturers and consultants work together as necessary. JMA supervises them.



The role of consultants differs for domestic manufacturers and international distributors in Japan. In the case of domestic manufacturers, the seismological institutes commission consultants to prepare manuals and guidelines for maintenance management plans, including inspection and repair plans.
For international distributors, the consultants supervise the delivery of the manual as part of the supplier's construction supervision, or prepare the manual as part of a technical cooperation project or follow-up after the provision of equipment.

Chapter 3 Discussion and Recommendations

Based on the information collected, JET recommended that developing countries to utilize the basic technologies and mechanisms of the observation equipment and devices to operate a stable seismic observation system, improve the efficiency of maintenance work, and maintain the accuracy of observation.

3.1 Discussion and Recommendations

3.1.1 Quality of Maintenance Level in Accordance with Purpose of Observation

Based on interview results, the recommended monitoring methods differ depending on the management system of the seismological measurement organization. For example, JMA which requires the immediate dissemination of earthquake information to all interested parties, requires 24/7 monitoring[17]. On the other hand, research institutes such as NIED, whose main focus is on data analysis and storage, may respond only during working hours and may not require immediate recovery of information.

Therefore, it is recommended to consider the monitoring system and maintenance plan according to the level of service required by each organization.

In addition, as these information and communication technologies are constantly changing, it is essential to review maintenance policy accordingly. The following is an analysis of the technologies and mechanisms installed in seismic equipment that contribute to efficient maintenance, based on the results of interviews with manufacturers.

3.1.2 Technologies and Know-How That Contribute to Efficient Maintenance

(1) Seismometer Manufacturers' Development Policy

Currently, the main feature of the instruments offered by the manufacturers is assurance of the stability of measurement conditions, such as the minimum of missing measurements, maintenance free, and compatibility with unstable power supply. The same feature can describe the development policy of future products. Increased durability, simplification and generalization are the characteristic responses of the companies, and it is likely that development will continue to aim at ensuring further stability rather than adding advanced features.

(2) Efficient Data-Driven Equipment Renewal

The service life of the seismic equipment of each manufacturer is recommended to be in the range of 5~10 years. However, even in Japan, where the quality of data is high, it is difficult to obtain users' understanding of the need for systematic renewal. As a result, equipment that is beyond its service life is still in operation in many places.

On the other hand, condition monitoring technology is advancing, so that data analysis can be used to identify signs of failure and to reduce maintenance costs by replacing only certain

[17] The exception to this is the University of Tokyo's Earthquake Research Institute, which has no immediate notification function, but has a 24/7 monitoring system.

components before a major failure occurs. It is important to implement efficient maintenance management by using such data analysis. In addition, the self-check function described can be used to monitor the condition of measuring equipment and recognize when it is time for replacement, rather than waiting for the set service life.

(3) Monitoring Status and Self-Check

At present, many seismic instruments have the feature to transmit not only seismic information (waveform data, seismic intensity information, etc.) but also status of health (SOH) monitoring information to a central monitoring system via satellite or internet communication. This is called *self-check*, *health-check*, or *self-test* by the manufacturers, and all of them recommend the use of this function. Some manufacturers indicated that they monitor this information on their own lines (with the customer's permission).

Some operators transmit periodic test data from the observation equipment to the monitoring system to confirm that these are being transmitted properly from the sensor. On the other hand, the manufacturers recommend that the following figures be sent to the monitoring system on a regular basis and stored on the server, so that changes in the figures over time can be analyzed, and abnormalities and failures can be detected at an early stage.

1. Mass position value
2. Temperature
3. Tilt angle
4. Calibration values, etc.

If mission-critical monitoring is required, it may be also useful to set up a network to monitor the status, as the manufacturer can directly monitor the equipment online. However, this will require additional communication infrastructure and an additional maintenance contract for status monitoring.

3.1.3 Effective Maintenance from Equipment Manufacturers' Point of View

(1) Establishment of a maintenance system during the installation stage

All companies have requested that the users to whom they supply the seismic equipment should establish a maintenance system starting from the delivery stage. For new installations, it is important to consider the maintenance of the equipment. In areas where lightning strikes frequently, lightning surge countermeasures should be taken, and in areas where the power supply is unstable, equipment such as uninterruptible power supply should be installed to ensure a stable supply of power.

In order to ensure stable earthquake observation and maintenance overseas, it is important to take into account the current situation.

(2) Clarification on Specification of Observation System

When equipment made in Japan is taken overseas, there is a risk that stable operation and maintenance may be impaired depending on environmental conditions. For this reason,

manufacturers are requested to clearly state in their specifications that if they are instructed to deliver equipment that does not satisfy the required specifications, they will verify that the equipment satisfies the requirements through testing.

It is important to encourage overseas seismological institutes to make it a requirement that not only the performance but also the test results are attached to the specifications at the time of product procurement.

(3) Implementation of Maintenance Training

Major international manufacturers (such as Nanometrics, Streckeisen, etc.) often have distributors in the target countries and are able to support maintenance operations in the local language. It will be desirable for Japanese manufacturers to cooperate with overseas agents to support maintenance and local operation. However, this is difficult to achieve in an industry with a limited market. Therefore, it is important to provide continuous maintenance training for observers.

In addition, it is necessary to assume that the administrative staff working in seismic observatories will be transferred periodically. It is important to introduce a system of quality management cycle, such as regular training sessions, assuming that the maintenance manual will be continuously utilized.

3.2 Tasks for Next Steps in Indonesia

JET had conducted a questionnaire survey on the current status and direction of equipment development, quality assurance of seismic observation data, and maintenance management for four Japanese manufacturers of seismic measurement equipment. It analyzed the common issues extracted from the survey results and discussed recommended approaches.

Based on the results of this study, the tasks for next steps by JET in Indonesia and developing countries are as follows:

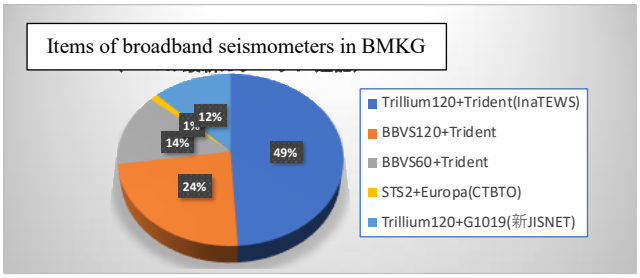
3.2.1 Suggestions for the Installation of Seismic Equipment

(1) Study of the seismic observation network based on the status of the existing equipment

It is essential to understand the current situation, as described in previous chapters, for providing recommendations.

In developing countries, seismic equipment and systems have been introduced by donors from other countries such as Germany and China. Therefore, JET should recommend to developing countries to understand the type of seismic equipment and its data acquisition method when installing new equipment or updating the observation network.

In the case of BMKG, broadband seismic instruments are in operation at 170 sites (154 of which are officially registered with IRIS), but the equipment used varies, depending on the time of installation and the donor country.



Sensor	Manufacture	Country
Trillium120	Nanometrics	Canada
BBVS120	GeoDevices	China
BBVS60	GeoDevices	China
STS2	Streckeisen	Swiss

Digitizer	Manufacture	Country
Trident	Nanometrics	Canada
Europa	CTBTO	CTBTO
G1019	MEISEI	Japan

Source: IRIS website[18]

Figure 3-1 Items of broadband seismometers in BMKG

The combination of the Nanometrics Trillium 120 sensor and the Trident digitizer, which was installed during the development of InaTEWS, is a system that allows the status of the sensor to be monitored and readjusted via the network, making it easy to maintain and manage. On the other hand, different types of observation equipment for grant-aid projects are used, so it is necessary to check the condition of the sensors on-site.

It is important to know what kind of signals are transmitted by the seismic observation equipment installed in developing countries, and whether they have a self-checking function in order to improve the efficiency of maintenance and management, as BMKG does. When adding observation equipment or rebuilding the observation network, it is possible to determine whether to include the automatic monitoring function of the measurement status.

[18] https://www.iris.edu/hq/

(2) Specification of equipment in accordance with local conditions

It is recommended that the current seismic monitoring equipment should be surveyed to identify any equipment that is not working properly, or that has failed or been damaged, and to identify the causes of any areas that are not being observed.

In some countries and locations, including Indonesia, there are likely to be unique local environments such as unstable voltage, unstable communication, easy submersion in water, and drastic changes in the temperature environment. Therefore, these problems can be avoided by understanding them in advance and providing feedback for procurement specifications of observation equipment and equipment to be used when building the observation network.

(3) Setting up the remote monitoring and control

Observation agencies, including BMKG, need to check the operational status of many seismic instruments. Based on the survey results, it is recommended that remote monitoring and control functions be introduced in order to improve the efficiency of doing this task.

As many seismic instruments perform not only monitoring of seismometers, but also status information of the surrounding area (e.g., power supply, battery status, self-check, health check, self-test, etc.), it should be possible to identify the cause of failure remotely whenever possible.

However, if the system is to be added to an existing seismic network, it is likely that it will be necessary to be taken into account the communication protocols.

3.2.2 Suggestions for the Maintenance of Seismic Equipment

(1) Establishment of maintenance support

Based on the survey results, major international manufacturers (such as Nanometric, Strecheisen, etc.) often have their own agents in the target country and have established a system for maintenance and operation in the local language. On the other hand, it is assumed that it is difficult for Japanese manufacturers to establish a similar support system in the delivery country by themselves. Therefore, it is recommended to support maintenance and management by local staff through grant-aid and technical cooperation projects.

(2) Preparation of operation and maintenance manual and sustainable training

Based on the survey results, maintenance training is essential in order to establish a sustainable observation system. Therefore, it is recommended that a manual on maintenance and management of observation systems be prepared, and training be provided through technical cooperation projects so that observation institutions of developing countries can operate the systems independently.

It is also important to implement a management cycle system, which will include periodic training sessions based on the manual, since administrative staff of public observatories are being reassigned periodically. In addition, when part of maintenance and management is outsourced, it is important that the staff have the knowledge on the task to provide guidance, without relying on the outsourcer, so that the outsourcing can be done at an appropriate cost, leading to efficient maintenance and management with quality assurance.

Appendixes

Appendix A: Datasheet of Seismographs

STRECKEISEN
SEISMIC INSTRUMENTATION

STS-2.5

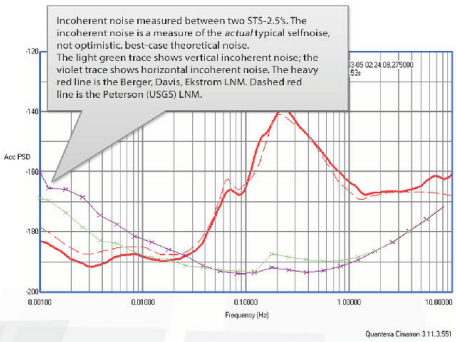
STS-2.5

High-Performance Portable Very Broadband Triaxial Seismometer

The World standard broadband seismometer other seismometers are compared to, with very low noise, high clipping level, low power, and wide operational temperature range without adjustment.

FEATURES

- Sensor performance equal to the world-standard STS-2 broadband sensor
- Improved high magnitude signal behavior compared to STS-2
- Improved ruggedness of cabling and hermetically sealed hostbox includes push button, visual status and robust one-press centering
- RS232 remote monitoring (serial number, inside temperature and humidity, power supply levels, tilt)
- Auxiliary signals (POS/RAW) and control of centering and locking either available by RS232 or direct access via remote command
- Improved tilt range compared to STS-2
- Significantly improved operating temperature range without centering; key requirements in many installations due to daily temperature variation



World-standard, Field-proven - 145 dB dynamic range - Mutually-aligned 3-components Robust locking - Low power - Wide temperature range without adjustment

SPECIFICATIONS

Response:	Flat to ground velocity from 8.33mHz (120s) to 50 Hz
Displacement resolution:	6.4 x 10^{-13} m/hz @10Hz (=-172dB)
Clip level:	±13 mm/s ground velocity up to 20Hz Linear derating down to ±5.3 mm/s ground velocity from 20 - 50Hz
Clip level normalized to gravity:	20.50Hz 0.34g / 10Hz 0.17 / 1Hz 0.017g / 0.1Hz 0.0017g / 0.03Hz 0.00055g
Generator constant:	2 x 750 Vsec/m
Parasitic resonances:	>140Hz vertical, >80Hz horizontal
No centering Tilt range:	± 0.03°, (centering range limit ±0.48°)
No centering Temperature range:	± 25° C
Power supply voltage:	10 - 30VDC, galvanically isolated
Power consumption:	Average: 0.45W, deteriorated state: up to 2.0W
Seismic signals output:	max. ±20V differential, 220Ω serial resistance per line
Auxiliary signal output:	max. ±10V single-ended, 1kΩ serial resistance
Calibration input:	max. ±10VDC
Control inputs:	3 - 30VDC, 0.5mA, galvanically isolated
Communication:	Push buttons or RS232, 9600 Baud, galvanically isolated
Operating temperature:	-20 °C to 70 °C guaranteed, -40 °C to 70 °C functional
Humidity:	0-100% RH
Enclosure Rating:	IP67 Equivalent
Various:	RoHS and CE Compliant Unit
Size:	Cylindrical package, ø 235mm, height 260mm(same package as STS-2)
Weight:	12kg

USA - 222 Vista Ave., Pasadena, CA 91107
Tel (626)795-2220 I Fax (626)795-0868

Switzerland - Z.I. Le Tresi 6B, 1028 Preverenges
Tel +41 (21) 803-2829 I www.kinemetrics.com

05-01-19

Figure A-1 Datasheet of STS-2.5

KINEMETRICS

Advancement through Innovation

MBB-2

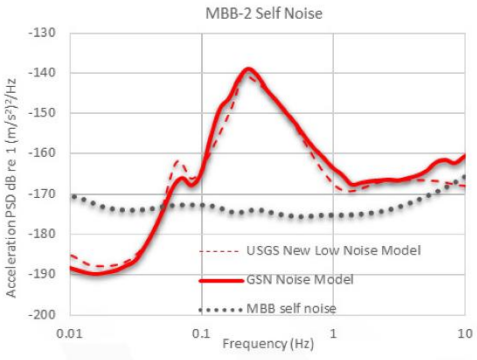
MBB-2

Miniature 120s BroadBand Seismometer

The Mini BroadBand Seismometer (MBB-2) is the latest sensor offering from Metrozet for vault or posthole installations. The MBB-2 offers high performance features in a small, rugged, low power and low cost system that is easy to install and deploy. Built with ease of installation in mind, the MBB-2 does not require mass lock, mass centering, and has a large operational tilt range which reduces installation time. The MBB-2 was engineered from the ground up to deliver best-in-class performance. An installation at 600m depth was tested in a dry borehole.

FEATURES

- No mass lock required
- No mass centering required
- Small, portable, 120 second broadband sensor
- Large operational tilt range
- Stainless steel housing rated IP68 with oceanographic-grade connector for immersed operation up to 100m depth
- Noise floor as in the plot below



Continued

Figure A-2 Datasheet of MBB-2 (1/2)

KINEMETRICS

Advancement through Innovation

MBB-2

SPECIFICATIONS

Sensor Technology	Triaxial orthogonal, XYZ oriented feedback sensor elements with capacitive displacement transducer
Sensitivity	750 V/(m/s), optionally 1500 V/(m/s), trimmed to ± 0.5% precision
Bandwidth	-3 dB points at 120 seconds and 160 Hz
Operable Tilt Range	± 2.5 Degrees
Dynamic Range:	155 dB at 1 Hz
Clipping Level:	26 mm/s peak from 0.0083 Hz to 40 Hz; proportional to 1/f above 40 Hz, reaching 10 mm/s at 100 Hz; proportional to $1/f^2$ below 0.0083 Hz
Velocity Output	Industry standard 40 V peak-to-peak differential output
Mass Position Output	Independent mass position output for each of the XYZ axes
Calibration	Calibration input for XYZ components; single digital control line to activate calibration on all three axes
Short Period Mode	1sec mode used for deployment; digital control line enables short period mode on all three axes
Voltage Input	9-36 V DC input (internally isolated)
Electrical Protection	Over-voltage, reverse-voltage, and current overload protection
Galvanic Isolation	Power input and digital control lines (setup mode and calibration enable lines have independent galvanic isolation)
Operational Temperature	-40 to +60 °C
Power Consumption	240 mW
Posthole Orientation	Yoke adapter and orientation poles available
Physical Dimensions	Height: Sensor Body and Connector: 5.44 inches (13.8 cm) Including Fixed Feet: 5.67 inches (14.4 cm) Diameter: 3.875 inches (9.8 cm) Weight: 6.5 pounds (2.95 kg)

Specifications subject to change without notice

USA - 222 Vista Ave., Pasadena, CA 91107
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04-27-21

Figure A-3 Datasheet of MBB-2 (2/2)

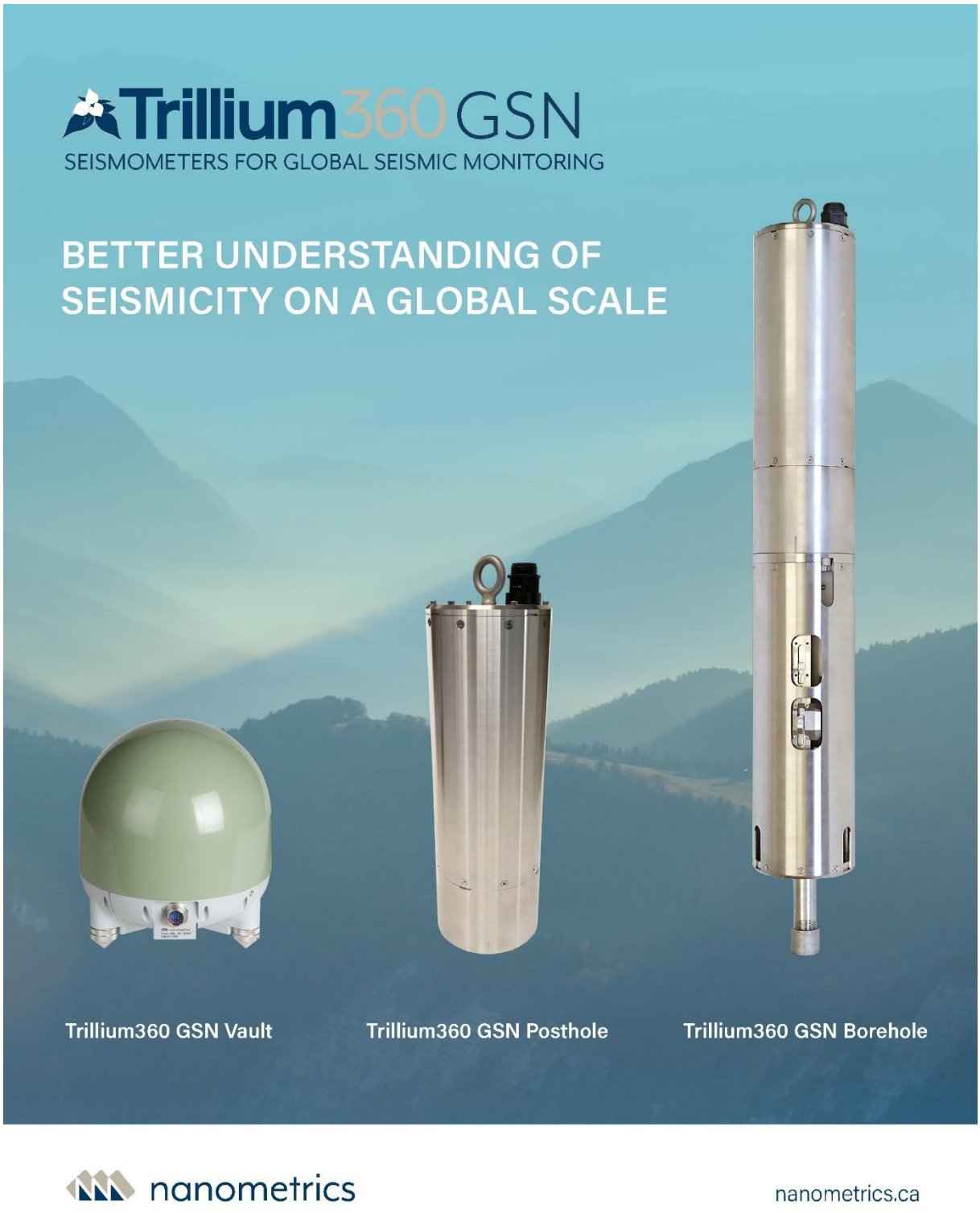


Figure A-5 Datasheet of Trillium360 (1/4)

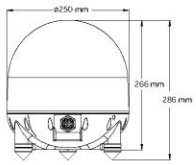
Trillium360 GSN

SEISMOMETERS FOR GLOBAL SEISMIC MONITORING

The Trillium 360 GSN Seismometers are highest-performing, lowest noise broadband seismometers in the world. Available in Vault, Posthole or Borehole form factors; the GSN series gives you full-bandwidth coverage for monitoring global and local seismicity with a single instrument.

Trillium 360 GSN Vault

Incorporates a patented thermal stability system to minimize the effect of diurnal temperature fluctuations



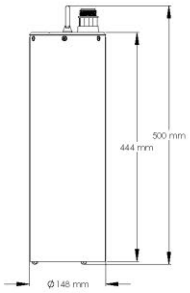
PHYSICAL

Case: (Enclosure) Powder-coated aluminum pressure vessel
Diameter: 250 mm
Height: 270 mm without leveling feet,
290 ±5 mm depending on leveling feet extension
Weight: 14 kg
Parasitic resonances: None below 150 Hz
Handling: Detachable carrying handle on case

Polar Certified Model available for operating temperatures down to −50°C

Trillium 360 GSN Posthole

A versatile seismometer with a robust, waterproof, stainless steel enclosure that protects the seismometer from hostile environments, suitable for installation in shallow direct burial, posthole, or at the bottom of deep boreholes



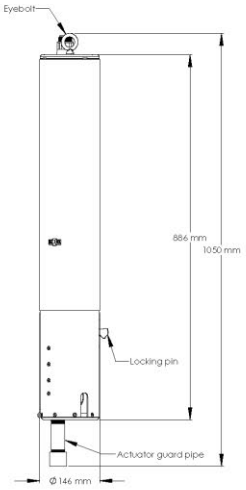
PHYSICAL

Case: Stainless steel pressure vessel
Diameter: 148 mm, including external magnetic shield
Height: 444 mm not including connector or feet
500 mm including feet and eyebolt
Weight: 18 kg
Parasitic resonances: None below 100 Hz
Handling: Eyebolt on lid for lifting cable.
1300 lbf (5800 N) rated

Polar Certified Model available for operating temperatures down to −50°C

Trillium GSN 360 Borehole

Designed for cased boreholes as deep as 500 m, with motorized a holelock to easily position the seismometer at any depth and fail-safe release mechanism



PHYSICAL

Case: Stainless steel pressure vessel and holelock
Diameter: 146 mm, including external magnetic shield
Height: 886 mm, not including connector or actuator guard pipe
1050 mm including connector and actuator guard pipe
Weight: 31 kg
Parasitic resonances: None below 100 Hz
Handling: Eyebolt on lid for lifting cable.
1300 lbf (5800 N) rated

* this drawing is not in proportion with the other line drawings on this page

Figure A-6 Datasheet of Trillium360 (2/4)

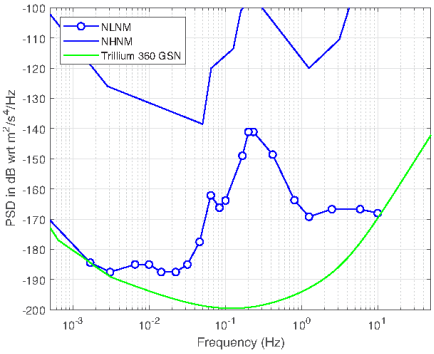
Outstanding performance

The Trillium 360 GSN Seismometer series is the culmination of more than 30 years experience designing and building the best seismological instrumentation in the world. Its industry-leading performance, including low self-noise, very wide bandwidth, precisely calibrated response and immunity to environmental effects makes it well suited for many applications, including the deployment of new seismic networks or the recapitalization and expansion of existing facilities.

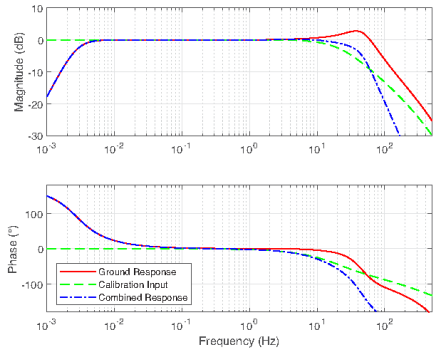
Easy to use

Its many simple-to-use features, such as automatic leveling and mass centering that can be remotely initiated, and digital case tilt reporting make for fast and successful installation every time.

- Very broadband, exceptional low-noise performance that meets GSN operational requirements
- Meets USGS Class A+ requirements
- An extended low-frequency range useful to beyond a 10,000-second time period
- Able to resolve below Peterson's new low-noise model (NLNM)
- Widest available flat response bandwidth, 360 seconds to 80 Hz
- A wide dynamic range with a clip level of ±10 mm/s
- Automatic leveling and mass centering that can be remotely initiated
- The lowest magnetic sensitivity of any broadband seismometer
- Ask about our harsh environment and extreme cold models



Acceleration Noise PSD



Transfer function amplitude and phase vs frequency

Comparison between 360 GSN Surface Vault, Posthole and Borehole Seismometers

	T360-SV1-GSN Trillium Vault 360	T360-PH1-GSN Trillium Posthole 360	T360-BH1-GSN Trillium Borehole 360
Global seismicity	●	●	●
Local and regional seismicity (exceptionally low noise at both high and low frequencies)	●	●	●
Tilt range ±5°		●	●
Environmentally robust:			
Rated to IP68 for outdoor use	●	●	●
Rated to IP68 for prolonged submersion		●	●
Above average magnetic immunity required	●	●	●
Digital tiltmeter reports tilt angle	●	●	●
Installation:			
Vault install	●		
Posthole, direct bury, borehole sand install		●	
Cased borehole locked at any depth			●

Figure A-7 Datasheet of Trillium360 (3/4)

TECHNICAL SPECIFICATIONS

Specifications subject to change without notice

TECHNOLOGY	VAULT	POSTHOLE	BOREHOLE
Topology	Symmetric triaxial	Symmetric triaxial	Symmetric triaxial
Feedback	Force balance with capacitive transducer	Force balance with capacitive transducer	Force balance with capacitive transducer
Leveling	Integrated bubble level, adjustable locking leveling feet	Internal automated leveling ±5°	Internal automated leveling ±5°
Leveling initiation	Control line or serial port command	Control line or serial port command	Control line or serial port command
Mass centering	Automatic motorized recentering, can be remotely initiated	Motorized recentering automatically initiated during leveling sequence, can be remotely initiated	Motorized recentering automatically initiated during leveling sequence, can be remotely initiated
Holelock	N/A	N/A	Motorized single jaw, non-jamming Adaptable to a wide range of hole sizes
Alignment	Vertical scribe marks for E/W, precision holes for 5/16 in. alignment rod for N/S	North line on top cap; optional alignment rod for downhole orientation	North line on top cap; optional alignment rod for downhole orientation
Digital tiltmeter	Reports case tilt from vertical for easy installation and remote troubleshooting	Reports case tilt from vertical for easy installation and remote troubleshooting	Reports case tilt from vertical for easy installation and remote troubleshooting
PERFORMANCE			
Self-noise	At or below the NLNM at all frequencies, see plot	At or below the NLNM at all frequencies, see plot.	At or below the NLNM at all frequencies, see plot.
Nominal sensitivity	2000 V-s/m (reference User Guide for precise value)	2000 V-s/m (reference User Guide for precise value)	2000 V-s/m (reference User Guide for precise value)
Precision	±0.5%	±0.5%	±0.5%
Bandwidth	-3 dB points at 360 s and 79 Hz	-3 dB points at 360 s and 79 Hz	-3 dB points at 360 s and 79 Hz
Clip level	10 mm/s up to 7 Hz	10 mm/s up to 7 Hz	10 mm/s up to 7 Hz
Dynamic Range	> 169 dB @ 1 Hz	> 169 dB @ 1 Hz	> 169 dB @ 1 Hz
Transfer function	Lower corner poles within ±0.5% of nominal provided High-frequency response within ±1 dB of nominal up to 50 Hz	Lower corner poles within ±0.5% of nominal provided High-frequency response within ±1 dB of nominal up to 50 Hz	Lower corner poles within ±0.5% of nominal provided High-frequency response within ±1 dB of nominal up to 50 Hz
Temperature sensitivity	±10°C without recentering	±10°C without recentering	±10°C without recentering
Magnetic sensitivity	<0.03 (m/s²)/T	<0.03 (m/s²)/T	<0.03 (m/s²)/T
INTERFACE			
Connector	19-pin MIL-C-26482, mounted on base	20-pin marine	20-pin marine
Velocity output	40 V peak-to-peak Selectable XYZ or UVW mode	40 V peak-to-peak Selectable XYZ or UVW mode	40 V peak-to-peak Selectable XYZ or UVW mode
Mass position output	Three independent voltage outputs	Three independent voltage outputs	Three independent voltage outputs
Control lines	Mass Center, Calibration Enable, XYZ/UVW mode	Auto-level and Mass Center, Calibration Enable, XYZ/UVW mode	Auto-level and Mass Center, Calibration Enable, XYZ/UVW mode
Calibration input	Single voltage input for all channels, independent calibration enable for each channel. Calibration in XYZ or UVW	Single voltage input for all channels, single calibration enable for all channels. Calibration in XYZ or UVW	Single voltage input for all channels, single calibration enable for all channels. Calibration in XYZ or UVW
Calebration enable	Isolated active-high referenced to DGND Three independent calibration enable inputs	Single calibration enable for all channels	Single calibration enable for all channels
Serial port	RS-232 compatible serial IP (SLIP) Onboard web server standard HTTP for enhanced instrument control and status: mass centering, case tilt UVW/XYZ mode, short/long period mode, firmware updates, temperature, mass position, case tilt, digital bubble level, serial number and factory info	RS-232 compatible serial IP (SLIP) Onboard web server standard HTTP for enhanced instrument control and status: auto-level and mass centering, case tilt UVW/XYZ mode, short/long period mode, firmware updates, temperature, mass position, case tilt, digital bubble level, serial number and factory info	RS-232 compatible serial IP (SLIP) Onboard web server standard HTTP for enhanced instrument control and status: auto-level and mass centering, case tilt UVW/XYZ mode, short/long period mode, firmware updates, temperature, mass position, case tilt, digital bubble level, serial number and factory info
POWER			
Power consumption	820 mW typical at 12 V input	820 mW typical at 12 V input	820 mW typical at 12 V input 2 A to operate holelock
Supply voltage	9 to 36 Volts DC isolated input	9 to 36 Volts DC isolated input For deep installations, a 24 V power system is recommended to allow for cable losses.	9 to 36 Volts DC isolated input For deep installations, a 24 V power system is recommended to allow for cable losses.
Protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection
ENVIRONMENTAL			
Ingress Protection	Rated to IP68 and NEMA 6P to 2 m for prolonged immersion	Rated to IP68 and NEMA6P to 300 m for prolonged immersion. A dry hole is recommended for best seismic performance	Seismometer is rated to IP68 and NEMA6P to 300 m for prolonged immersion. A dry hole is recommended for best seismic performance. Holelock motor is rated to IP68 and NEMA6P to 30 m for prolonged immersion
Insulating cover	Optional insulating cover available for quick and convenient installation	N/A	N/A
Operating temperature	–20°C to 60°C (Standard Model) –50°C to 60°C (Polar Certified Model)	–20°C to 60°C (Standard Model) –50°C to 60°C (Polar Certified Model)	–20°C to 60°C
Storage temperature	–40°C to 70°C	–40°C to 70°C	–40°C to 70°C
Shock	20 *g* half sine, 5 ms without damage, 6 axes No mass lock required for transport	20 *g* half sine, 5 ms without damage, 6 axes No mass lock required for transport	20 *g* half sine, 5 ms without damage, 6 axes No mass lock required for transport

nanometrics

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1001.18.05

Figure A-8 Datasheet of Trillium360 (4/4)

Appendix B: Survey Interview Sheet

1. Questionnaire

(Date)

JICA Expert Team Output 1

PACIFIC CONSULTANTS CO., LTD.

Interview Survey for "The Project for Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination"

Dear Sir,

The Japan International Cooperation Agency (JICA) has started the above technical cooperation project with the Meteorology, Climatology and Geophysics Agency (BMKG) of Indonesia as counterpart. BMKG has been conducting seismic observations in 100 stations located in various islands in Indonesia. Based on its experience, however, the operation rate of the equipment in these stations is just about 60-80% and the observation quality is not high. Consequently, this project that consists of 4 outputs, targets the following three items as the results of Output 1:

1-1 Investigate and analyze the current maintenance and management system of seismic observation and communication equipment, and identify problems.

1-2 Develop guidelines and manuals to standardize the maintenance procedures of the equipment.

1-3 Provide on-the-job training on the maintenance and replacement of seismic and communication equipment.

In preparation for the above activities, a survey on the current status of maintenance and management of seismic observation systems in Japan will be carried out for three user organizations: National Institute for Earth Science and Disaster Prevention (NIED), Japan Meteorological Agency (JMA), and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Additionally, JICA Expert Team (JET) has decided to conduct a survey on the maintenance and management of seismic equipment and systems from the viewpoint of the manufacturers of seismometers.

In line with this, JET would like to know ways by which your company ensures the quality of observation data and to avoid missing data in extreme natural environments.

We would be grateful if you could take the time out from your busy schedule to participate in this survey.

Yours sincerely,

Shusaku NAKAMURA

Figure B-1 Questionnaire (1/2)

Questionnaire

JET would like to ask the following questions about the seismometers that you provide.

1) Basic information on seismic equipment

(1) What kind of seismometers does your company provide widely? What is the performance and characteristics of each type of equipment in terms of ensuring the quality of observation data and avoiding missing data?

(2) In relation to the above, what direction do you plan to develop the technology in the future?

(3) What kind of handling do you recommend to the users in order to avoid missing data and to ensure stable data?

(4) How often do you recommend updating or replacing the systems for the equipment that you have developed and provided?

2) Recommended maintenance methods

(1) What operation policy do you recommend to maintain the delivered observation system stably and efficiently?

(2) What methods do you recommend for detecting failures and speedy recovery?

(3) What kind of daily inspection do you recommend for the maintenance and management of seismometers delivered by observing organizations?

3) Do you provide any guidelines or manuals for maintenance and management to users? If so, can you provide copy of these as project's reference material?

4) (Question for distributors only) As the distributor in Japan of *XXXXXX*, one of the world's leading manufacturers of seismometers, you introduce it to the Japanese market, give it the opportunity to develop seismometers that meet the needs of the market, and provide construction and installation services for seismometer network systems and earthquake early warning systems.

JET would like to ask you to answer the above questions about these companies, focusing on their delivery status to developing countries.

Figure B-2 Questionnaire (2/2)

2. Answers of each company

The following symbols added to the start of each item indicate the source.

A: Basic information on seismic equipment

A-1: What kind of seismometers does your company provide widely? What is the performance and characteristics of each type of equipment in terms of ensuring the quality of observation data and avoiding missing data?

A-2: In relation to the above, what direction do you plan to develop the technology in the future?

A-3: What kind of handling do you recommend to the users in order to avoid missing data and to ensure stable data?

A-4: How often do you recommend updating or replacing the systems for the equipment that you have developed and provided?

B: Recommended maintenance methods

B-1: What operation policy do you recommend to maintain the delivered observation system stably and efficiently?

B-2: What methods do you recommend for detecting failures and speedy recovery?

B-3: What kind of daily inspection do you recommend for the maintenance and management of seismometers delivered by observing organizations?

C: Do you provide any guidelines or manuals for maintenance and management to users? If so, can you provide copy of these as project's reference material?

D: Would you like to give any comments?

(1) Clovertech Inc.

Questionnaire A-1:

- ✓ Our company provides a wide range of seismometers manufactured by Nanometrics and Lennartz.
- ✓ In order to minimize the number of missing measurements as much as possible, our company tries to respond quickly when our customers contact us about measurement problems with their seismometer data.

Questionnaire A-2:

- ✓ It is conducted on a case-by-case basis, based on customer needs.
- ✓ For example, our company can combine a Lennartz seismometer and a competitor's inclinometer in a single seismometer housing, including cable and logger.

Questionnaire A-3:

- ✓ Our company recommends to check online information as appropriate.

Questionnaire A-4:

- ✓ A useful life of 5 to 10 years is recommended. However, there are no renewal rules, as this depends on the environment and operation at the installation site.

Questionnaire B-1:

- ✓ The sensors that our company provides include a feature that monitor the status of the seismometer remotely. Our company suggests that this is a realistic way of maintaining the system.

Questionnaire B-2:

- ✓ Same as above. It is important to detect faults at an early stage.

Questionnaire B-3:

- ✓ Same as above. It is important to detect faults through online support at an early stage. Nanometrics and Lennartz monitor status of the items below:
  Nanometrics: Output of mass position value, temperature, tilt angle, etc.
  Lennartz: Calibration (the degree of fall of the seismometer can be determined by the degree of hanging)

Questionnaire C:

- ✓ Not provided (prepared by consultants)

(2) OYO Seismic Instrumentation Corp.

Questionnaire A-1:

- ✓ Our company provides seismometers to the Japan Meteorological Agency, the National Research Institute for Earth Science and Disaster Prevention, and JAMSTEC.
- ✓ All of these agencies use open competitive bidding for delivery only. Maintenance is contracted and carried out separately, but it is difficult for other manufacturers to enter the market.
- ✓ There are probably about 20 competitors in Japan, but the market is small and there are no associations in the seismic field in Japan, so our company does not have clear figures. As a result, no industry standard has been established.
- ✓ It is important for seismometers to keep working with minimum maintenance. It is important to check them every month.

Questionnaire A-2:

- ✓ Cutting-edge devices are coming out all the time, and our company has to adapt to them. There is also the reliability of memory cards, which needs to be considered.

Questionnaire A-3:

- ✓ Our company thinks that it is necessary to implement a maintenance plan before the delivery phase, but our company sometimes feel that our clients do not understand this well.

Questionnaire A-4:

- ✓ Our company recommended that update frequency is now 7 years after manufacture.
- ✓ In the past, our company used to say 10 or 15 years, but the development speed of new devices is getting faster, so the frequency of updates is getting shorter.
- ✓ Without proper maintenance, it is difficult to check on a device after 7 years. It depends on the customer whether the renewal is planned or not.

Questionnaire B-1:

- ✓ It is necessary for the manufacturer to propose not only the type of machine but also the installation site.
- ✓ It may be necessary for the manufacturer to propose a maintenance policy.
- ✓ Failure detection and regular inspection are two different things. In many cases, the manufacturer will deliver equipment that can be remotely recognized for fault detection.
- ✓ Fault detection also differs between manufacturers. Our company sends out a message when our company detects a partial malfunction.
- ✓ It is necessary to check the equipment periodically as it ages. Periodic checks are carried out by the manufacturer in Japan.

Questionnaire B-2:

- ✓ Our company thinks that maintenance training is important.

Questionnaire B-3:

- ✓ Not involved, because the maintenance work is ordered by the customer.

Questionnaire C:

- ✓ The guideline and manual are made by consultants.
- ✓ There is an instruction manual, however, inspection items are not included it. It includes how to deal with abnormal values.
- ✓ It is good for domestic use; however, for overseas use, it is necessary to start with training. It seems that it is not possible to respond simply by handing out materials.

Questionnaire D:

- ✓ Foreign products have a different concept and design philosophy. For example, imported products need different environmental conditions compared with domestic products. The guaranteed operating temperature is set at -20°C to 70°. For products delivered in Japan, the temperature range is usually -5°C to 50°C.
- ✓ Our company thinks that Japanese equipment should not be marketed overseas. It should be subjected to verification tests to ensure that it meets the required specifications, and the result sheet should be attached. It is often the case that if it is written on the performance sheet, it is judged that it satisfies the required specifications.
- ✓ It is important to write about local circumstances such as measures against lightning strikes and instantaneous electric shocks in the specifications. If these are not given, it will be difficult to replace after the order is received.

(3) Meisei Electric Co., Ltd.

Questionnaire A-1:

- ✓ Our company provides seismometers, as well as volcano observation equipment, to government, municipalities and overseas customers. In addition, our company provides seismometers for the private sector, dam operators and others.
- ✓ Important aspect for operators: It is important to improve the installation environment, regular maintenance, regular replacement of consumables, and routine health checks.
- ✓ Important aspect for manufacturers: It is important to have environmentally resistant equipment, low power consumption equipment, simple equipment configuration (to reduce the risk of failure), common manufacturing parts to eliminate special parts and extend product life, and software to monitor the status of observation equipment.

Questionnaire A-2:

- ✓ Our company is considering making products that are more resistant to the environment, and simplifying the equipment.

Questionnaire A-3:

- ✓ Our company recommends improvements to the installation environment, daily health checks by the operator to monitor equipment operation, improvements to the power supply and communication infrastructure, regular maintenance and regular replacement of consumables.

Questionnaire A-4:

- ✓ Server systems: 5 to 6 years
- ✓ Batteries: Depends on the manufacturer's recommended year (about 3 years)
- ✓ Equipment renewal is 10 years. If this is not possible, periodic replacement of individual units may be used.

Questionnaire B-1:

- ✓ Periodical maintenance is recommended once every 2 years.

Questionnaire B-2:

- ✓ It is recommended to add a health check function to the observation equipment.
- ✓ It is recommended to add the function of daily inspection to the server such as failure report and communication check.

Questionnaire B-3:

- ✓ It is recommended to monitor the health of the instruments.
- ✓ If it is possible to visit the observation point, it is recommended to check the condition of the cabling, and in the case of solar cells, to check for overgrowth, dust, animal damage, wind, dust and rain.

Questionnaire C:

- ✓ Operating instructions are distributed, but there is no mention of operations.

(4) Hakusan Corporation

Questionnaire A-1:

- ✓ The equipment is published on the website.
- ✓ Our company provided observation equipment and loggers to K-net of the National Research Institute for Earth Science and Disaster Prevention.
- ✓ Our company is responsible for the transmission of the data. In order to ensure the quality of the data, our company sends out error information (when there is no commercial power, the sensor is instructed to send out a test signal once a week to the logger, which is received by the center).

Questionnaire A-2:

- ✓ Our company is developing a versatile seismometer network and low-cost seismometers.
- ✓ Our company is developing a protocol called ACT that can hold data in seismometers for several weeks and transmit data dynamically if communication is restored; ACT manages the communication speed autonomously.

Questionnaire A-3:

- ✓ It is important not to expect a high quality communication line at the time of operation. The data center in Sakurajima has a dedicated telephone line, however, if the lower limit has been set to the metropolitan area, data cannot be transmitted.

Questionnaire A-4:

- ✓ It is recommended to be replaced after 7 years.

Questionnaire B-1:

- ✓ Monitoring status includes sensor tests, loggers, etc. Operators can identify faulty parts without having to go to the site.
- ✓ The network of the Disaster Prevention Research Institute is accessed and monitored by us.
- ✓ In recent years, the expiration dates of consumables have become shorter, so it is also useful to monitor development on consumable parts and media capacity.

Questionnaire B-2:

- ✓ Items such as changes in time and the number of errors can be checked via SNMP communication. It depends on the customer whether the recovery is carried out promptly or not. The National Research Institute for Earth Science and Disaster Prevention responds during business hours, while the University of Tokyo's network is monitored 24 hours a day, 365 days a year.

Questionnaire B-3:

- ✓ Our company is monitoring status constantly. No visual inspection is carried out.
- ✓ As a guarantee of strength, self-testing of the 1g sensor is carried out weekly (depending on the institution’s request).

- ✓ Periodic inspections depend on the user, however, some are carried out every six months.

Questionnaire C:

- ✓ There are standard product manual, a quick-start manual, an operation manual with error code descriptions, etc. There is also a test signal manual for the K-net of the Disaster Prevention Research Institute.
- ✓ Our company can provide product manuals. Others can be delivered to the customer upon request.

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APPENDIX 8-13

The Study on Installation and Maintenance for Seismic Observation Networks in Developing Countries

The Study on Installation and Maintenance for Seismic Observation Networks in Developing Countries

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

November 2021

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
ACP	(Panama) Panama Canal Authority
BMKG	(Indonesia) Meteorological, Climatological and Geophysical Agency
CNE	(Costa Rica) National Emergency Commission
COEN	(Peru) National Emergency Operations Center
COPECO	(Honduras) Permanent Commission of Contingencies Honduras
DHN	(Peru) Directorate of Hydrography and Navigation
DOST	(Philippines) Department of Science and Technology
FMS	(Fiji) Fiji Meteorological Service
JAMSTEC	Japan Agency for Marine-earth Science and Technology
JET	JICA Expert Teams
JICA	Japan International Cooperation Agency
JISNET	(Indonesia) Japan-Indonesia Seismic Network
JMA	Japan Meteorological Agency
IGC-UPA	(Panama) University of Panama, Institute of Geosciences
IGP	(Peru) Peru's Geophysical Institute
IGUT	(Iran) Institute of Geophysics, University of Tehran
IIEES	(Iran) International Institute of Earthquake Engineering and Seismology
INDECI	(Peru) National Institute of Civil Defense
INETER	(Nicaragua) Nicaraguan Institute for Territorial Studies
INSIVUMEH	(Guatemala) National Institute of Seismology, Volcanology, Meteorology and Hydrology
IRSC	(Iran) Iranian Seismological Center
LIPI	(Indonesia) Indonesian Institute of Sciences
MARN	(El Salvador) Ministry of the Environment and Natural Resources
NIED	National Research Institute for Earth Science and Disaster Resilience
NDMO	(Iran) National Disaster Management Organization
NDMP	(Pakistan) National Disaster Management Plan
OVSICORI	(Costa Rica) Volcanological and Seismological Observatory of Costa Rica
PHIVOLCS	(The Philippine) Philippine Institute of Volcanology and Seismology
PTWC	(Costa Rica, Panama) Pacific Tsunami Warning System
RSN	(Costa Rica) National Seismological Network
SINAMOT	(Costa Rica) National Tsunami Monitoring System
SINAPROC	(Panama) National Civil Protection System
SE-SINAPROC	(Panama) Executive Secretary - National Civil Protection System
TDMMO	(Iran) Tehran Disaster Mitigation and Management Organization
UCR	(Costa Rica) University of Costa Rica
UNR	(Costa Rica) National University of Costa Rica
USGS	United States Geological Survey
VMGD	(Vanuatu) Vanuatu Meteorology and Geo-hazards Department

Chapter 1 Introduction

1.1 Background

In many developing countries, the operation rate of observation systems for earthquakes and tsunamis is lower than that in developed countries. One of the reasons is that the maintenance system, including the skills of staff members and the guidelines/manuals/SOP for the observation system (i.e., equipment for measuring earthquake and control system), are insufficient.

In order to implement capacity-building projects to improve seismic observation maintenance and management systems in countries with different socio-environmental situations from Japan, it is essential to understand the differences between their situation and that of Japan, and to adjust the knowledge, skills, and experiences of Japanese experts to suit local conditions. Since JICA has previously conducted related technical cooperation projects in some developing countries, analyzing the practices in these previous projects can bring valuable insights.

1.2 Objective of the Survey

The objective of the survey is to highlight the efforts and ingenuity of Japanese experts who have worked in previous JICA projects. In particular, this survey analyzes the tips and practices to operate stable seismic observation networks, improve the efficiency of quality maintenance activities, and maintain observation accuracy in selected countries. This result is expected to be utilized to consider methods for improving seismic observation and maintenance capacity in developing countries, including Indonesia. The method of this survey, which consists of JICA report survey and interview survey, as well as the flow of the survey are as follows:

(1) JICA Report Survey

In the beginning, the JICA report survey was conducted by performing the following steps. The objective of this survey is to understand the situations and conditions of seismic observation systems in developing countries that JICA has previously supported. The observation agencies in each studied country were also clarified.

- ✓ Search the JICA Website for suitable projects using the terms “disaster management,” “earthquake-observation” or “risk management,” etc.
- ✓ Confirm in each report if the project meets our objectives or not. If the information meets our criteria, JET will proceeded to the next step.
- ✓ Extract the relevant sections from each report and combine them to write a report.
- ✓ Summarize and analyze the above reports.

(2) Interview Survey with JICA Experts

Following the JICA report survey, an interview survey was conducted targeting the JICA experts who were involved in the studied projects of the JICA report survey. The purpose of this survey is to highlight the efforts and ingenuity of JICA experts in introducing seismic observation networks in these developing countries, such as establishing stable observation status, improving the efficiency of the quality and the maintenance system, and maintaining observation accuracy.

The framework of this study is explained by the flow and structure below.

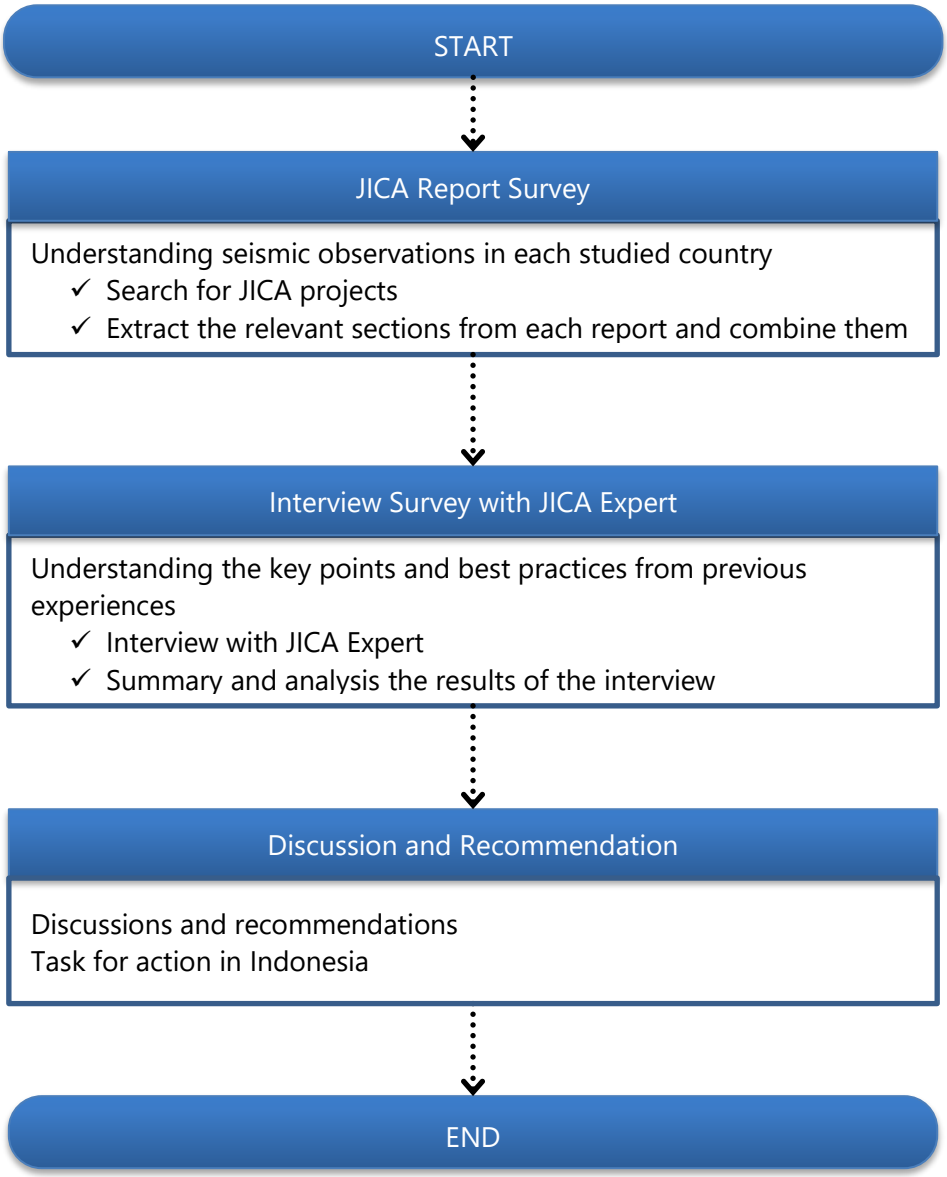


Figure 1.1 Flow and Structure of this Study

Chapter 2 Data Collection and Interview Survey

2.1 JICA Reports Survey

2.1.1 Outline

Using the keywords “disaster management,” “earthquake-observation,” and “risk management,” JET searched for suitable projects for this survey among the numerous JICA projects introduced in the JICA website[1]. Following this, JET selected eight specific projects that JICA has supported to improve seismic observation networks in different countries shown below:

1) PREPARATORY SURVEY REPORT ON THE PROJECT FOR IMPROVEMENT OF EQUIPMENT FOR DISASTER RISK MANAGEMENT IN REPUBLIC OF INDONESIA JULY 2014
2) DATA COLLECTION SURVEY REPORT ON EARTHQUAKE MANAGEMENT IN IRAN AUGUST 2019
3) THE PROJECT FOR NATIONAL DISASTER MANAGEMENT PLAN IN THE ISLAMIC REPUBLIC OF PAKISTAN MARCH 2013
4) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF PERU 2013
5) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF EL SALVADOR 2013
6) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF VANUATU 2013
7) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF FIJI 2013
8) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF THE PHILIPPINES 2013

The following table illustrates the project outline of these targeted projects which were organized by country. For the investigation of the seismic observation networks implemented or surveyed in JICA projects, the status of the seismic observation network and system in each country are summarized by referring to JICA project reports.

[1] https://libportal.jica.go.jp/library/public/Index.html

Table 2.1 Surveyed JICA Projects

Project Title	Country	Project Outline
1) PREPARATORY SURVEY REPORT ON THE PROJECT FOR IMPROVEMENT OF EQUIPMENT FOR DISASTER RISK MANAGEMENT IN REPUBLIC OF INDONESIA	INDONESIA	Project: Grant Aid Subject：Water Resources and Disaster Prevention Amount of Grant: 1.50 billion yen Project Implementation: August 2014 - July 2016 Project Outline: 1) Procurement equipment for civil engineering works: seismographs (200), broadband seismographs (20), broadband strong-motion seismographs (20), strong-motion seismographs (93), IT seismographs (200), satellite communication system, new observatory building, etc., PS tester, microtremor array detector, strong-motion seismograph (10) 2) Consulting/software component: preparation of bidding documents, bidding and contract assistance, supervision of equipment installation work
2) DATA COLLECTION SURVEY REPORT ON EARTHQUAKE MANAGEMENT IN IRAN *Feasibility study on support for earthquake disaster prevention.	IRAN	Phase 1 Project: Technical Cooperation Subject: Water Resources and Disaster Prevention Amount Provided: 345 million yen Period of Cooperation: November 2006 - March 2010 Project Summary: 18 experts dispatched; 25 trainees accepted. Provision of Equipment: seismographs, servers, PCs, printers, etc. Provision of Equipment: seismographs, servers, computers, printers, etc. Phase 2 Project: Technical Cooperation Issues: Water Resources and Disaster Prevention Amount Provided: 445 million yen Cooperation Period: March 2012 - March 2015 Project Summary: 16 experts dispatched; 26 trainees accepted Provision of Equipment: GIS software, printers, GPS receivers, accelerometers, etc. GIS software, printers, GPS receivers, accelerometers, etc.
3) THE PROJECT FOR NATIONAL DISASTER MANAGEMENT PLAN IN THE ISLAMIC REPUBLIC OF PAKISTAN MARCH	PAKISTAN	Not included in the survey because this project focused on community disaster prevention.
4) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF PERU	PERU	Project: Technical Cooperation Subject：Water Resources and Disaster Prevention Amount Provided: 699 million yen Period of Cooperation: March 2010 - March 2015 Project Brief: Procurement of equipment for tide level measurement system and emergency warning system.
5) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF EL SALVADOR	EL SALVADOR	Project: Grant Aid (Gift Aid Agreement (G/A)) Subject：Water Resources and Disaster Prevention Amount of Grant: 400 million yen Project Outline: 1) Equipment procured seismograph system (8), broadband observation system (5), GPS observation system (3), tide level measurement system (1),tsunami monitoring camera system (2), wireless system (550) 2) Consulting/software component: 1 seismograph system, GPS observation system, tide level measurement system, equipment procurement supervision

Project Title	Country	Project Outline
6) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF VANUATU	VANUATU	Project: Grant Aid Subject：Water Resources and Disaster Prevention Amount of Grant: 390 million yen Period of Cooperation: July 2017 - June 2020 Project Outline: 1) Dispatch of experts (about 68 man-months) 2) Training in Japan 3) Provision of equipment: portable seismographs (1), seismometers (10) terminals and software for tide level analysis (1 set) terminal and software for seismic intensity display (1 set)
7) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF FIJI	FIJI	Project: Grant Aid Issue: Water Resources and Disaster Prevention Cooperation Period: May 2013 - February 2015 (planned) Amount of Grant: 300 million yen Project Outline: 1) Civil works, procurement equipment, etc. tide level measurement system: 1 location VSAT satellite communication observation system (5 locations) wind profiler system: 1 location One (1) automatic weather station (AWS) Calibration equipment: 1 set Lightning detection system (6 locations) 2) Consulting/software component: consulting services for preparation of bidding documents, bidding and contract assistance, and supervision of equipment installation work
8) PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF THE PHILIPPINES	THE PHILIPPINES	Project: Grant Aid Issues: Water Resources and Disaster Prevention Cooperation Period: September 2013 - February 2015 (planned) June 2012 Amount provided: 1.00 billion yen Project Outline: 1) Civil engineering works, procurement equipment, etc. real-time earthquake observation system real-time tsunami observation system 8 drainage pump vehicles 2) Consulting/software components preparation of bidding documents, assistance in bidding and contract negotiations Supervision of equipment installation work

2.1.2 Extracts from JICA Survey Reports

JET extracted and summarized the following information from JICA project reports to understand the situation and conditions of seismic observations networks in each targeted country.

- ✓ Seismic observation agency
- ✓ Seismic observation network
- ✓ Equipment provided through the Japanese grant

(1) Indonesia

1) Seismic Observation Agency

Under the direct supervision of the President, BMKG is the organization for disaster management at the national level. As mentioned in the "Law of the Republic of Indonesia Number 24 of 2007 Concerning Disaster Management," BMKG is ordained by the law to play a role in the observation and monitoring of disaster management.

2) Seismic Observation Network

Characteristics of the disaster

Indonesia, similar to the Japanese archipelago, is an island country which is formed along an undersea trench. Therefore, huge earthquakes (ocean-trench earthquakes) occur frequently. Huge earthquakes (greater than magnitude 7) that occurred in 2000 or later off the coast of Sumatra are shown in the following table as of 2014.

Table 2.2 Earthquakes that Occurred in 2000 or Later Off the Coast of Sumatra

Date	Name	Epicenter		Magnitude (Deaths)
		Latitude	Longitude	
4 Jun 2000	Sumatera earthquake (2000)	3°43'21"S	102°4'48"E	7.9 (100)
26 December 2004	Sumatera earthquake (2004)	3°18'58"N	95°51'14"E	9.1 (220,000)
28 March 2005	Sumatera earthquake (2005)	2°4'26"N	97°0'47"E	8.6 (2,000)
12 December 2007	Sumatera earthquake (2007)	4°31'12"S	101°22'26"E	8.5 (17)
30 September 2009	Sumatera earthquake (2009)	0°43'30"S	99°51'22"E	7.5 (1,100)
25 October 2010	Sumatera earthquake (October 2010)	3°29'2"S	100°6'50"E	7.7 (400)
11 Avril 2012	Sumatera earthquake (April 2012)	2°18'40"N	93°3'47"E	8.6 (5)

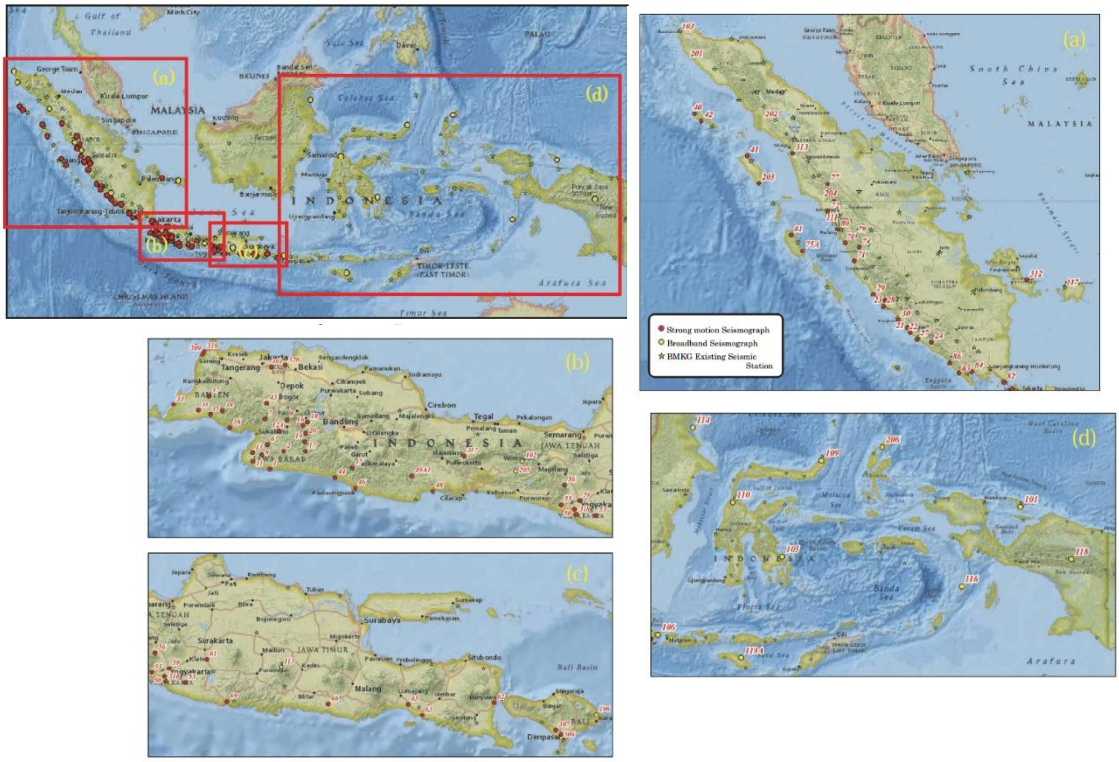
Source: Wikipedia

As cited in the Preparatory Survey Report on the Project for Improvement of Equipment for Disaster Risk Management in the Republic of Indonesia, July 2014.

Seismic Observation Network

BMKG has expanded its earthquake observation network, and 236 strong motion seismograph stations are currently installed. Data from the broadband seismographs have been used to identify earthquake sources, determine the magnitude, analyze earthquake mechanism, among other things. A total of 162 broadband seismograph stations have been installed thus far.

Those included are the "Ina-TEWS"; earthquake and tsunami information system introduced by Germany; "ICDSN" introduced by China; and "JISNET" supported by the National Research Institute for Earth Science and Disaster Prevention (NIED) in Japan. A total of 110 stations of the 162 have been installed with strong motion seismographs. JISNET, on the other hand, was launched in 1997. Some of the equipment has since malfunctioned and requires replacement.



Source: JICA, Preparatory Survey Report on the Project for Improvement of Equipment for Disaster Risk Management in Republic of Indonesia, July 2014.

Figure 2.1 Observation Points

3) Equipment Provided by the Japanese Grant

The following components were procured through the Japanese grant aid.

Table 2.3 Equipment Provided through the Japanese Grant in Indonesia

Type of Equipment	Expected Outcome	Input
1. Existing broadband seismic station installed by National Research Institute for Earth Science and Disaster Prevention (NIED), Japan (JISNET site) (15) (supply of equipment and replacement)	Equipment of JISNET site that has reached the end of its life cycle will be replaced and the accuracy of earthquake analysis and information on seismic intensity will be improved.	• Broadband seismograph (velocity meter) (15) • Broadband strong motion seismograph (velocity meter) (15) • Strong motion seismograph (accelerometer) (15) *Solar power system (1) *Seismic station construction (6)
2. Existing shelter constructed by the Indonesian government (BMKG existing site) (5) (supply of equipment and installation)	Equipment will be installed in the existing BMKG site and the accuracy of earthquake analysis and information on seismic intensity will be improved.	• Broadband seismograph (velocity meter) (5) • Broadband strong motion seismograph (velocity meter) (5) • Strong motion seismograph (accelerometer) (5)

Type of Equipment	Expected Outcome	Input
		*Solar power system (2)
3. New station for strong motion seismograph, including civil works and installation (73) (supply of equipment, civil works and installation)	It will contribute to the early realization of Indonesia's plan, which is to install 500 strong motion seismographs throughout the country. It will also contribute to rapid earthquake response in the event of a large-scale earthquake predicted to occur in Sumatra in the future.	• Strong motion seismograph (accelerometer) (73) *Solar power system (6) *Seismic station construction (67)
4. New installation of satellite communication system (for data transmission from each site to the BMKG HQ)	Observed data from each site will be sent and obtained in real time at the BMKG HQ.	• Satellite communication system (93) (for all target sites)
5. Seismic intensity meter (supply of equipment only)	Accuracy of seismic intensity observation will be improved.	• Seismic intensity meter (200)
6. BMKG HQ (seismic intensity information system server, earthquake waveform information acquisition server)	Seismic intensity data will be collected, which will contribute to the creation of a database and analysis for future earthquake early warning.	• Seismic intensity information system server (1) • Earthquake waveform information acquisition server (2)

Source: JICA, Preparatory Survey Report on the Project for Improvement of Equipment for Disaster Risk Management in Republic of Indonesia, July 2014.

(2) Iran

1) Seismic Observation Agency

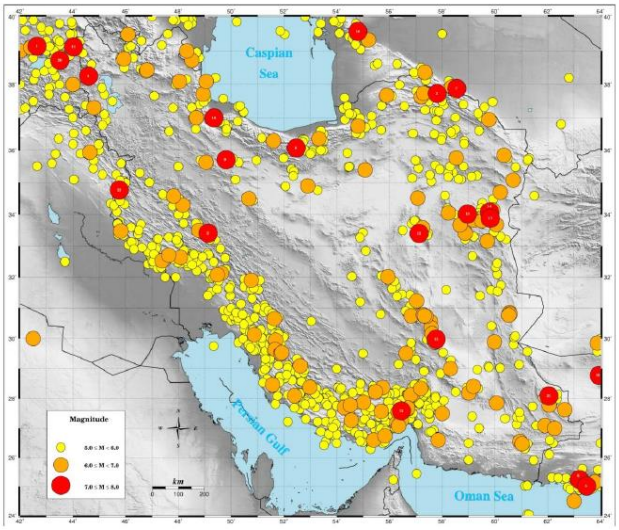
IGUT is a geophysics institute operated by the University of Tehran that is mandated by law to manage information on earthquakes throughout Iran and to conduct research on earthquake precursors and probabilities, as stated in "5 Ministers' Council Act No. 23157/33302 of 09/07/2005." The organization has six main divisions, two of which perform earthquake observation and research: the Research Center for Earthquake Precursors (RCEP) and the Iranian Seismological Center (IRSC).

2) Seismic Observation Network

Characteristics of the disaster

Seismic activity in Iran is among the world's highest due to the country's location on the boundary of the Arabian and Eurasian tectonic plates. The following figure shows the locations of the tremors recorded on November 12, 2017 that damaged the Kermanshah region along with earthquakes of magnitude 5 or greater that have been observed since 1900.

Epicenters are clearly concentrated in certain locations, such as near the border with Iraq and along the Persian Gulf. Many are found on the boundary of the Arabian/Eurasian tectonic plates or along active faults.



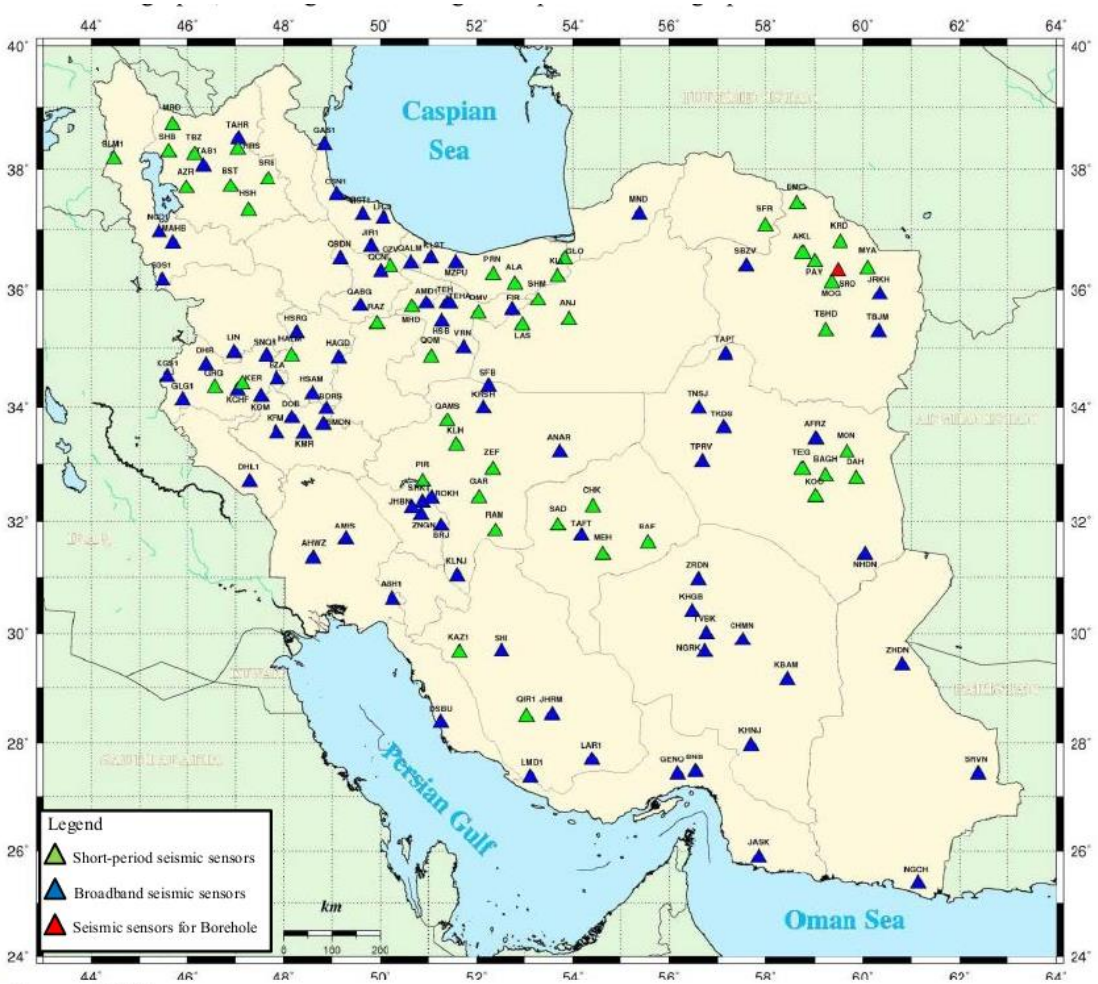
Date	Location	Magnitude	Fatalities
01.23. 1909	Silakhor	7.4	8,000
05.01.1929	Baghan	7.1	> 3,800
05.06.1930	Salmas	7.1	2,514
09.01.1962	Bu'in	7.0	12,200
07.02.1957	Band-e Pay	7.1	> 1,500
12.13.1957	Farsinaj	6.8	1,200
08.31.1968	Dasht-e Bayaz	7.1	10,000
09.16.1978	Tabas-e Golshan	7.3	20,000
11.27.1979	Koli	7.1	20
07.28.1981	Sirch	7.0	1,300
06.20.1990	Rudbar	7.3	13,000 – 40,000
05.10.1997	Zirkuh	7.2	1,568
12.26.2003	Bam	6.6	31,828 – 43,200
04.16.2013	Saravan	7.7	40
11.12.2017	Kermanshah province (Ezgele – Sarpo e Zahab: near the Iran-Iraq border)	7.3	620

Source: JICA, Data Collection Survey Report on Earthquake Management in Iran, August 2019

Figure 2.2 Epicenter Distribution (January 1, 1900 – December 31, 2018, M ≥ 5.0)

Seismic Observation Network

In the event of an earthquake in Iran or the surrounding areas, IGUT provides epicenter information as a public service for emergency disaster preparedness. IRSC was established within IGUT in 2004 and runs an earthquake observation network, with data consisting of information from the IIEES network with as many as 130 digital seismograph observation points and an availability ratio consistently above 80%. The following figure illustrates the IRSC network, with triangles in red showing borehole-type seismographs; in blue showing broadband seismographs; and in green showing short-period seismographs.



Source: JICA, Data Collection Survey Report on Earthquake Management in Iran, August 2019

Figure 2.3 IRSC Seismic Observation Network

The service life of earthquake management equipment such as broadband seismometers and strong-motion seismometers is generally 20 to 30 years, and such units require regular maintenance in order to function properly. Because major manufacturers of observation equipment are located in specific countries such as the United States, Canada, and Japan, it is currently difficult for Iran to procure new units as well as obtain replacement parts/consumables for existing equipment in light of the economic sanctions imposed by the United States. As a result, related facilities and equipment are aging, and support for replacement/repair has been stagnant.

3) Equipment Provided though the Japanese Grant

JICA has supported the country to improve its seismic observation networks. For instance, between 2012 and 2015, a pilot scale EEWS consisting of a limited number of stations was developed as part of the Project for "Capacity Building for Earthquake Risk Reduction and Disaster Management in Tehran," as shown in Table 2.4 and Figure 2.4, respectively. Technical transfer for system development was conducted through the development process, providing support for understanding of JMA's earthquake early warning system in detail. Simultaneously, the development of an optimized algorithm for Tehran has progressed, and

an action plan for a practical/operational EEWS to be applied to Tehran City in the future[2] has been drafted by selecting the necessary tasks.

Table 2.4 List of Procured Seismic Equipment in "The Project for Capacity Building for Earthquake Risk Reduction and Disaster Management in Tehran"

No	Equipment	Specification	Quantity	Place of Use
1	GPS receiver	GeoSIG RS-232	4	TDMMO
2	Triaxial Force Balance Accelerometer	GeoSIG AC73	4	TDMMO
3	GMSplus Measuring System	GeoSIG	4	TDMMO

Source: PROJECT COMPLETION REPORT of "The Project for Capacity Building for Earthquake Risk Reduction and Disaster Management in Tehran"[3] (extracted by JET)

Figure 2.4 Donated Seismic Equipment (Upper Left: Sensor; Upper Right: GPS; Lower: Controller)

Furthermore, as part of the Project on the Establishment of Emergency Response Plan for the First 72 Hours After an Earthquake, the Japanese side procured seismic equipment, including strong motion sensors, between 2006 and 2010 as shown in Table 2.5

Table 2.5 List of Seismic Equipment Procured by the Japanese Side

No	Equipment (Specification)		Installation place
1	Strong Motion Sensor	10 sets	TDMMO & Location of Sensor
2	Digitizer	10sets	TDMMO & Location of Sensor
3	Communication Interface	10sets	TDMMO & Location of Sensor
4	Monitoring PC	1 set	TDMMO
5	Acquisition Sensor	1 set	TDMMO
6	Software	1 set	TDMMO & Location of Sensor

[2] https://openjicareport.jica.go.jp/pdf/12252722_02.pdf
[3] https://openjicareport.jica.go.jp/pdf/12252722_02.pdf

No	Equipment (Specification)		Installation place
7	MPLS Modem	10 sets	TDMMO & Location of Sensor
8	Satellite Modem	10 sets	TDMMO & Location of Sensor
9	UPS	10 sets	TDMMO & Location of Sensor
10	UPS	1 set	TDMMO
11	Cable	400m	TDMMO & Location of Sensor

Source: Project Evaluation Report of "Project on the Establishment of Emergency Response Plan for the First 72 Hours After an Earthquake" (extracted by the JET)[4]

In addition to these provided equipment, the following equipment were requested by the government of Iran according to "Data Collection Survey Report on Earthquake Management in Iran (AUGUST 2019)."

Table 2.6 Equipment Requested by Iran (Partial)

No	Equipment	Qty	Unit	User
1	Broadband seismic sensor for boreholes (BB type)	20	Set	IGUT
2	Broadband seismic sensor for surface (BB type)	25	Set	
3	Broadband seismic sensor for surface (SP type)	75	Set	
4	Accelerometer sensor	120	Set	
5	Digitizer 6 Ch	120	Set	
6	Portable broadband sensor for surface (BB type)	35	Set	IIEES
7	Portable broadband sensor for boreholes (BB type)	30	Set	
8	Portable short-period sensor for surface	65	Set	IGUT/IIEES
9	Portable short-period sensor for boreholes	30	Set	IIEES
10	Digitizer 3 Ch	160	Set	IGUT/IIEES
11	Server (computer)	2	Set	
12	Radio modem	200	Set	
13	GPRS modem	80	Unit	
14	UPS	20	Unit	
15	Solar panel and battery	260	Set	

Source: JICA, Data Collection Survey Report on Earthquake Management in Iran, August 2019

[4] https://libopac.jica.go.jp/images/report/11995149_02.pdf

(3) Peru

1) Seismic Observation Agencies

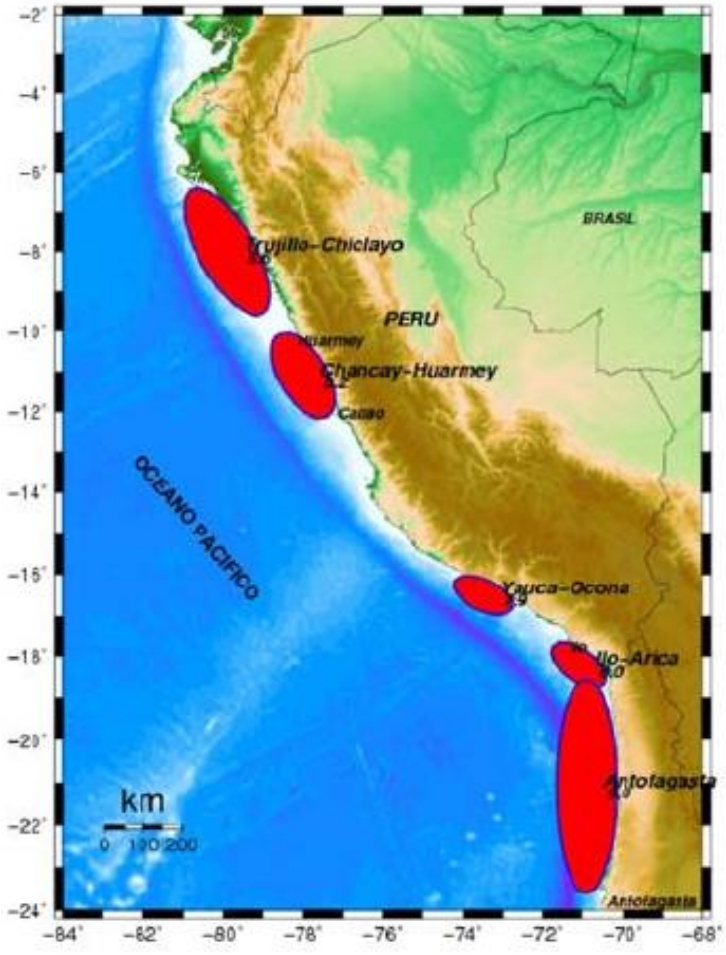
IGP, DHN and INDECI are responsible for governmental seismic observation as mandated by the law (Decree No. 136). Seismic observation and analysis are carried out by the Scientific Research Department of the IGP. On the other hand, the DHN is in charge of tsunami forecasting and observation. This information is collected by INDECI, and warnings and advisories are prepared and provided to the public through COEN.

2) Seismic Observation Network

Characteristics of the disaster

Peru, located in the Pacific Rim seismic zone, has repeatedly experienced major earthquakes and is constantly exposed to the risk of tsunami disasters.

While Peru's economy is growing, the country's lack of preparedness for natural disasters has led to an increase in damage over the past 30 years, making it a challenge to improve earthquake and tsunami monitoring and warning to the population.



Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Peru, 2013.

Figure 2.5 Estimated Occurrence Area of Earthquakes Accompanied by Tsunami

Seismic Observation Network

A total of 23 broadband seismographs, 27 short-period seismographs, and 36 acceleration seismographs are deployed throughout the country. The data are collected at the IGP headquarters through terrestrial telephone lines. Within 5 to 15 minutes after the occurrence of an earthquake, the seismic source (epicenter location, seismic intensity, and magnitude) is analyzed and reported to the relevant organizations.

Regarding the method and points of observation, the following information is described in the report as of 2013.

Table 2.7 Current Status and Issues in Seismic Observation

Current Situation	Problems and Challenges
Institute: IGP Equipment: broadband seismograph: 23 short-cycle seismograph: 27 acceleration seismograph: 36 Data transmission: telecommunication line and optical fiber Data analysis: Analysis from wave-form data Notification method: Telephone, radio wave, fax, web page Decision on tsunami warning: DHN is responsible for deciding on the issuance of tsunami warnings. However, determining the possibility of a tsunami based on the IGP's own criteria is an internal document.	Data transmission: Ground lines were disconnected during the earthquakes in Arequipa in 2001 and Pisco in 2007, respectively. In order to establish a system that can issue early warning information on earthquakes and tsunamis within five minutes, it is planned to connect seven observation stations via satellite. Network between institutes: Information from the IGP to the relevant agencies is also provided through telephone, radio and SMS, and a communication satellite network between the IGP, INDECI and DHN has been established. Analysis speed: Current seismic data collection and analysis takes 5-15 minutes, which means that tsunamis generated by earthquakes in nearby seas will be issued too late. Therefore, improving the analysis speed is an issue.

Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Peru, 2013.

3) Equipment Provided through the Japanese Grant

Equipment for seismic observation has not been provided by JICA, but the tide level monitoring system, early warning system and digital broadcasting system were provided through the Japanese grant. The table below shows the results of the listing-up of requested equipment and corresponding quantity.

Table 2.8 Equipment Provided through the Japanese Grant in Peru

No	Items	Qty
1	Tide gauge	12
2	Sharing information system for early warning	1
3	Digital broadcasting system	9

Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Peru, 2013.

(4) El Salvador

1) Seismic Observation Agency

The earthquakes that cause tsunamis are classified into near-field earthquakes that occur in the trench off El Salvador, and far-field earthquakes that occur overseas. Near-field earthquakes and tsunamis are analyzed by the Directorate General of Environmental Monitoring within MARN. For far-field earthquakes and tsunamis, information is obtained from the USGS, the Pacific Tsunami Warning Center (PTWC), and the JMA.

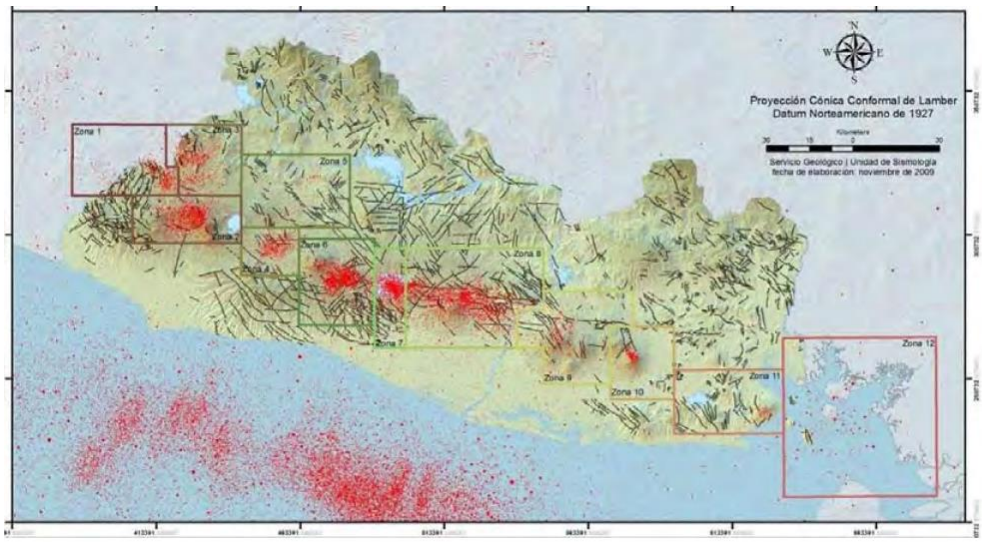
2) Seismic Observation Network

Characteristics of the disaster

El Salvador is located on the Pacific coast of the Central American region, with the Cocos Plate approaching from the Pacific, the Caribbean Plate from the Caribbean, and the Norte America Plate from the north. Central America is along the Mesoamerican Trench, where the Cocos Plate subducts under the Caribbean Plate.

In El Salvador, the coupling (sticking strength) near the plates of the Mesoamerican Trench is weak, and the coupling under the volcanic belt called the Sierra Madre Mountains, which is a chain of volcanoes, is strong. Strong earthquakes occur underground along the Sierra Madre Mountains.

Earthquake epicenters in El Salvador are shown below, and most of the earthquakes occur in the subducting trench of the Coco Plate and along the volcanic belt of the Sierra Madre Mountains.



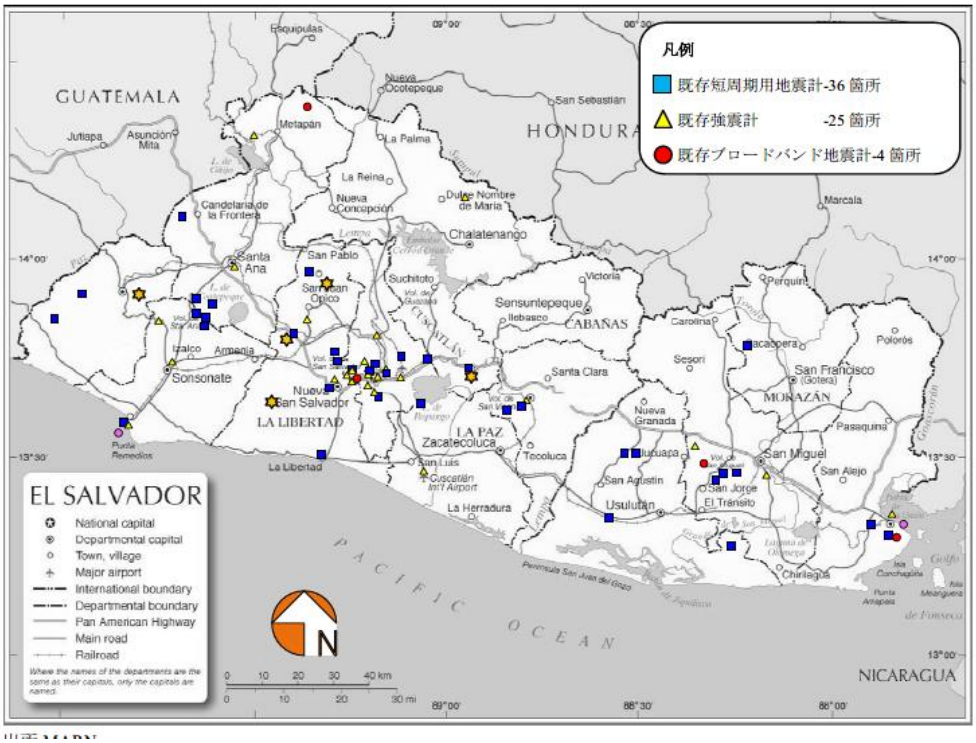
Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of El Salvador, 2013

Figure 2.6 Epicenter Distribution Map of El Salvador

Seismic Observation Network

Seismic observation equipment such as short-period seismometers, strong-motion seismometers, broadband seismometers, and GPS observation equipment are inspected about once every two months by the person in charge of seismic observation at MARN. Data are recorded in real time and transferred to the MARN headquarters through the internet and UHF/SHF wireless communication networks. Data from some seismic stations and GPS stations will be manually captured locally and analyzed later.

The figure below shows the observation points as of 2013.



Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of El Salvador, 2013

Figure 2.7 Seismic Observatory Location Map

The seismic and GPS data is observed 24 hours a day, and is recorded in real time on the MARN system installed at the MARN headquarters through the internet and UHF/SHF radio communication network. In addition, Earth Warm and SEISCOMP, which are compliant with USGS, are used to analyze the source elements (location, depth, magnitude, etc.) from the seismic waveforms. Seismic waveform data, seismic source elements and seismic source location maps are displayed on the MARN system in real time. The data from some seismic and GPS observation points are manually imported in the field and analyzed later.

3) Equipment Provided through the Japanese Grant

The following components were procured through the Japanese grant aid.

Table 2.9 Equipment Provided through the Japanese Grant in El Salvador

No	Equipment
1	Seismograph observation system
2	Broadband seismic observation system
3	GPS observation system
4	Tide level observation system
5	Tsunami monitoring cameras system
6	Wave radio system

Source: JICA, Preparatory survey report for disaster management system plan in the Republic of El Salvador, 2013

(5) Vanuatu

1) Seismic Observation Agency

VMGD is a Department within the Ministry of Climate Change Adaptation, Meteorology, Geo-Hazards, Energy, Environment and Disaster Management. The VMGD consists of seven divisions which are the following: Administration; Weather Forecasting and Services; Climate; Climate Change/Project Management Unit; Geo-Hazards; Observations; and ICT/Engineering.

The Observations Division maintains adequate observational network to provide the required data and information needed within VMGD and for other national, regional and international users and further networks. This division installs, maintains and updates all observational networks that provide adequate coverage, real-time, accurate and high-quality observation data for weather, climate and water. This division also works closely with regional and international technical partners to meet the VMGD's network data and information reporting obligations.

2) Seismic Observation Network

Characteristics of the disaster

Oceania around Vanuatu suffers little earthquake and tsunami damage, but in 2009, there were around 192 victims of earthquake and tsunami in Solomon Islands. Despite the fact that earthquakes with magnitudes of seven or stronger with epicenters in and around Vanuatu have occurred six times since 1990, no serious damage has been reported.

Seismic Observation Network

VMGD already conducts seismic observations in Vanuatu, where short-period seismometers and broadband seismometers have been installed. The existing seismic data is transmitted via wireless transmission to the main office of VMGD and iGov network, and analyzed and displayed by the seismic data observation system. VMGD has also established a method to analyze the seismic source from the observations of short-period and broadband seismographs using a program called "Seiscomp3", as well as correct the magnitude and other source elements from the strong-motion seismograph observations.

As for seismic data, VMGD observes earthquakes caused by crustal movements, with two seismographs on Efate Island and one on Espirito Santo Island. Each instrument is connected to the seismic data processing system at the VMGD headquarter, and the data is observed in real time. The seismographs and other information from each island are transmitted to VMGD through iGov network operated by the government of Vanuatu.

Source: VMGD Website[5]

Figure 2.8 Location Map of Existing Weather, Sea and Geological Observation Points in Vanuatu

3) Equipment Provided through the Japanese Grant

The following components were procured through the Japanese Grant.

Table 2.10 Equipment Provided through the Japanese Grant in Vanuatu

No.	Name of Island	Name of Site
1. Tide Observation System (2 locations)		
T-1	Malakula	Litzlitz
T-2	Tanna	Lenakel
2. Strong Motion Accelerometer and Broadband Station System (3 locations)		
SB-1	Malakula	Lakatoro
SB-2	Efate	VMGD
SB-3	Tanna	Isangel
3. Automatic Weather Station (AWS) (2 locations)		
A-1	Espiritu Santo	Pekoa Airport
A-2	Efate	Bauerfield Airport
4. GTS Server and MSS (1 set)		
G-1	Efate	VMGD

Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Vanuatu, 2013

[5] http://www.vmgd.gov.vu/vmgd/index.php/geohazards/network

(6) The Fiji Islands

1) Seismic Observation Agency

Fiji's seismic observation agency is Fiji Meteorological Service (FMS). The mission of FMS is to observe and understand regional weather, Fiji's climate and hydrological patterns, and provide meteorological and hydrological services in support of the well-being of communities, economic growth, environmental sustainability and international obligations.

2) Seismic Observation Network

Characteristics of the disaster

Countries in the South Pacific are among the most disaster-prone areas in the world, and Fiji is no exception. Because the country is located in the vicinity of the Pacific Ring of Fire, earthquakes, earthquake-induced tsunamis and landslides are all possibilities.

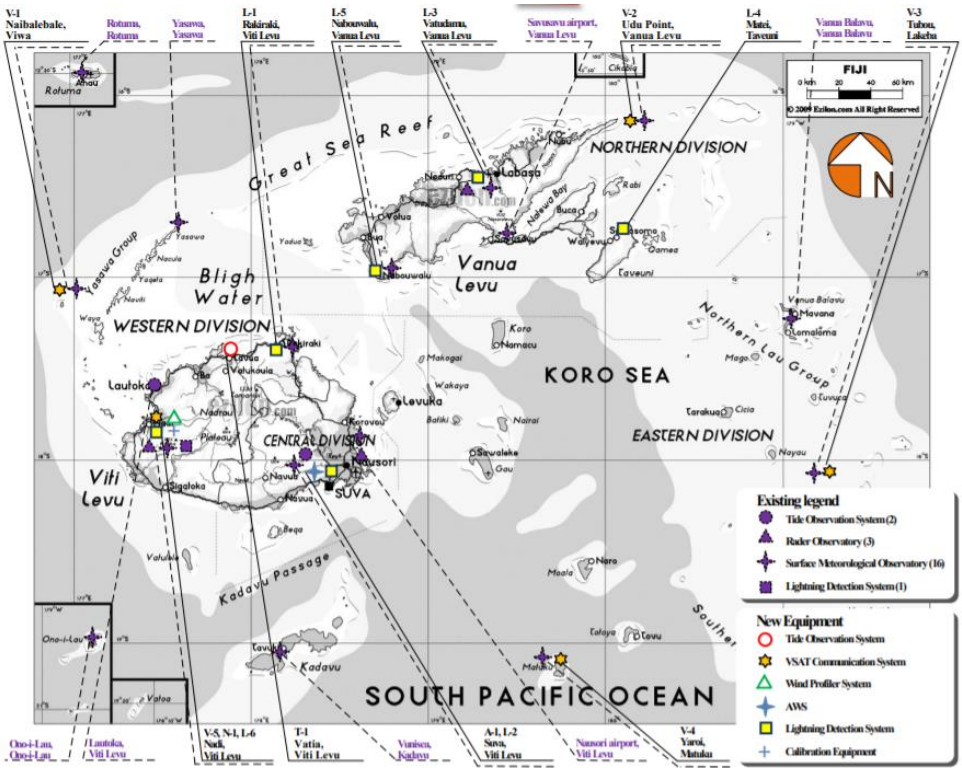
There are also two active volcanoes located in the region, and the volcanic soil is inherently unstable, increasing the risk of landslides especially in areas where farming and settlement are spreading to fertile slopes. Cyclones, heavy rain and flooding are yearly occurrences, and the most common disasters in the past have been the result of high-impact hydrometeorological events. Majority of the population and infrastructure are located in the Disaster Risk Reduction in the Republic of Fiji.

Seismic Observation Network

The FMS was built with technical assistance from Japan, and while most of the equipment is automated, there is still some analog equipment that needs to be updated. The figure below shows the existing meteorological and tide level observation points.

The meteorological data acquired by the FMS is shared internationally through the Global Telecommunication System (GTS) operated by the WMO, and meteorological data is automatically registered and transmitted to the GTS. This data is distributed to each country.

Since it is necessary to conduct comparative observations about once a month and detailed inspections about once a year to maintain the accuracy of meteorological and oceanographic observations, it is essential to establish a system for regular maintenance and management.



Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Fuji, 2013

Figure 2.9 Existing Meteorological and Tide Level Observation Points Location Map

3) Equipment Provided through the Japanese Grant

The following components were procured through the Japanese grant aid.

Items	Q'ty	Location			
1 Tide Observation System	1				
		T1	Vatia	Viti Levu	1
2 VSAT Communication System					
		V1	Naibalebale	Viwa	1
		V2	Udu Point	Vanua Levu	1
		V3	Tubou	Lakeba	1
		V4	Yaroi	Matuku	1
		V5	Nadi (FMS Headquarters)	Viti Levu	1
3 Wind Profiler System					
		N1	Nadi (FMS Headquarters)	Viti Levu	1
4 Automatic Weather Station (AWS)					
		A1	Suva	Viti Levu	1
5 Calibration Equipment					
			Nadi (FMS Headquarters)	Viti Levu	1
6 Lightning Detection System					
		L1	Rakiraki	Viti Levu	1
		L2	Suva	Viti Levu	1
		L3	Vatudamu	Vanua Levu	1
		L4	Matei	Taveuni	1
		L5	Nabouwalu	Vanua Levu	1
		L6	Nadi (FMS Headquarters)	Viti Levu	1

Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of Fuji, 2013

(7) The Philippines

1) Seismic Observation Agency

The PHIVOLCS, the agency responsible for conducting earthquake and tsunami observations, is positioned as a scientific and technical service agency of the DOST. The responsibilities of PHIVOLCS are defined by Executive Order No. 128 as follows:

- Prediction of volcanic eruptions, earthquake occurrence, and related crustal movement phenomena;
- Elucidation of the mechanisms of volcanic eruptions and earthquakes, and determination of the affected areas;
- Development of effective use of volcanoes and volcanic landforms in the promotion of socio-economic development by the government;
- Generation of necessary data for forecasting volcanic eruptions and earthquakes and
- Disaster mitigation using detection, prediction, and warning systems for volcanic activity.

2) Seismic Observation Network

Characteristics of the disaster

Since the Philippines is located on the Pacific Ring of Fire similar to Japan, volcanic and seismic activities are brisk, and earthquake disasters occur frequently. In particular, the earthquake in Central Luzon that struck Baguio City and other urban areas on July 16, 1990 killed over 1,200 people and caused extensive damage in many areas. There have also been many tsunamis, and the earthquake that hit Mindanao on August 16, 1976 killed more than 4,000 people.

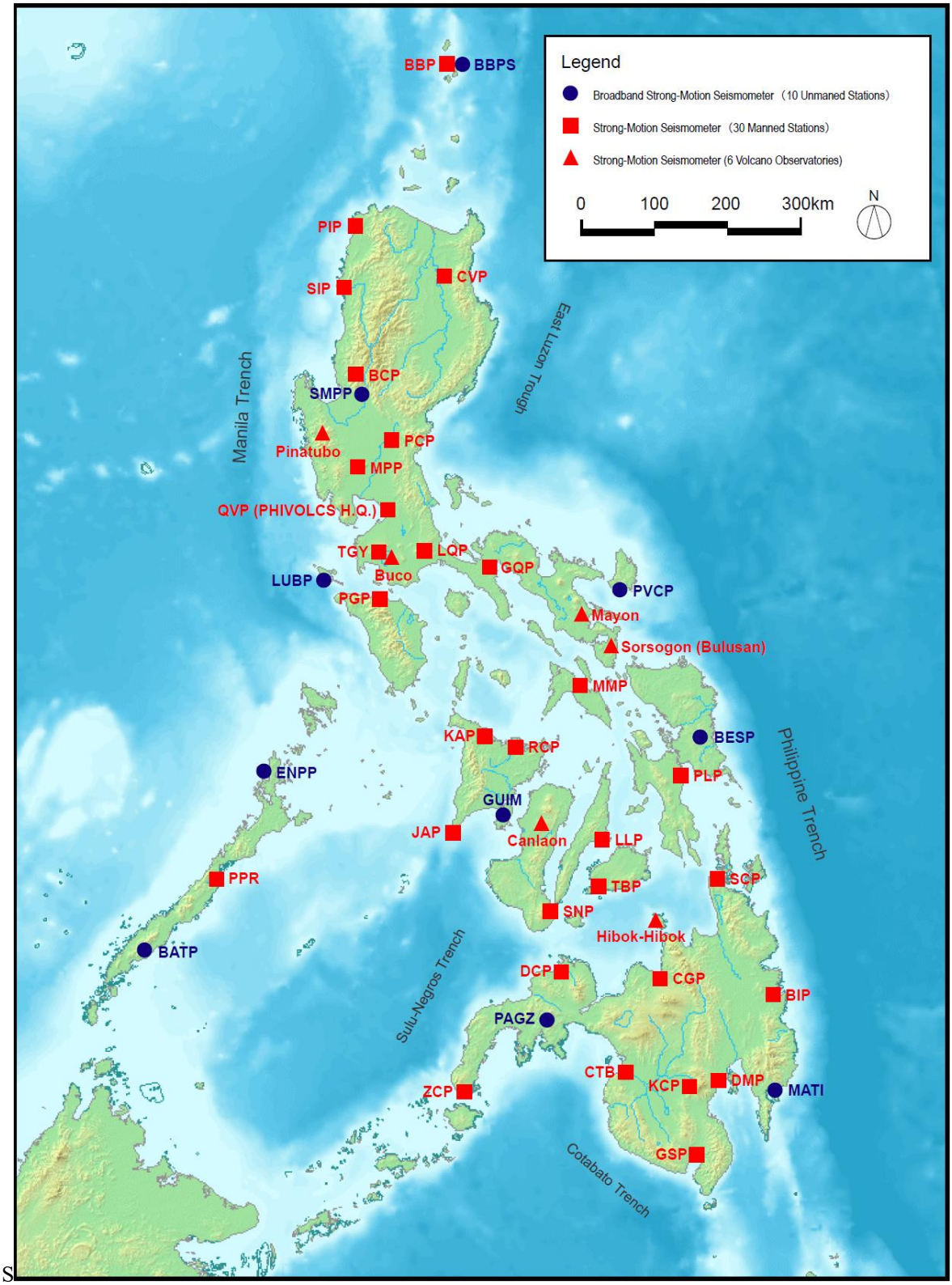
Seismic Observation Network

Regarding method and points of observation, the following information is described in the report as of 2013.

The 30 manned seismic stations, 6 manned seismic and volcanic stations, and 31 unmanned seismic stations of PHIVOLCS have been equipped with a basic observation network covering the entire country through the previous Japanese grant aid, "Seismic and Volcanic Observation Network Development Project (1st and 2nd)." The basic evaluation and analysis techniques for the recorded data were transferred through the technical cooperation.

PHIVOLCS is already operating the similar type of equipment and systems to be developed under this project, and their maintenance and management systems are well established. In addition, there are no problems in the financial aspects of the implementing agencies, and it can be determined that they have sufficient capacity to operate and maintain the equipment to be developed under this project.

The seismic observation network in the Philippines consists of 31 unmanned seismic stations, 30 manned seismic stations, and 6 manned seismic and volcanic stations. However, more than 10 years have passed since the implementation of the above grant project, and some of the seismic observation equipment is due for renewal. In addition, since the 2004 Sumatra earthquake and the Indian Ocean tsunami, telemeter observation networks for earthquake measurement and tsunami early warning systems have been rapidly developed in Asian countries. In the Philippines, the development of telemeter observation networks for strong-motion seismographs has been delayed, and the country has not been able to ascertain the magnitude of seismic motion at the epicenter and to issue tsunami early warnings.



Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of the Philippines, 2013.

Figure 2.10 Project Site Location Map
(PHIVOLCS Real-time Seismic Observation System Target Site)

3) Equipment Provided through the Japanese Grant

The following components were procured through the Japanese grant aid.

Table 2.11 List of Major Seismic Observation Equipment Owned by PHIVOLCS

Observation Site	Equipment	Quantity	In real time	Relevant Project			
				Japanese ODA			Others
				Grant 1	Grant 2	SATREPS	
Manned	Short-period seismograph	35	No	v	v		
	Strong motion seismograph	35	No	v	v		
	Broadband seismograph	10	No	v	v		v
	Mid-period seismograph	6	No		v		
	Digitizer	36		v	v		v
	Drum recorder	35		v	v		
	Wave-form recorder and analyzer including software	36		v	v		v
	GPS clock	35		v	v		
	Emergency generator	12			v		
	Solar generator	2					v
	Battery	13			v	v	
Unmanned	Short-period seismograph	21	Yes		v		
	Strong motion seismograph	10	Yes			v	
	Broadband seismograph	10	Yes			v	
	Satellite communication modem	31			v		
	Digitizer	36			v	v	
	Antenna	31			v		
	Satellite communication receiver	31			v		
	GPS clock	31		v	v		
	Solar generator	31			v		
	Battery	31			v		
Data collection center (PHIVOLCS HQ)	Antenna				v		
	Satellite communication tool					v	
	Wave-form recorder including software					v	
	Data analyzer including software				v		
	GPS clock			v	v		
Backup center (Dabaw, tagaytay)	Antenna				v		v
	Satellite communication receiver				v		v
	Wave-form recorder including software				v		v

Source: JICA, Preparatory Survey Report for Disaster Management System Plan in the Republic of the Philippines, 2013.

2.2 Interview Survey with JICA Experts

2.2.1 Outline

JET sought out and interviewed JICA experts who were involved in the selected projects mentioned in Section 2.1. As a result, JET was able to interview experts in charge of projects in the Philippines, Indonesia, and Fiji. During the interviews, while keeping the confidentiality of each project in mind, JET asked a wide range of questions about their experiences, points of concerns, efforts, and ingenuities as engineers, including their experiences in the three countries mentioned above, as well as other countries in which the interviewees had experience.

(1) Interviewee

Of the surveyed projects in Section 2.1, the projects in which interviewees participated are as follows:

- ✓ PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF THE PHILIPPINES
- ✓ PREPARATORY SURVEY REPORT ON THE PROJECT FOR IMPROVEMENT OF EQUIPMENT FOR DISASTER RISK MANAGEMENT IN REPUBLIC OF INDONESIA
- ✓ PREPARATORY SURVEY REPORT FOR DISASTER MANAGEMENT SYSTEM PLAN IN THE REPUBLIC OF FIJI

In addition to the above projects, the interviewees have experience in planning, preparing, installing seismic observation systems, as well as supporting the operation and management in other developing countries. Some of the projects they are involved in are listed below:

- ✓ THE PROJECT FOR EVALUATION AND MITIGATION OF SEISMIC RISK FOR COMPOSITE MASONRY BUILDINGS IN BHUTAN
- ✓ ENHANCEMENT OF EARTHQUAKE AND VOLCANO MONITORING AND EFFECTIVE UTILIZATION OF DISASTER MITIGATION INFORMATION IN THE PHILIPPINES
- ✓ PROJECT ON CAPACITY DEVELOPMENT FOR DISASTER RISK MANAGEMENT IN CENTRAL AMERICA, PHASE 2

(2) Survey Items

Survey items are as follows:

- ✓ Considerations for the maintenance of the seismic observation system during the preparation survey
- ✓ Current situation of the observing organization
- ✓ Others

2.2.2 Survey Results

(1) Considerations for the maintenance of the seismic observation system during the preparation survey

1) Perspectives on the preparation of observation equipment

The following issues were considered by the interviewees on the preparation of observation equipment:

- ✓ Solar panels were used since the power supply was unstable. The power supply is unstable in most developing countries.
- ✓ Since the voltage was unstable, additional devices such as UPS were installed.
- ✓ Since the area was prone to lightning strikes, experts installed a lightning surge protection device.
- ✓ Since it was raining a lot, experts took measures to protect the building.
- ✓ Experts added an equipment that can send SOH (State of Health) to the central monitoring system and control it from a central location.
- ✓ Experts chose a manufacturer that could provide support through a local distributor. It is difficult to select Japanese manufacturers because they do not have local support systems.
- ✓ Experts selected equipment with a wide range of operating temperatures to be used for observation in locations with drastic temperature changes.
- ✓ Since there was a possibility of submersion in water, water-resistant equipment was selected.
- ✓ In Turkmenistan, optical fibers were used for communication lines whenever possible.
- ✓ In Myanmar, the communication environment was poor in many places, and it was necessary to check the logs on site.
- ✓ In the Philippines, experts did not need to consider the installation environment because experts were updating the existing observation points.
- ✓ In Tonga, the equipment provided had failed and was replaced. In Fiji, satellite equipment was replaced so that data from Tonga could also be received.
- ✓ In Bhutan, as part of the SATREPS work, experts first installed used equipment from Kyoto University and the Disaster Prevention Research Institute. For the seismic intensity meter, experts procured low-cost equipment with the same configuration (Raspberry-Pi) as in the Philippines.

2) Perspective on operation

The following were considered by the interviewees on the preparation of operation and maintenance:

- ✓ An operation manual for local staff was prepared at the time of introduction.
- ✓ On-the-job training on the operation of equipment and systems was conducted at the time of installation.
- ✓ When digital seismographs were introduced for the first time, it was necessary to provide training on the handling of digital equipment.
- ✓ A secure installation site was selected to prevent theft and destruction of observation

equipment.

- ✓ An SOP was created to establish a system for daily data collection, processing, and management. The processing and management does not include technical manuals such as how to check seismic profiles.
- ✓ The roles of each organization, including regional observatories and headquarters, were defined.
- ✓ If the main purpose is not to provide early warnings but to analyze data for seismic countermeasures, it would be effective to outsource the analysis to universities.
- ✓ In addition to the national observation period, there are countries where earthquake observation is conducted by universities and the private sector. For these countries, it is also necessary to consider the data distribution system.
- ✓ Since private companies such as electricity and gas companies have financial resources, it may be effective to have private companies develop observation systems and share the data.
- ✓ In order to operate the observation system for disaster prevention, cooperation among universities and engineering organizations is also necessary.
- ✓ In the Philippines, experts did not have to worry about lack of skills because experts had staff with a lot of experience in telemetered weak-motion observation. The analysis software for the broadband seismograph was provided by NIED, but the display software was developed by local staff.
- ✓ Tonga had inadequate budget and staffing for maintenance and management, and the system was not functioning and had been abandoned. On the other hand, Fiji was able to secure a system to observe earthquakes. Therefore, during the follow-up, the observation system was integrated with Fiji to reduce maintenance costs and strengthen the system by sharing technical information.
- ✓ Fiji had 20 years of experience, including JICA's analog seismic observation network since 1980, so there were no major problems.

3) Others

- ✓ In Myanmar, it was more effective to gather the staff of local observatories at the headquarters for group training than to make rounds.
- ✓ In Tonga, the technical cooperation ended with the installation and operation of satellite telemetry equipment and did not extend to instruction on analysis. In developing countries, experts believe that it would be easier for staff to maintain the network if private internet connections (3G, 4G) were used as a means of communication.
- ✓ Bhutan has had incidents such as communication problems with the telemetering network and hacker intrusion, but they have not been able to respond because they do not have IT engineers who can solve these problems. There were no problems with the seismic intensity meter.

(2) The current situation of the observing organization

1) Operation

The following items are lessons learned from observation agencies after technical cooperation.

- ✓ In Myanmar, follow-up operations for repairs were carried out, and regular inspections and replacement of parts for malfunctioning equipment were carried out as well.
- ✓ In the Philippines, IT seismographs could not be installed due to problems in the communication environment, and follow-up operations are being conducted.
- ✓ In Tonga, follow-up work is being conducted for a World Bank project. Experts are considering the adoption of communication by those who use internet connection. There had been no issues reported in Fiji.
- ✓ In Bhutan, six telemetered weak-motion seismographs have been shut down due to communication and security problems, and solutions are currently being considered and proposed.

2) Good practice to be conducted by local staffs

The items listed below are good practices for observing organizations following technical cooperation.

- ✓ In Myanmar, the country purchased its own seismographs and conducted observations.
- ✓ In Chile, a university conducted strong-motion observation and shared data with other universities and researchers.
- ✓ In Guatemala, a private university had established its own seismic observation network which was disseminated via the internet.
- ✓ In Nicaragua, a 24-hour observation system was operated by junior staff of the Meteorological Observatory. Because of the damage caused by tsunamis in the past, the country has a high awareness of the need to disseminate information.
- ✓ In Honduras, they used observation data from neighboring country Nicaragua.
- ✓ In Colombia, there was a collaboration between the government and universities, with the government conducting strong-motion observation and the universities conducting analysis.
- ✓ In Mexico, a ground survey was conducted using constant microtremor measurements at strong-motion observation points for the purpose of studying earthquake resistance.
- ✓ In the Philippines and Fiji, on-site work was carried out by local staff only.
- ✓ In the Philippines, all of the systems for receiving, displaying, processing, and archiving seismic intensity data are manufactured by local staff.
- ✓ The Bhutanese seismograph program is being modified by local staff.

(3) Others

- ✓ There are several textbooks on seismology in Japan, but there are no textbooks on seismic observation in developing countries (textbooks are available in English-speaking countries).

- ✓ In many developing countries, there are no courses in seismology at universities, and only a portion of the geology department deals with earthquakes.
- ✓ It is necessary to consider cooperation that includes not only the installation of equipment, but also maintenance, information transmission, data sharing, and utilization.
- ✓ It is important to spread seismic observation not only to national observatories, but also to private organizations with funds, such as electric power and gas companies. Since national observatories have limited funding resources, a system that includes the private sector by providing data for a fee would be effective.
- ✓ In developing countries, there are few people who want to work for seismological organizations. In Turkmenistan, geology students are employed in the field of oil, gas, and mineral resources.
- ✓ The Japanese Meteorological Agency seismic intensity scale can be obtained with Japanese seismographs, but they are also equipped with systems that can be used for earthquake disaster prevention and monitoring of infrastructure facilities, and they are relatively inexpensive. The system is expected to be widely used in developing countries by private companies with financial resources.
- ✓ It would be effective to standardize the seismic data processing system and share the technology for use.
- ✓ Seismic intensity meters should remain inexpensive, and multi-point observations should be made to quickly grasp the disaster situation near the epicenter and determine the cause of the disaster.

Chapter 3 Discussions and Recommendation

JET has collected data and conducted an interview survey to understand key points and best practices from past experiences, such as a establishing stable observation status, bringing efficiency to the quality and the maintenance system, and maintaining observing accuracy.

JET collects good practices and suggests tasks for action in Indonesia and in other countries based on the results of this survey.

3.1 Discussion and Recommendation

(1) Perspectives on the preparation of observation equipment

1) Provision of equipment to provide a stable electric supply

Unlike developed countries such as Japan, it has been confirmed that there are many places in developing countries where electric power is unstable (voltage is not uniform and there are many power outages due to lightning strikes). As a countermeasure for this, the following equipment items are often installed:

- ✓ Lightning surge
- ✓ Solar power generation
- ✓ Battery, uninterruptible power supply

It is important to have a proper understanding of the power situation at the delivery site to guarantee stable operation of the equipment.

2) Provision of communication equipment to be maintained and operated on site

Although data communication is carried out using dedicated lines, dedicated analog radios, satellite communication, etc., it has been confirmed that there are cases in which the equipment is left unattended when it breaks down due to the lack of personnel in the field with knowledge of these methods. On the other hand, guaranteed lines are being offered for private communication lines, and installation and maintenance are simplified because they use the same technology as smartphones.

For sensitive equipment such as broadband seismographs, it is important to use dedicated lines, unless the equipment is to be installed in an area where only a few people visit, so that local staff can easily maintain and operate the communication environment.

3) Provision of equipment that can operate in harsh local environments

In developing countries, equipment may have to be installed in areas where the temperature changes rapidly, such as desert areas, or where there is a high risk of flood inundation. When installing Japanese equipment, it is necessary to select an equipment that has a guaranteed operating temperature and water resistance. If the equipment is to be installed in a place where the temperature exceeds the guaranteed operating temperature, it is important to conduct an operation verification test.

(2) Perspective of operation of observation equipment

1) Definition of organization and roles

Observation systems operate differently depending on whether the purpose is to analyze data or to disseminate early warning information. Therefore, in an organizational unit, it is important to define the roles of data acquisition, collection, analysis, provision, and archives. It is also beneficial to collaborate with universities and academic societies (engineering organizations) for data analysis.

2) Comprehensive technology transfer, including maintenance and management

Many of the projects where equipment is provided include the preparation of operation manuals and provision of local staff training. However, there are some projects that are left unattended because the project managers lack expertise to deal with equipment breakdowns after the start of the operation. There are also cases where the equipment has been rendered unusable by hackers due to lack of technical training on how to check seismic waveforms and the lack of local staff who can take cyber security measures and respond to incidents.

Rather than a project that ends with the installation of equipment, it is important to implement a comprehensive project that includes operation and maintenance.

(3) Others

Although not directly related to the efficient maintenance of seismic observation, the following summary shown below may be useful from a medium- to long-term perspective.

1) Establishment of an educational system for seismic observation

There are several Japanese textbooks on seismology in Japan, but there are no local language textbooks on seismic observation in developing countries. For this reason, many developing countries do not offer seismology courses in universities. By disseminating textbooks on seismology in local languages and raising the level of knowledge, it is hoped that the shortage of human resources in developing countries can be resolved from a medium- to long-term perspective.

2) Cooperation with private companies with financial resources

Even in developing countries, companies that provide infrastructure such as electricity and gas are said to have financial resources, and these companies are also said to a have high need for earthquake observation. Therefore, it would be effective to establish a data distribution system in which the public and private sectors collaborate, where private companies develop observation systems and the public sector uses the data. It would also be effective to integrate and manage observation systems in collaboration with smaller countries that have similar environments.

3.2 Task for Action in Developing Countries Including Indonesia

Based on discussions and recommendations, JET recommends agencies of developing countries to consider the following points in the next action for improving seismic observation capacity and maintenance ability in Indonesia and in developing countries.

Table 3.1 Tasks for improving seismic observation capacity and maintenance ability

Categories	Items
Preparation	(1) To check the conditions of electric supplies
	(2) To check the conditions of telecommunication supplies
	(3) To check site climate conditions such as participants, temperature and others
	(4) To check skills of local staff regarding the installation of observation equipment
Operation and maintenance	(1) To consider the possibility of cooperation with universities and institutes in the areas of roles observation, analysis and accumulation
	(2) To check the skills of local staff regarding the operation and management of observation equipment
Others	(1) To consider an educational system for seismic observation and analysis
	(2) To consider the possibility of cooperation with private infrastructure companies

For the project activity in Indonesia, confirming the status of the above measures and extracting issues are conducted in the baseline survey as needed. Based on the baseline results, the work plan will be modified to reflect the current situation and to implement effective and feasible activities related to the issues.

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APPENDIX 8-14

The Study of Quality Management in Maintenance for Observation System for Tide in Japan

The Study of Quality Management in Maintenance for Observation System for Tide in Japan

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

March 2021

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
BIG	Geospatial Information Agency (Indonesian: Badan Informasi Geospasial)
BMKG	Meteorological, Climatological, and Geophysical Agency (Indonesian: Badan Meteorologi, Klimatologi, dan Geofisika)
CMDC	Coastal Movements Data Center
GSI	Geospatial Information Authority of Japan
JCG	Japan Coast Guard
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
NOWPHAS	Nationwide Ocean Wave information network for Ports and HArbourS
PHB	Ports and Harbours Bureau, MLIT
SOH	State of Health

Chapter 1 Introduction

1.1 Background

The counterpart (C/P), BMKG, is responsible for issuing early warning for tsunami, earthquake and other disasters to residents in Indonesia. However, the operation rate of observation systems for tides and tsunamis is quite low and not enough to ensure the satisfactory issuances of early warning. One of the main causes of this is that the maintenance system, including the skills of staff members and the guidelines / manuals / SOP for observation system (i.e., equipment for measuring tides and control system) is insufficient.

1.2 Objective of the Study

This study investigated the current state of quality maintenance management of tide level observation systems in Japan, and analyzed the basic technologies, mechanisms, and ingenuity for maintaining work efficiency and observation accuracy. This study includes the interview of several Japanese organizations which manage the observation systems for tides and tsunamis (i.e., JMA, GSI, PHB-MLIT, and JCG). The results of this study can be used for other technical cooperation projects.

Chapter 2 Data Collection and Interview Survey

2.1 Outline

The quality management methods of observation systems for tides and tsunamis by Japanese major operational organizations (i.e., JMA, GSI, PHB-MLIT, and JCG) were collected by conducting interview surveys and document research such as users' guideline and manuals of operational organizations.

(1) Methods of Research

- Internet research
- Interview survey

(2) Targets of Research

- JMA: Japan Meteorological Agency
- GSI: Geospatial Information Authority of Japan
- PHB: Ports and Harbours Bureau, MLIT (Ministry of Land, Infrastructure, Transport and Tourism)
- JCG: Japan Coast Guard

2.2 Basic Information on Tide Observation

(1) Observation facility

The tide station is a small structure that can accommodate several people, as shown in the photo below. There is a well in the building, which is connected to the sea through a water pipe. This water pipe inside the well functions to provide a water surface height that is the same as the sea level outside. The tide level is observed by using a radio wave type or float type tide gauge installed at the tide gauge. The tsunami observatory is installed in a corner of the harbor without a tide station building, and the tide level is observed by radio wave or sound wave method.

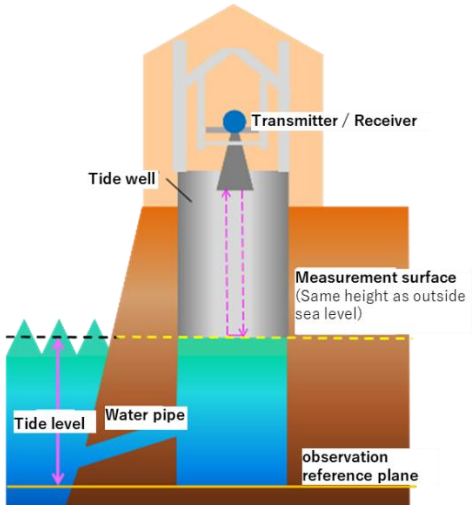
Source: JMA

Figure 2.1 Appearance of a tide station

(2) Types of tide gauge

1) Radio wave gauge

It is a device that observes the tide level by emitting radio waves from a transmitter / receiver installed above the well toward the water surface and measuring the time until they are reflected and returned back.

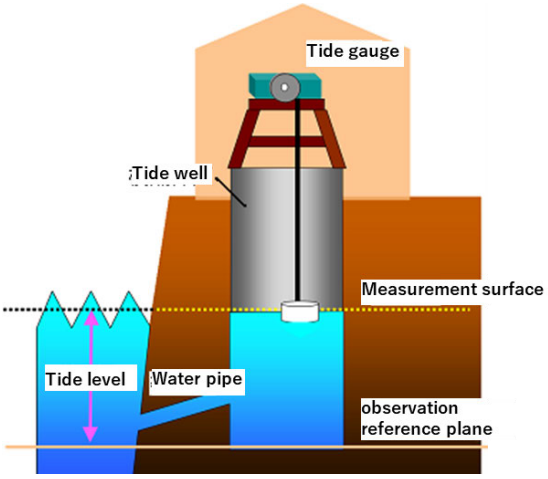


Source: JMA

Figure 2.2 A radio wave type gauge

2) Float gauge

A float is placed on the well of the tide station to measure the tide level. The float moves up and down according to the vertical movement of the sea surface, and this floating movement is measured with an instrument installed in the well. This is the oldest type of tide gauge.



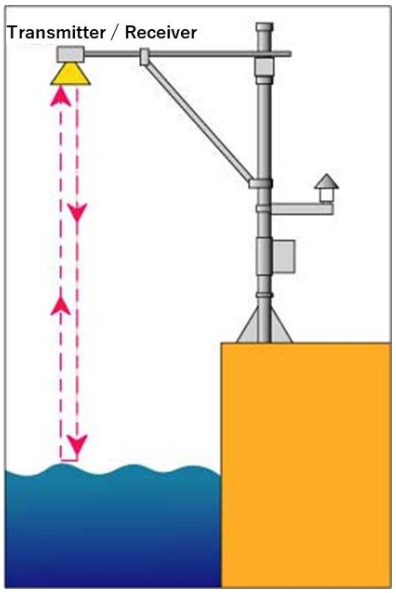
Source: JMA

Figure 2.3 A float type gauge

3) Ultrasound wave tsunami gauge

This gauge calculates the tide level from the time it takes for the ultrasonic waves to be emitted toward the sea surface, reflected, and returned back.

It is installed on the dike or quay of a harbor where the waves are quiet, instead of putting it inside a well.



Source: JMA

Figure 2.4 An ultrasound wave tsunami gauge

4) Radio wave tsunami gauge

Similar to the radio wave type tide gauge, the tide level is calculated from the time it takes for the radio waves to be emitted toward the sea surface, reflected, and returned back.

It is also installed on the dike or quay of a harbor where the waves are quiet.

Source: JMA

Figure 2.5 A radio wave tsunami gauge

5) Distant tsunami observer

In the past, a tsunami caused by a large earthquake near South America crossed the Pacific Ocean in about a day and caused great damage to the coast of Japan (the 1960 Chile earthquake tsunami). The "distant tsunami observer" is the observation device installed to detect remote tsunamis crossing the Pacific Ocean before reaching the mainland of Japan. This is installed on the seabed near Minamitorishima, the southeasternmost point of Japan. The water pressure is measured with a pressure sensor, and the height of the seawater above it is calculated.

Source: JMA

Figure 2.6 A distant tsunami observer

2.3 Data Collection Survey

Information on the following items related to quality management in maintenance method or observation sites of key organizations were collected through internet research.

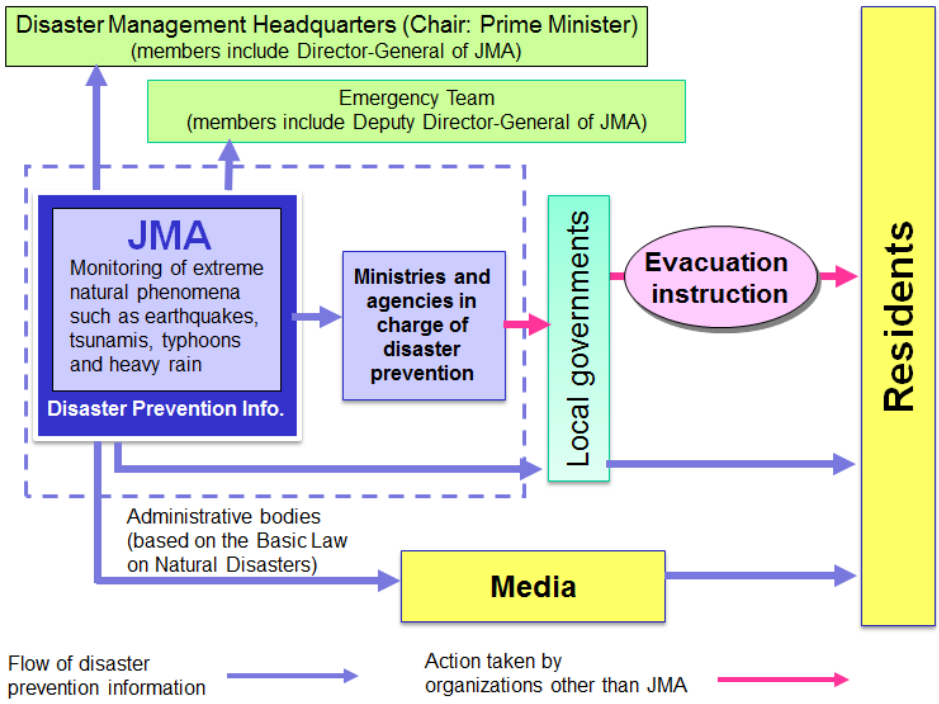
- Observation sites
- Equipment for observation
- Tender documents for operation and maintenance of observation system

2.3.1 Japan Meteorological Agency (JMA)

(1) Mission and Organizational Structure

As part of Japan's government, the Japan Meteorological Agency (JMA) implements its services with the following ultimate goals in compliance with the Act for Establishment of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Meteorological Service Act.

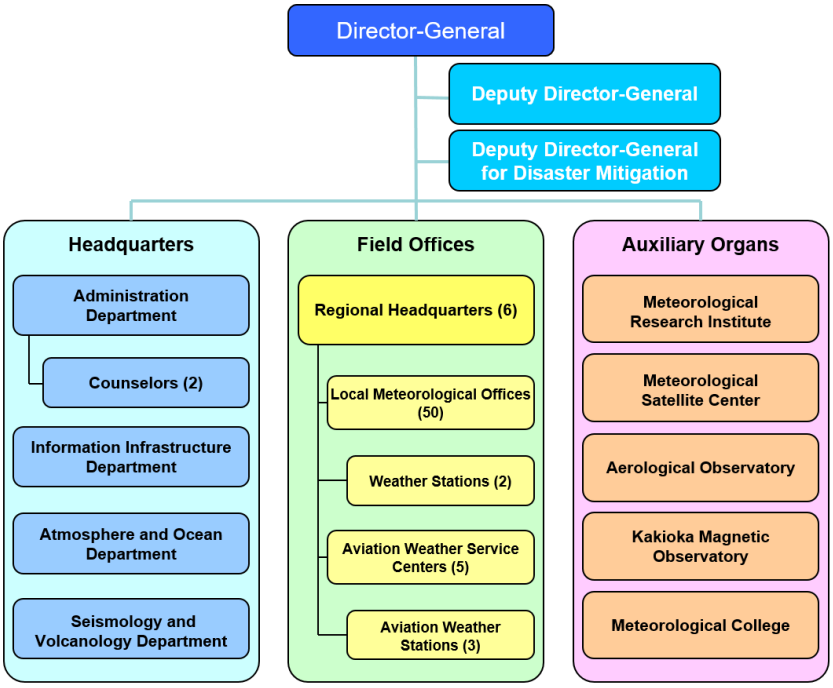
- Prevention and mitigation of natural disasters
- Safety of transportation
- Development and prosperity of industry
- Improvement of public welfare



Source: JMA

Figure 2.7 Disaster Prevention Operation Schemes and Role of JMA

JMA is comprised of the headquarters, regional headquarters, local meteorological offices and weather stations, and auxiliary facilities.

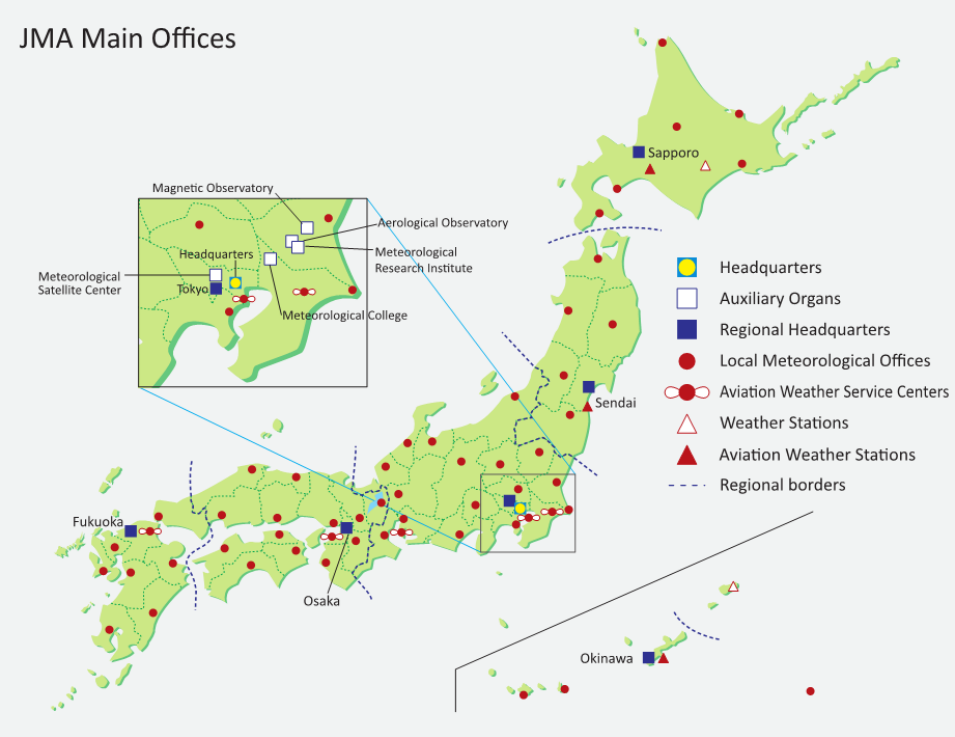


Source: JMA

Figure 2.8 Organizational Structure of JMA

To provide a wide range of services for local communities, JMA operates a number of observatories and weather stations across the country. The Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Okinawa Regional Headquarters (RHQs) serve as regional central offices directing 50 Local Meteorological

Offices (LMOs) and 2 weather stations, both of which provide information services at the prefectural and sub-prefectural levels.



Source: JMA

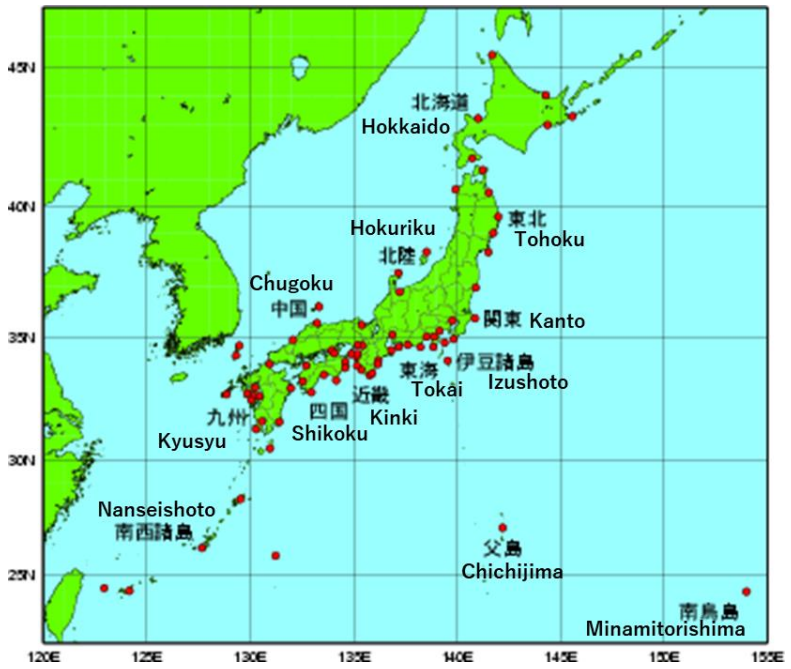
Figure 2.9 JMA Main Offices

(2) Observation of Tides and Tsunamis

JMA constantly observes the tide level using a tide station and tsunami observer.

1) Location of tide observation points

Tide observation points are used to monitor water levels. These are used to detect tsunami after an earthquake and helps in issuing tsunami warning. These are also used for monitoring daily or annual water level along Japan coast to check sea level rise caused by climate change around Japan.



Source: JMA

Figure 2.10 Locations of Tide Observation Points (JMA)

2) List of tide observation points

JMA monitors water elevation in 70 tide stations along Japan coast.

Table 2.1 List of JMA Tide Stations

No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation
1	Wakanai	45°24'	141°41'	Radio wave type
2	Abashiri	44°01'	144°17'	Radio wave type
3	Hanasaki	43°17'	145°34'	Radio wave type
4	Kushiro	42°59'	144°22'	Radio wave type
5	Hakodate	41°47'	140°43'	Radio wave type
6	Otaru	43°12'	141°00'	Radio wave type
7	Shimokita	41°22'	141°14'	Radio wave type
8	Miyako	39°39'	141°59'	Radio wave type
9	Ofunato	39°01'	141°45'	Radio wave type
10	Ayukawa	38°18'	141°30'	Radio wave type
11	Onahama	36°56'	140°54'	Radio wave type
12	Mera	34°55'	139°50'	Radio wave type
13	Tokyo	35°39'	139°46'	Radio wave type
14	Okada	34°47'	139°23'	Radio wave type
15	Miyakejima (Tsubota)	34°03'	139°33'	Radio wave type
16	Chichijima	27°06'	142°12'	Radio wave type
17	Minamitorishima	24°17'	153°59'	Water pressure type
18	Odawara	35°14'	139°09'	Radio wave type
19	Ishirozaki	34°37'	138°51'	Radio wave type
20	Uchiura	35°01'	138°53'	Radio wave type
21	Shimizuminato	35°01'	138°31'	Radio wave type
22	Omaezaki	34°37'	138°13'	Radio wave type
23	Maisaka	34°41'	137°37'	Radio wave type

No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation
24	Akabane	34°36'	137°11'	Radio wave type
25	Nagoya	35°05'	136°53'	Radio wave type
26	Toba	34°29'	136°49'	Radio wave type
27	Owase	34°05'	136°12'	Radio wave type
28	Kumano	33°56'	136°10'	Radio wave type
29	Uragami	33°34'	135°54'	Radio wave type
30	Kushimoto	33°29'	135°46'	Radio wave type
31	Shirahama	33°41'	135°23'	Radio wave type
32	Gobou	33°51'	135°10'	Radio wave type
33	Wakayama	34°13'	135°09'	Radio wave type
34	Tannoa	34°20'	135°11'	Radio wave type
35	Osaka	34°39'	135°26'	Radio wave type
36	Kobe	34°41'	135°11'	Radio wave type
37	Sumoto	34°21'	134°54'	Radio wave type
38	Uno	34°29'	133°57'	Radio wave type
39	Matsuyama	33°52'	132°43'	Radio wave type
40	Takamatsu	34°21'	134°03'	Radio wave type
41	Komatsujima	34°01'	134°35'	Radio wave type
42	Awayuki	33°46'	134°36'	Radio wave type
43	Murotomisaki	33°16'	134°10'	Radio wave type
44	Kochi	33°30'	133°34'	Radio wave type
45	Tosashimizu	32°47'	132°58'	Radio wave type
46	Uwajima	33°14'	132°33'	Radio wave type
47	Saiki	32°57'	131°58'	Radio wave type
48	Aburatsu	31°35'	131°25'	Radio wave type
49	Kagoshima	31°36'	130°34'	Radio wave type
50	Makurazaki	31°16'	130°18'	Radio wave type
51	Tanegashima	30°28'	130°58'	Radio wave type
52	Atsumi	28°19'	129°32'	Radio wave type
53	Naha	26°13'	127°40'	Radio wave type
54	Minamidaito	25°52'	131°14'	Radio wave type
55	Ishigaki	24°20'	124°10'	Radio wave type
56	Yonagunijima	24°27'	122°57'	Radio wave type
57	Reihoku	32°28'	130°02'	Radio wave type
58	Oura	32°59'	130°13'	Radio wave type
59	Kuchinotsu	32°36'	130°12'	Radio wave type
60	Nagasaki	32°44'	129°52'	Radio wave type
61	Fukue	32°42'	128°51'	Radio wave type
62	Tsushimahitakatsu	34°39'	129°29'	Radio wave type
63	Hamada	34°54'	132°04'	Radio wave type
64	Sakai	35°33'	133°15'	Radio wave type
65	Saigo	36°12'	133°20'	Radio wave type
66	Maizuru	35°29'	135°23'	Radio wave type
67	Noto	37°30'	137°09'	Radio wave type
68	Toyama	36°46'	137°13'	Radio wave type
69	Sado	38°19'	138°31'	Radio wave type
70	Fukaura	40°39'	139°56'	Radio wave type

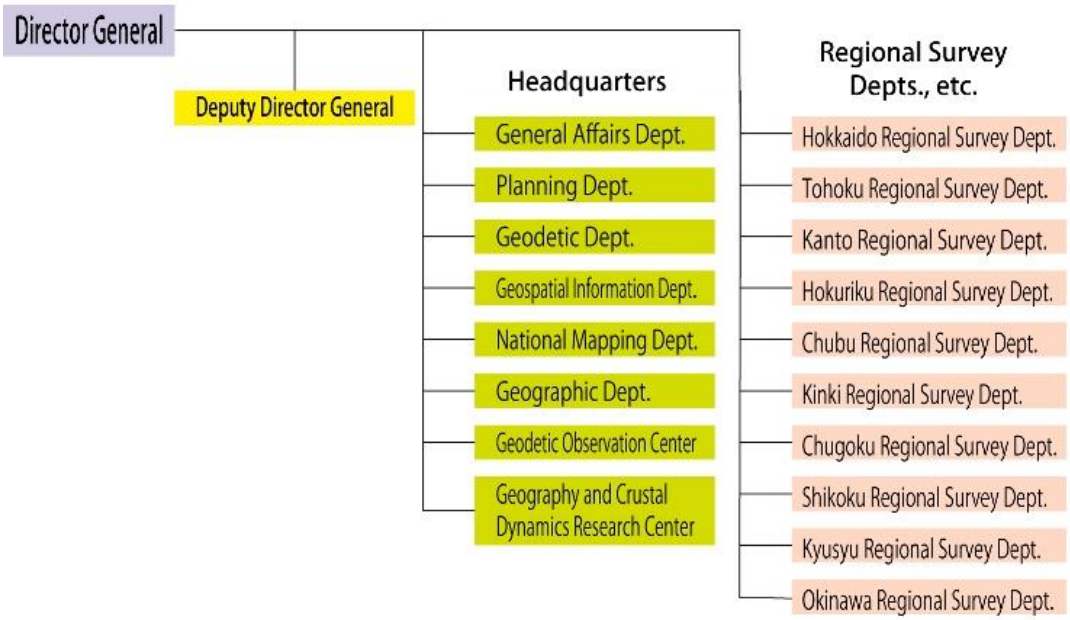
Source: JMA

2.3.2 Geospatial Information Authority (GSI)

(1) Overview and Organizational Structure

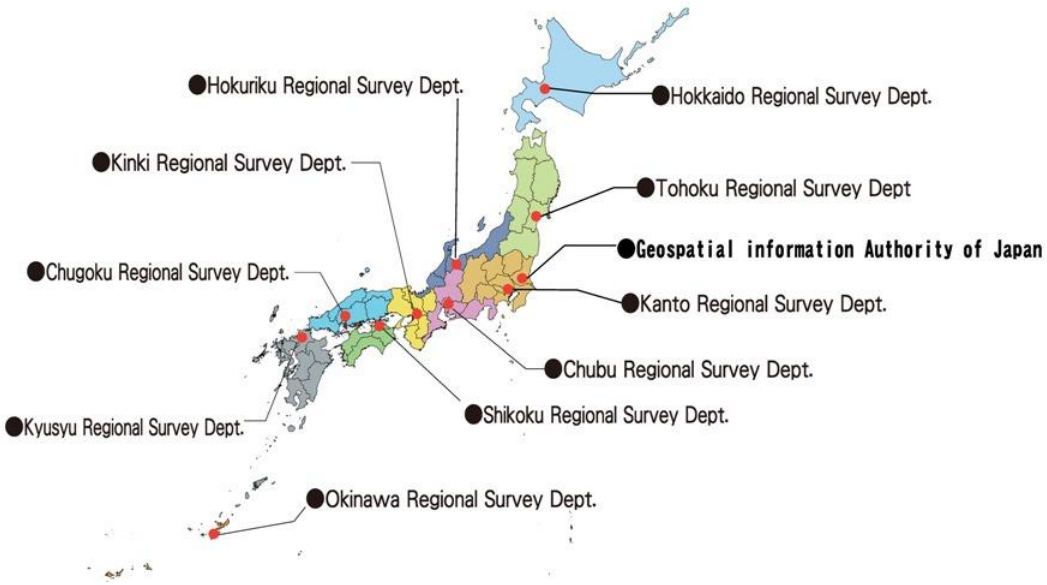
GSI, being the competent authority of the Survey Act, conducts national surveying and mapping activities which provide basis for land management.

As the country's foremost map-making organization, GSI is promoting the development, updating and promotion of geospatial information in adherence with the Survey Act and the Basic Act on the Advancement of Utilizing Geospatial Information, and is making a continuous effort toward the realization of a "geospatially enabled society" where geospatial information can be available and utilized by anyone, anytime, anywhere.



Source: GSI

Figure 2.11 Organizational Structure of GSI



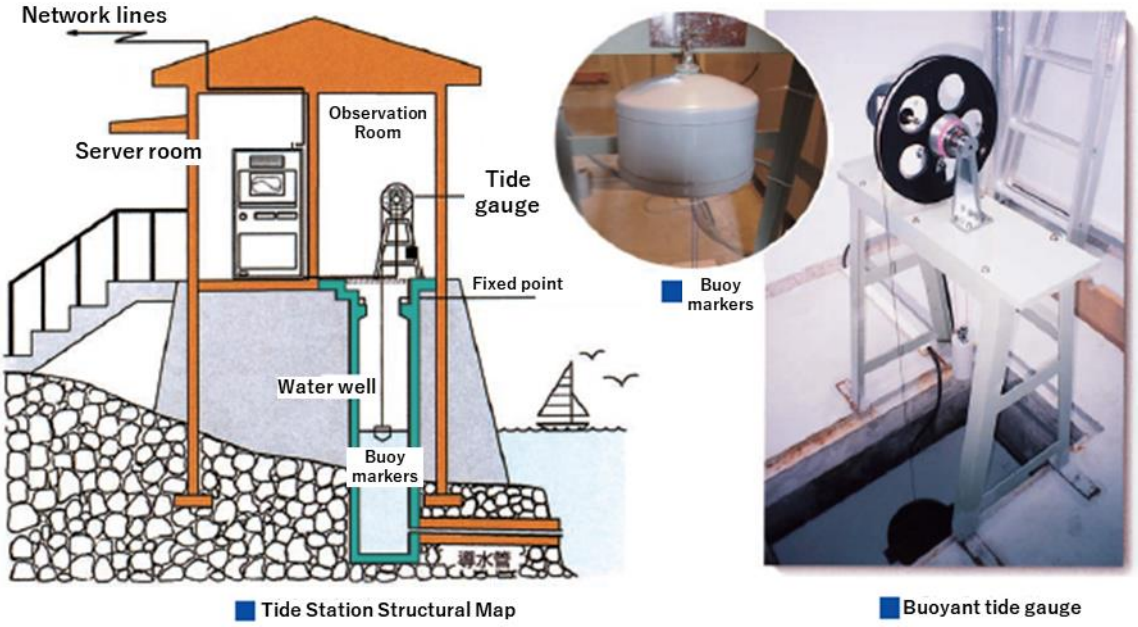
Source: GSI

Figure 2.12 Locations of GSI Head Office and Regional Offices

(2) Observation of Tides

The basic structure of the tide gauge setup by GSI consists of a well, a water pipe, an observation room (tide gauge room), and a computer room.

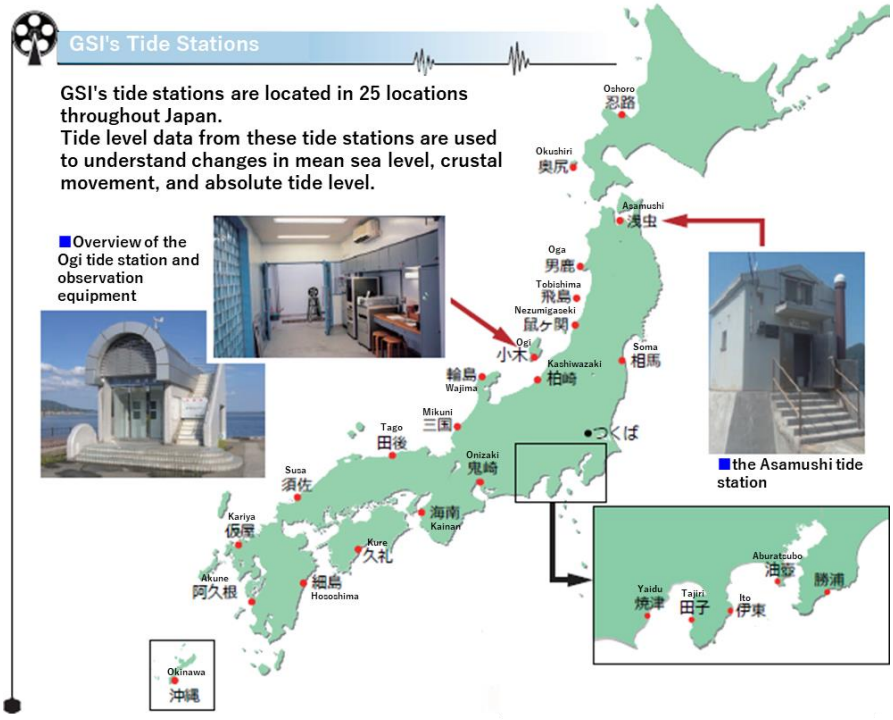
The tide gauge records the up-and-down movement of seawater which is entering and exiting through the water pipe. Such movement can be measured by capturing the movement of the buoy suspended from the tide gauge in the well. GSI employs the float type tide gauge for all stations.



Source: GSI

Figure 2.13 Tide observation at GSI

GSI has 25 tide stations in Japan's coasts. The tide level data in the fields set up nationwide are used to grasp the average sea level, crustal movements, changes in absolute tide levels, etc.



Source: GSI

Figure 2.14 Locations of GSI's Tide Observation Points

Table 2.2 List of GSI Tide Stations

No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation	Starting year
1	Aburatsubo	35°10'	139°37'	Float type	1894/07
2	Hososhima	32°26'	131°40'	Float type	1894/01
3	Wajima	37°24'	136°54'	Float type	1894/01
4	Oshoro	43°13'	140°52'	Float type	1905/11
5	Kainan	34°09'	135°12'	Float type	1953/02
6	Asamushi	40°54'	140°52'	Float type	1954/05
7	Nezumigaseki	38°34'	139°33'	Float type	1955/03
8	Kashiwazaki	37°21'	138°31'	Float type	1955/06
9	Onizaki	34°54'	136°49'	Float type	1963/01
10	Tajiri	35°36'	134°19'	Float type	1966/01
11	Katsuura	35°08'	140°15'	Float type	1967/06
12	Mikuni	36°15'	136°09'	Float type	1967/12
13	Kure	33°20'	133°15'	Float type	1972/06
14	Oga	39°57'	139°42'	Float type	1970/01
15	Akune	32°01'	130°11'	Float type	1970/07
16	Susa	34°38'	131°36'	Float type	1992/01
17	Kariya	33°28'	129°51'	Float type	1972/02
18	Soma	37°50'	140°58'	Float type	1973/05
19	Ito	34°54'	139°08'	Float type	1973/07
20	Ogi	37°49'	138°17'	Float type	1973/08
21	Okinawa	26°11'	127°49'	Float type	1975/08
22	Tago	34°48'	138°46'	Float type	1977/08
23	Yaidu	34°52'	138°20'	Float type	1977/08
24	Okushiri	42°05'	139°29'	Float type	1994/12
25	Tobishima	39°11'	139°33'	Float type	1995/03

Source: GSI

2.3.3 Ports and Harbours Bureau (PHB)

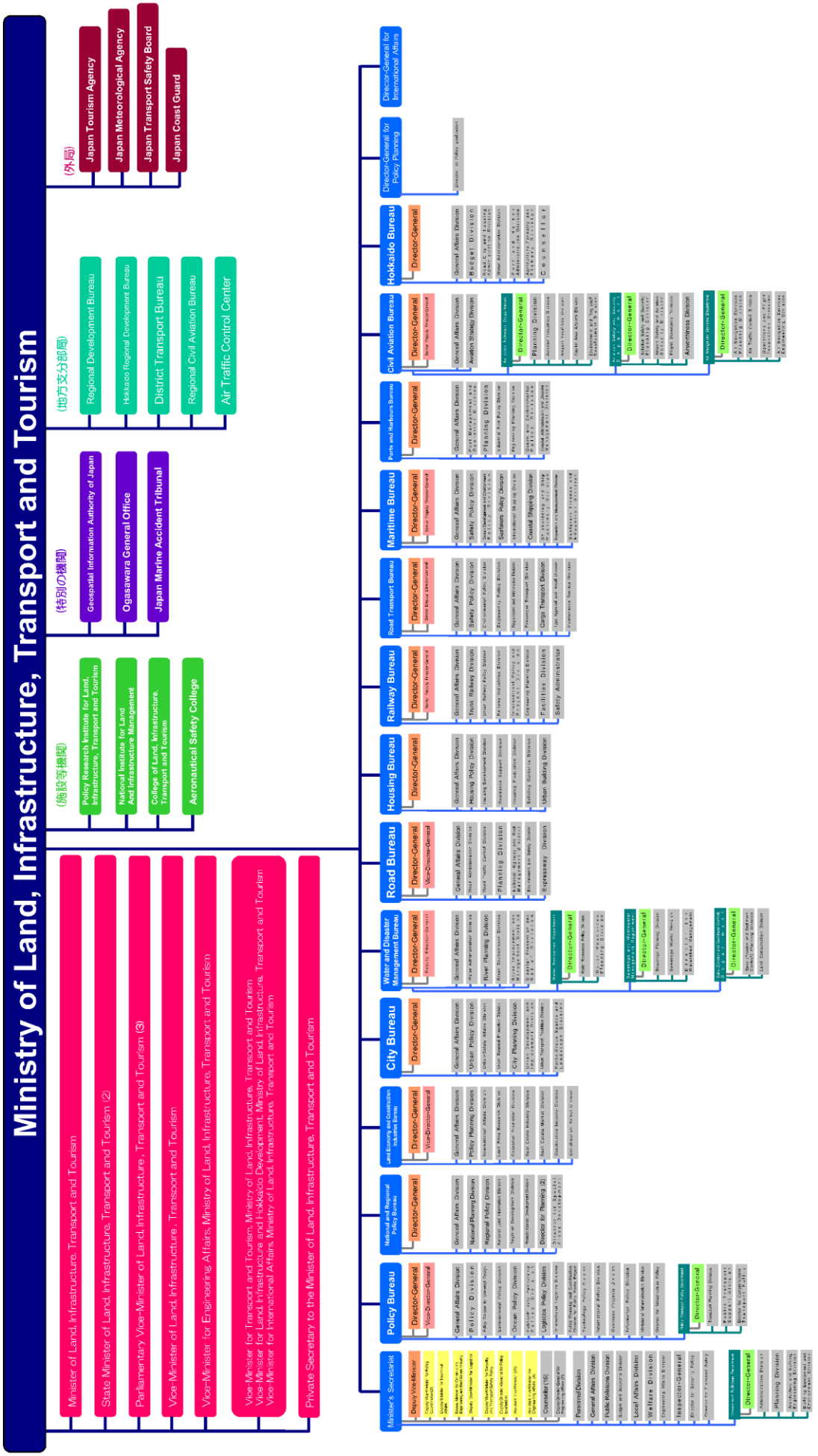
(1) Overview

Japan is a long, narrow island nation traversed in the center by steep mountains. Since ancient times, the country's inhabitants and their activities have been concentrated in the coastal areas, with harbors forming the core.

At present, Japan relies on marine transport to move majority of the goods essential for its inhabitants' daily lives. About 99.7% of all goods involved in foreign trade pass through Japan's ports and harbors; marine transport accounts for 38.7% of all domestic cargo distribution on a ton/kilo basis.

Ports and harbors serve as focal points for the industrial activities that support regional economies. They also function as marine recreation sites, as well as processing areas for sewage and other waste products.

Japan's ports and harbors, therefore, play essential roles in the social and economic activities of its citizens.


Ministry of Land, Infrastructure, Transport and Tourism
Minister of Land, Infrastructure, Transport and Tourism
State Minister of Land, Infrastructure, Transport and Tourism (2)
Parliamentary Vice-Minister of Land, Infrastructure, Transport and Tourism (3)
Vice Minister of Land, Infrastructure, Transport and Tourism
Vice-Minister for Engineering Affairs, Ministry of Land, Infrastructure, Transport and Tourism
Vice-Minister for Transport and Tourism, Ministry of Land, Infrastructure, Transport and Tourism
Vice-Minister for Land, Infrastructure and Hokkaido Development, Ministry of Land, Infrastructure, Transport and Tourism
Vice-Minister for International Affairs, Ministry of Land, Infrastructure, Transport and Tourism
Private Secretary to the Minister of Land, Infrastructure, Transport and Tourism
(施設等機関)
Policy Research Institute for Land, Infrastructure, Transport and Tourism
National Institute for Land And Infrastructure Management
College of Land, Infrastructure, Transport and Tourism
Aeronautical Safety College
(特別の機関)
Geospatial Information Authority of Japan
Ogasawara General Office
Japan Marine Accident Tribunal
(地方支分部局)
Regional Development Bureau
Hokkaido Regional Development Bureau
District Transport Bureau
Regional Civil Aviation Bureau
Air Traffic Control Center
(外局)
Japan Tourism Agency
Japan Meteorological Agency
Japan Transport Safety Board
Japan Coast Guard
Minister's Secretariat
Policy Bureau
National and Regional Policy Bureau
Land Economy and Construction Industries Bureau
City Bureau
Water and Disaster Management Bureau
Road Bureau
Housing Bureau
Railway Bureau
Road Transport Bureau
Maritime Bureau
Ports and Harbours Bureau
Civil Aviation Bureau
Hokkaido Bureau
Director-General for Policy Planning
Director-General for International Affairs

港湾局	Ports and Harbours Bureau
局長	Director-General, Ports and Harbours Bureau
審議官	Deputy Director-General, Ports and Harbours Bureau
技術参事官	Deputy Director-General for Engineering Affairs, Ports and Harbours Bureau
総務課	General Affairs Division
職員管理室	Personnel Office
事業調整官	Director for Project Coordination
港湾管理高度化指導官	Director for Port Administration Advancement
調整官	Director for Port Administration Affairs
港湾経済課	Port Management and Operation Division
港湾物流戦略室	Port Logistics Strategy Office
港湾経済企画官	Director for Port Management and Operation
港運高度化対策官	Director for Advanced Port Transport Development
港湾運送サービス活性化対策官	Director for Port Transport Service Quality Improvement
港湾利用調整官	Director for Port Use Coordination
特定港湾運営会社指導官	Director for Designated Port Operating Company Supervision
港湾情報化企画調整官	Director for Intelligent Port Policy Promotion
計画課	Planning Division
企画室	Planning Office
官民連携推進室	Public-Private-Partnership Promotion Office
計画企画官	Director for Policy Planning
港湾計画審査官	Director for Port Planning
事業企画官	Director for Project Planning
産業港湾課	Industrial Port Policy Division
クルーズ振興室	Cruise Promotion Office
国際企画室	International Policy Planning Office
産業連携企画調整官	Director for Industrial Partnership Planning
首席国際調整官	Chief Director for International Policy
国際調整官	Director for International Policy
技術企画課	Engineering Planning Division
建設企画室	Project Management Office
港湾保全政策室	Port Management Office
技術監理室	Engineering Administration Office
技術企画調整官	Director for Engineering Policy Planning and Coordination
港湾工事安全推進官	Director for Safety Management
品質確保企画官	Director for Quality Control
技術基準調整官	Director for Technical Standards Coordination
国際標準化推進官	Director for International Standardization
港湾技術政策分析官	Director for Port Engineering Policy Analysis
海洋・環境課	Ocean and Environmental Policy Division
海洋利用開発室	Ocean Development Office
港湾環境政策室	Environmental Policy Office
海洋利用調査センター	Coastal Utilization Research Center
海洋汚染対策官	Director for Ocean Environment
海岸・防災課	Coastal Administration and Disaster Management Division
災害対策室	Disaster Risk Management Office
危機管理室	Security and Emergency Management Office
港湾保安対策室	Port Security Management Office
海岸・防災企画官	Director for Coastal and Disaster Management
津波対策企画調整官	Director for Tsunami Disaster Prevention
高潮対策企画調整官	Director for Storm Surge Disaster Prevention
広域連携推進官	Director for Regional Pertnership
総括災害査定官	Director for Disaster Assessment
災害査定官	Deputy Director for Disaster Assessment
首席港湾保安管理官	Chief Port Security Inspector
港湾保安管理官	Port Security Inspector

Source: PHB

Figure 2.15 Organizational Structure of MLIT and PHB

(2) Observation of Tides

Ports and Harbours Bureau (PHB), which is an agency under the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), has observed tides as well as waves along Japan's coasts for a long time. It established the Nationwide Ocean Wave information network for Ports and HArbourS (NOWPHAS) system for integration of observed data on tides and waves as described below.

NOWPHAS has been conducted by the following organizations since 1970 for the purpose of safe marine construction works and cargo handling, port planning, design of port and coastal facilities, and monitoring the long-term change in wave climate.

- Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport, and Tourism (MLIT)
- Tohoku, Kanto, Hokuriku, Chubu, Kinki, Chugoku, Shikoku, and Kyushu Regional Development Bureaus, MLIT
- Hokkaido Bureau, MLIT

- Okinawa General Office, Cabinet Office
- National Institute for Land, Infrastructure and Management (NILIM)
- Port and Airport Research Institute (PARI)

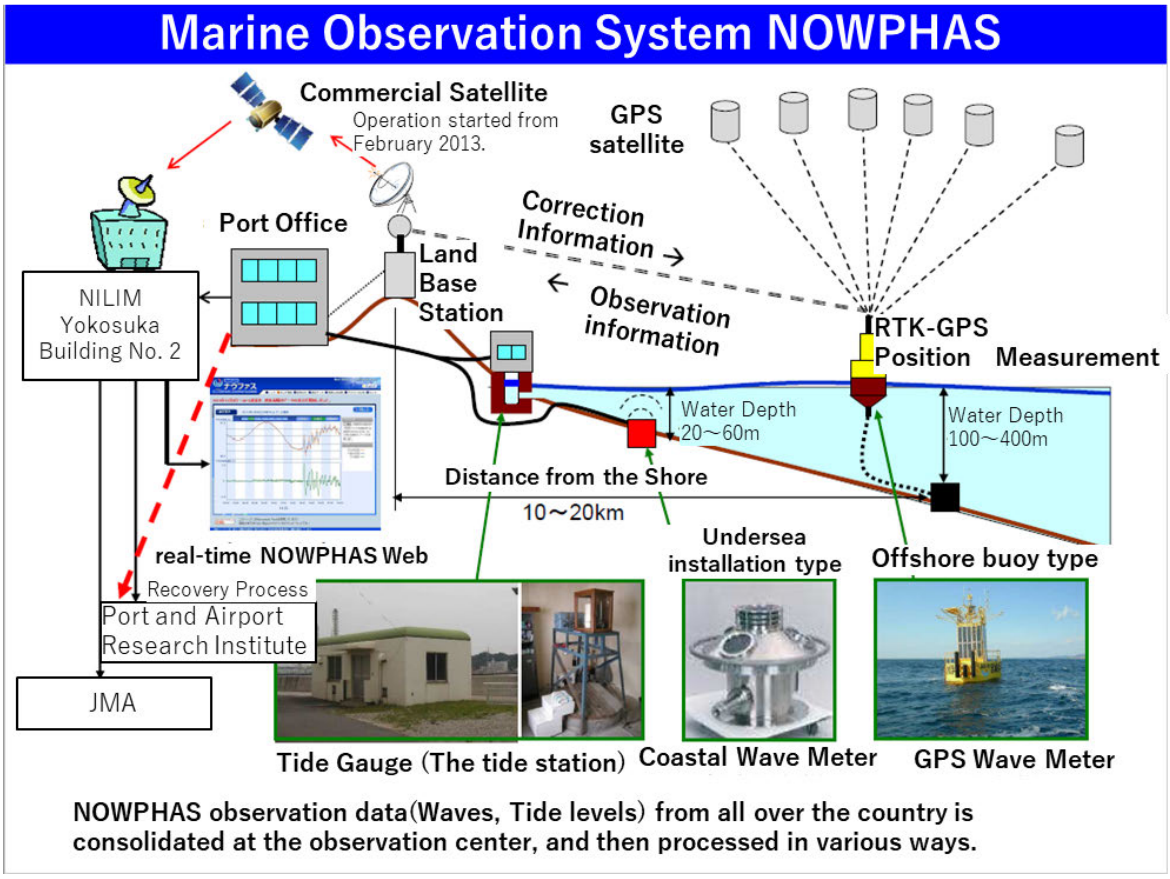
In the joint group, PARI is playing an important role to:

- receive wave data from the port offices of MILT through internet and telephone lines
- calculate wave parameters and provide them on the website 'Real-time NOWPHAS'
- publish annual reports on wave statistics

The network includes the following types of wave gauges at 69 points all over Japan, while wave information at 66 points as shown on the website.

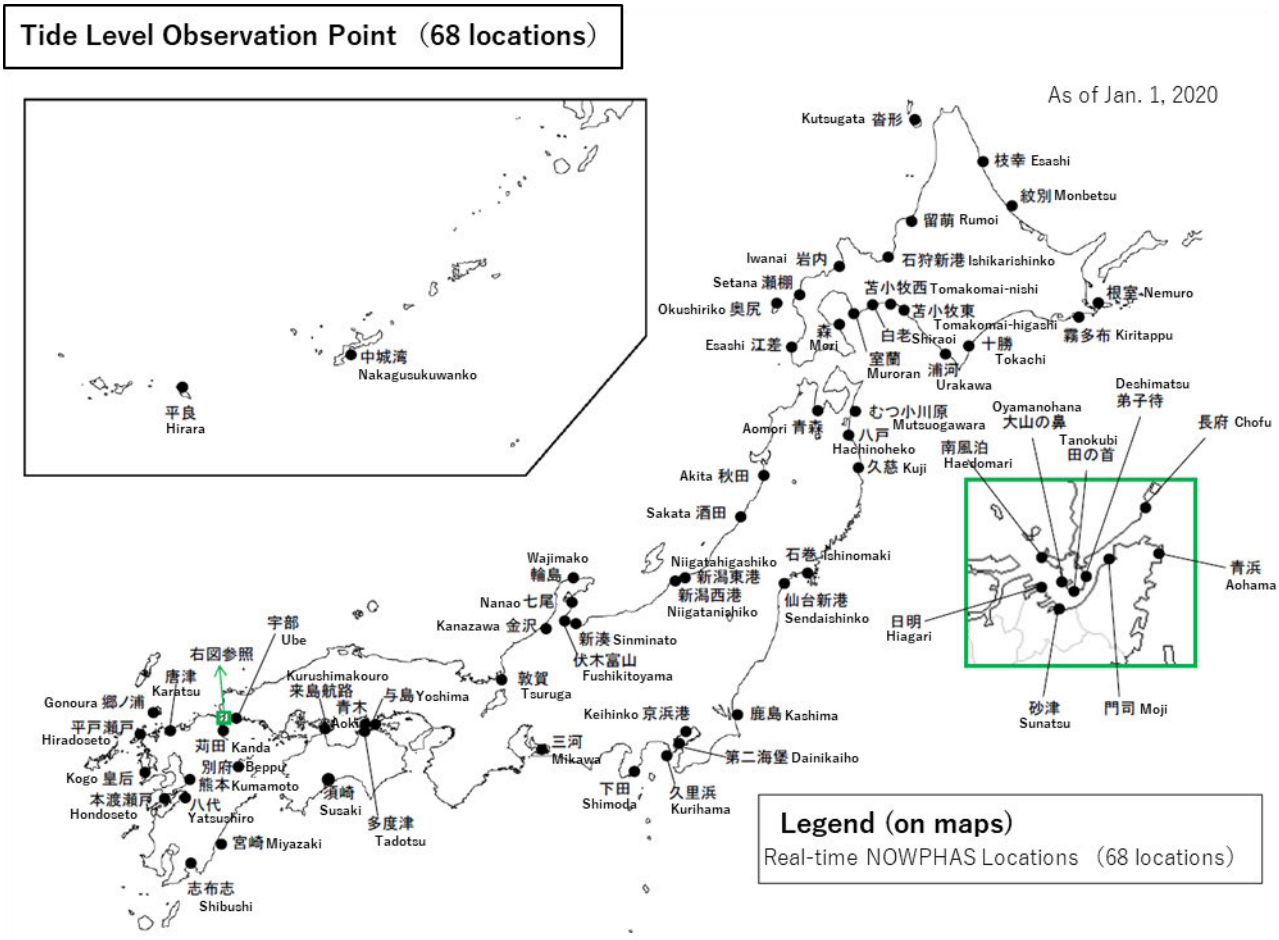
- pressure gauges, measuring the variation of water pressure on the sea bed with time and converting into the water surface profile
- ultrasonic wave gauges, measuring the distance from the sea bottom to the sea surface
- Doppler-type wave directional meters, combining four ultrasonic wave sensors with a pressure sensor, estimating the directional wave spectrum
- moored GPS-mounted buoys, measuring the 3D position of the buoy every one second by using RTK-GPS technology

The seabed gauges (pressure gauges, ultrasonic wave gauges, and Doppler-type wave directional meters) are generally installed at a water depth of 20 to 50 m within a few kilometers from the coast, while the GPS-mounted buoys are moored at a water depth of 100 to 300 m and a distance of 10 to 20 km.



Source: PHB

Figure 2.16 PHB's tide observation and network



Source: PHB

Figure 2.17 Locations of PHB's Tide Observation Points

Table 2.3 List of PHB Tide Stations

No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation
1	Esashi	44°56′	142°35′	Float type
2	Kutsugata	45°11′	141°8′	Float type
3	Rumoi	43°57′	141°38′	Float type
4	Ishikarishinko	43°13′	141°18′	Float type
5	Iwanai	42°59′	140°30′	Ultrasound type
6	Monbetsu	44°21′	143°22′	Float type
7	Nemuro	43°21′	145°35′	Ultrasound type
8	Kiritappu	43°5′	145°7′	Ultrasound type
9	Tokachi	42°18′	143°19′	Float type
10	Tomakomai-higashi	42°36′	141°49′	Float type
11	Tomakomai-nishi	42°38′	141°37′	Float type
12	Muroran	42°21′	140°57′	Float type
13	Shiraoi	42°31′	141°19′	Float type
14	Urakawa	42°10′	142°46′	Float type
15	Mori	42°7′	140°36′	Ultrasound type
16	Setana	42°27′	139°51′	Float type
17	Okushiriko	42°10′	139°31′	Float type
18	Esashi	41°52′	140°8′	Float type
19	Aomori	40°50′	140°46′	Float type

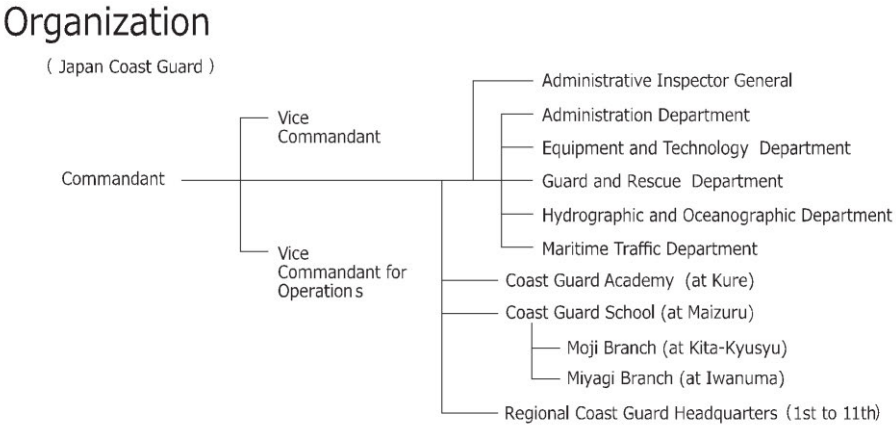
No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation
20	Hachinoheko	40°32′	141°33′	Float type
21	Mutsuogawara	40°56′	141°23′	Float type
22	Akita	39°45′	140°4′	Float type
23	Kuji	40°12′	141°48′	Float type
24	Ishinomaki	38°24′	141°16′	Float type
25	Sendaishinko	38°16′	141°0′	Float type
26	Sakata	38°55′	139°49′	Float type
27	Kashima	35°56′	140°42′	Float type
28	Keihinko	35°28′	139°38′	Float type
29	Shimoda	34°40′	138°58′	Float type
30	Mikawa	34°44′	137°19′	Float type
31	Niigatahigashiko	37°59′	139°13′	Float type
32	Niigatanishiko	37°56′	139°4′	Float type
33	Sinminato	36°46′	137°7′	Float type
34	Fushikitoyama	36°48′	137°4′	Float type
35	Wajimako	37°24′	136°54′	Float type
36	Nanao	37°3′	136°58′	Float type
37	Kanazawa	36°37′	136°36′	Float type
38	Tsuruga	35°40′	136°4′	Float type
39	Yoshima	34°23′	133°49′	Float type
40	Aoki	34°22′	133°41′	Float type
41	Tadotsu	34°16′	133°45′	Float type
42	Kurushimakouro	34°7′	132°59′	Float type
43	Chofu	34°1′	131°0′	Float type
44	Tanokubi	33°55′	130°55′	Float type
45	Oyamanohana	33°55′	130°54′	Float type
46	Haedomari	33°57′	130°53′	Float type
47	Ube	33°56′	131°15′	Float type
48	Deshimatsu	33°55′	130°56′	Float type
49	Kanda	33°47′	130°59′	Float type
50	Hiagari	33°55′	130°53′	Float type
51	Aohama	33°57′	131°1′	Float type
52	Moji	33°57′	130°57′	Float type
53	Sunatsu	33°54′	130°53′	Float type
54	Beppu	33°18′	131°30′	Float type
55	Kogo	32°43′	129°50′	Float type
56	Hiradoseto	33°22′	129°35′	Float type
57	Gonoura	33°45′	129°41′	Float type
58	Karatsu	33°28′	129°58′	Float type
59	Yatsushiro	32°31′	130°34′	Float type
60	Kumamoto	32°45′	130°34′	Float type
61	Hondoseto	32°26′	130°13′	Float type
62	Miyazaki	31°54′	131°27′	Float type
63	Shibushi	31°29′	131°7′	Float type
64	Nakagusukuwanko	26°20′	127°50′	Float type
65	Hirara	24°49′	125°17′	Float type
66	Dainikaiho	-	-	-
67	Susaki	-	-	-
68	Kurihama	-	-	-

Source: PHB

2.3.4 Japan Coast Guard (JCG)

(1) Overview

The mission of JCG is to ensure maritime safety and security. In order to fulfill this mission in the vast sea, it conducts various operations, such as ensuring security; marine rescue; conservation of marine environment; response to natural disasters; oceanographic research; collection, management and provision of maritime information; and securing of the safety of the ship traffic while strengthening the collaboration and cooperation system, not only with relevant domestic organizations, but also with overseas coast guard agencies.



Source: JCG

Figure 2.18 Organizational Structure of JCG

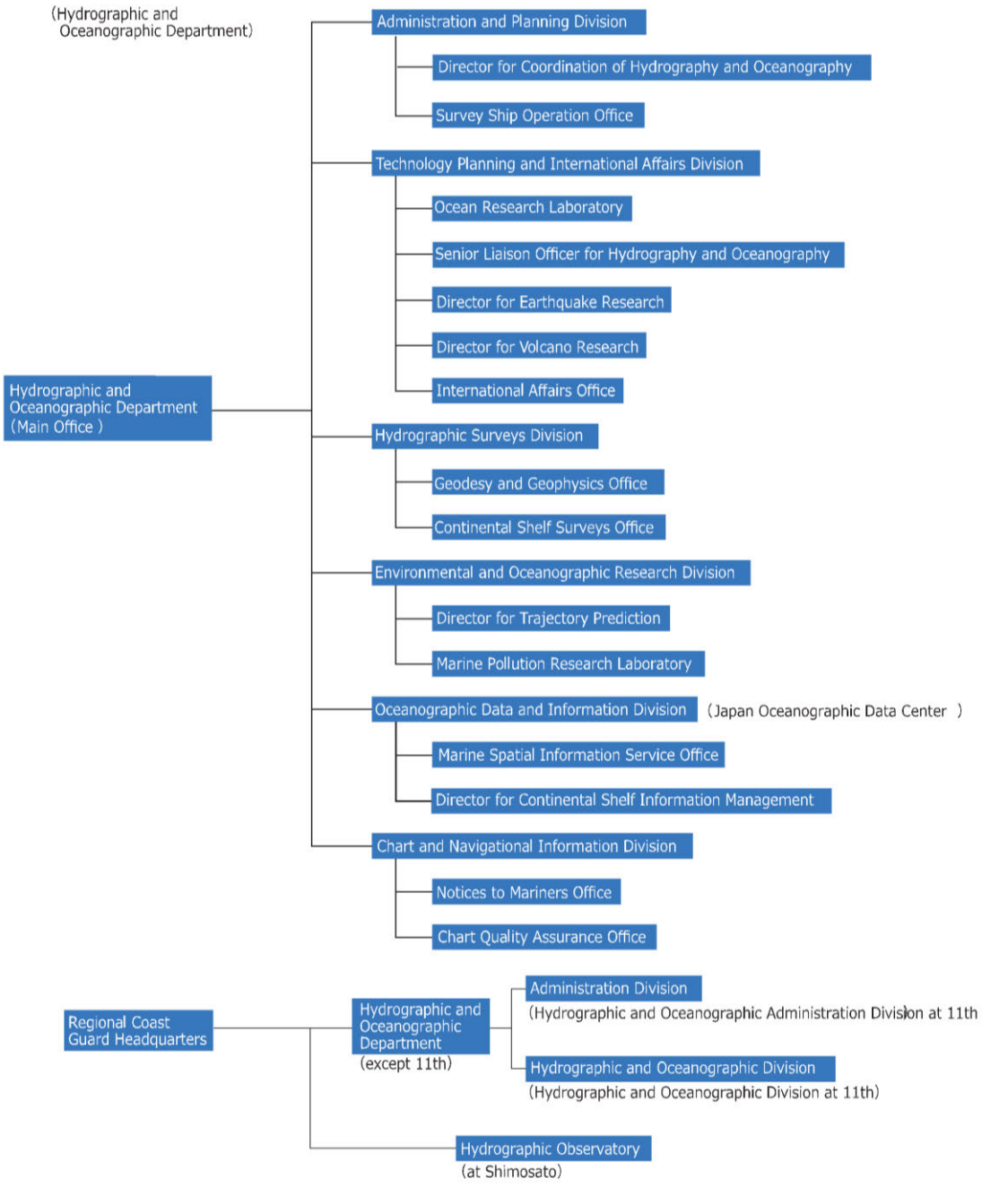
The Hydrographic and Oceanographic Department (HOD) of the Japan Coast Guard has been providing nautical publications, such as nautical charts, which are essential information for maritime traffic, supporting the Japanese economy.

The fundamental mission of HOD is to collect and disseminate information for the safety of navigation and the conservation of marine environment.

Its main tasks are following:

- Safety of Navigation
- Environment Conservation
- Disaster Prevention
- Preservation of Marine Interests
- Information and Data Service
- International Cooperation

These tasks have been increased in various fields where the expertise of HOD can be applied to, responding to the increasing demands.

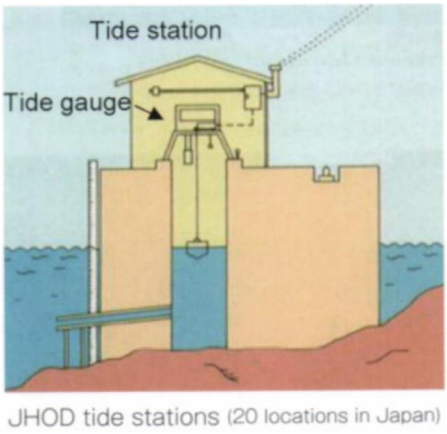


Source: JCG

Figure 2.19 Organizational Structure of HOD Within Japan Coast Guard

(2) Observation of Tides

JCG has installed tide stations at 20 locations in Japan, and observes the tidal changes from vertical movement of a float in the station. JCG monitors all the data at the JCG Headquarters in Tokyo and provides the calculated tidal curve through the internet. The observed tidal changes are utilized for tidal prediction, tidal correction for the surveyed bathymetry, calculation of the ocean current, monitoring of the crustal displacement as well as detection of tsunamis.



Source: JCG

Figure 2.20 JCG's tide observation station

Table 2.4 List of JCG Tide Stations

No.	Station Name	Latitude (Northing)	Longitude (Easting)	Type of Observation
1	Tappi	41°15′	140°23′	Float type
2	Kamaishi	39°16′	141°53′	Float type
3	Kozushima	34°13′	139°8′	Float type
4	Miyakejima (Ako)	34°4′	139°29′	Float type
5	Hachijojima (Kaminato)	33°8′	139°48′	Float type
6	Chiba	35°34′	140°3′	Float type
7	Yokosuka	35°17′	139°39′	Float type
8	Yokohama	35°27′	139°39′	Float type
9	Awashima	38°28′	139°15′	Float type
10	Kure	34°14′	132°33′	Float type
11	Hiroshima	34°21′	132°28′	Float type
12	Tokuyama	34°2′	131°48′	Float type
13	Hakata	33°37′	130°24′	Float type
14	Oita	33°16′	131°41′	Float type
15	Sasebo	33°9′	129°43′	Float type
16	Izuhara	34°12′	129°18′	Float type
17	Nakanoshima	29°51′	129°51′	Float type
18	Naze	28°24′	129°30′	Float type
19	Odomari	31°1′	130°41′	Float type
20	Iriomote	30°44′	130°60′	Float type

Source: JCG

2.4 Interview Survey

The interview survey items for quality management in maintenance method or observation sites of the key organizations (i.e., JMA, GSI, PHB and JCG) are following:

1. Basic information on observation equipment
2. Organization for maintenance of observation equipment
3. Maintenance methods of observation system
4. Guidelines for maintenance manuals

2.4.1 JMA

(1) Basic Information on Observation Equipment

1) Systems of tide observation network in operation

- JMA has observed tides and tsunamis at 69 points, for usual tides and tsunamis; and at 91 points, for giant tsunamis.
- The observed data are transmitted in real time from the observation points to the processing centers in Tokyo and Osaka. In addition, the network is equipped with satellite communication (Iridium satellite) as a backup line in an emergency.

2) Operating rate / failure rate

- The operating rate and missing rate were not obtained from the database.

3) Frequency of system updates / replacements

- The processing central system is replaced every 6 years, and the observation equipment is replaced every 15 years.
- The Department of Atmosphere and Oceans plans the replacement of observation points and apply for its budget.
- JMA outsources the replacement work of the processing center software and observation equipment. It prepares the specifications of the renewal works, and the contractor replaces the equipment.

(2) Organization for Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- The Environment and Ocean Meteorological Division of the Atmosphere and Ocean Department is the main body.
- The Global Environment and Ocean Divisions in the Okinawa Meteorological Observatory, and the Local Meteorological Observatory are in charge of management and operation of respective regions where there are observation points.

2) System and scale of management / operation department

- The Environment and Marine Meteorological Division in the Atmosphere and Ocean Department has 6 people for the management function.
- The Okinawa Meteorological Observatory and Local Meteorological Observatory have about 18 people for the management function.

3) Status of utilizing outsourced / seconded staff, etc.

- JMA makes a spot contract with the manufacturer for maintenance and repair of observation equipment.

- JMA has 24-hour on-call maintenance arrangement with Fujitsu as a maintenance contract for the central processing system.

(3) Maintenance Method of Observation System

1) Policy

- The Environment and Marine Meteorology Division of the Atmosphere and Ocean Department monitors and maintains the processing center system.

2) Defect detection method and recovery method

- The observation equipment delivers the observed data with error information to the processing center system. The person in charge recognizes the error by receiving the mail sent from the processing center system.
- Power outages and sensor failures are automatically detected. The noise in observation data is interpolated to the previous value by the processing center.
- The staff checks data deviations every day, and human eyes mainly detect data defects. The important point to be able to detect these errors is to watch the data every day.
- Repairs are carried out after making a spot contract with the manufacturer.

3) Regular inspections

- The Environment and Marine Meteorology Division of the Atmosphere and Ocean Department confirms errors of data in the processing center system every day.
- The staff inspects the building of the observation station once a year.
- The inspection of observation points is outsourced about once every two years for inside observation stations, and once a year for outside observation stations.
- The inspection of the central processing system is implemented by the manufacturer every year.

(4) Maintenance Status of Manuals, Guidelines, etc.

- JMA has manuals that provide specifications when procuring or outsourcing maintenance works.
- There is no training for staff on maintenance and operation of tide observation. OJT is necessary because the staff are not ready to deal with the manual immediately.
- The following manuals have been received for this study.
  - Tide and tsunami observation facility maintenance procedure
  - Inspection of transmission equipment of tide observation data and troubleshooting procedure for each cause

(5) Others

- When a new tide station is planned to be installed, the location is the most important aspect to consider for tsunami detection. The port site should be selected so that early tsunami can be detected.
- The observation data are transmitted in near real time to the department in charge of warning and are utilized for warning and forecasting.
- For data sharing with the related organization (GSI, PHB, JCG, etc.), the information sharing method (i.e., pull type or push type) is decided upon by coordinating with the organization. Data are acquired (shared) in near real time through the servers of the organizations connected by an IP-VPN line.

- Basically, the related organizations do not cooperate in dealing with problems based on the agreement that each organization is not responsible for the transmitted observed values. If the problem lasts for a long time, JMA inquiries about the cause and recovery time.
- An agreement is needed for cooperation with related organizations. The agreement should describe the reference standard level. The conversion values being used by respective organizations should also be identified to obtain the values in the same standard level.

2.4.2 GSI

(1) Basic Information on Observation Equipment

1) Contents and composition of the tide observation network in operation

- There are 25 tide stations nationwide managed by GSI. One-second (1s) observation data are collected in real time and aggregated in the automated centralized control system of tide observations located in Tsukuba.
- Thirty-second (30s) observation data calculated from 1s observation data are published online.
- GSI uses an IP-VPN line for communication of observation data. FOMA (Freedom Of Mobile multimedia Access) is also used as a backup line. Although FOMA is not used in all tide observation points, it is used in the 14 locations assigned as tsunami observation sites and others.
- At the observation sites, a backup power supply is secured so that it can operate for three days even if there is a power outage.
- The observation data are linked with JMA, which have access to the GSI database to retrieve the data of 1s and 30s every 6 minutes. JMA publishes tide level data as well.
- A maintenance plan is decided with the priority tide stations (e.g., Aburatsubo).
- There is only one tide sensor and well in each point, and the server is installed only in Tsukuba (it is not duplicated for redundancy).

2) Operating rate / failure rate

- The tide observation system rarely stops due to equipment failure. If the power supply is lost due to a power outage, missing data may occur.
- If the power is supplied for the tide gauge, the data are recorded and can be obtained from the equipment even if communication is interrupted.
- Maintenance and inspection performed once a year lead to missing data at this time. In addition, because seawater is drawn into the well, seaweed and shells near the water pipe should be removed once or twice a year. Therefore, data are also missing at this time.
- The missing rate is 0.5 to 1% or less.
- The data may not be acquired accurately in case the water pipe is clogged, even if the power supply is secured and the equipment is functioning well. In this case, the data are deleted from the published data.
- The quality of the data is judged by predicting and calculating the astronomical tide level and comparing it with the measured values. There are no clear criteria for abnormal value.

3) Frequency of system updates / replacements

- Basically, the equipment should be replaced about every 10 years. However, because the budget is limited, replacement seems to be about every 15 years. Therefore, maintenance is carried out regularly to manage and keep the equipment in good condition.
- The frequency of replacement is determined, taking into consideration the importance of the tide observation points (tsunami observation designation, Aburatsubo, etc.).

- Since the tide station also has GNSS, it is possible to accurately measure not only the water level but also the horizontal position. Communication costs are budgeted by GNSS which seems to be updated every 5 years.
- Regarding the server, 2 sets of a LINUX server for receiving and storing tide observation data are installed. Logger control and time synchronization are conducted by using Windows servers. There is also a server for publishing the 30-second value of the tide observation data, and each has redundancy. The frequency of updates of these units are less than 10 years.

(2) Organization for Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- The Geodetic Observation Center of GSI manages the observation points. The center is responsible for electronic reference point GNSS, crustal monitoring, and tide observation.
- There are four people in the Crust Monitoring Division: 1 coastal ascent and descent monitoring staff, 1 instructor, 1 assistant, and 1 non-regular staff.

2) System and scale of management / operation department

- In addition to the abovementioned four people in the center, a guard who can immediately go to the tide observation point is hired in 20 out of 25 locations through outsourcing. He/She performs regular monthly inspections, including check of the air conditioner and equipment adjustment, etc. The remaining 5 sites are operated by GSI which has secured human resources who can immediately go to all 25 observation sites.
- The regional survey department (branch) is responsible for the maintenance of the tide observation in the region. The survey department has 14 to 15 people, of which 1 or 2 are in charge of management and maintenance of the tide observation site.
- The maintenance of the system is conducted once a year by a system maintenance company that has a contract with GSI.
- There is no staff training for management and maintenance, and it is carried out through OJT based on the manual.

3) Status of utilizing outsourced / seconded staff, etc.

- Nearly 20 locations are outsourced to carry out regular annual inspections, although not all 25 locations conduct inspection every year because of budget constraints.
- Monthly appearance inspection is also conducted by outsourced guardians.
- In addition, GSI outsources the cleaning of water pipes and diving work because specialized machines/ equipment are required for these.

(3) Maintenance Methods of Observation Systems

1) Policy

- The important tide stations are selected and managed with priority. Currently, there are 11 priority stations. Other tide stations are set at a slightly lower priority.
- The tide stations of GSI have never been robbed. The small building of the tide station is locked and managed. It is not monitored by a camera.

2) Defect detection method and recovery method

- Since there are only 25 tide stations of GSI, defects are detected by human eye. The staff checks the observation data with astronomical tide every day.
- If there is a big difference from the astronomical tide, an alert is issued. However, only human eye can detect the small errors because the data gradually shift due to the clogging

of the water pipe.

- The errors can be checked by the graph and value shown on the terminal of the centralized control system.
- When an error is detected, the cause is analyzed and an individual recovery method is implemented for the identified cause. In case that the cause is due to meteorological factors, such as low pressure, the fluctuations in the surrounding sea area are checked.
- Since the observation data are shared with JMA, said agency is contacted immediately and the abnormal value information are shared, in case abnormal values are observed.

3) Regular inspections

- There are monthly inspections, annual maintenance inspections, and cleaning of water pipes, etc. (once every year or 2 years, depending on the characteristics of the location).
- There is a check sheet for monthly inspection items (e.g., inside and outside the tide gauge, equipment system, atomic measurement).
- There is another sheet for annual maintenance and inspection (entire system, data collection device, battery, etc.). It is filled out by an outsourced company.
- Because some of the tide stations have been operating for about 100 years, the timing of cleaning is set appropriately according to the local condition. The timing of cleaning is updated according to the clogging situation to be confirmed during cleaning.

(4) Guidelines for Maintenance Manuals

- Basically, a series of manuals is prepared for all works.
- The use of manuals is only for troubleshooting of GSI, and some manuals cannot be shared.
- The table of contents of these manuals are provided.

(5) Others

- GSI has no plan of establishing a new tide station, and it seems that the number of its tide stations will decrease in the future.
- When constructing a new building, the following advice is given:
  - Do not install a tide station in a place which is affected by flow near the river.
  - Install it in a place facing the open sea.
- The purpose of tide observation in GSI is to find the height standard in millimeters. Therefore, the observation value is published in millimeters.
- JMA, GSI, PHB, and JCG are sharing observation data based on their agreements. These are a little behind real-time data, and JMA has access to the GSI server to get the data once every 6 minutes (1s and 30s data). Published are 30s data. GSI and JMA have dedicated lines for sharing observation data.

2.4.3 PHB

(1) Basic Information on Observation Equipment

1) Contents and composition of the tide observation network in operation

- The NOWPHAS system collects tide and wave data from all over the country (tide level gauge: 68 locations), and gathers them at the National Institute for Land and Infrastructure Management (NILIM) in Yokosuka. All the observation points are listed in this system.
- The tide level data are connected to a nearby port office by wire, and they are collected at

NILIM through the network called "Kouwan WAN".

- PHB employs a float type of tide gauge generally, but an ultrasonic type in some stations.
- NILIM transfers the offshore wave and water level data to JMA in real time. GPS wave observer has been used to detect tsunamis. For example, in the Great East Japan Earthquake, GPS wave gauge caught signs of tsunamis, and then JMA raised the predicted tsunami height.
- The GPS wave gauge is installed offshore and sends data wirelessly to base stations installed on the coast. Since the buoy is located offshore, the power source is provided by a solar panel and lead-acid battery.
- In the past, during the Great East Japan Earthquake, port offices located in coastal areas were damaged and observation data could not be obtained. Therefore, port offices now are sending observation data from land-based stations via artificial satellites.
- The main objective of observation of tides and waves is to contribute to port development. Support to disaster risk reduction is a secondary objective. Consequently, JMA, GSI, JCG and PHB have installed 187 locations nationwide, taking into consideration the coverage of the observation points.

2) Operating rate / failure rate

- The operating rate and failure rate are not estimated. The basic recovery policy is to take prompt action in the event of a failure.
- Examples of failures include missing data due to power outages, and missing data due to equipment abnormalities due to lightning strikes (i.e., occurrence of abnormal values).
- If an abnormal value is found in the observation data, the staff of the local office goes to the observation point and restores it. If it is difficult to deal with, a maintenance and inspection company is asked to handle it.

3) Frequency of system updates / replacements

- PHB purchases and uses up the sensor. Its standard lifespan is about 10 years, but it is difficult to determine the lifespan uniformly because different local environments can affect it. It is judged based on the results of annual regular inspections. Based on the inspection results, replacement is planned according to the secured budget. There are procedures for requesting and securing a budget.
- PHB manufactured and installed GPS wave gauges from 2006 and has operated for around 10 years. Some of these wave gauges have been replaced.
- The server equipment of the NOWPHAS system is rented through a lease contract.

(2) Organization for the Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- Since the main purpose of tide/wave observation is to develop ports, the observation equipment is managed by the department in charge of the port. It is operated by the port office of each regional development bureau.
- There is a maintenance and inspection manual as an internal rule, and the observation equipment is operated and managed according to this.

2) System and scale of management / operation department

- The regional development bureau and the port office are in charge of management and operation of the observation equipment. The scale of operation of the department is expected to be handled by about a few people.

3) Status of utilizing outsourced / seconded staff

- Each regional development bureau outsources annual regular inspections in several points

altogether. Since GPS wave gauge is highly specialized equipment, its maintenance and inspection are outsourced to a specific company.

- NILIM also outsources the constant monitoring of the system. Other daily inspections are carried out by staff.

(3) Maintenance Methods of Observation Systems

1) Policy

- PHB mainly measures the reference water level for construction to comprehend waves and tide levels for port development. The observation of tsunamis and storm surges is a secondary purpose.
- As mentioned above, the observation equipment is used as long as possible and the necessity of replacement is confirmed by regular inspections.

2) Defect detection method and recovery method

- If an error occurs, a monitoring company outsourced by NILIM contacts the relevant parties (regional development bureau, port offices, NILIM, etc.) by e-mail.
- The e-mail is sent in case of missing data or obvious outliers.
- Basically, it is necessary to restart on-site when an error occurs.

3) Regular inspections

- Regular inspections are conducted once a year.
- The regional development bureau of PHB orders the maintenance and inspection works based on a manual.

(4) Guidelines for Maintenance Manuals

- Although there are regular maintenance and inspection manuals, some of them are difficult to obtain confidentiality.
- There is no manual for the software (implemented by a contractor).
- There is a manual on maintenance of observation equipment. It is divided into two, one section for each equipment: tide gauge and GPS wave gauge.
- Because most of the tide gauges are located on the coast, ships are usually not necessary for maintenance and inspection.

(5) Others

- The focal point of installing a new facility varies, depending on the purpose of observation. It is different for port development and for tsunami countermeasures. The location and specifications should be suitable for each purpose.
- The buoy has never been lost in PHB, but it may collide with a ship. Although measures are taken by lighting and attaching radar reflectors, contact accident may still occur in case of bad weather, bad sea condition, or carelessness. When this happens, the brittle antenna or the like may be damaged. In addition, the solar panel may come off due to a typhoon.
- It may take time to repair the broken items because they are ordered by a contractor rather than directly managed. The procedures for outsourced work and budgeting are required.
- Regarding data sharing issues, it is better to be careful about the differences in tide level standards depending on the organizations. JMA is based on T.P. while PHB is based on CDL. It is necessary to calculate and reflect the difference for data sharing.
- The GPS wave gauge measures data every 1s, and the tide stations measure data at 0.5s intervals.

The measured data (raw data) are sent to JMA.

2.4.4 JCG

(1) Basic Information on Observation Equipment

1) Contents and composition of the tide observation network in operation

- There are 20 tide stations nationwide being managed by JCG.
- One second (1s) observation data are measured in real time and collected in the main office. Then the 30s average data are calculated.
- NTT's IP-VPN line (that is, mainly wired, optical but ADSL in some sites) is used for communication from the tide station to the head office.
- Because the purpose of disaster prevention is secondary, the communication line and power supply are not redundant, for example, it has no duplication.
- In case of power outage, an uninterruptible power supply can be used to continue tide observation for several hours.
- Data are shared with JMA in real time.
- There is only one tide sensor and well in each site, and the two servers are installed at the main office for backup function.
- JCG website publishes 30-second average data updated every 5 minutes.
- CMDC stores noise-processed tide data as archive.
- Past data are archived in the main office after digitization.

2) Operating rate / failure rate

- Statistics such as operating rate, failure rate, and missing rate are collected. Since the missing data dates are published in the tide table of CMDC, it is possible to grasp the rough missing data rate from them. However, it should be noted that the data of the tide table published by CMDC may include data that were not acquired in real time but provided late.
- The major causes of failure are power outages and line disconnection, and the minor causes are errors in recording devices, wells, clogging of water pipes, and deterioration and entanglement of wires.
- Tide level data continue to be recorded as long as there is power supply even if communication is interrupted.

3) Frequency of system updates / replacements

- Electronic equipment is replaced by a new unit with a lease term of 5 years.
- Other equipment, wells, buildings, etc. are used as long as possible. However, they may be replaced when inspections reveal that they are nearly damaged.
- The life span of wells and buildings is more than 30 years, and observation equipment and wires last for more than 10 years. Errors occur in devices such as recording boards, and wires can be visually confirmed to be frayed.

(2) Organization for the Maintenance of Observation Equipment

1) Organizational position of the management / operation department

- Coastal Survey Division, in the Hydrographic and Oceanographic Department (HOD) of JCG, is in charge of the main body and has about four staffs in charge of tide observation, although they also carry out other duties.

- In the observation sites, several members of HOD in the Regional Coast Guard Headquarters are also in charge of tide observation, although they also do other duties.

2) System and scale of management / operation department

- Management and operation of these facilities are during working hours on weekdays; none on holidays and nighttime. That means, they do not have a 24-hour management system.
- There is no training for staff on management and operation of tide observation facilities, and it can be carried out within the technical fields that they studied at the JCG school.

3) Status of utilizing outsourced / seconded staff

- Basically, JCG staff conducts the inspection. In some remote islands, the inspections are outsourced to local contractors.
- The leased materials are renewed by the contractor. In addition, if an error occurs in the observation equipment, repairing them may be outsourced.
- Cleaning of water pipes and wells is outsourced to a professional contractor.

(3) Maintenance Methods of Observation System

1) Policy

- The main objectives of tide observation in JCG is to measure the reference height of the sea chart, and disaster prevention purpose from tsunami and storm surge is secondary. Therefore, duplication measures other than uninterruptible power supply have not been taken.
- JCG responds to large-scale disasters but does not monitor them 24 hours a day due to its main policy stated above.
- The tide gauge of JCG has never been stolen because the tide station is located in a building that can be secured and managed. Basically, it is not monitored by a CCTV camera although the tide station in the security area may be under the supervision of a camera.

2) Defect detection method and recovery method

- The low uninterruptible battery and communication abnormalities are monitored by the head office. JCG also has a contract with NTT for communication to inform failure of the system.
- The system in each tide station can be restarted remotely from the main office.
- If necessary, JCG staff visits the nearby tide station, but the outsourced company covers tide stations in remote islands.
- The abnormal values are detected with human eye, and compared with the predicted astronomical tide level. The margin of error is based on the experience of the staffs. Since the characteristics of the tide level vary depending on location, the standards to detect errors cannot be unified for all observation points.

3) Regular inspections

- Regular inspections for the 20 locations are carried out once every two years.
- The daily inspections for tide stations near JCG are conducted every month.
- If the water pipe is clogged, JCG gets professional contractors to clean. The frequency of the cleaning work depends on the characteristics of the location (Hakata, Izuhara, Hiroshima, etc., are easily clogged). The frequency of declogging these sites is once a year.

(4) Guidelines and Maintenance Manuals

- There is no manual for daily inspection or check sheet. However, there is an in-house manual

for regular inspections (standard surveys), which are conducted once every two years.

- There are lease manuals and materials within the department (e. g., memorandum of the person in charge).

(5) Others

- JCG has no plans to establish a new facility.
- The type of sensor used in the equipment is changing from the float type to radio wave type. The initial cost is low, and changing the sensor will reduce wire failures and associated missing data. However, due to budget constraints, JCG has maintained the float type of tide gauges for now. It has been pointed out also that radio waves are reflected inside the observation well and data cannot be obtained sufficiently.
- JCG has never been required to take any special action in the event of an earthquake or tsunami disaster. The main purpose of tide observation in GSI is to capture ground fluctuations, while the main purpose in JCG is to capture sea level fluctuations. The Kamaishi Tide Station was destroyed by tsunami, but it has been newly established.
- There was some difficulty in terms of security regarding data sharing with other organizations. When JCG replaced the machine, it was blocked by the gateway.
- The technical terms may differ depending on the organization. DL refers to the observation reference level for JMA, but it refers to the lowest water surface for JCG. It has also a different meaning for PHB.
- There is no priority in the conduct of inspections of the 20 tide stations nationwide, but the frequency of inspections may change due to physical restrictions (i.e., remoteness of location).
- By comparing past observation tide data, the ground subsidence, ground rise due to the influence of Great East Japan Earthquake, and the sea level rise due to climate change can be found.

2.5 Summary of the Survey Results

The results of the interview survey are summarized in Table 2.5, Table 2.6, and Table 2.7. The results of the interview survey and desktop data collection are listed below:

(1) Operation rates of all observation systems are quite high (almost more than 99%), although all organizations did not estimate the exact rates.

(2) Policy of operation and maintenance highly depends on the main purpose of the organization, although the secondary purpose is the same: disaster risk reduction for tsunami and storm surge.

(3) Since the organizations are relatively small, they cooperate with the regional staff and subcontractors.

(4) Major failures are detected by human eye, although obvious errors can be detected by system.

(5) Data sharing network in near real time is built to unify the tide data observed by the related organizations.

(6) The related organizations have no plan to install new tide stations. There are some rules to be followed when installing new tide station.

(7) The organizations have their own manuals or guidelines for system maintenance and operation. Staff members in charge of operation and maintenance are taught mainly through OJT (on-the-job training).

Table 2.5 Summary of Survey Results (1)

	JMA	GSI	PHB	JCG
(1) Basic information				
1)Systems of tide observation network in operation	•JMA has observed tide and tsunami at 69 points for usual tide and tsunami, and at 91 points for giant tsunami. •These observed data are transmitted in real time from the observation points to the processing centers in Tokyo and Osaka. In addition, the network is equipped with satellite communication (Iridium satellite) as a backup line in an emergency.	•There are 25 tide stations nationwide managed by GSI. One second observation data is collected in real time and aggregated in the automated centralized control system of tide observation which is located in Tsukuba. •GSI uses an IP-VPN line for communication of observation data. FOMA is also used as a backup line. Although FOMA is not used in all tide observation points, it is used in the 14 locations assigned as tsunami observation and others. •At the observation sites, a backup power supply is secured so that it can operate for three days even if there is a power outage. •There is only one tide sensor and well in each poits, and the server is installed only in Tsukuba (it is not duplicated for redundancy).	•The NOWPHAS system collects tide and wave data from all over the country (tide level gauge: 68 locations) and gathers them at the National Institute for Land and Infrastructure Management (NILIM) in Yokosuka. All the observation points are listed in this system. •The tide level data is connected to a nearby port office by wire, and it is collected at NILIM through the network called “Kouwan WAN”. •The GPS wave gauge is installed offshore and sends data wirelessly to base stations installed on the coast. Since the buoy is located offshore, the power source is provided from a solar panel and a lead-acid battery. • now port offices are sending observation data from land base stations via artificial satellites.	•There are 20 tide stations nationwide managed by JCG. •One second observation data is measured in real time and collected in the main office. Then the 30s average data is calculated. •NTT's IP-VPN line (that is mainly wired, optical but ADSL in some sites) is used for communication from the tide station to the head office. •Because the purpose of disaster prevention is secondary, the communication line and power supply are not redundant such as duplication. •In case of power outage, an uninterruptible power supply can continue to observe tide for several hours.
2)Operating rate / failure rate	•The operating rate and missing rate are not obtained in the database.	•It rarely stops due to equipment failure. If the power supply is lost due to a power outage, missing data may occur. •The missing rate is 0.5 to 1% or less.	•The operating rate and failure rate are not estimated. The basic recovery policy is to take prompt action in the event of a failure. •Examples of failures include missing data due to power outages and missing data due to equipment abnormalities due to lightning strikes (i.e. occurrence of abnormal values).	•Statistics such as operating rate, failure rate, and missing rate are collected. •The major causes of failure are power outages and line disconnections and minor causes are errors in recording devices, wells, clogging of water pipes, and deterioration and entanglement of wires.
3)Frequency of system updates / replacements	•The processing central system is replaced in every 6 years, and the observation equipment is replaced in every 15 years. •The Department of Atmosphere and Oceans plan the observation points to be replaced and apply for its budget. •JMA outsorces the replacement work of the processing center software and observation equipments. JMA prepares the specification of the renewal works and the contactors replace these equipments.	•Basecally the equipments should be replaced about every 10 years. However, because the budget is limited, it seems to be about every 15 years. Therefore, maintenance is carried out regularly to maintain and manage the equipment. •The frequency of replacement is determined taken into consideration the importance of the tide observation points (tsunami observation designation, Aburatsubo, etc.). •GNSS: to be updated in about every 5 years. • The frequency of updates of the server units are less than 10 years.	•PHB purchases and uses up the sensor. A standard lifespan is about 10 years, but it is difficult to determine the lifespan uniformly because the different local environment can affect it. It is judged based on the results of annual regular inspections. •The server equipment of the NOWPHAS system is rent with lease contract.	•Electronic equipment is renewed with a lease term of 5 years. •Other equipment, wells, buildings, etc. are used as long as they can be used. However, they may be replaced when inspections reveal that they will be damaged near future. •The life span of wells and buildings are for more than 30 years, and observation equipment and wires last for more than 10 years.
(2) Organization for Maintenance of Observation Equipment				
1)Organizational position of the management / operation department	•The Environment and Ocean Meteorological Division of the Atmosphere and Ocean Department is the main body. •The Global Environment and Ocean Divisions in the Okinawa Meteorological Observatory and the Local Meteorological Observatory are in charge of management and operation of each region where there are the observation points.	•The Geodetic Observation Center of GSI manages the observation points. The center is responsible for electronic reference point GNSS, crustal monitoring, and tide observation. •There are four people in the Crust Monitoring Division: 1 coastal ascent and descent monitoring staff, 1 instructor, 1 assistant, and 1 non-regular staff.	•Since the main purpose of tide/ wave observation is to develop ports, the observation equipment is managed by the department in charge of the port. It is operated by the port office of each regional developnet bureau. •There is a maintenance and inspection manual as an internal rule, and it is operated and managed according to it.	•Coastal Survey Division in the Hydrographic and Oceanographic Department (HOD), JCG, is in charge of the main body, and has about four people in charge of tide observation. •In the observation sites, several members of the Hydrographic and Oceanographic Department in the Regional Coast Guard Headquarters are also in charge of tide observation.

Table 2.6 Summary of Survey Results (2)

	JMA	GSI	PHB	JCG
2)System and scale of management / operation department	•Environment and Marine Meteorological Division in the Atmosphere and Ocean Department has 6 people for the management. •The Okinawa Meteorological Observatory and Local Meteorological Observatory have about 18 people for the management.	•In addition to the above four people in the center, a guard who can immediately go to the tide observation point is hired in 20 out of 25 locations with outsourcing. The remaining 5 sites are operated by GSI. •The regional survey department (branch) are also responsible for the maintenance of the tide observation in thir own region. The survey department has 14 to 15 people, of whom 1 or 2 are in charge of manage and maintenance of the tide observation.	•The regional development bureau and the port office are in charge of management and operation of the observation. The scale of the department is expected to be about a few people.	•Management and operation of these facilities are available during working hours on weekdays, not on holidays and at nights. That is not a 24-hour management system.
3)Utilization status of outsourced / seconded staff, etc.	•JMA makes a spot contract with the manufacturer for maintenance and repair of observation equipment. •JMA has a contract of a 24-hour on-call maintenance with Fujitsu as a maintenance contract for the central processing system.	•Nearly 20 locations are outsourced to carry out regular annual inspections, alhough not all 25 locations are conducted every year because of budget constraints •Monthly appearance inspection is also conducted by outsourced guardians. •In addition, GSI outsource clean of water pipes and diving work, because specialized machines/ equipements are required.	•Each regional development bureau outsorces annual regular inspections in several points together. Since GPS wave gauge is highly specialized, the maintenance and inspection are outsourced to a specific company. •NILIM also outsources the constant monitoring of the system. Other daily inspections are carried out by staff.	•Basically, JCG staff conducts the inspection. In some remote islands, the inspections are outsourced to local contractors. •The lease materials are renewed by the contractor. In addition, if an error occurs in the observation equipment etc., repairing of them may be outsourced. •Cleaning of water pipes and wells is outsourced to a professional contractor.
(3)Maintenance Method of Observation System				
1)Policy	•The Environment and Marine Meteorology Division of the Atmosphere and Ocean Department monitors and maintains the processing center system.	•The important tide stations are selected and managed with priority. Now there are 11 places. Other tide stations is set a slightly lower priority. •The tide stations of GSI have never been stolen. The small building of the tide station is locked and managed. It is not monitored by a camera.	•PHB mainly measures the reference water level for construction to comprehend waves and tide levels for port development. The observation of tsunamis and storm surges is a secondary measure. •As mentioned above, the observation equipment is used as long as possible and the necessity of replacement is confirmed by regular inspections.	•The main objectives of tide observation in JCG is to measure the reference height of the sea chart, and disaster prevention purpose from tsunami and storm surge is secondary. Therefore, measures such as duplication have not been implemented although there is an uninterruptible power supply. •JCG responds to large-scale disasters, but does not monitor them 24 hours a day for that reason.
2)Defect detection method and recovery method	•The observation equipments delivers the observed data with error information to the processing center system. The person in charge recognizes the error by receiving the mail sent from the processing center system. •Power outages and sensor failures are automatically detected. The noise in observation data is interpolated to the previous value by the processing centers. •The staff checks data deviations every day and human eyes mainly detect data defects. The important points to detect these errors is to watch the data every day. •Repairs are carried out after making a spot contract with the manufacturer.	•Since there are only 25 tide station of GSI, defects are detected by human eyes. The staff checks the observation data with astronomical tide every day. •If there is a big difference from the astronomical tide, an alert is issued. However only human eye can detect the small errors because the data is gradually shifted due to the clogging of the water pipe. •The errors can be checked by the graph and value shown on the terminal of the centralized control system. •Since the observation data is shared with JMA, we contact JMA immediately and share the abnormal value information in case of abnormal values observed.	•If an error occurs, a monitoring company outsourced by NILIM contacts the relevant parties (regional development bureau, port offices, NILIM, etc.) by e-mail. •The e-mail is sent in case of missing data or obvious outliers. •Basically, it is necessary to restart on-site when an error occurs.	•The low uninterruptible battery and communication abnormalities are monitored by the head office. JCG also have a contract with NTT regarding communication that inform a failure. •The system in each tide station can be restarted remotely from the main office. •If necessary, the JCG staff visit the nearby tide station, but the outsourced company covers tide stataions in remote islands. •The abnormal values is detected with human eyes, compared with the predicted astronomical tide level. The margin of error is based on the experience. Since the characteristics of the tide level are different from each other depending on the location, the standards to detect errors can not be unified for all observation points.

Table 2.7 Summary of Survey Results (3)

	JMA	GSI	PHB	JCG
3)Regular inspections	•The Environment and Marine Meteorology Division of the Atmosphere and Ocean Department confirms errors of data in the processing central system every day. •The staff inspects the building of observation station once a year. •The inspection of observation points are outsourced about once every two years for inside observation stations and once a year for outside observation stations. •The inspection of the central processing system is implemented by the manufacturer every year.	•There are monthly inspections, annual maintenance inspections, and cleaning of water pipes, etc. (once every 1 or 2 years, depending on the characteristics of the location). •Because some of the tide stations have been operated for about 100 years, the timing of cleaning is set appropriately according to the local condition. The timing of cleaning is updated according to the clogging situation to be confirmed during cleaning.	•Regular inspections are conducted once a year. •The regional development bureau of PHB orders the maintenance and inspection works based on a manual.	•The regular inspections for the whole 20 locations are carried out once every two years. •The daily inspections for tide stations near JCG are conducted every month. •If the water pipe is clogged, JCG ask the cleaning to professional contracts. The frequency of the cleaning work depends on the characteristics of the location: Hakata, Izuhara, Hiroshima, etc. are easily clogged. The frequency of these sites is once a year.
(4)Maintenance Status of Manuals, Guidelines, etc.				
	•JMA has manuals as specifications when procuring or outsourcing maintenance. •There are no traing for maintenace and operation of tide observation. OJT is necessary because the staff cannot deal with the mannual immediately. •The following manuals are received. ➢Tide and tsunami observation facility maintenance procedure ➢Inspection of transmission equipment of tide observation data and troubleshooting procedure for each cause	•Basically, a series of manuals is prepared for all work. •It is only for troubleshooting of GSI and some manuals cannot be shared. •The table of contents of these manuals are provided. •There is a check sheet for monthly inspection items (e.g. inside and outside the tide gauge, equipment system, atomic measurement). •There is another sheet for annual maintenance and inspection (entire system, data collection device, battery, etc.). It is carried out by a outsourced company.	•Although there are regular maintenance & inspection manuals, some of them are difficult to be provided for its confidencials. •There is no manual for software, etc. (implemented by a contractor). •There is a manual on maintenance of observation equipment. It is divided into each equipment: tide gauge and GPS wave gauge. •Because most of the tide gauges are located on the coast, ships are usually not necessary for maintenace and inspection.	•There is no manual for daily inspection or check sheet. There is an in-house manual for regular inspections (standard surveys) which is conducted once every two years. •There are lease manuals and materials within the department (memorandum of the person in charge). •There is no training for management and operation of tide observation and it can be carried out within the range studied at the JCG school.

More descriptions of the above results are specified below.

(1) Operation rates of all observation systems are quite high (almost more than 99%), although all organizations did not estimate the exact rates.

Based on the results of interview survey, GSI's answer is "the missing rate is less than 0.5 % to 1.0%", which means that the operation rate is higher than 99%.

As for JMA, operation rate or missing data rate is not compiled as a database. According to the results of the interviews with PHB and JCG, missing data is very rare to happen, and the main causes of this are power outage and line disconnection. Its minor causes are equipment errors, clogging of water pipes, deterioration and entanglement of wires.

The summary of interview results regarding missing data is indicated in Table 2.8.

Table 2.8 Missing Rate and Causes

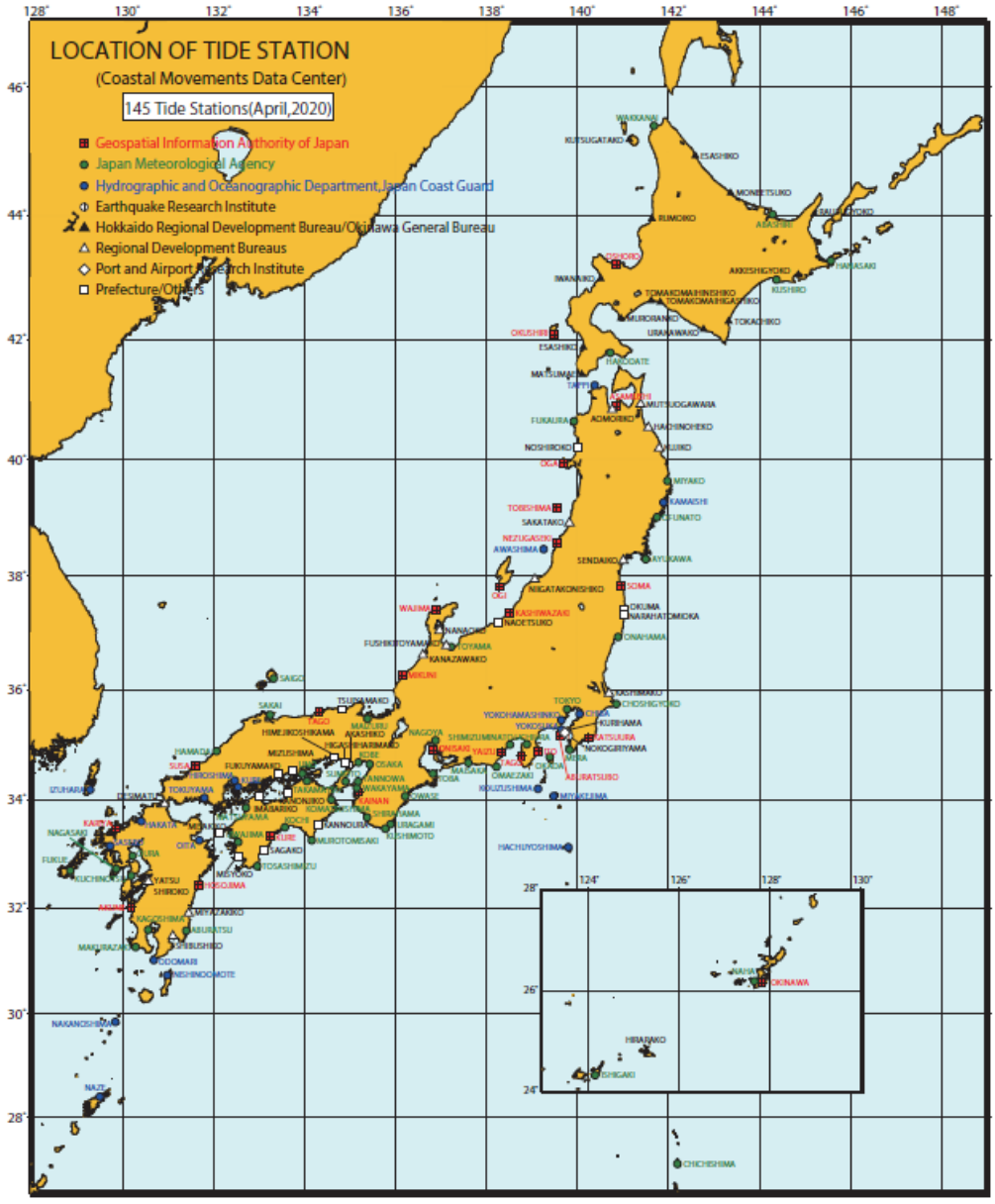
Terms	JMA	GSI	PHB	JCG
Missing rate	No statistical data	Less than 0.5 to 1.0%	No statistical data	No statistical data
Causes of missing data	Nothing to mention	- equipment failure: very rare - power outage - cleaning - regular inspection	- power outages - equipment abnormalities due to lightning strikes	- power outages - line disconnection Minor causes - clogging of water pipes - deterioration and entanglement of wires.

Source: JST

Since the related organizations do not estimate and calculate the missing rate of tide observation directly as statistical data, the tide tables published by the Coastal Movements Data Center are reviewed.

The Coastal Movements Data Center has unified these materials in order to detect crustal movements from the tide records of the tide fields set up by respective institutions for their own purposes and to use them for earth science research such as earthquake prediction research. The unified material is quickly compiled and published in the form. CMDC is operated by the Earthquake Research Institute, the University of Tokyo, JMA, JCG, PHB, GSI, and academic experts.

The organizations that have registered tide level observation facilities in CMDC and provided the tide level observation records are the Earthquake Research Institute of the University of Tokyo, the JMA, JCG, GSI, PHB, the Hokkaido Regional Development Bureau of MLIT, the Okinawa General Secretariat of the Cabinet Office, local governments, etc. The number of the registered tide stations is 145 as of April 2020 as shown in Figure 2.21.



Source: CMDC

Figure 2.21 Locations of Tide Observation Points Registered in CMDC

The missing rates of all tide observation points collected in CMDC are calculated according to the annual tide data that it published from 2017 to 2020. The results of average missing rate from 2017 to 2020 are shown in Table 2.9. The results clarified that the operation rate is almost more than 99% and the quite high and accurate data could be observed.

Table 2.9 Average Missing Rates in Recent Years (CMDC)

	No. of observation sites registered in CMDC						Average Missing Rate
Year	JMA	GSI	PHB	JCG	Others	Total	(%)
2017	52	20	14	20	52	158	0.61%
2018	52	25	15	20	48	160	1.10%
2019	52	25	15	20	48	160	0.73%
2020	51	25	15	20	48	159	0.76%

Source: JICA Survey Team, based on the data from CMDC

(2) Policy of operation and maintenance highly depends on the main purpose of the organization, although the secondary purpose is the same as that of surveyed organizations: disaster risk reduction for tsunami and storm surge.

Based on the results of interview survey with the related organizations, it is clarified that the maintenance and operation policies of tide observation facilities are quite varied and depend on the main purpose of each organization. For instance, the main objective of JMA is to monitor water level for disaster prevention and mitigation; while the other 3 organizations have other main purposes, but similar secondary purpose, and that is disaster risk reduction for tsunami and storm surge.

JMA has 24-hour monitoring system for disaster risk reduction and mitigation, while the other 3 organizations do not employ this monitoring system. The 3 organizations use the equipment as long as possible. The regular inspection results determine the timing of replacement or renewal of equipment.

Table 2.10 Main Objectives of Tide Observation, and Operation and Maintenance Policy of Surveyed Organizations

Terms	JMA	GSI	PHB	JCG
Main objective of observation	Prevention and mitigation of natural disasters/ Monitoring water level	Finding height standard (inland and sea)	Measuring the reference water level for construction / port development	Measuring the reference height of the sea chart for maritime safety
Operation and maintenance policy	The department monitors and maintains the processing center with 24-hour monitoring system	The important tide stations are selected and managed as priority facilities. Currently, there are 11 priority station. Other tide stations are set at slightly lower priority.	The observation equipment is used as long as possible. The necessity of replacement is confirmed by regular inspections.	- duplication measures - Do not monitor them 24 hours a day. - Equipment, wells, buildings, etc. are used as long as possible - Replace equipment according to the inspection results

Source: JST

According to the basic policy of operation and maintenance, the organizations have determined the frequency of renewal of the system, replacement of observation equipment, as well as regular inspections. As for system renewal, JMA renews the central system every 6 years and GSI renews it in less than 10 years. PHB and JCG have lease contracts for their systems which are renewed in about 5 years. JMA replaces the observation equipment every 15 years, while the other 3 organizations use them as long as possible. The organizations have 2 kinds of inspections: daily inspection and regular inspection. All organizations

conduct daily inspection every day or every month. Regular inspections are conducted once every 1 or 2 years based on the local characteristics and planned budget. The frequencies of replacing the equipment and regular inspections of these organizations are summarized in Table 2.11.

Table 2.11 Frequencies of Equipment Replacement and Regular Inspections

Terms	JMA	GSI	PHB	JCG
Renewal of System	Every 6 years	Less than 10 years	With lease contract	With lease contract (5 years)
Replacement of observation equipment	Every 15 years	15 years or as long as possible	As long as possible	As long as possible
Daily inspections	Every day	Every month	-	Every month
Regular inspections	Staff inspection: every year Outsourced: once every 1 or 2 years	Once every 1 or 2 years	Once a year	Every 2 years

Source: JST

(3) Since the organizations are relatively small, they cooperate with the regional staff and outsourcing companies.

The number of staffs in charge of tide observation are relatively small in all 4 organizations. Therefore, these organizations cooperate with their regional offices where the tide stations are located as well as with private companies outsourced by the organizations.

・ JMA

Environment and Marine Meteorological Division in the Atmosphere and Ocean Department has 6 people for the management work. The Okinawa Meteorological Observatory and Local Meteorological Observatory have about 18 people for the same work. On the other hand, JMA makes a spot contract with the manufacturer for maintenance and repair of observation equipment. JMA has an arrangement for 24-hour on-call maintenance with Fujitsu as covered in the maintenance contract for the central processing system.

・ GSI

There are four people in the Crust Monitoring Division. In addition, a guard who can immediately go to the tide observation point is hired in 20 out of 25 locations through outsourcing. The remaining 5 sites are operated by GSI. The regional office is also responsible for the maintenance of the tide observation facility in its own region. On the other hand, the survey department has 14 to 15 people, and 1 or 2 of them are in charge of management and maintenance of the tide observation facility. Nearly 20 locations are outsourced for carrying out regular annual inspections, although not all 25 locations have inspections that are conducted every year. Monthly appearance inspection is also conducted by outsourced guards. Also, the cleaning of water pipes and diving work are outsourced.

・ PHB

The regional development bureau and the port office are in charge of management and operation of the observation facilities. The department is expected to have about a few people. Each regional development bureau outsources the annual regular inspections in several points altogether. NILIM also outsources the constant monitoring of the system. Other daily inspections are carried out by staff.

・ JCG

The main office has about four people in charge of tide observation although they also have other duties. In the observation sites, several staff from regional offices are also in charge of tide observation. Basically, JCG staff conducts the inspection. In some remote islands where it has observation facilities, the inspections are outsourced to local contractors. The leased materials are renewed by the contractor. In addition, if an error occurs in the observation equipment, repair may be outsourced. Cleaning of water pipes and wells is outsourced to a professional contractor.

Table 2.12 Scale of the Organizations for Tide Observation

Terms	JMA	GSI	PHB	JCG
Main office	6 people	4 people	---	4 people
Regional office	18 people	1 or 2 /each regional office	A few people /regional office and port office	Several staff/ regional office
Outsourced staff/ company	- 24-hour on call maintenance - Spot contract for repairing observation equipment	- Guardians (20 sites/ 25 sites) - Monthly appearance inspection - Cleaning work	- Monitoring of system - Annual regular inspections	- Inspections in remote islands - Renewal of leased materials - Repair of equipment - Cleaning work

Source: JST

(4) Major failures are detected by human eye although obvious errors can be detected by the system.

The related organizations have similar systems to detect obvious errors so that alerts will be issued when this happens. But major failures are detected only by human eye so that checking the observation data is needed every day.

・ JMA

The observation equipment delivers the observed data with error information to the processing center system. The person in charge recognizes the error by receiving the mail sent from the processing center system. Power outages and sensor failures are automatically detected. The noise in observation data is interpolated to the previous value by the processing center. The staff checks data deviations every day and human eye mainly detects data defects. Repairs are carried out after making a spot contract with the manufacturer.

・ GSI

Since GSI has only 25 tide station, defects are detected by human eye. The staff checks the observation data with astronomical tide every day. If there is a big difference from the astronomical tide, an alert is issued. However, only human eye can detect the small errors because the data are gradually shifted due to the clogging of the water pipe. The errors can be checked by the graph and value shown on the terminal of the centralized control system.

・ PHB

If an error occurs, a monitoring company outsourced by NILIM contacts the relevant parties (regional development bureau, port offices, NILIM, etc.) by e-mail.

・ JCG

The low uninterruptible battery and communication abnormalities are monitored by the head office. JCG also has an arrangement with NTT regarding communication to inform a failure. The system in each tide station can be restarted remotely from the main office. If necessary, the JCG staff visits the nearby tide station, but the outsourced company covers tide stations in remote islands. The abnormal values are detected with human eye, and compared with the predicted astronomical tide level.

Table 2.13 Major Failures in Tide Observation and Methods of Detection

Terms	JMA	GSI	PHB	JCG
Major failures	- System error - Abnormal values	- System error - Abnormal values - Clogging of water pipes - Deterioration and entanglement of wires	- System error - Abnormal values	- Clogging of water pipes - Deterioration and entanglement of wires
Method to detect errors	- System detects obvious errors (power outage/ sensor failure/ noise) - Staffs monitor the data every day	- Staffs monitor the data every day - An alert is issued in case of big difference from calculated astronomical tide	- A monitoring company (outsourced) detects errors - Inform the staffs about the detected error	- Head office detects connection abnormalities - Human eye detects abnormal values
Method to recovery	- Making a spot contract with the manufacturer	- Depends on the errors	- Making a spot contract with the manufacturer	- Restart remotely from head office - Staff or outsourced company visits the site

Source: JST

(5) Data sharing network in near real time is built to unify the tide data observed by the related organizations.

JMA and other organizations have shared the observed tide data in near real time and utilized them for issuing warning and prediction for disaster risk reduction.

・ JMA

For data sharing with the related organizations, the information sharing method (i.e., pull type or push type) is decided by coordination with all concerned (GSI, PHB, JCG, etc.). Data are acquired (shared) in near real time through the servers of the organizations connected by an IP-VPN line.

・ GSI

The observation data are linked with JMA, which has access to the GSI database to retrieve the data of 1s and 30s every 6 minutes. JMA publishes tide level data as well. JMA, GSI, PHB, and JCG are sharing the observation data based on agreements. These are a little behind real time, and JMA accesses the GSI server to get the data once every 6 minutes (data are 1s and 30s). The published data are 30s data. GSI and JMA have dedicated lines for sharing observation data.

・ PHB

The GPS wave gauge measures data every 1s, and the tide stations measure data at 0.5s intervals. The measured data (raw data) are sent to JMA.

Regarding data sharing issues, it is better to be careful about the differences in tide level standards whose values depend on the respective organizations. JMA is based on T.P., while PHB is based on CDL. It is necessary to calculate and reflect the difference for data sharing.

・ JCG

Data are shared with JMA in real time.

There were some difficulties in terms of security on data sharing with other organizations. When JCG replaced the machine, it was blocked by the gateway. The technical terms may also differ depending on the organization. For instance, DL refers to the observation reference level for JMA, but it refers to the lowest water surface for JCG. It has also a different meaning for PHB.

Table 2.14 Data Sharing Methods and Mechanism for Smooth Coordination

Terms	JMA	GSI	PHB	JCG
Data sharing method	- In near real time through the servers connected by an IP-VPN line.	The observation data are linked with JMA. JMA has access to the GSI database to retrieve the data of 1s and 30s every 6 minutes.	The GPS wave gauge (every 1s) and the tide station (every 0.5s) data (raw data) are sent to JMA.	Data are shared with JMA in real time.
Coordination	- Agreement is needed for cooperation - The reference standard level and the conversion values can be identified.	- Agreement - Dedicated lines for sharing	- Differences in tide level standards	- Gateway issue - Observation reference level

Source: JST

(6) The related organizations have no plan to install new tide station, but they know that there are some rules to follow when installing a new one.

・ JMA

When a new tide station is planned to be installed, the location is the most important factor to consider for tsunami detection. The port site should be selected so that early detection of tsunami can be done.

・ GSI

GSI has no plan of establishing a new tide station, and it seems that the number of its tide

stations will decrease in the future.

When constructing a new station building, the following advice should be considered:

- Do not install a tide station in a place which is affected by flow near the river.

- Install it in a place facing the open sea.

・ PHB

The focal point of installing a new facility varies depending on the purpose of observation. It is different for port development and for tsunami countermeasure. The location and design specifications should be suitable for each purpose.

・ JCG

JCG has no plan to establish a new facility. The Kamaishi Tide Station was destroyed when the 2011 tsunami occurred. After that, it has been newly established.

(7) The related organizations have their own manuals or guidelines for system maintenance and operation. Staff members in charge of operation and maintenance are taught mainly through OJT (on-the-job training).

The organizations have their own operation and maintenance manual for system maintenance and operation, although most of them are for internal use. There are no formal trainings for operation and maintenance, and the staffs are mainly taught through OJT.

・ JMA

JMA has manuals for the specifications when procuring or outsourcing maintenance services. There is no training for maintenance and operation of tide observation facilities. OJT is necessary because the staffs cannot readily use the manual.

・ GSI

Basically, a series of manuals is prepared for all works. The manuals are only for troubleshooting of GSI and some of them cannot be shared. The table of contents of these manuals have been provided to the survey team.

・ PHB

Although there are regular maintenance and inspection manuals, some of them are difficult to be provided due to confidentiality. There is no manual for software (works on this are implemented by a contractor). There is a manual on maintenance of observation equipment with section for each equipment, i. e., tide gauge and GPS wave gauge.

・ JCG

There is no manual for daily inspection or check sheet. However, there is an in-house manual for regular inspections (standard surveys) which are conducted once every two years. There are also lease manuals and materials within the department (e.g., memorandum of the person in charge).

Table 2.15 Manuals and Trainings in the Related Organizations

Terms	JMA	GSI	PHB	JCG
Manuals	- Maintenance procedure (see Figure 2.22 to Figure 2.27)	- Maintenance procedure (see Figure 2.28, Figure 2.29)	- Regular maintenance and inspection manuals (tide	- Manual for regular inspections - Lease manuals - Memorandum

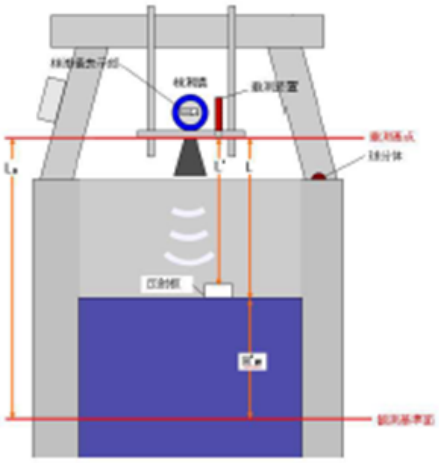
	- Inspection of transmission equipment	- Trouble-shooting	gauge and GPS wave) - No manual for software	
Trainings	No formal training (only OJT)	No formal training (only OJT)	No formal training (only OJT)	No formal training (only OJT)

Source: JST

Appendix 1-1

Tide gauge (radio wave type) check card

Location Name		Signature of person in charge		Name of Checker	
Date :	DD/ MM/ YYYY			Name of person confirming results	



Vertical measurement inspection

- L_0 Height from the observation reference plane to the base point of vertical measurement
- H_{ws} Tide level displayed on the tide gauge
- H_w One-minute average of the tide level displayed on the tide gauge
- L_s Measured with a laser rangefinder on the base point of the vertical measurement
- L' One-minute average of the data measured by the laser distance meter on the base point of the vertical measurement
- T Thickness of reflector (=30mm)
- H'_w Height from the observation reference plane to the sea level.

X is the order in which the values were read every 10 seconds for 1 minute

(Notes on the calculation of inspection results)

In calculating Hw and L', round off the decimal point. The integer values of Hw and L' after rounding are used to calculate △H.

Time (HH:MM)	:	:	:	:	:
L0					
Hw1					
Hw2					
Hw3					
Hw4					
Hw5					
Hw6					
Hw (Hw1～Hw6の平均)					
L1					
L2					
L3					
L4					
L5					
L6					
L' (L1～L6の平均)					
T	30	30	30	30	30
H'w (L0－L'－T)					
ΔH (Hw－H'w)					

※Double-click the table to edit it.

ΔH Average (3 times) _____mm (hh: mm)

If the difference between the maximum and minimum values of △H at three times is 5 mm or more, add two more times, and the calculation of the average value uses the three values excluding the maximum and minimum values out of a total of five times.
(e.g., if the results of five times are -1, 5, 6, 4, and 5, in that order, the ΔH average (three times) is 4.6 mm, which should be within 5 mm)

For time, fill in the second of the averaged △H.

Other errors, etc.

Figure 2.22 Tide gauge (radio wave type) Check Sheet for regular inspection (JMA)

Appendix 1-2

Tide station check card

Location Name

Signature of person in charge

Date : DD/ MM/ YYYY

Name of Checker

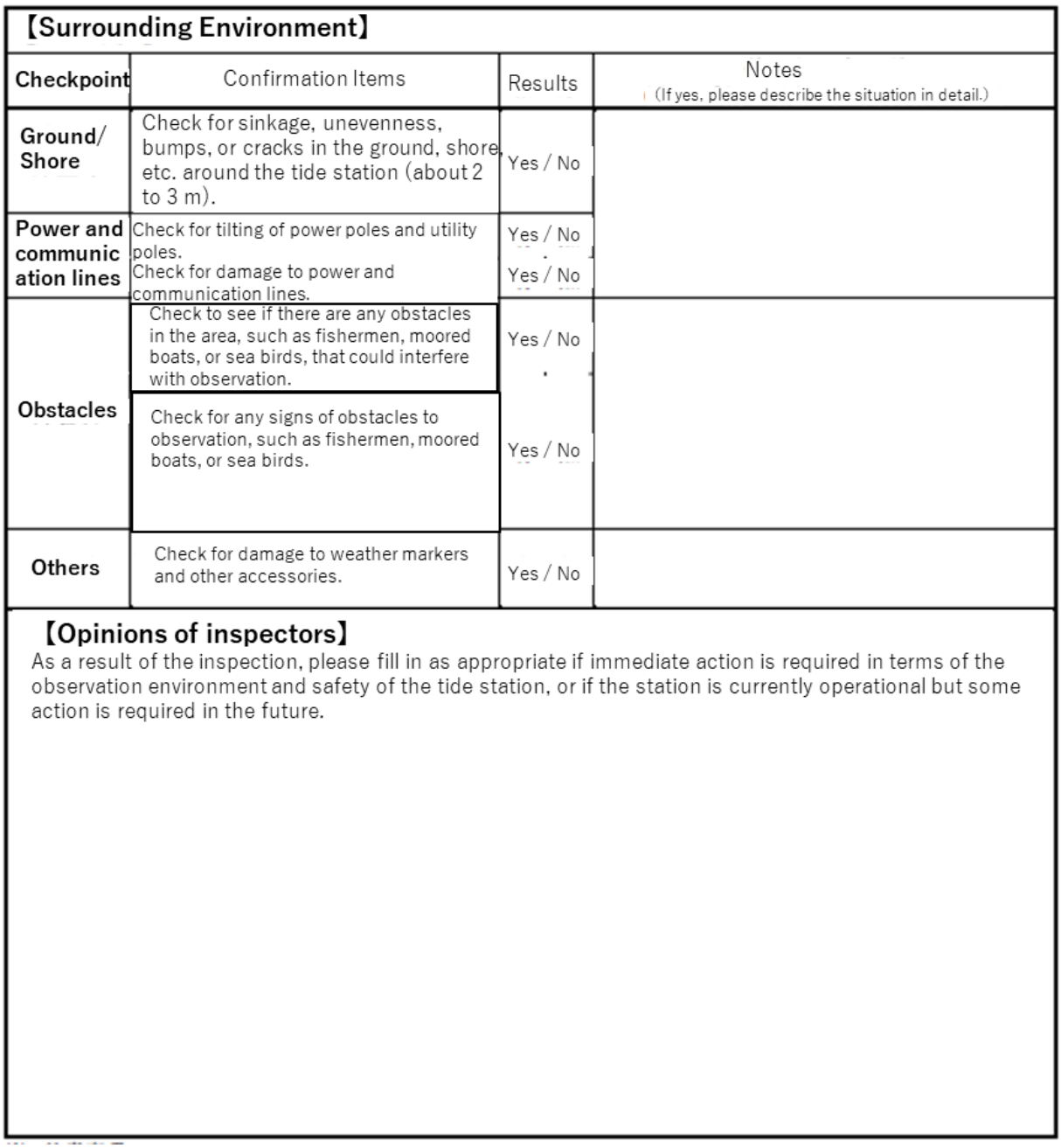
【Exterior of the tide station】

Checkpoint	Confirmation Items	Results	Notes (If yes, please describe the situation in detail.)
Foundation	Check for cracks and damage	Yes / No	
	Check for misalignment between building and foundation	Yes / No	
Exterior walls and roofs	Check for peeling, staining, cracking, or lifting on the exterior walls.	Yes / No	
	Check for peeling, staining, cracking, or lifting on the roof.	Yes / No	
Water pipes	Check for broken or damaged water pipes.	Yes / No	
	Check for shellfish and accumulation of trash and sediment at the end of the conduit.	Yes / No	
	Check that there are no wave dissipating blocks built up on top of the water pipes.	Yes / No	
Others	Check for damage to fences, stairs, bridges, fittings and other attachments.	Yes / No	

【Inside the tide station】

Checkpoint	Confirmation Items	Results	Notes (If yes, please describe the situation in detail.)
Interior walls Ceiling and floor	Check for peeling, staining, cracking, or lifting on the interior walls, ceiling, and floor.	Yes / No	
	Check for floor inclination. To check the inclination of the floor, put a small ball on the floor and check to see if it rolls.	Yes / No	
Water well	Check for spalling, cracking, or lifting of the well's interior walls.	Yes / No	
	Check for floating debris on the sea level in the well.	Yes / No	
	Check for accumulation of trash, sediment, etc. in the water part of the well.	Yes / No	
Tide gauge stand	Check for rust and corrosion.	Yes / No	
Others	Check for damage to other attachments.	Yes / No	

Figure 2.23 Tide station Check Sheet for regular inspection (1) (JMA)



【Surrounding Environment】

Checkpoint	Confirmation Items	Results	Notes (If yes, please describe the situation in detail.)
Ground/ Shore	Check for sinkage, unevenness, bumps, or cracks in the ground, shore, etc. around the tide station (about 2 to 3 m).	Yes / No	
Power and communication lines	Check for tilting of power poles and utility poles.	Yes / No	
	Check for damage to power and communication lines.	Yes / No	
Obstacles	Check to see if there are any obstacles in the area, such as fishermen, moored boats, or sea birds, that could interfere with observation.	Yes / No	
	Check for any signs of obstacles to observation, such as fishermen, moored boats, or sea birds.	Yes / No	
Others	Check for damage to weather markers and other accessories.	Yes / No	

【Opinions of inspectors】

As a result of the inspection, please fill in as appropriate if immediate action is required in terms of the observation environment and safety of the tide station, or if the station is currently operational but some action is required in the future.

Figure 2.24 Tide station Check Sheet for regular inspection (2) (JMA)

別紙２

Check card for Tide Level and Tsunami Observation Facilities

Location Name		Signature of person in charge	
Date ： DD/ MM/ YYYY		Name of Checker	

【Installation quay】

Checkpoint	Confirmation Items	Results	Notes (If yes, please describe the situation in detail.)
Around the facility (about 2 to 3 meters)	Check the top surface of the wharf for sinkholes, uneven ground, bumps, and cracks.	Yes / No	
	Check for inclination of the top of the quay. To check the inclination of the floor, put a small ball on the floor and check to see if it rolls.	Yes / No	
	Check for cracks and fissures in the submarine ground.	Yes / No	
	Check for gaps between the quay and the seabed.	Yes / No	
The whole shore wall	Check the top surface of the wharf for sinkholes, uneven ground, bumps, and cracks.	Yes / No	

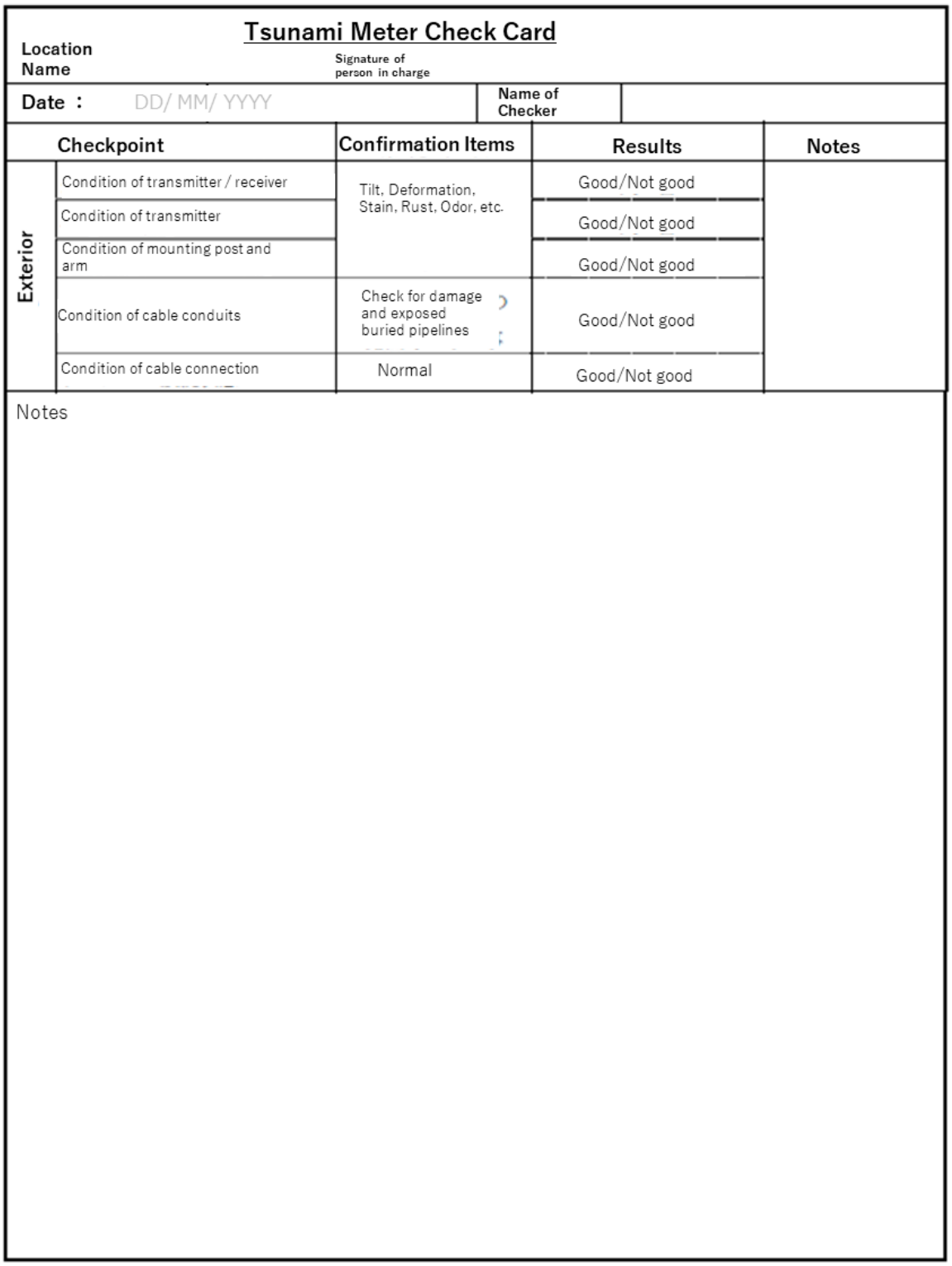
【Surrounding Environment】

Checkpoint	Confirmation Items	Results	Notes (If yes, please describe the situation in detail.)
Power and communication lines	Check for tilting of power poles and utility poles.	Yes / No	
	Check for damage to power and communication lines.	Yes / No	
Obstacles	Check to see if there are any obstacles in the area, such as fishermen, moored boats, or sea birds, that could interfere with observation.	Yes / No	
	Check for any signs of obstacles to observation, such as fishermen, moored boats, or sea birds.	Yes / No	
Others	Check for damage to the satellite communication equipment foundation and other accessories.	Yes / No	

【Opinions of inspectors】

As a result of the inspection, please fill in as appropriate if immediate action is required in terms of the observation environment and safety of the tide station, or if the station is currently operational but some action is required in the future.

Figure 2.25 Check Sheet for regular inspection of tide level and tsunami observation facilities (JMA)



Tsunami Meter Check Card

Location Name

Signature of person in charge

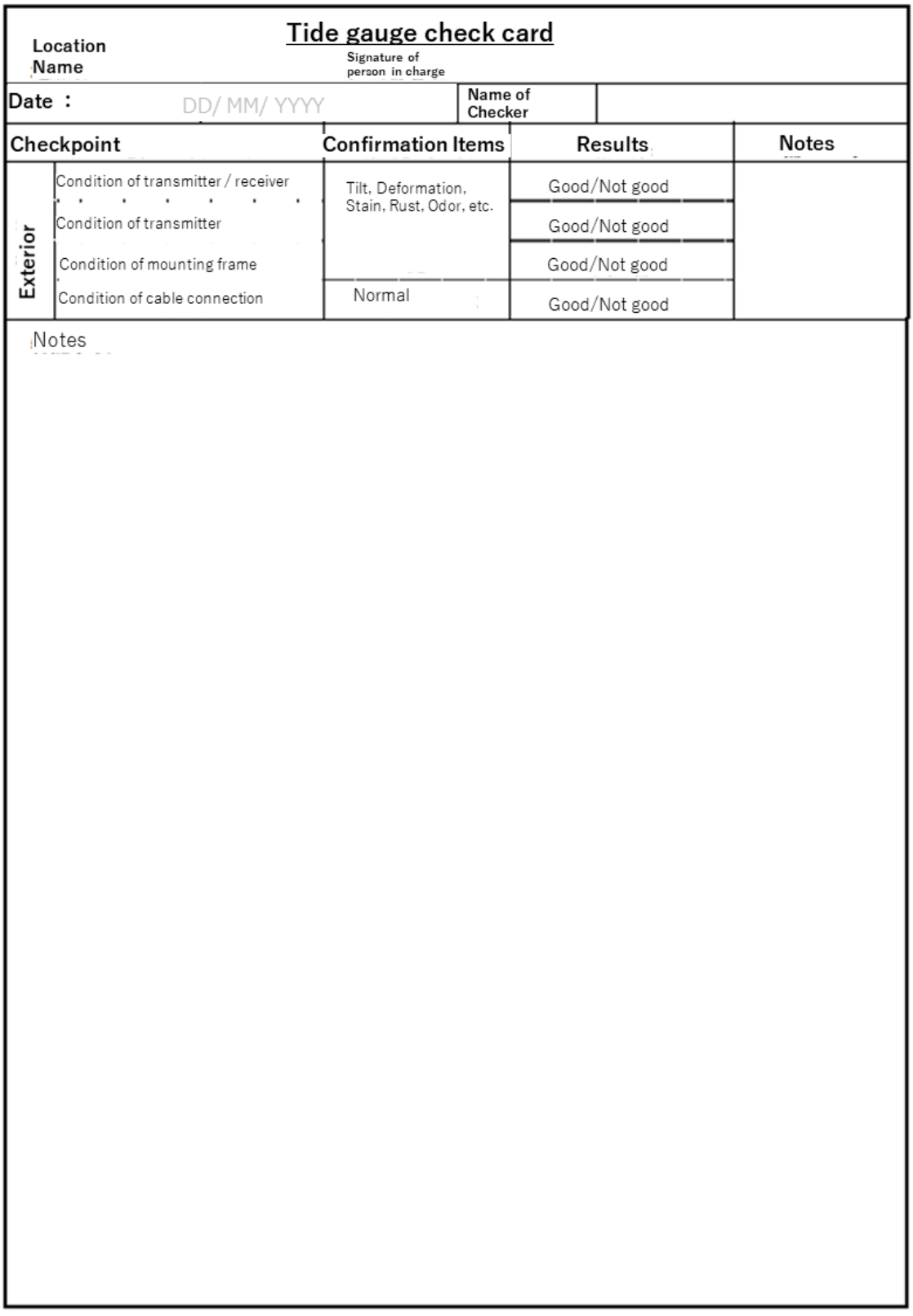
Date : DD/ MM/ YYYY

Name of Checker

	Checkpoint	Confirmation Items	Results	Notes
Exterior	Condition of transmitter / receiver	Tilt, Deformation, Stain, Rust, Odor, etc.	Good/Not good	
	Condition of transmitter		Good/Not good	
	Condition of mounting post and arm		Good/Not good	
	Condition of cable conduits	Check for damage and exposed buried pipelines	Good/Not good	
	Condition of cable connection	Normal	Good/Not good	

Notes

Figure 2.26 Check Sheet for for regular inspection of tsunami meter (JMA)



Tide gauge check card

Location Name

Signature of person in charge

Date : DD/ MM/ YYYY

Name of Checker

Checkpoint		Confirmation Items	Results	Notes
Exterior	Condition of transmitter / receiver	Tilt, Deformation, Stain, Rust, Odor, etc.	Good/Not good	
	Condition of transmitter		Good/Not good	
	Condition of mounting frame		Good/Not good	
	Condition of cable connection	Normal	Good/Not good	

Notes

Figure 2.27 Check Sheet for regular inspection of tide meter (JMA)

様式1

Regular Maintenance Check Sheet

Name of Tide Station:

Date and Time of Maintenance : hh: mm DD/ MM/YYYY ～ hh: mm DD/ MM/YYYY

Name :

1.Inside and outside the tide station (check for damage)

No.	Checkpoint	Confirmation Items	Check for errors.	Notes (If yes, please describe the situation in detail.)
①	Checkpoint	Damaged	Yes / No	
②	Exterior and interior walls	Spalling, Cracking, Lifting	Yes / No	
③	Air conditioner outdoor unit	Damaged, Abnormal drainage	Yes / No	
④	Around water pipe	Breakage, Drifting debris	Yes / No	
⑤	Telephone pole	Leaning of pillars, Deterioration of communication lines	Yes / No	
⑥	Electronic reference point	Damaged, Collapsed	Yes / No	

2.Tide gauge (check for wheel drop, corrosion, entanglement, and deterioration)

No.	Checkpoint	Confirmation Items	Check for errors.	Notes (If yes, please describe the situation in detail.)
⑦	Pulley of a tide gauge	Corrosion	Yes / No	
⑧	Tide gauge wire	Entanglement, Wheel Breakage, Corrosion	Yes / No	
⑨	Tide gauge string	Entanglement, Wheel Breakage, Deterioration	Yes / No	
⑩	Tide gauge weight	Corrosion, Tangling of strings, Wheel breakage	Yes / No	
		Lubricate the shaft of the pulley (check YES after lubricating).	Yes / No	
⑪	Well Covers	Check that the wire and weight are not in contact with the well cap.	Yes / No	
⑫	Base plate	Damaged	Yes / No	
⑬	Bucket for atomic measurement	Damaged	Yes / No	
⑭	Buoy markers	Dirt, Damaged, Damaged mounting hardware	Yes / No	

3.Devices (check for proper operation)

No.	Checkpoint	Confirmation Items	Check for errors.	Notes (If yes, please describe the situation in detail.)
⑮	Automatic and centralized tide detection and management system	Displayed numbers (See Attachment 2)	Yes / No	
⑯	GNSS observation devices	Illuminated lamp	Yes / No	
⑰	Air-conditioning	Set temperature (See Attachment 3)	℃	
		Operating conditions	Yes / No	

⑱	Other	

※If you find any new errors, please contact the person in charge at the local surveying department or branch office.

Figure 2.28 Regular Maintenance Check Sheet (GSI)

様式2

Tide gauge atomic measurement chart

Name of Tide Station:	Name:		
Date of Maintenance	DD/ MM/ YYYY	DD/ MM/ YYYY	DD/ MM/ YYYY
Measurement start time	hh: mm	hh: mm	hh: mm
Measured Data (Before Atomic Measurement)			
Measured Data			
Measured Data (after atomic measurement)			
Ocean Specific gravity measurement seawater temperature	. ℃	. ℃	. ℃
Ocean Specific gravity of seawater	.	.	.
In the well Specific gravity measurement seawater temperature	. ℃	. ℃	. ℃
In the well Specific gravity of seawater	.	.	.
Depth from fixed point to well bottom	. m	. m	. m
Notes			

Figure 2.29 Tide gauge atomic measurement chart (GSI)

Chapter 3 Analysis and Issues of Tide Observation Systems on Quality Management, Operation and Maintenance

3.1 Analysis

Collected data and information are analyzed for policy of operation, organization of observation system, stability of operation, and quality management as detailed below.

3.1.1 Policy of operation

As previously described, the policy of operation depends on the main role of the observation system.

(1) System for Disaster Risk Reduction

The first priority of the tide observation system of the DRR (disaster risk reduction) organization (e.g., JMA in Japan) is to detect disaster in real time and provide the necessary data that suit the situation during disaster. According to the first objective, the DRR organization should perform 24-hour, 365 days of observation and operation to continuously observe and prevent missing data. The operation policy is focused to prevent failure on all processes of recording real time of water level (i.e., astronomical tide or extreme tide) at the station, transmitting the observation data through the communication line, and processing at the data center. In addition to these, it is important to minimize time for recovery (i.e., data missing period) if an error occurs. The data accuracy is also necessary for supporting activities for disaster risk reduction. The unit of observation tide for DRR is centimeter, although the data unit for the refence level for ground survey or sea chart is millimeter (e.g., GSI, JCG).

(2) System for Organizational Responsibility

The main objectives of tide observation of the related organizations are quite variable, depending on the organizational responsibility. For DRR activities, the observed data should be utilized for data sharing among the related organizations.

The main objectives of the related organizations in Japan are following:

・ GSI

Finding the height standard of whole Japan land and at sea

・ PHB

Measuring the reference water level for construction / port development

・ JCG

Measuring the reference height of the sea chart for maritime safety

The organizations do not have the responsibility of 24-hour, 365 days tide observation and operation of facilities. However, they should maintain and continue tide observation for carrying out their own objectives. Therefore, they should keep the best condition for observation through regular inspection and maintenance activities.

3.1.2 Organization and Human Resource

Operating organization depends on the scale (i. e., number of stations) of the observation system. Table 3.1 shows a summary of the operating organizations of tide observation systems in Japan. A total of around 10 stations are being managed by one person at JMA. On the other hand, GSI and

JCG assign one person every around 5 stations on the average, while PHB has managed all stations through outsourcing companies.

Table 3.1 Operating Organizations of Tide Observation Systems

Terms	JMA	GSI	PHB	JCG
Monitoring hours	- 24 hours, 365 days	- Business hours	- 24 hours (outsourcing)	- Business hours
Number of stations	70	25	68	20
Number of staffs in main office	6	4	Few hours (mainly outsourcing)	4
Number of staffs in regional offices	3/region (18/ 6 regions)	2/region	1-3/region	1-3/region
Stations/staff in main office	11~12	6~7	--- (mainly outsourcing)	5

Source: JST

3.1.3 Measures for Stable Operation of Tide Observation System

Tide observation system is required to function 24 hours for 365 days for DRR purposes. The critical points of stable operation are follows:

(1) Prevention of failure

It is crucial to keep the robustness of observation facilities and to establish the redundancy for the causes of failures. Similar to the measures in operating earthquake observation system, the examples are as follows:

1) Procure reliable observation equipment, server, and communication equipment.
2) Use reliable power supply and communication line, or establish redundancy by multiplexing. Example: GSI adopts a system that can secure three-day observation after power outage.
3) Select a suitable place to install equipment (e.g., avoiding currents, with good connection to sea).
4) Duplicate the server system. Example: GSI and JCG have 2 servers for ensuring the observation data.
5) Conduct regular inspection. Example: JMA conducts regular inspections every year.

(2) Quick recovery

In order to minimize the time for recovery (i.e. missing data period), it is required to identify failure as early as possible and to establish recovery as quick as possible.

Obvious failures or errors are detected by monitoring at the central system based on abnormal values (too low or high), strange waveform, no data transmission, and disconnection of communication line. However, small errors cannot be detected by the central system because some errors gradually increase, and tide may be affected by meteorological phenomena (low pressure, ocean current, etc.). It is necessary to watch and confirm the observed data every day in order to find such small errors. Detected failure is analyzed to identify the source of failure using all obtained information. Based on the failure causes specified, the response should be determined.

The following measures are necessary:

1) Detect failure earlier.

✓ Monitor for 24 hours.

✓ Improve monitoring and self-diagnosis function of the system such as sending SOH (state of health).

✓ Enhance monitoring capability/ skills of staffs.

2) Find the source of failure and quickly establish recovery measures.

✓ Select the equipment to easily find failure sources (as many SOH information).

✓ Create a standard procedure to find failure sources by using check sheets.

✓ Enhance response capability/ skills of staffs.

✓ Establish an emergency response organization system in the event of failure by securing a contract with a company to provide a 24-hour response service during emergency.

3.1.4 Measures for Quality Management of Tide Observation System

It is significant to keep a good condition of observation facilities, early detection of degrading quality and recovery in order to ensure the high quality of observation data.

(1) Keeping a facility in good condition for tide observation

It is necessary to maintain constant and stable performance of the equipment, static circumstances, and quality of the observation facility including sensor, wire and other equipment in order to keep a good observation condition. Examples are as follows:

1) Replace equipment before deterioration. The observation equipment should be replaced every 15 years. The electric devices and computers should be renewed every 5 years.

2) Prevent changes of surrounding circumstances at stations. The characteristics of the location of tide station should be clarified and the maintenance plan should consider the characteristics to ensure the quality of observation data.

3) Avoid cause of damage to the equipment such as thunderstroke and others.

4) Keep stable the electric power using a stabilized power supply or a solar power system.

(2) Early detection of degrading observation data quality

As mentioned above, obvious failures or errors are detected by monitoring at the central system based on abnormal values (too low or high), no data transmission, and so on. However, small errors cannot be detected by the central system because some errors gradually increase, and tide may be affected by meteorological phenomena (low pressure, ocean current, etc.). Major errors can be detected by human eye. Therefore, the staff in charge of tide observation should build sufficient experience regarding management of tide observation data. The following are examples of how to do this:

1) Watch and check the observation data every day in order to detect small errors by human eye. Since the characteristics of the tide level are different from each other depending on the location, the standards to detect errors cannot be unified for all observation points.

2) Compare the observation data with the predicted astronomical tide level using the graph and value shown on the terminal of the control system. The criteria of errors should be determined based on the experience and historical records.

3) Build experience of detecting small errors and organize the characteristics of the tide level and repeating period of clogging of water pipe. The data are gradually shifted, because the effect of clogging of water pipe increases gradually. The person in charge of observation should record and build the characteristics of each location of tide stations and make memorandum for next person in charge (i.e., technical transfer).

3.2 Tasks for Action in the Country

The main purpose of BMKG's tide observation system is on the aspect of disaster risk reduction activities. Therefore, real-time observation is the first priority.

Table 3.2 shows the tasks for a stable operation of the system and for keeping the quality of obtained data.

Table 3.2 Stable Operation of the BMKG System and Keeping Quality Data

Purpose	Issues	Measures
Stable operation	Prevention of failure	1) To procure reliable observation equipment, server, and communication equipment. 2) To use reliable power supply and communication line, or to establish redundancy by multiplexing. 3) To select a suitable place to install equipment. 4) To duplicate the server system. 5) To conduct regular inspection.
	Finding cause of failure and establish quick recovery	1) To detect failure earlier - To monitor for 24 hours - To improve monitoring and self-diagnosis function of the system such as sending SOH - To enhance monitoring capability/ skills of staffs 2) To find the source of failure and quickly establish recovery measures - To select the equipment to easily find failure sources (as many SOH information) - To create a standard procedure to find failure sources by using check sheets, etc. - To enhance response capability/ skills of staffs. - To establish an emergency response organization system in the event of failure by securing a contract with a company to provide a 24-hour response service during emergency, etc.
Quality management	Keeping a good condition for observation	1) To replace equipment before deterioration. 2) To prevent changes of surrounding circumstances at stations. 3) To avoid cause of damage to the equipment such as thunderstroke and others. 4) To keep stable electric power using a stabilized power supply or a solar power system.
	Early detection of degrading observation data quality	1) To watch and check the observation data every day in order to detect small errors by human eye. 2) To compare the observation data with the predicted astronomical tide level. 3) To build experience of detecting small errors and organize the characteristics of the tide level and repeating period of clogging of water pipe.

Source: JST

There are also other organizations (such as the organizations of spatial maps, ports and fishery, etc.) aside from BMKG which have possibility to conduct tide observation for their own purposes, although BIG has already been observing tides. It is very challenging for one organization, i.e., BMKG, to cover the whole Indonesian coast for tide observation. Therefore, data sharing with related organizations is critical to cover the whole area of Indonesia for tsunami detection.

Table 3.3 shows the tasks for sharing observation data for disaster risk reduction activities.

Table 3.3 Tasks for Sharing Observation Data for Disaster Risk Reduction Activities

Purpose	Issues	Measures
Sharing observation data	Smooth Coordination	✓ An agreement between related organizations is needed for cooperation. The agreement includes the responsibility of own observation data, connection method, and troubleshooting activities.
	Quality Management	✓ The reference standard levels in tide stations of each organization should be clarified to integrate the observation data because each organization has its own observation method based on its purpose ✓ The conversion values shall be also identified and indicated in the agreement mentioned above. ✓ Constant communication is necessary to solve some network troubles (e.g., Gateway issue)

Source: JST

The results of this study will contribute in the improvement of tide observation of BMKG. However, the current status of the above issues and measures should be confirmed by obtaining local information in field survey. Using such information, the improvement of tide observation and the maintenance and operation of facilities will be recommended more effectively.

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APPENDIX 8-15

The Review on Cooperation Between Japan Meteorological Agency and Other Institutions in the Field of Disaster Prevention Information Transmission

The Review on Cooperation Between Japan Meteorological Agency and Other Institutions in the Field of Disaster Prevention Information Transmission

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

May 2021

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
BMKG	Agency of Meteorology, Climatology and Geophysics (Indonesian: Badan Meteorologi, Klimatologi, dan Geofisika)
BUFR	Binary Universal Form for the Representation of Meteorological Data
CATV	Community Antenna Television; Cable Television
DAU	Daily Active Users
COVID-19	Coronavirus Disease 2019
CSR	Corporate Social Responsibility
DPI XML	Disaster Prevention Information XML
DRR	Disaster Risk Reduction
EEW	Earthquake Early Warning
EPOS	Earthquake Phenomena Observation System
FDMA	Fire and Disaster Management Agency
GEJE	Great East Japan Earthquake
GIS	Geographic Information System
GPS	Global Positioning System
GRIB	Gridded Binary or General Regularly Distributed Information in Binary Form
InaTEWS	Indonesia Tsunami Early Warning System
JCBA	Japan Community Broadcasting Association
JCG	Japan Coast Guard
JETT	JMA Emergency Task Team
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
JMBSC	Japan Meteorological Business Support Center
MIC	Ministry of Internal Affairs and Communications
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
NHK	Japan Broadcasting Corporation
NMAPS	News Mash Up Advanced Probe System
NPA	National Police Agency
NTT	Nippon Telegraph and Telephone
PVMBG	Volcanological Survey of Indonesia (Indonesian: Pusat Vulkanologi dan Mitigasi Bencana Geologi)
SMS	Short Message Service
SNS	Social Networking Service

Chapter 1 Introduction

1.1 Background

The Project implemented the survey "The Review on Disaster Prevention Information Transmission from the Perspective of Residents in Indonesia" prior to this study. The survey identified the challenges in raising the awareness of stakeholders on earthquake and tsunami observation and issuing the tsunami warning, as well as in strengthening the collaboration with related agencies. According to the said survey, residents in Japan and Indonesia have significant differences in information sources and customs for taking actions against earthquake and tsunami disasters.

The table below indicates the major differences between Japan and Indonesia on disaster information dissemination for residents and in collecting information related to evacuation actions.

Table 1.1.1 Notable differences between Japan and Indonesia on disaster information dissemination

Japan	Indonesia
・Private sectors develop mobile applications, or administrative bodies order private sectors to develop mobile applications related to disaster information. Residents download the applications of their municipalities or private sources based on their preferences. ・Private portal sites (such as Yahoo!) provide disaster information, including those for earthquake and tsunami. ・Most of the information sources (such as TV, radio, and other media and mobile applications) issue disaster information simultaneously. ・JMA provides data to private sector and other government organizations ・Communication facilities and equipment, including disaster wireless network, prevail and residents can take actions in case of blackout. ・There are cases wherein residents underestimate the risk because they fail to understand the warning correctly, and cannot take proper evacuation actions.	・Agency of Meteorology, Climatology and Geophysics (BMKG), a central government agency, directly operate the disaster information mobile application. ・SMS, SNS, and information from mobile application, directly issued by BMKG's tsunami information system called InaTEWS, provide disaster information faster than other means of communication. Each SNS issues the information in slightly different timing. ・Since SNS provides information faster than TV and radio, more than ten million residents follow BMKG's SNS. ・Since private mobile applications are not available, share of BMKG's mobile application in information dissemination is dominant. Other major mobile applications are also official applications of government agencies. ・Disaster information infrastructure, such as tsunami siren towers, are not well-equipped to cover the population (Example: Only one tsunami tower is equipped in Palu City which has a population of approx. 300,000.) ・Communication of administrative information is not done well, and residents evacuate on their own decision or from recommendation of neighbors or friends.

Source: JICA Expert Team

Since the existing disaster information infrastructure and available disaster information sources between Japan and Indonesia are significantly different, it is essential to consider measures that fit the circumstances in Indonesia, thus a full-fledged Japanese system cannot be introduced.

In the short term, it will be effective to improve public relations media (such as BMKG's official website, SNS, and mobile applications), which currently have dominant share on information dissemination among residents. To do this, it is necessary to improve the content of information issued by BMKG to make it easier to understand, and take an approach to improve the provision of information so that the residents can correctly understand them and take appropriate evacuation actions.

1.2 Objective of the Review

In order to promote better understanding for improving the content of information issued by BMKG for residents, and adopt approaches to enhance the provision of information so that residents can correctly understand BMKG's information and take appropriate evacuation actions, the survey aims to (1) introduce ways by which Japanese private companies provide information in mobile applications that are easy for recipients to understand, and (2) do activities conducted by JMA and the Local Meteorological Offices to promote understanding among recipients of information.

As for improving the content of information, in the short term, the objective is to enhance BMKG's understanding of the overall picture of mobile application improvement by introducing various examples of applications and websites of private companies and mobile applications of local governments that can be references for improving the contents of BMKG's website and mobile applications.

In the long term, it is necessary to establish a system to provide information to a wider range of residents in a timely manner in cooperation with private companies and local governments, including the media. It is expected that this report will serve as a reference for the long-term development of the earthquake/tsunami information infrastructure in the BMKG by introducing Japan's efforts to instantly provide accurate information to residents in cooperation with other organizations, both public and private, through technical cooperation and data provision.

Chapter 2 Cooperation Between Japan Meteorological Agency and Other Institutions for Prompt Disaster Prevention Information Transmission

This chapter illustrates the current information flow from JMA and related agencies including public and private agencies. JMA and its auxiliary organization, the Japan Meteorological Business Support Center (hereinafter referred to as "JMBSC"), issue editable information which related agencies promptly convert into easy-to-understand format for residents. This chapter also introduces the actual case studies of the private actors that utilize the information from JMA. These private bodies play essential roles to deliver necessary information to residents. Local governments are also service providers of disaster information through various means of communication. Consequently, the involvement of public and private sectors contributes to secure redundancy of information, which is critical in case of large-scale disaster.

2.1 Information Transmission from JMA and JMBSC to Other Organizations

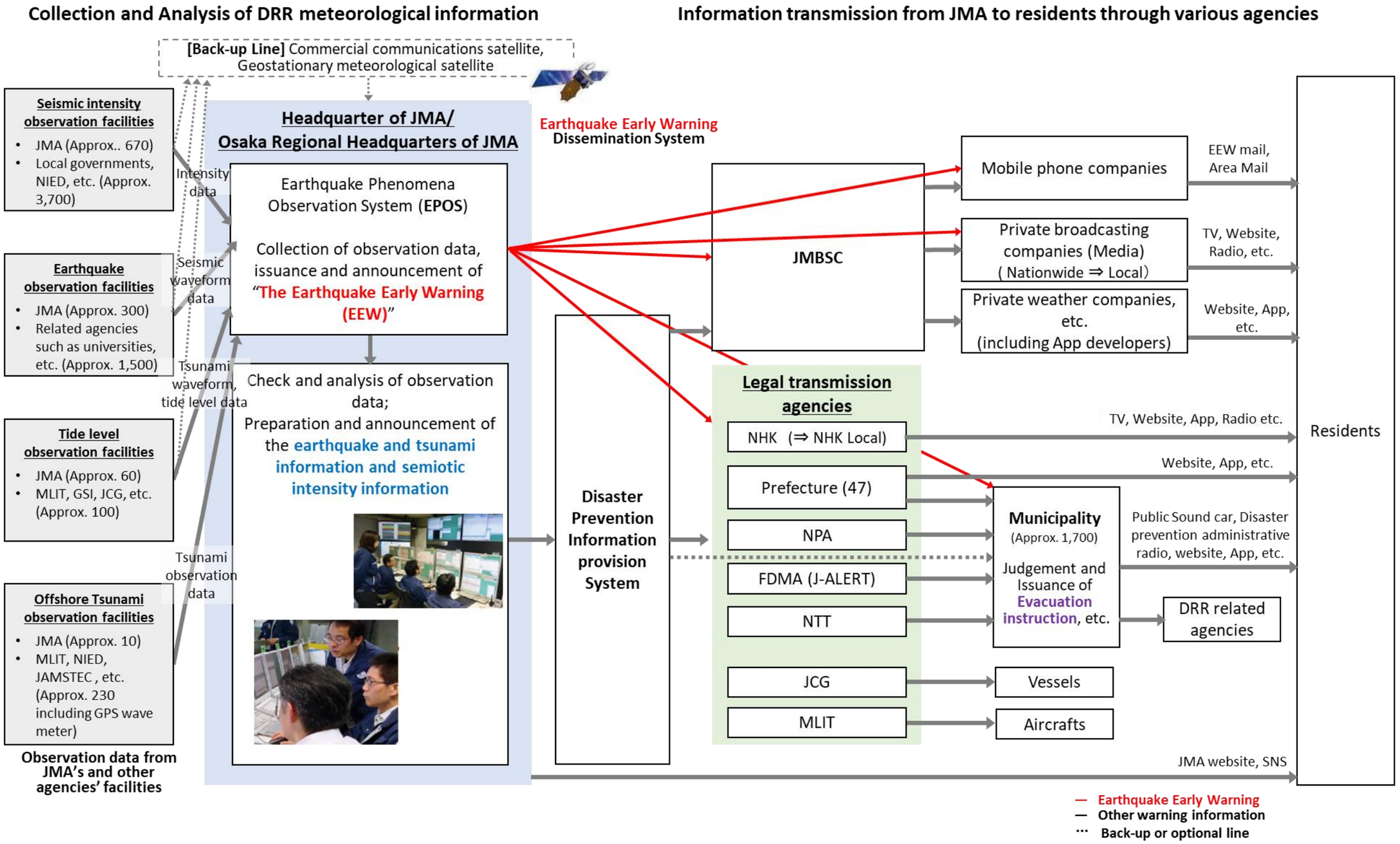
2.1.1 Functions of JMA in terms of disaster-related information transmission

As one of the national DRR-related agencies, JMA collects and analyzes meteorological observation data and predicts disasters in accordance with the "Basic Act on Disaster Management" and "Meteorological Service Act". The various DRR meteorological information issued by JMA are widely disseminated to residents through DRR-related agencies including government organizations and news media. The flow of information, from collection and analysis to dissemination to residents, is summarized below and shown in Figure 2.1.1.

(1) Collection and analysis of DRR meteorological information

JMA operates an array of observation networks to monitor weather, climate, and the environment on a nationwide scale. The observation data include the latest data of surface observation (e.g., temperature, rain, wind), upper-air observation (wind profilers and radiosondes), sea-level gauge data, tide gauge data, oceanographic and marine meteorological observation, seismic intensity data, as well as observation data from other relevant agencies including local governments and Japan Coast Guard (JCG). Particularly, in terms of earthquake- and tsunami-related information, the JMA headquarters, JMA in Tokyo and Osaka Regional Headquarters, monitor round-the-clock the observation data of seismic intensity, seismic waveform, tsunami waveform and tide level, and offshore tsunami from its facilities as well as those from other agencies. In order to promptly process, analyze and provide warning information including the Earthquake Early Warning and Tsunami Warning, JMA utilizes the Earthquake Phenomena Observation System (EPOS). This system is installed at JMA headquarters, JMA in Tokyo and Osaka Regional Headquarters, so that even in the occurrence of a large-scale disaster in either Tokyo or Osaka, warnings can be issued without fail. Since the Great East Japan Earthquake (GEJE) backup power supplies for seismographs and seismometers have been also strengthened in order to avoid functional degradation of the communication network and to enable observation of seismic waveforms and seismic intensity due to prolonged power outages even after a large scale earthquake. Furthermore, the use of backup lines utilizing satellite communications (commercial communications satellite and geostationary meteorological satellite) has been reinforced[1].

[1] JMA (2012) https://www.jma.go.jp/jma/kishou/books/hakusho/2012/HN2012.pdf



Source: JICA Expert Team (Reference: JMA)[2]

Figure 2.1.1 Flow of DRR-related information from JMA to residents

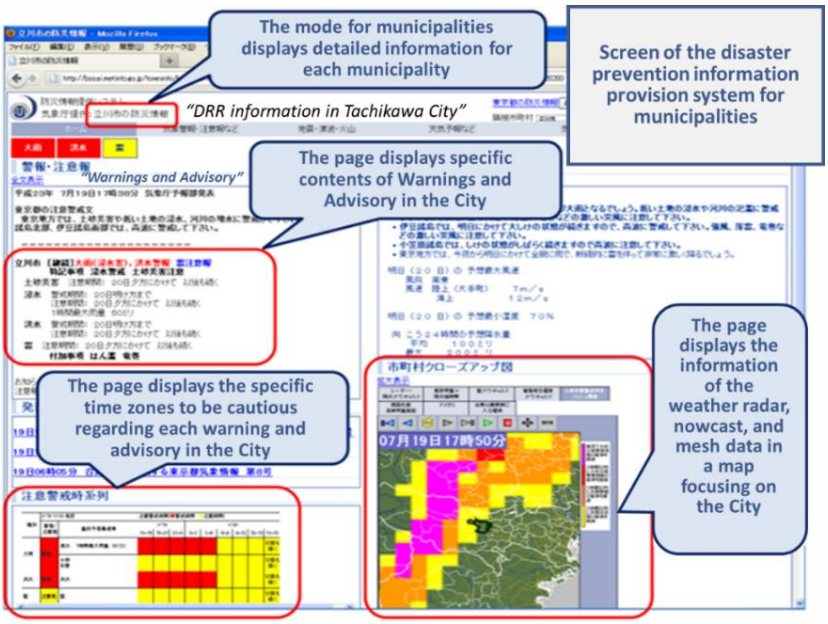
[2] Kyushu and Yamaguchi pref. Disaster Prevention and Meteorological Information Handbook 2020 (Japanese)

(2) Transmission of disaster-related meteorological information

1) Information transmission from JMA to DRR-related agencies

According to the Meteorological Service Act, JMA shall immediately notify the warning information to the National Police Agency (NPA); Fire and Disaster Management Agency (FDMA); Ministry of Land, Infrastructure, Transport and Tourism (MLIT); Japan Coast Guard (JCG); prefectures; Nippon Telegraph and Telephone (NTT) and the Japan Broadcasting Corporation (NHK), which are referred to as "legal transmission agencies". Therefore, regarding earthquakes and tsunami, JMA immediately disseminates the information on earthquake early warning, tsunami warnings, seismic intensity, and other information to these agencies. In order to reliably transmit information to these agencies, JMA utilizes the Disaster Prevention Information Provision System which connects JMA and each of these agencies by a dedicated line.

In terms of information transmission between prefectures and municipalities, it is also stipulated in the Meteorological Service Act that prefectures shall immediately transmit warning information to municipalities. However, JMA also directly provides DRR-related information to municipalities through an internet version of the Disaster Prevention Information Provision System optionally as requested. This mode provides municipalities with specialized information, which are not only DRR meteorological information, forecast and observation data, but also commentaries by forecasters so that the municipalities can appropriately respond to disasters (see Figure 2.1.2).



Source: JMA (2012)[3] (Translated by JICA Expert Team)[4]

Figure 2.1.2 Screen example of the disaster prevention information provision system for municipalities

Since the Earthquake Early Warning needs to be promptly transmitted, this system is not utilized for its early warning. Instead, the EPOS promptly disseminate the warning information to a part of legal transmission agencies, municipalities and mobile phone companies in order to rapidly inform the warning information to residents. JMA also utilizes the J-ALERT system which is a satellite-based system managed by FDMA to automatically and immediately transmit the warning information to the systems of prefectures and municipalities.

The information issued by JMA is provided in the "JMA disaster prevention information XML

[3] https://www.jma.go.jp/jma/kishou/shingikai/kentoukai/H24johokaizen/part1/part1-shiryo5.pdf
[4] The warnings and advisories have been issued for each municipality by JMA since 2010 so that local administrative officers and residents can easily recognize that they are in the warned areas.

Format (JMA-XML)", a highly versatile format that is easy for users to utilize. Therefore, legal transmission agencies and municipalities are able to easily utilize the information, process them into a format suitable for each means of dissemination, and then disseminate them to residents. In addition, in May 2018, the JMA Emergency Task Team (JETT) was established to support disaster prevention responses of local governments, such as support for understanding DRR and meteorological information; and advice for issuing evacuation advisories. The team is dispatched from JMA to the local disaster management headquarters when a disaster occurs or is expected to occur[5].

In addition to the information transmission between JMA and these public agencies, JMA provides information to private agencies including private weather companies, smartphone application developers, private broadcasting companies (news media) among others, through the information provision service of JMBSC (See Section 2.1.2 for details). As with legal transmission agencies, JMA utilizes the Disaster Prevention Information Provision System to transmit warning information to JMBSC.

2) Information transmission to residents

As stipulated in the Basic Act on Disaster Management, municipalities promptly disseminate the warning information to residents and determine the necessity of issuing evacuation advisories and evacuation orders based on the information. However, JMA also provides the information directly to residents through the JMA website and SNS (Twitter). NHK broadcasts the warning information as well. In addition, the disseminated warning information to private companies through JMBSC is originally processed in these companies and is provided in an easy-to-understand information format (see Section 2.2.1).

Table 2.1.1 shows information types and means of dissemination from JMA to residents through prefectures and municipalities. According to the Basic Disaster Management Plan, there are obligations to make the best efforts that municipalities ensure prompt dissemination of disaster-related information to residents through the disaster prevention administrative radio system, IP communication system among others, as well as to promote the multiplexing and diversifying the means of dissemination of warning information through utilizing systems of email, social media, L-Alert, and other. Particularly, the need of multiplexing and diversification has been strongly demanded based on the lessons learned from the Great East Japan Earthquake.

Table 2.1.1 Information types and means of information transmission

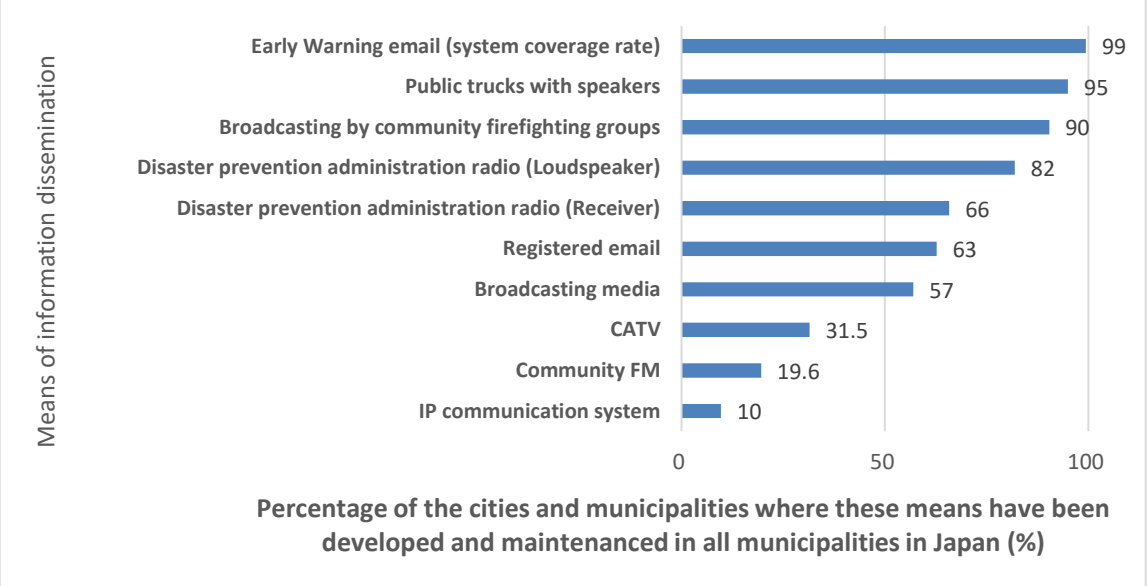
Information type	Issuing agency	Contents	Means of information transmission -1 (JMA to prefectures/ municipalities)	Means of information transmission -2 (prefectures/ municipalities to residents)
DRR and meteorological information	JMA	• Earthquake Early Warning (EEW) • Seismic intensity information • Tsunami warnings or advisories • Estimated initial tsunami arrival time • Estimated maximum tsunami height • Tsunami observation information, etc.	**JMA to prefectures** • JMA disaster prevention information provision system (dedicated line or internet) • Data distribution from JMA based on agreements • JMA website • J-ALERT, etc. **Prefectures to municipalities** • Fax • Email • Prefecture DRR information system (except for fax and email), etc. **JMA to municipalities** • JMA disaster prevention information provision system (Internet)	• Loudspeaker and/or receivers (disaster prevention administrative radio, Digital MCA network, 280MHz Digital network, IP communication system) • Phone (emergency call) • Fax • Email (area mail, early warning email, registered email) • Community radio • CATV • websites • SNS • Public trucks with speakers • Broadcasting by

[5] Pp.I-5, Japan Meteorological Agency Guidebook 2020

Information type	Issuing agency	Contents	Means of information transmission -1 (JMA to prefectures/ municipalities)	Means of information transmission -2 (prefectures/ municipalities to residents)
			• JMA website • J-ALERT, etc.	community firefighting groups • Digital signage • Smartphone application, etc.
Evacuation information	Cities and Municipalities	• Evacuation preparation, start of evacuation for elderly people • Evacuation instructions (emergency)	—	

Source: JICA Expert Team (Reference: FDMA (2020)[6], MIC (2018)[7], MLIT(2012)[8], Disaster Management, Cabinet Office (2021[9])

According to a survey conducted by FDMA in 2016, as shown in Figure 2.1.3, while relatively numerous municipalities have introduced mail service and public trucks with speakers for disseminating disaster-related information and evacuation instructions to residents, the number of municipalities that utilize CATV, community FM, and IP communication system is relatively small. Furthermore, according to a survey on smartphone applications conducted by the Osaka Prefecture in 2019 for all 43 municipalities located in the prefecture, more than half of the municipalities (55.8%, or 24 municipalities) have developed and provided disaster prevention-related information applications to residents. There is a growing tendency that many municipalities utilize smartphone applications as a tool to disseminate warning information to residents.



Source: FMDA (2019)[10] and MIC (2017)[11] (organized and translated by JICA Expert Team)

Figure 2.1.3 Means of information dissemination by municipalities for residents (2016)

Regarding information dissemination by the disaster prevention administration radio, since it is difficult to accurately convey a large amount of information on this audio system, municipalities are required to utilize concise sentences expressed with a sense of urgency to encourage residents

[6] https://www.fdma.go.jp/mission/prepare/transmission/items/0203_tebiki.pdf
[7] https://www.soumu.go.jp/main_content/000573617.pdf
[8] https://www.mlit.go.jp/common/000206278.pdf
[9] http://www.bousai.go.jp/oukyu/hinanjouhou/r3_hinanjouhou_guideline/pdf/hinan_guideline.pdf)
[10] https://www.fdma.go.jp/publication/bousai/items/honpen_r1.pdf
[11] https://www.soumu.go.jp/main_content/000525713.pdf

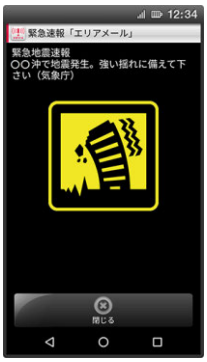
to evacuate, specify the actions that residents should take, and repeatedly transmit the message as the example in Figure 2.1.4 shows.

In case of issuance of "Major Tsunami Warning" by JMA
"Emergency announcement! Emergency announcement!
This is XX City. Due to the issuance of Major Tsunami Warning, the City issued the evacuation instruction to XX area. Evacuate immediately from coastal regions and riverside areas to higher ground, such as in XX evacuation center, wherever possible."
*An urgent call like "There is a *Tsunami! Evacuate!!*" is also effective.

Source: Disaster Management, Cabinet Office (2021)[12] (Translated by JICA Expert Team)

Figure 2.1.4 Example of an emergency call by municipalities

In terms of highly urgent information, including the EEW and tsunami warnings, the national warning alert system called "J-ALERT" is utilized to transmit information to residents by using artificial satellites and ground lines nationwide via transmission equipment of FDMA. This system enables to quickly disseminate information on national protection from the Cabinet Secretariat and disaster-related warnings from JMA to residents by automatically activating the local disaster prevention administrative radio without human intervention. In addition, there is also an email system for disseminating the urgent J-ALERT information, which is called "Area Mail" or Early Warning email. In this system, individuals are able to receive emails with emergency information via mobile phone companies as Figure 2.1.5 illustrates. Furthermore, an evacuation information announced by municipalities is also delivered to individuals in many areas by this email system.



(Title) Early warning "Area Mail"

"Earthquake Early Warning

Earthquake occurs off the coast of XX.
Be wary of strong ground motion (JMA)."

(Title) Early warning "Area Mail"

"Tsunami Warning

Evacuate immediately from coastal regions and riverside areas to a safer place such as high ground. (JMA)"

Source: NTT Docomo, Inc.[13] (Translated by JICA Expert Team)

Figure 2.1.5 Examples of area mail by utilizing J-ALERT system

Since each means of information dissemination has advantages and disadvantages, municipalities are required to understand them, take regional characteristics into account, consider disaster types and time passages and, consequently, decide effective means to ensure delivering warning information to all residents. According to the guideline on disaster information dissemination by FDMA (2020)[14], particularly for earthquakes and tsunami, it is desirable that municipalities utilize rapid dissemination means such as disaster prevention administrative radios, Early Warning emails, and IP communication systems. After a disaster occurs, it is effective to utilize the disaster prevention administrative radio for providing new information, followed by the push-pull communication methods (e.g., SNS, FM broadcasting, registered email, CATV, websites) with detailed information.

(3) Conclusion on the functions of JMA and local governments in terms of disaster-related information transmission

As this chapter shows, JMA observes and analyzes disaster-related information, and issue and disseminate disaster warnings to residents via multiple information transmission networks. In

[12] http://www.bousai.go.jp/oukyu/hinanjouhou/r3_hinanjouhou_guideline/pdf/hinan_guideline.pdf
[13] https://www.nttdocomo.co.jp/service/areamail/
[14] FDMA (2020) "Guidance on the Development of Disaster Information Communication Methods"

order to avoid functional degradation of the communication networks and to ensure the information transmission, JMA utilizes dedicated lines to connect with legal information transmission agencies and adopts backup systems. JMBSC also plays a vital role to disseminate warning information to residents through promptly providing information to private sectors (e.g., news media, smartphone application developers) on its information provision services. Furthermore, municipalities utilizes various means of information dissemination to ensure delivery of information to residents. Therefore, in Japan, in consideration of the disruption of communication networks due to disasters, JMA and all government administration levels promote multiplexing and diversifying the means of dissemination of warning information to ensure delivery of necessary information to all residents regardless of their attributes and conditions.

2.1.2 Functions of JMBSC regarding meteorological and disaster-related information provision

As mentioned in the previous section, various meteorological information (including earthquake and tsunami information issued by JMA) are provided to news media and private weather companies through JMBSC. These private agencies process the data to the demanded form and provide them to customers and residents. This section explains the function and services of JMBSC regarding information provision.

(1) Organization overview of JMBSC

JMBSC is a general incorporated foundation established in 1994 to promptly and reliably deliver information issued by JMA to private information users such as weather companies, information dissemination companies, news media, transportation companies, research institutes, among others. It is doing the business of providing various meteorological information issued by JMA to contract users, conducting an examination of Certified Weather Forecasters, verifying meteorological instruments, doing various surveys and seminars, international cooperation activities as well as publishing related books. Through these services, JMBSC aims the attainment of high quality meteorological information services and comprehensive meteorological businesses by the division of roles between public and private sectors. In terms of information dissemination, JMBSC disseminates meteorological data, products and information to various users as the officially designated authorized organization under the Meteorological Service Act. Furthermore, due to a large amount of transmitted real-time data, the maintenance and management cost of communication equipment for information provision is considerable. Since the meteorological information can be utilized for commercial purposes, it had been considered unfair to cover these costs for specific private companies with national funds. Therefore, private companies receiving information from JMBSC bear the necessary maintenance costs approved by JMA for the equipment.

(2) Collection and provision of information by JMBSC to other relevant agencies

1) Data dissemination service (except for Earthquake Early Warning)

There are two types of meteorological data that JMBSC provides to user communities: real-time base data and non-real-time base data.

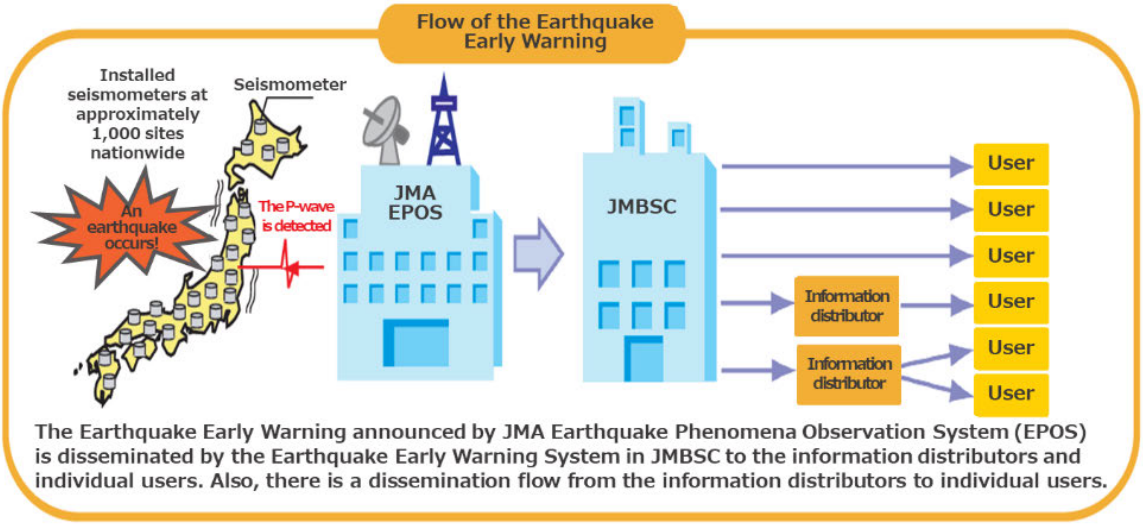
In terms of non-real-time data, JMBSC provides various information that JMA has such as observation data including those of radar, tides, ocean waves and earthquakes; meteorological satellite imagery; monthly and annual observation reports; JMA analysis products including re-analysis with the numerical models of JMA; reports on meteorological, environmental and marine observations. Each type of data has an original sales price and provided in HD/DVD/CD-ROM.

Regarding real-time data, various meteorological data, products, and information are disseminated to users under contract with JMBSC on a real-time basis. Provided data mainly utilizes the JMA Disaster Prevention Information XML (DPI XML) format or international regulated format (BUFR format, GRIB format) so that data users (e.g., disaster-related agencies,

news media, and private meteorological companies) easily and effectively deal with the DRR information issued by JMA. In particular, DPI XML is a unified format for all data types and has a basic structure that allows users to mechanically process roughly 70 types of JMA data regardless of disaster types in a unified manner, which enables users to easily transform data for customers' needs.

2) Earthquake early warning service

The EEW system provides an advanced announcement of the expected arrival time and the estimated seismic intensities of the principal motion. These estimations are based on prompt analysis of the focus and magnitude of the earthquake using P waveform data observed by seismographs near the epicenter. JMBSC immediately disseminates the EEW data provided by JMA-EPOS through the earthquake warning dissemination system of JMBSC to private contract users. There are two types of warning data: EEW (Warning) utilized for informing residents in facilities or on TVs and radios, and EEW (Prediction) including information that enable contract data users to estimate seismic intensities and expect arrival time of specific spots by the clients' original process. The contract data users generally utilize the prediction data, originally estimate the seismic intensity in the customer's location, and disseminate the value-added information along with the estimation.



Source: JMBSC[15] (Translated by JICA Expert Team)

Figure 2.1.6 Communication flow of earthquake early warning

3) User fees of the dissemination services provided by JMBSC

In order to receive real-time data, the data users are required to apply for the data dissemination services to JMBSC in advance and pay four types of user fees, as Table 2.1.2 explains.

Table 2.1.2 User fees of the dissemination data services by JMBSC

Name	Description	User fee (Example: Provision of EEW service)
Opening charge (Once)	To register the user and establish the connection between the user's system and the JMBSC system	50,000 yen / each receiving terminal
Administrative Charge (Monthly)	To cover the common expense for running the dissemination service	3,600 yen/ month (for each business establishment)
Data charge (Per service)	To cover the expense for the establishment, operation, and maintenance of data distribution	EEW (Warning): 20,200 yen EEW (Warning and prediction): 22,600 yen

[15] http://www.jmbsc.or.jp/jp/online/pamphlet.pdf

Name	Description	User fee (Example: Provision of EEW service)
	system.	Real-time seismic intensity information and EEW (Warning and prediction): 38,500 yen
Communication facility charge (Monthly)	To cover the expense for maintaining communication facilities of each distribution system (facility, common communication lines)	Dedicated line: 2,400 yen IP-VPN: 12,100 yen

Source: JMBSC[16] (Organized and translated by JICA Expert Team)

4) Weather information fax dissemination service

DRR and meteorological information facsimile service provides users with various DRR weather information (text and diagram format) announced by JMA via facsimile. Users are able to receive information by using their own facsimiles without any special devices. The user fee is 380 yen per month as an administrative expense, and 28 yen per fax as a delivery cost. The provided information are shown in Table 2.1.3.

Table 2.1.3 Provided information by the JMBSC facsimile service

Information type	Contents
Tsunami information	• Tsunami warnings and forecasts • Tsunami information
Earthquake information	• Information on hypocenter region and seismic intensity • Information on seismic intensity at individual locations • Estimated seismic intensity distribution map • Commentary materials regarding earthquake • Nankai Trough Earthquake Information
Volcanic activity information	• Volcanic warnings and Forecasts • Monitoring information of volcanic activity • Commentary materials regarding volcanic activity • Consensus view of the Coordinating Committee for Prediction of Volcanic Eruptions • Volcanic gases forecasts • Volcanic ash fall forecasts • Eruption notice
Warnings/Advisories	• Emergency warnings/ warnings • Advisories
Flood warnings and advisories for designated rivers	• Flood warnings and advisories for designated rivers
Landslide alert information	• Landslide alert information
Weather forecasts	• Local daily forecasts • One-week forecasts • Seasonal forecasts (one month/ three months/warm period and cold period) • Three-hourly forecasts • Distribution forecasts
Tropical cyclone information	• Tropical cyclone general information • Tropical cyclone track information • Tropical cyclone track forecast map
Marine Warnings	• General marine warnings • Regional marine warnings
Other Information	• Meteorological information • Weather overview • Information on a record-breaking deluge in a short period • Smog weather information

16 http://www.jmbsc.or.jp/jp/online/c-onlineF.html

Information type	Contents
	• Sea (tidal) level information • Information related to the weather • Hazardous wind watch • Extreme high temperature forecast • Government office original information, etc.

Source: JMBSC[17] (Translated by JICA Expert Team)

(3) Conclusion on the functions of JMBSC regarding meteorological and disaster-related information provision

As this chapter shows, JMBSC plays a vital role to ensure the prompt and reliable information distribution from JMA to private users of meteorological information, including broadcasting companies (media) and weather service providers.

In particular, in case of the EEW which requires prompt provision of information, JMBSC receives the warning information directly from the JMA EPOS and promptly distributes the information to registered private companies through the JMBSC's EEW distribution system. This enables, for instance, private broadcasting companies to promptly distribute earthquake information on TV and radio, and smartphone application developers to quickly distribute the risks of ground shaking for each user's location on their smartphone application. As the only organization that provides the private sector with meteorological and disaster-related information owned by JMA, JMBSC promotes the utilization of the information by the private sector and, therefore, contributes to the multiplicity of the means of warning information gathering for residents. JMBSC also assists to the strengthening of the system for providing weather and disaster-related information in Japan through appropriately distributing the burden of maintenance and management costs for information dissemination equipment among registered private companies.

17 http://www.jmbsc.or.jp/jp/online/pamphlet.pdf

2.2 Utilization of Weather and Disaster Information from JMA

Two important tools for disseminating disaster-related information to residents in Japan are smartphone applications and websites developed or managed by private companies. This chapter explains how private companies process the information issued by JMA and provide them to users as a profitable business.

2.2.1 Case Study: Private Sector

(1) Yahoo Japan Corporation

Yahoo Japan Corporation (hereinafter referred to as "Yahoo") is an information and communication company doing e-commerce business, member services business, and internet advertising business. The company founded and has managed one of the most popular search engines in Japan ("Yahoo! Japan") which provides handy services such as email, auction, shopping as well as various information including news and weather. In terms of disaster and meteorological information, the company developed and manages an internet site "Yahoo! Japan Weather and Disaster" and the app "Yahoo! Bosai Sokuho". The number of users of the app reached 20 million as of January 2021.

1) Outline of disaster and meteorological information dissemination services

Smartphone App "Yahoo! Bosai Sokuho"

"Yahoo! Bosai Sokuho" is a for free smartphone app that delivers disaster-related information by push notifications including earthquake early warning, tsunami information, evacuation information and disaster information caused by heavy rains. After the Great East Japan Earthquake in March 2011, an email service of "Yahoo! Bosai Sokuho" was launched in July 2011, followed by the iOS smartphone app in December 2011 and the Android app in March 2012.

Table 2.2.1 Earthquake and tsunami information notified by the app

Information	Contents
Earthquake early warning	Notified when an expected seismic intensity of the arriving earthquake reaches the intensity that the users set in advance (from seismic intensity 3 or higher) in the registered areas
Earthquake information	Notified when an earthquake with a seismic intensity of 3 or higher occurs in registered prefectures (or an earthquake with a seismic intensity of 4 or higher in neighboring prefectures that users registered) and reaches the intensity that the users set in advance.
Tsunami information	Major tsunami warning, tsunami warning and advisories (dates issued and lifted)

Source: Yahoo Japan Corporation[18] (Translated by JICA Expert Team)

Yahoo also provides various contents for disaster preparedness on the app such as evacuation simulation, lessons from previous disasters, preparations for earthquake and tsunami, disaster calendar (past disaster history), disaster risk reduction notebook (e.g., list of evacuation facilities, hazard maps, safety confirmation service, stockpile list for emergency situations) and services for sharing information of disaster damages among users.

Website "Yahoo! Japan Weather and Disaster"

"Yahoo! Japan Weather and Disaster" is a comprehensive weather and disaster information website operated by Yahoo for free. This website enables the quick browsing of various weather and disaster information from multiple information providers including WEATHERMAP Co.,

[18] https://notice.yahoo.co.jp/emg/sokuho/service/earthquake.html

Ltd. In July 1996, a website specializing in weather forecasts was released. Since 2004, the website has been disseminating disaster-related information including those for earthquakes and tsunamis. As of October 2017, the number of daily users was approximately 3 million for the PC version, and 3 to 4 million for smartphone users via the website. Since Yahoo is not a meteorological company, it is impossible to differentiate the contents of meteorological information. Therefore, the company concentrates on the creation of a simple, easy-to-understand, and easy-to-use site through consolidating information received from multiple related organizations and companies into their own site. Table 2.2.2 illustrates earthquake and tsunami information issued by JMA and shown on Yahoo website.

Table 2.2.2 Earthquake and tsunami information issued by JMA and shown on Yahoo website

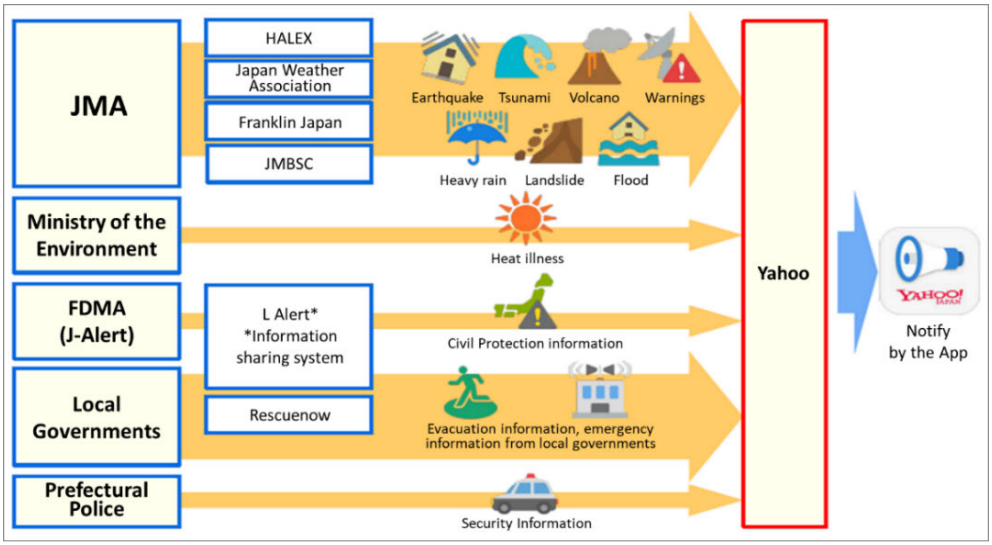
	Accessible information
Earthquake information	Provision of updated information issued by JMA Earthquake occurrence time, epicenter, maximum seismic intensity, magnitude, depth of the epicenter, seismic intensity in each municipality, earthquake history
Tsunami information	Tsunami advisories and warnings, past tsunami observation information (earthquake occurrence time, epicenter, depth of epicenters, magnitude, arrival points of the tsunami and height)

Source: Yahoo Japan Corporation[19] (Translated by JICA Expert Team)

The site also provides information on real-time seismic intensity that enables to visually check the shakings caused by an earthquake in real-time. This content is to disseminate the information of the "Kyoshin Monitor" provided by the National Research Institute for Earth Science and Disaster Prevention, and visualizes the current ground motions in an easy-to-understand form. Furthermore, the website also provides educational contents regarding disasters such as a disaster prevention notebook, a disaster calendar, hazard maps published by municipalities and evacuation site maps.

2) Information dissemination flow

The smartphone application "Yahoo! Bosai" handles various information issued by JMA, MLIT and local governments, among others and weather and related information provided by meteorological companies. The flow of information varies as Figure 2.2.1 shows.



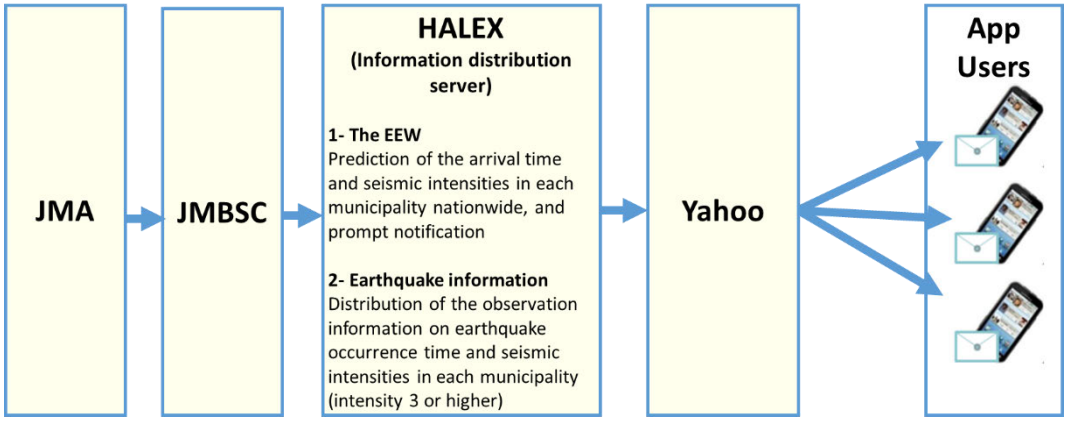
Source: Ministry of Internal Affairs and Communications[20] (Edited and translated by JICA Expert Team)

Figure 2.2.1 Flow of information processes for the App

[19] References were the information dissemination webpages of the company and https://support.yahoo-net.jp/PccWeather/s/article/H000007776

[20] https://www.soumu.go.jp/main_content/000566080.pdf

In the case of the EEW, JMA promptly analyzes the observation data captured by the seismographs near the epicenter immediately after the occurrence of the earthquake, predicts the arrival time and seismic intensity of the shaking, and provides data to certificated private weather forecasting companies (seismic motion), including HALEX CORPORATION through JMBSC. Based on the data from JMBSC, HALEX predicts the arrival time and seismic intensity of the shaking in each municipality nationwide, and distributes them to the Yahoo system. Since this service utilizes data for advanced users, it can provide quick and specific warnings to users without elaboration.



Source: JICA Expert Team[21]

Figure 2.2.2 Flow of information processes from HALEX to users

When an earthquake (maximum seismic intensity of 3 or more) is observed, JMA issues the earthquake information such as occurrence time, place, depth, magnitude, and seismic intensity in each area. Yahoo immediately provides the notification of the earthquake information to users of the app, and shows detailed earthquake information on the website. Users easily access the information on the website from links and buttons on the app.

While JMA aims to prevent disasters by distributing DRR and meteorological information, such as warnings, certificated private weather forecasting companies play a role in the distribution of high-value-added information that meet the needs of the sophisticated and diversified meteorological market. In Yahoo, while the app promptly warns each user of the imminent shaking caused by earthquakes in the user's registered area, the website aggregates and organizes disaster information from various organizations and displays them in an easy-to-read and easy-to-understand way. Both services provide suitable and high-value-added information for users and meet their demands as a private company.

3) Business model

"Yahoo! Bosai" is completely for free smartphone application with no advertisements. On the company's website, *"Supporting Disaster Relief and Social Issues*" is listed as one of "*Problem Solving Measures Taken by Yahoo! JAPAN"* as corporate social responsibility (CSR) initiative. This webpage has a feature that "quickly notify all disaster information" and introduces the smartphone application[22].

Z Holdings Corporation, a parent company of Yahoo! Japan, explains the company's Basic Policies of Growth Strategies as follows: *Media business attracts a large number of users by providing a wide range of media services that are essential to people's daily lives, and records earnings through advertising...* [23] CSR is expected to improve corporate value and brand image; therefore, it encourages consumers to continue utilizing the company's products and services, which contribute to stable customer acquisition and sales improvement. Thus, there is an aspect that Yahoo aims by attempting to acquire a number of users, increase its corporate value, and improve the profitability

[21] HalexCorporation webpage (https://www.halex.co.jp/introduction/2507.html)
[22] https://about.yahoo.co.jp/en/csr/message/, https://about.yahoo.co.jp/csr/effort/category02.html
[23] https://www.z-holdings.co.jp/integrated-report/en/performance/media/

of its main business through providing free DRR-related information services as a CSR.

(2) Weathernews Inc.

Weathernews Inc. is the largest private meteorological service company that provides weather-related contents and risk communication services around the world. The company analyzes a huge amount of meteorological observation data collected from various countries, and generates highly accurate meteorological forecasts.

The company developed and operates the weather forecast website "Weathernews", the weather forecast smartphone application "Weathernews", and the earthquake- and tsunami-related information application “Quake and Tsunami Community” in order to disseminate disaster prevention information for individuals. The weather forecast application has gained a large number of users, with a cumulative total of over 24 million downloads as of October 2020.

In April 2016, the company started cooperation with BMKG to mitigate damage caused by meteorological disasters in Indonesia. The contents of the cooperation include the enhancement of the observation network by installing the company’s own observation infrastructure, sharing of knowledge and observation information on meteorology and geography, as well as the implementation of training for BMKG staff to share the management skills of Weathernews[24].

1) Outline of the disaster and meteorological information dissemination services

Weather forecast app “Weathernews”

The weather forecast application "Weathernews" is basically for free smartphone app that provides a wide range of weather and disaster-related information such as occurrence of heavy rains, earthquakes and tsunamis, as well as weather forecasts. The app provides detailed information on the location and intensity of an earthquake at any time, and notifies the latest weather information by push notification. The company released the iPhone smartphone app "Weathernews Touch" in January 2009, and currently offers the app "Weathernews". Table 2.2.3 illustrates the earthquake and tsunami information issued by JMA and shown on the app.

Table 2.2.3 Earthquake and tsunami information issued by JMA and shown on the app

	Information contents
Earthquake early warning	Alarming notification (only available for premium members)
Earthquake information	Seismic intensity of each area and the earthquake epicenter
Advisory and warnings	Tsunami advisory and warnings map
Tsunami information	Expected tsunami height, expected arrival time and high tide time, tsunami observation data

Sources: Weathernews Inc.[25], Google Play[26], Smartphone application screen (Translated by JICA Expert Team)

Meteorology and weather forecast website “Weathernews”

“Weathernews” is an internet website that delivers the most, latest, fastest and optimal weather information in ordinary times, and even during disasters. In 1999, the website "WNI Weather Information” (currently named Weathernews) was released for individual users, and has become a website with a lot of users. Table 2.2.4 shows earthquake and tsunami information which are issued by JMA and provided on the website.

[24] https://jp.weathernews.com/news/7192/
[25] https://weathernews.jp/s/topics/201608/210085/
[26] https://play.google.com/store/apps/details?id=wni.WeathernewsTouch.jp&hl=ja&gl=US

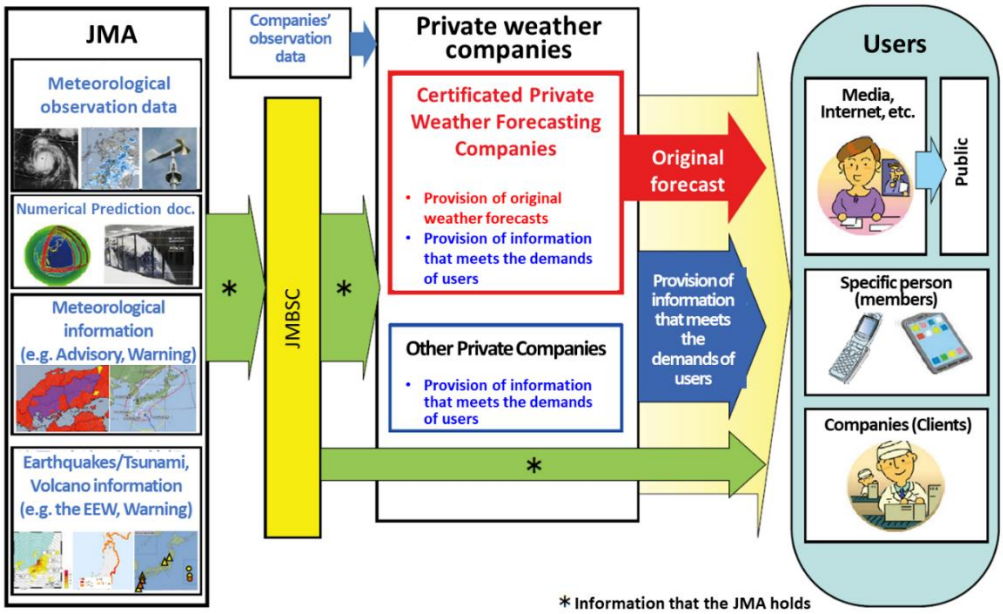
Table 2.2.4 Earthquake and tsunami information issued by JMA and shown on the website

	Information contents
Earthquake information	Epicenters, magnitudes, depth of the epicenter, earthquake information list (e. g., earthquake occurrence time, epicenter, maximum seismic intensity) * Seismic intensity in each municipality is available only for registered members (330 yen/month)
Tsunami information	Warnings and advisory, expected tsunami height, expected arrival time and high tide time, tsunami observation data

Source: Weathernews Inc.[27] (Translated by JICA Expert Team)

Information dissemination flow

As a certificated private weather forecasting company, Weathernews Inc. obtains and processes the information (e.g., EEW data for advanced users) provided by JMA, and delivers them for its customers. The company also distributes highly accurate meteorological information by utilizing meteorological observation networks at 13,000 locations and original meteorological forecast methods. The figure below shows the information dissemination flow of certificated private weather companies, including Weathernews Inc.



Source: JMA Guidebook 2020[28] (Translated by JICA Expert Team)

Figure 2.2.3 Information dissemination flow of private weather companies

Business model

The weather forecast app "Weathernews" adopts a "freemium" monetization model in which some of the users pay usage fees (360 yen/month) and others can use it with in-app advertisements free of charge. Premium users are able to exclude in-app advertisements, gain access to premium information including rain cloud radar information, as well as receive push notifications of the emergency information regarding users' current location based on GPS information. The emergency information cover those for EEW, earthquake, tsunami, typhoon, tornado, heavy snow, volcano, among others. In addition to the weather forecast app, the company also developed and operates an app "Quake and Tsunami Community" with a subscription monetization model (monthly charge of 300 yen). For instance, when the EEW is issued by JMA, this app provides the users' smartphones with notifications on earthquake information such as the epicenter, scale

[27] Information were obtained from disaster-related information dissemination pages on the website of Weathernews such as https://weathernews.jp/s/quake/
[28] https://www.jma.go.jp/jma/kishou/books/jma-guidebook/chapter7.pdf

of the earthquake, depth of the epicenter, maximum seismic intensity on the screen, as well as displays of the countdown of shaking arrival by voice. Therefore, the company disseminates meteorological and disaster-related information by multiple apps in different monetization models through raising profits from the usage fees and in-app advertisement fees. The company takes advantage of the users' attitudes toward the app such as the high frequency and long time spent on their usage for business purposes. Due to increasing attention to meteorological and disaster-related information owing to the occurrence of large-scale disasters as well as the increase of the number of news articles in its applications, the number of Daily Active Users (DAU) has increased, which have contributed to the increase of the sales of services for smartphones and the number of advertisers.

(3) RC Solution Co. Ltd.

RC Solution Co. Ltd. is an IT company doing information provision business related to disaster prevention and mitigation, system development services, consultation services, among others. The company's smartphone app "Yurekuru Call" has been downloaded 5.5 million times, and being utilized by numerous individual users. The company also offers similar services to private companies in the field of communications and advertising.

1) Outline of the disaster and meteorological information dissemination services

"Yurekuru Call" is basically for free EEW information app (renewed app "PREP") that notifies the expected seismic intensity and estimated arrival time of the shaking by push notification. Based on the founder's experience after the Niigata Chuetsu Earthquake in Japan in 2004, the company released this early warning information service in October 2007 for private companies such as construction companies and retail stores. Then, the company released the smartphone app in November 2010 so that every individual can receive warnings more easily. In August 2020, the company released a comprehensive DRR app "PREP" for iOS users as the renewed version of the "Yurekuru Call". This renewed app provides information not only on earthquakes, but also on various disasters in real-time such as tsunamis, typhoons, heavy rains, tornado and river flood forecast as well as evacuation information. Table 2.2.5 explains earthquake and tsunami information which are issued by JMA and notified on the app.

Table 2.2.5 Earthquake and tsunami related information notified by the app

	Information contents
Earthquake early warning	Push notification of information on earthquake occurrence time, expected seismic intensity with a map, etc. as soon as possible
Earthquake information	Seismic intensity in each area
Tsunami information	Expected tsunami height based on the location and scale of the earthquake, push notifications of the tsunami warnings and advisories nationwide

Source: RC Solution Co. Ltd.[29] (Translated by JICA Expert Team)

In terms of EEW, the app displays the expected seismic intensity and arrival time of the shaking, earthquake epicenter and magnitude before a few seconds to a few tens of seconds of a large shaking arrival. The expected arrival time of the shaking will be notified in a countdown method with optimal messages according to the expected magnitude of the earthquake, such as "Please protect yourself until shaking stops". The company aims to encourage users to prepare for the shaking and protect themselves and, therefore, reduce the damage of the disaster.

In November 2016, the new content "+ Sonae" was implemented in the app. This content explains useful information and DRR-related knowledge for everyday life and during earthquakes. Furthermore, app users can utilize the functions for creating their own DRR plans (e.g., evacuation facility maps, disaster relief material lists), and for safety registration.

2) Information dissemination flow

The company receives and processes EEW data provided by JMA for advanced users via JMBSC

[29] https://www.rcsc.co.jp/yurekuru

in the company's data center, and distributes the estimated seismic intensity and estimated arrival time of the shaking at the user's location.

3) Business Model

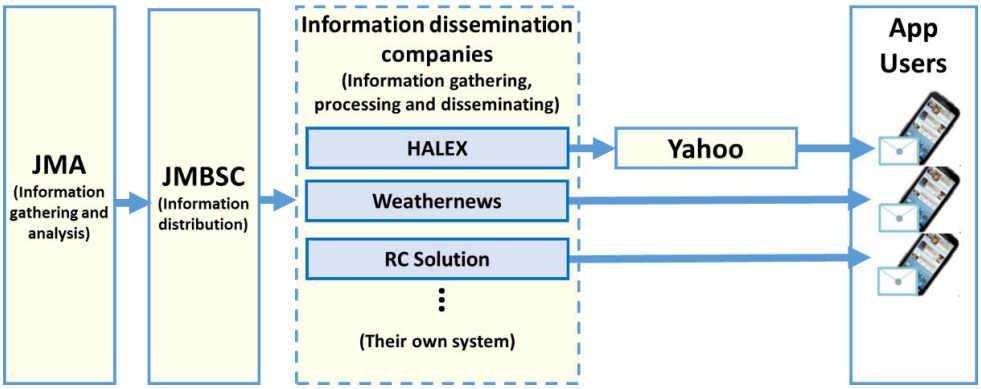
The app "Yurekuru Call" and "PREP" adopt a "freemium" monetization model and continuously operated by the revenues of the in-app advertisements and usage fees of some users (120 yen/month). Premium users are able to exclude in-app advertisements, gain access to premium information including up to the last 50 earthquake information, DRR and meteorological information of registered multiple locations, as well as receive the fastest push notification of the EEW through a dedicated server for premium users. The premium version notifies the EEW approximately 3 to 5 seconds earlier than that for the free version.

The company also provides private companies with services by utilizing these apps or the same system of these apps. These services are as follows:

- Provision of the "Yurekuru Call" with specific functions suitable for private companies
- In-app advertisement posting services (Top banner: 300,000 yen~/week)
- Development of new systems and dissemination of disaster-related information (e. g., Bosai Cloud)

(4) Conclusion of the case study regarding the cooperation with private sectors

As explained above, in Japan, since JMA provides meteorological and disaster-related information to private companies in a unified format via JMBSC, a wide range of private companies with different specializations (e. g., information provision, meteorological prediction and IT system development) are able to process the information and add unique values in accordance with customer needs. Then these companies provide the processed information by utilizing their respective specializations. Based on their needs, individual users are able to choose suitable services from various information provision services operated by different companies, and sometimes pay the usage fees. The information dissemination flow from JMA to users, and the summary of business models of the three companies introduced previously in this chapter are shown in Figure 2.2.4 and Table 2.2.6, respectively.



Source: JICA Expert Team

Figure 2.2.4 Information dissemination flow from JMA to users via JMBSC and application developers

Table 2.2.6 Summary of business models of the introduced three companies

	Yahoo	Weathernews	RC Solution
Core business	Operation of Internet portal site, etc.	Meteorological observation data analysis, meteorological forecast	IT system development, operation and maintenance
Names of Apps and webpages	• Yahoo! Bosai Sokuho	• Weathernews • Quake and Tsunami Community	• Yurekuru Call (former name of app) • PREP
Types of	Free	Weathernews:	Free/Premium(120

	Yahoo	Weathernews	RC Solution
membership and usage fees		Free/Premium (360 yen/month) Quake and Tsunami Community: Free/Premium (300 yen/month)	yen/month)
Business model	• Operation of a DRR app and website as a CSR initiative • Acquisition of advertising revenues by attracting users and guiding them to the portal site enables the company to provide free use of DRR app	• Freemium model: In-app purchases (usage fee) and in-app advertising	• Freemium model: In-app purchases (usage fee) and in-app advertising • Development and customize services for business sectors

Source: JICA Expert Team

2.2.2 Case Study: Local Government

In Japan, municipalities are responsible for disseminating disaster-related information and warnings to residents, and have the authority to issue evacuation advisories to them. In some cases, prefectures also disseminate disaster-related information directly to residents through smartphone applications and websites. This section introduces the means of information dissemination in some prefectures and cities, and clarifies their methods of processes in order to further understand the means of information dissemination to residents at local administrative levels.

(1) Selection criteria of prefectures and cities for the case study

The JICA Expert Team investigated the means of information dissemination in some Japanese prefectures and cities which have similar locational characteristics (e. g., metropolitan areas, and rural areas) and population size as the pilot areas of the Project since the types of disaster information provision service varies depending on the size of municipality, population density, age distribution, municipal budget and so on. The survey results are organized in a matrix table so that the differences in the means of information transmission can be easily compared. The selection criteria and selected local governments for the case study are shown in Table 2.2.7.

Table 2.2.7 Selection criteria and selected prefectures and cities

Selection criteria for target prefectures and cities	The target prefectures and cities meet the following two criteria: • have similar locational characteristics and population sizes as pilot areas of the Project in Indonesia (Jakarta, Banten, Central Sulawesi, Palu City) • have estimated risks of the damage caused by subduction zone earthquakes and following tsunamis
Selected Prefectures and Cities for this survey	a. Prefecture corresponding to Jakarta (capital city): • Tokyo Metropolis b. Prefectures corresponding to Banten Province (adjacent province of the capital, coastal area): • Kanagawa Prefecture • Chiba Prefecture c. Prefectures corresponding to Central Sulawesi province (rural and coastal area, population size: approx. 2.8million): • Shizuoka Prefecture (approx. population: 3.6million) • Miyagi Prefecture (approx. population: 2.3million) d. Cities corresponding to Palu City (rural and coastal area, population size:approx. 370,000): • Ichikawa City, Chiba Prefecture (approx. population: 490,000) • Yokosuka City, Kanagawa Prefecture (approx. population: 390,000) • Wakayama City, Wakayama Prefecture (approx. population: 350,000)
References	• Local disaster management plan of each prefecture and city • Local tsunami evacuation plan (Ichikawa City)

	• Official website of each prefecture and city

Source: JICA Expert Team

(2) Survey results

1) Overall

All selected prefectures have their DRR information websites and SNS (Twitter) accounts to disseminate DRR and meteorological information to residents. Most prefectures also adopt email service for the same reason. In contrast, there are only two prefectures that developed and operated smartphone applications directly for residents.

Table 2.2.8 Means of information dissemination in each prefecture

	Population	Location	Means of information dissemination directly to residents (○: Existing, ×: Not Existing)				
			Web site	SNS Tw: Twitter FB: Facebook	Smartphone application	Email	Others
Tokyo metro.	13,960,236 (2021.1)	Capital region	○	○: TW	○	×	○: L-Alert
Kanagawa Pref.	9,216,009 (2020.9)	Capital region	○	○: TW	×	○: Early warning email (flood risk)	○: L- Alert
Chiba Pref.	6,281,869 (2021.1)	Capital region	○	○: TW	×	○: Registered email	○: L- Alert
Shizuoka Pref.	3,613,788 (2021.1)	Rural region	○	○: TW, FB	○	○: Early warning email, registered email	○: L-Alert, Public trucks with speakers and helicopter, if needed
Miyagi Pref.	2,290,915 (2021.1)	Rural region	○	○: TW	×	○: Registered email (warning and advisory on heavy rains and landslide)	○: L-Alert

Source: JICA Expert Team[30]

All selected cities utilize the disaster prevention administrative radio system, websites, SNS, email, fax or phone services as means of information dissemination during disasters. Although DRR smartphone application is not introduced in all cities, Ichikawa City introduces an information provision service on LINE[31] (communication app) to disseminate warnings which are also transmitted by the disaster prevention administrative radio. In Wakayama City, DRR meteorological information issued in the city can be seen on a DRR smartphone application developed and managed by Wakayama Prefecture.

[30] References: Tokyo Metropolis Local Disaster Management Plan website (https://www.bousai.metro.tokyo.lg.jp/); Kanagawa Prefecture Local Disaster Management Plan websites (https://www.pref.kanagawa.jp/docs/ie2/socialmedia/oficial_twitter.html, https://www.pref.kanagawa.jp/docs/f4i/bosai/push_mail.html, https://www.bousai.pref.kanagawa.jp/); Chiba Prefecture Local Disaster Management Plan websites (https://www.pref.chiba.lg.jp/kouhou/homepage/socialmedia-tw.html, https://www.pref.chiba.lg.jp/bousai/saigaitaisaku/jouhou/bousaijouhou.html); Shizuoka Prefecture (Local Disaster Management Plan websites (https://shizuoka.secure.force.com/portal/, https://www.pref.shizuoka.jp/bousai/application.html, http://wni-shizuoka.bosai.info/bosaimail/index01.html, https://www.facebook.com/shizuoka.bousai/, http://www.pref.shizuoka.jp/bousai/kinkyusokuho.html, https://play.google.com/store/apps/details?id=jp.shizuoka.pref.bousai&hl=ja); Miyagi Prefecture Local Disaster Management Plan websites (https://www.pref.miyagi.jp/soshiki/kikitaisaku/kikitaisakukakoshikitwitterkaisetu.html, https://www.pref.miyagi.jp/soshiki/kikitaisaku/miyagikenbosai-portal.html, https://miyagi-bousai.secure.force.com/, http://www.doshasaigai.pref.miyagi.jp/midski/mail/DoshaMail_pc.htm).

[31] LINE in Japan is equivalent to WhatsApp in Indonesia. Approximately 68.8% of entire population in Japan use LINE. https://www.linebiz.com/sites/default/files/media/jp/download/EN_LINE%20Business%20Guide_202101-06_summary.pdf

Table 2.2.9 Means of information dissemination in each city

	Population	Location	Means of information dissemination directly to residents (○: Existing, ×: Not Existing)						
			Admin. Radio	Web site	SNS	Smartphone app	Email	Fax, phone	Others
Ichikawa City	491,209 (2021.2)	Capital region	○	○	○: TW, FB, LINE	× Apps (provided until 2021) only for educational contents	○: Early warning email, registered email	○: Phone, fax	○ Public trucks with speakers, CATV, FM radio
Yokosuka City	389,172 (2021.1)	Capital region	○	○	○: TW, LINE	×	○: Early warning email, registered email	○: Phone	○: Public trucks with speakers, FM radio, TV, Digital signage
Wakayama City	353,667 (2021.1)	Rural region	○	○	○: TW, FB, LINE	×: (Push notification from prefecture's App)	○: Early warning email, registered email	○: Phone	○: Public trucks with speakers, media

Source: JICA Expert Team[32]

2) Procedures in utilizing multiple means of communication in the selected prefectures and cities

This section describes the means of information dissemination in the surveyed prefectures, and the methods for utilizing multiple means of information dissemination in the surveyed cities and other cities. Although there are few differences in the means of information dissemination in each local government, the contents and methods vary by prefectures.

Means of information dissemination at the prefectural level

a) Metropolitan Government

Tokyo Metropolitan Government operates a website dedicated to disaster-related information, on which emergency information and evacuation information are posted. On the website, evacuation instructions and the status of evacuation centers are shown on a map, which makes it easier to understand these locations. A smartphone app "Disaster Preparedness Tokyo App" provides push notifications of weather information, earthquake and tsunami information, and evacuation information of registered cities. Although the format of the information is different, the areas for which weather and evacuation warnings have been issued are provided in the same way as on the website. In addition, on SNS (Twitter), weather and warning information are briefly explained

[32] References: Ichikawa City Local Disaster Management Plan and Local Tsunami Evacuation Plan websites (https://www.city.ichikawa.lg.jp/cri03/1111000052.html, https://www.city.ichikawa.lg.jp/pla09/1111000011.html, https://www.city.ichikawa.lg.jp/gen06/1221000001.html, https://www.city.ichikawa.lg.jp/gen06/1521000001.html, https://www.city.ichikawa.lg.jp/gen06/1111000008.html, https://play.google.com/store/apps/details?id=jp.co.mapple.android.ichikawa&hl=ja&gl=US); Yokosuka City Local Disaster Management Plan websites (https://www.city.yokosuka.kanagawa.jp/2426/bousainavi/sonae/jouhou/musen.html#terehongaid, https://www.city.yokosuka.kanagawa.jp/2426/bousainavi/sonae/jouhou/bousaimail.html, https://www.city.yokosuka.kanagawa.jp/0520/line.html, https://www.city.yokosuka.kanagawa.jp/2426/bousainavi/hassei/kisyou.html, https://www.city.yokosuka.kanagawa.jp/2426/bousainavi/index.html); Wakayama City Local Disaster Management Plan websites (http://www.city.wakayama.wakayama.jp/kurashi/bousai_bouhan_koutsu/1001075/1006044.html, http://www.city.wakayama.wakayama.jp/kurashi/bousai_bouhan_koutsu/1001075/1005997.html, http://www.city.wakayama.wakayama.jp/shisei/hasshin/1009141/1001158/index.html, http://www.city.wakayama.wakayama.jp/shisei/hasshin/1009141/1028937.html, http://www.city.wakayama.wakayama.jp/shisei/hasshin/1009141/1001157/index.html).

with links to the JMA website.

b) Kanagawa Prefecture

Kanagawa Prefecture's website comprehensively shows links to the websites of JMA and the River Management Division of the Prefectural Government to encourage access to earthquake and tsunami information and water level information, respectively. In addition to the website, Kanagawa Prefecture operates a disaster information portal site. The portal site provides warning information, including for earthquakes and tsunamis, as well as information on evacuation instruction and evacuation centers. In addition, the site explains the relationship between evacuation information and warning levels and has links to hazard maps, so that residents can know what to do in an emergency and prepare for disasters. In contrast, the information on SNS (Twitter) regarding earthquakes are only the maximum seismic intensities and their impacts on lifelines. The email service utilizing the early warning e-mail system provided by mobile-phone companies specializes in flood warnings and does not cover earthquakes and tsunamis.

c) Chiba Prefecture

Chiba Prefecture also operates a dedicated disaster prevention portal site. On this website, warning and disaster information including those for earthquakes and tsunamis, evacuation information, as well as lifeline and traffic information are provided. The site also has links to hazard maps of earthquakes, tsunamis and liquefaction, and earthquake damage estimates, which can encourage viewers to prepare for disasters. The mail service delivers earthquake intensity information, and tsunami warning and advisories to pre-registered residents. The SNS (Twitter) distributes information, including those for earthquakes (e. g., epicenter, maximum intensity) and their damage status, and educational content and information on the prefecture's disaster prevention activities.

d) Shizuoka Prefecture

Shizuoka Prefecture also operates a disaster prevention portal site that enables users to view a map of areas with issued warnings and evacuation information in the prefecture. Unlike other prefectures' portal sites, major components of the website are links to other disaster information sites operated by the prefecture or JMA. For instance, the link to the JMA website leads to access to warning information; the link to the "civil engineering disaster prevention information website SIPOS-RADAR" is for earthquake and tsunami information (e.g., earthquake scales, epicenters, seismic intensities, and tsunami warnings nationwide); and the link to the website of the "Shizuoka Prefecture GIS" is for evacuation centers' information. Each site provides detailed information. The SNS (Twitter) distributes information on warnings, disasters (e.g., earthquake scales, epicenters, seismic intensities of each city in the prefecture), and evacuation, as well as provides information on lectures regarding disaster prevention. The e-mail service also delivers all disaster-related information, including for earthquake and tsunami, to registered residents. In addition, the smartphone application developed by the prefecture provides push notifications of warning and evacuation information, as well as educational content including hazard maps and evacuation drills. Shizuoka Prefecture, considered to be advanced on disaster prevention[33], has established a well-developed information distribution system.

e) Miyagi Prefecture

Miyagi Prefecture also operates a dedicated portal site for disaster prevention. The website includes earthquake and tsunami information (e.g., earthquake epicenters, depth of the epicenters, earthquake scales), a list of seismic intensity information, and a map showing seismic intensity for each city in the prefecture. Regarding tsunami and seismic intensity information, there is also a link to the JMA website that can provide detailed information. Information on evacuation instruction and open status of evacuation centers within the prefecture can also be seen on the website. A unique feature of the website is that residents can register their respective locations and view a list of warnings, disasters, and evacuation information all at once. In addition, the

[33] https://www.pref.shizuoka.jp/kikaku/ki-030/documents/bosaisenshin.pdf

email service delivers warning information on heavy rains and landslides to registered residents, but none for earthquakes and tsunamis. The SNS (Twitter) provides information on earthquakes, evacuation and evacuation centers in concise sentences, with a link to the prefecture's portal site for more detailed information.

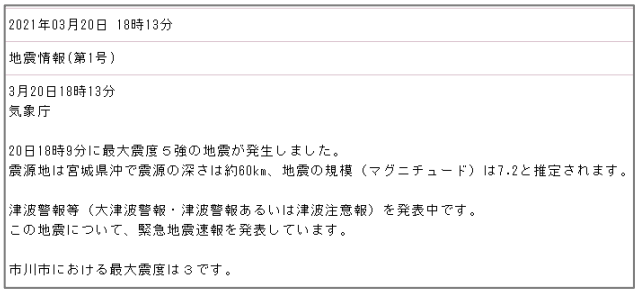
As described above, prefectures collect and compile warning and evacuation information from JMA and from each city, and send them to residents through various means, even though this is not required by the Basic Act on Disaster Management and Meteorological Service Act. Some portal websites have links to the JMA website and to other specialized websites of prefectures to minimize the amount of information in the portal and to encourage access to detailed information. The means and contents selected by each prefecture are likely to differ, depending on the disaster types with high risk of occurrence and on the characteristics of the residents living in disaster-prone areas. Functions and contents of some disaster information smartphone apps are introduced in Appendix, including those for Tokyo Metropolitan Government and Shizuoka Prefecture.

Multiple methods of information dissemination by cities

a) Ichikawa City

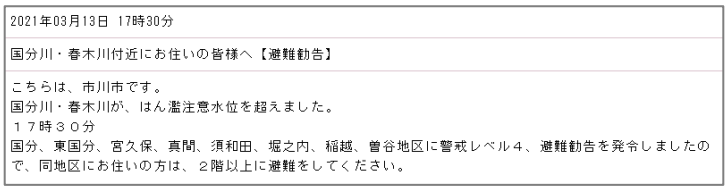
Ichikawa City's email service employs a mechanism in which earthquake and tsunami information issued by JMA are automatically sent to registered users as soon as they are received. Furthermore, the city disseminates its particular information, such as evacuation advisories, in its own wordings and sent using the same mailing system. In addition, while the city's Twitter has not posted earthquake information issued by JMA as conveyed by the email service, information on evacuation advisories are sent on Twitter simultaneously with the email, and they have almost the same content. Therefore, this email service disseminates information by utilizing different distribution methods (automatic or manual), depending on the type of information. The text of evacuation information issued by the city is almost the same in various means of communication such as email and SNS.

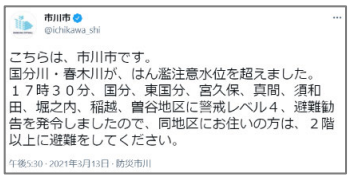
<Earthquake information by JMA>



Sent at 18:13 on March 20, 2021
Title: Earthquake Information (1st)
Contents: 18:13 on March 20, 2021 JMA An earthquake with a maximum seismic intensity of 5 occurred at 18:09 in March 20. The epicenter is off the coast of Miyagi Pref., depth of the epicenter is approx. 60 km, and the magnitude of the earthquake is estimated to be 7.2. Tsunami warning is issued. The earthquake early warning is released. The max seismic intensity in Ichikawa City is 3.

<Evacuation advisory>





Sent (posted) at 17:30 on March 13, 2021
Title: For those who live near Kokubu River and Haruki River "Evacuation is recommended"
Contents: This is Ichikawa City. Kokubu River and Haruki River exceeded the advisory water level. At 17:30, the City issued Alert Level 4 "Evacuation is recommended" to the area of Kokubu, Higashi kokubu, Miyakubo, ... If you live in any of these districts, please evacuate to the second floor or higher."

Source: Ichikawa City[34] (Translated by JICA Expert Team)

Figure 2.2.5 Warning information messages from Ichikawa City (email and Twitter)

[34] https://service.sugumail.com/ichikawa/member/portals/list_mail/7041 , https://twitter.com/ichikawa_shi?lang=en

b) Yokosuka City

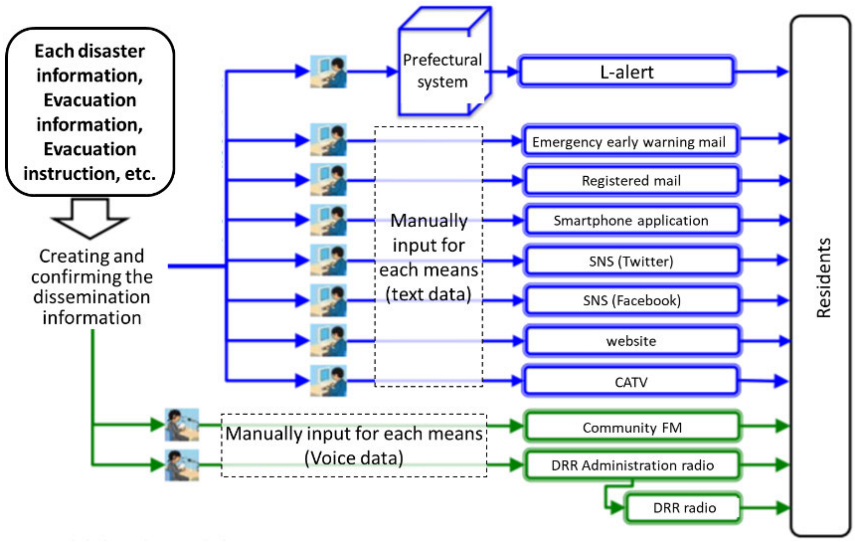
Yokosuka City disseminates information by email. Same information are broadcasted by the disaster prevention administrative radio of the city. The specific contents of the disseminated information in the email are DRR meteorological information related to the city (e.g., meteorological warnings, information on large earthquakes, large-scale accidents) and evacuation-related information. These are disseminated via the mail service based on the judgment of the levels of disaster risks in the city. Thus, the information is not necessarily the same as those that have been announced by JMA[35]. The city introduces the system wherein information announced by JMA is not automatically distributed, but the information collected by the city are distributed with content based on its own judgment.

c) Wakayama City

The disaster prevention information email service of Wakayama City delivers DRR-related information, including broadcasted ones via the disaster prevention administrative radio. The contents of the distributed information by the service are not only the original information generated by the City Office according to the situation (such as meteorological warning information, earthquake information including seismic intensity and evacuation information), but also the information automatically delivered instantly from J-ALERT (such as tsunami warnings and national protection information) through utilizing the system of FDMA. Therefore, the same with Ichikawa City, this email service adopts the automatic or manual distribution system depending on the information types, and disseminates various emergency information to residents by using the one system.

Other informative cases

According to a survey by FDMA (2019), the disaster information dissemination method in a city, which has a population of approximately 400,000, is manually done for each information transmission medium as shown in Figure 2.2.6.

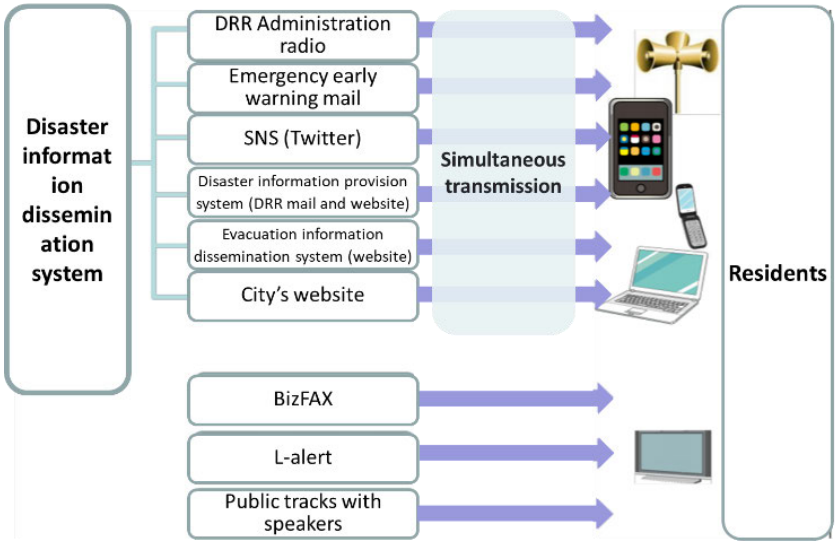


Source: FDMA (2019)[36] (Translated by JICA Expert Team)

Figure 2.2.6 Information dissemination system in City A

[35] https://www.city.yokosuka.kanagawa.jp/2426/bousainavi/sonae/jouhou/bousaimail.html
[36] FDMA (2019), https://www.fdma.go.jp/singi_kento/kento/items/%E7%81%BD%E5%AE%B3%E6%83%85%E5%A0%B1%E4%BC%9D%E9%81%94%E6%89%8B%E6%AE%B5%E3%81%B8%E3%81%AE%E4%B8%80%E6%96%89%E9%80%81%E4%BF%A1%E6%A9%9F%E8%83%BD%E3%81%AE%E5%B0%8E%E5%85%A5%E3%81%AB%E9%96%A2%E3%81%99%E3%82%8B%E6%89%8B%E5%BC%95%E3%81%8D.pdf

On the other hand, Sendai City introduced a disaster information dissemination system in 2016 which enables city officers to comprehensively operate various means of information dissemination all at once, including the disaster prevention administrative radio, early warning email, SNS and the city's website which had been operated individually in the past. This system has speed up information dissemination, created uniformity of the information arrival times, and reduced the operating risks such as input errors and the burden of information dissemination work.



Source: FDMA (2020)[37]

Figure 2.2.7 Disaster information dissemination system in Sendai City

While it is required to multiplex and diversify the means of information dissemination during disasters, as what the prefectures and cities mentioned above have done, the local governments have to face challenges such as the numerous time spent for inputting information in different systems, and the shortage of staff for these input works[38]. Therefore, it is also necessary to consider the introduction of a comprehensive system and personnel system for information dissemination, if local governments plan the multiplexing and diversification of information dissemination tools.

(3) Conclusion of the case studies of prefectures and cities

In Japan, Basic Disaster Management Plan requires the central and local government to ensure the redundancy of the means of disaster information dissemination. In response to the Plan, prefectures and cities in Japan strive to multiplex and diversify the means of communication regardless of the population size.

At the city level, some cities, including Wakayama City, utilize prefectural systems and tools (e. g., smartphone applications) in order to distribute emergency information. Since effective means of information dissemination will differ depending on the local conditions (e.g., population distribution, land use) and the type of expected disasters, it is necessary to develop various means of information dissemination suitable for local conditions, in consideration of limited financial resources (e.g., budget and human resources) and existing facilities. When considering the multiplexing and diversification of information dissemination methods, it is also required to consider the operation system of the multiple tools.

[37] https://www.fdma.go.jp/mission/prepare/transmission/items/0203_soukoujirei.pdf
[38] https://www.fdma.go.jp/publication/ugoki/items/rei_0108_08.pdf

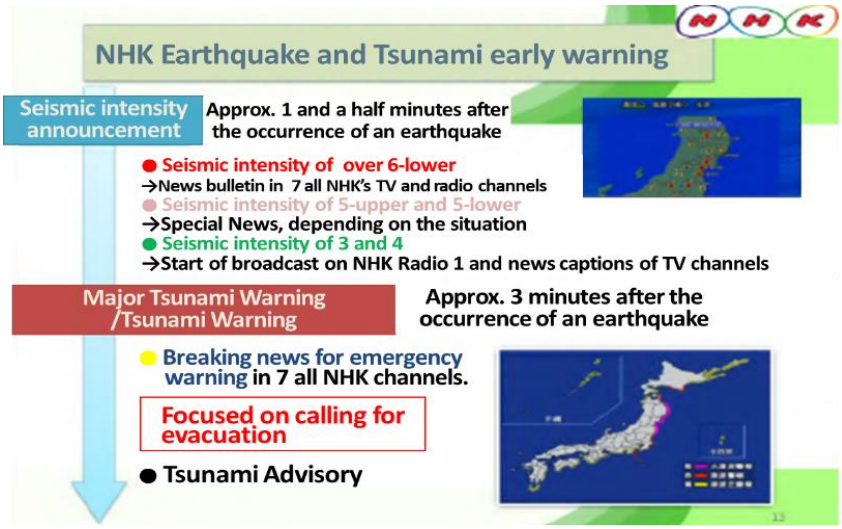
2.2.3 Case Study: Media

It has been stipulated in both Basic Act on Disaster Management and Meteorological Service Act that JMA has to transmit warning information immediately to designated organizations, including NHK, and they have to start broadcasting to disseminate those information. When a disaster occurs, many residents tune in to NHK, the main media responsible for disaster coverage in Japan. However, the disaster coverage by commercial broadcasters is not inferior to that of NHK, and residents can also collect disaster-related information immediately from the broadcasts of most commercial broadcasters. This section summarizes how the media, like NHK, utilize information related to earthquakes and tsunamis received from JMA and JMBSC.

(1) Outline of the instant broadcasting system

In the case of NHK, when an earthquake occurs and its maximum seismic intensity is predicted to be more than 5-lower, the Earthquake Early Warning (EEW) is sent from JMA about one second later. This information is automatically shown on TV as superimposed text without confirmation by TV channels, and the seismic intensity of each area is announced as breaking news about one and a half minutes after the earthquake.

In addition, the broadcasting method is classified in stages based on the magnitude of the maximum seismic intensity as shown in Figure 2.2.8. JMA informs NHK of the presence or absence of tsunamis in about three minutes, and when "major tsunami warning" and "tsunami warning" are issued, all NHK-owned TV and radio channels start breaking news for disseminating warnings and calling for evacuations.



Source: Hashizume (2018)[39] (Translated by JICA Expert Team)

Figure 2.2.8 System of NHK's instant broadcast for earthquakes and tsunamis

As mentioned above, the Earthquake Early Warning is disseminated by the instant broadcasting system. Furthermore, Emergency Warning Broadcast System, including tsunami warning, is also categorized in the system transmitted by the instant broadcasting system. Outline of these two systems are described below.

1) Earthquake Early Warning (EEW)

Earthquake Early Warning (EEW) is one of the earthquake warning systems provided by JMA, which conveys earthquake information prior to a strong shaking. EEW is categorized into two types: one is "for advanced users" and the other is "for general users". The latter is transmitted by TV and radio, and provides information on the time of occurrence of the earthquake, its expected epicenter and the area where strong shaking is expected.

[39] The Meteorological Society of Japan (https://www.metsoc.jp/default/wp-content/uploads/2018/10/07_SS2018.pdf)

2) Emergency Warning Broadcast System

The Emergency Warning Broadcast System becomes active when a large-scale disaster occurs or a tsunami warning is issued. When the situations[40] below occur, alarm sounds are broadcasted from each TV and radio station. This alarm sound is an FSK-modulated signal sound, which contains control information to activate the standby receiver, and automatically switches on the standby TV/radio receiver.

- In case a tsunami warning is issued.
- In case the head of the local government requests broadcasting, such as an evacuation order based on the Basic Act on Disaster Management.

Table 2.2.10 Summary of Earthquake Early Warning and Emergency Warning Broadcast System

	Earthquake Early Warning (EEW)	Emergency Warning Broadcast System	
Information dissemination agency	JMA	JMA, Cabinet Office, Municipality	
Broadcast conditions	A broadcasting station immediately receives earthquake occurrence information from JMA, and based on that information, the EEW is automatically broadcast when the maximum seismic intensity is 5 lower or higher.	The Emergency Warning Broadcast is a broadcast stipulated by law, and is mainly broadcast on NHK when a warning declaration for a large-scale earthquake is issued, when a tsunami warning is issued, or when there is a request for broadcasting from municipalities.	
Information flow	Earthquake occurrence observation point ▶ JMA ▶ Broadcasting station ▶ Radio station	Tsunami Warning	Warnings for other than tsunami
		Tsunami occurrence ▶ JMA ▶ Broadcasting Station (mainly NHK) ▶ Radio Station	Signs of large-scale earthquakes, riots, etc. ▶ Government agencies, municipalities, etc.▶ (Broadcast request) ▶ Broadcasting Station (mainly NHK) ▶ Radio Station
Contents	After the chime sound is repeated twice, an announcement prompting the evacuation action is broadcast immediately. The chime sound is common to all broadcasting stations.	After the signal sound, an announcement recommending evacuation advisories, cautions, etc. is broadcast. (The content of the announcement depends on the broadcasting station.) The signal sound is a special one that automatically activates the receiver corresponding to the emergency warning broadcast. Similarly, an end signal for notifying the end of the alarm is provided, and it is a signal sound that automatically terminates the receiver corresponding to the emergency warning broadcast.	
Notices	Each broadcasting station broadcasts an explanation of EEW to disseminate knowledge to general viewers.	On the 1st of every month, a test signal is broadcast for the purpose of testing the receiver that supports emergency warning broadcasting. The end signal is used for this test signal.	

Source: Japan Kyastem Co., Ltd[41]

(2) TV screen and anchor scripts for the instant broadcast

All information on seismic intensity and tsunami information sent from JMA are automatically converted for TV screen, and they can be broadcast immediately as described below.

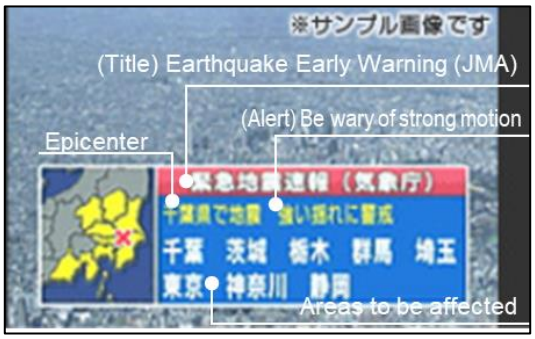
1) Earthquake Early Warning (EEW)

NHK broadcasts EEW on all TV and radio broadcast waves. On TV, a chime sound, a map and text tell the location of the earthquake and the area where strong shaking is expected. On the radio, the regular program is interrupted, and following the chime sound, the same content on the TV is broadcast.

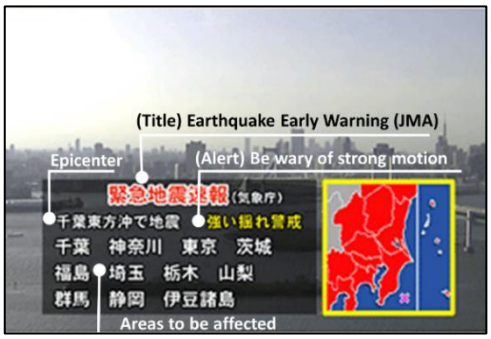
Even in commercial broadcasts, although there are differences in the colors and designs of TV screens, the displayed contents tare the same. When “strong shaking in Kanto region” is predicted,

[40] Broadcast Guideline 2020, NHK (https://www.nhk.or.jp/pr/keiei/bc-guideline/pdf/guideline2020.pdf)
[41] https://www.kyastem.co.jp/technical/ewseew/

breaking news is displayed, the name of place where strong shaking (estimated seismic intensity 4 or higher) is predicted, and a map is displayed as necessary. The title is displayed on the first line, the epicenter and caution are on the second line, and the caution areas are on the third and fourth lines. Broadcasting stations in each region also make breaking news in response to "strong shaking" in their respective broadcasting areas. Information are also displayed in the breaking news during commercials.



Source: NHK[42]

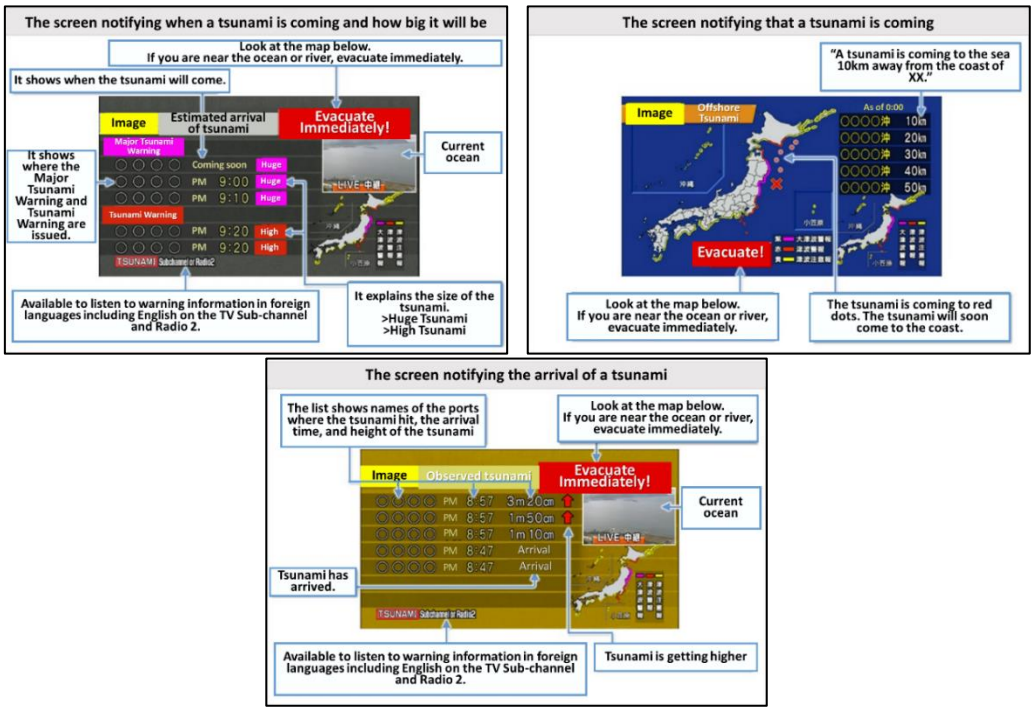


Source: Fuji Television Network[43]

Figure 2.2.9 EEW on NHK's Broadcast **Figure 2.2.10 EEW on Fuji TV's Broadcast**

2) Major Tsunami Warning / Tsunami Warning (Emergency Warning Broadcast System)

If a strong shaking is observed and there is a risk of a tsunami, the disaster broadcast gives top priority to calling for evacuation from the tsunami. During such time, the video of the "robot camera" (described in the following section) and the information transmitted by JMA are utilized, and evacuation is strongly called for.



Source: NHK NEWS WEB[44] (Translated by JICA Expert Team)

Figure 2.2.11 Tsunami Warning on NHK's Broadcast[45]

[42] https://www.nhk.or.jp/sonae/bousai/about.html
[43] https://www.fujitv.co.jp/jishin/
[44] https://www3.nhk.or.jp/news/easy/tsunamikeihou/index.html
[45] Tsunami warning information is displayed in Japanese on the actual TV screen. The English translation text by JET is superimposed on each screen captures for convenience sake.

In addition to automatic converting of information from JMA for TV, telegrams sent by them are also automatically converted to manuscript form for anchors. The manuscript is displayed on monitors for anchors to deliver immediately as latest information. After the Great East Japan Earthquake, the anchors' delivery of information has been set to a stronger tone than usual when major tsunami warning is announced to emphasize the need for immediate evacuation.

(3) System for advanced use of the information from JMA

At NHK, observation data of JMA such as rainfall, wind speed, risk of sediment disasters and river inundation are displayed on a special monitor in the TV studio, and a reporter with expertise in meteorological disasters explains the danger in detail while operating the monitor. This broadcasting method is called real-time commentary. During such time, a large amount of data from JMA is processed by a system called NMAPS (News Mash Up Advanced Probe System), and names of places and graphics of wind moving can be shown by operating the monitor.

As introduced above, NHK has installed a system that processes data from JMA at a high level, and is devising ways to make residents understand that danger is imminent in their area.

(4) Information collecting system established by TV stations

In NHK's disaster reporting, in addition to the information from JMA mentioned above, the effect of reporting is enhanced by appropriately combining information materials collected independently by NHK under the following system:

- Robot camera network: It is installed in about seven hundred locations nationwide at broadcasting stations and major facilities in each region, and can be controlled remotely from the news center of the Tokyo headquarters.
- Helicopters: NHK has fifteen helicopters dedicated to video coverage at twelve airport bases nationwide. During the day, cameraman and pilots are on standby at all airport bases. In Tokyo and Osaka bases, they are on standby 24 hours a day.

(5) Conclusion of the case study regarding the cooperation with media

NHK has a system that automatically displays information from JMA on the TV screen. The information are also reflected in the anchor's reading manuscript, so that he/she can immediately convey earthquake information, tsunami warnings, etc. to residents. In addition, the system can also operate and process JMA's information automatically as necessary. Furthermore, NHK has installed monitoring cameras and has standby helicopters nationwide so that its staff can collect information by themselves and utilize them in collaboration with the information from JMA, and achieve the disaster coverage with an emphasis on damage prevention that encourages evacuation.

Chapter 3 Cooperation Between Japan Meteorological Agency and Related Organizations for Disaster Prevention Education and Awareness Raising

JMA sets policies to strengthen the partnership with local DRR stakeholders as reported on the "Study Session on Weather and Disaster Prevention Services in Local Communities"[46]. JMA and the local meteorological offices have established partnership and collaboration with various stakeholders including local governments, educational bodies and mass media. These collaborations, some of which are described below, contribute to raise the awareness of disaster information at community level by educating the officials who directly communicate with residents. These activities are also useful for JMA and its local offices to grasp the level of understanding of residents about disaster-related information and improve the disaster information to be more understandable. Lessons learned are reflected on the messages from JMA or other DRR-related agencies to residents for them to make proper actions against imminent disaster.

1.1 Wakayama Local Meteorological Office

"Kinokuni Disaster Prevention Human Resource Development"[47]

(1) Background

In Wakayama Prefecture, as the occurrence of the Tonankai and Nankai earthquakes in the first half of this century is expected, DRR measures are significant issues for local governments including the prefecture. In this context, training of local DRR leaders, who are responsible for the local community volunteering DRR self-help groups, is important in order to spread self-help and mutual help among local residents and to improve their DRR capabilities. Therefore, a new type of training program for local DRR leaders was launched by the prefecture in 2005 in cooperation with Wakayama University.

(2) Summary

Wakayama prefecture holds lectures providing knowledge and techniques for disaster prevention in order to develop local DRR leaders who become key players in DRR activities in community disaster prevention groups and companies. After this program, participants can take an examination on disaster prevention to be a Disaster Prevention Expert accredited by Japan Bousaisi Organization.

(3) Functions of the Local Meteorological Office

Planning and Administration of the course are managed by Wakayama Prefecture. Wakayama local meteorological office dispatches lecturers for the course. In 2020, the lectures conducted by said office are as follows:

- **Date**: On 29 November 2020 at Wakayama City/ On 15 November 2020 at Tanabe City
- **Lecturers**: Director/Deputy Director for Disaster Prevention of the Wakayama local meteorological office
- **Theme**: Meteorological Characteristics in Wakayama Prefecture and Disaster Prevention Information
- **Description**: Wakayama Prefecture frequently suffers from inundation, landslide, and flood disasters. Lecturers explained basic knowledge of natural phenomena causing disasters. In

[46] The report stipulates specific initiatives to be promoted as follows (extracted): 1) JMA strengthens its efforts in normal times to build relationships of trust, hold workshops, and promote the use of experts in meteorological and disaster risk reduction , so that local governments and residents will be more aware of disaster risks according to their local characteristics, and will be able to "read and understand" meteorological information in emergencies and make use of them in disaster management.
2) In order for residents to be able to take safe self-evacuation actions, JMA continues to promote efforts to improve the disaster preparedness of the entire region in cooperation with local media by elaborating the ways of providing and disseminating understandable information.

[47] https://www.pref.wakayama.lg.jp/prefg/011400/d00154039.html

addition, they introduced cases of heavy rains in July 2018 and during the 21st typhoon in 2018. The lecturers also explained the meteorological characteristics of Wakayama Prefecture, including disaster prevention and meteorological information. Furthermore, they discussed the topic "Information Equivalent to Alert Level" which was launched in 2019 as part of meteorological information.

1.2 Kobe Local Meteorological Office

"Hyogo Disaster Management Leader Training Course"[48]

(1) Background

These days, large-scale disasters have frequently occurred throughout the country such as the Northern Osaka Earthquake (2018), the Heavy Rain Event of July 2018, the 2018 Hokkaido Eastern Iburi Earthquake and typhoon disasters. Furthermore, since this year (2020), the COVID-19 pandemic has spread around the world. In consideration of these situations, DRR activities led not only by local governments but also by residents in the prefecture should be further promoted based on the consideration of human safety first, with focus on various disasters including the Nankai Trough earthquake, large-scale accidents such as the nuclear accident and countermeasures for infectious diseases which should be considered at the citizen level. From these perspectives, the Hyogo Prefecture continually conducts this course to improve local resilience against disasters by collaboration with the Japan Bousaisi Society.

(2) Summary

With the aim of the training of voluntary leaders who will be in charge of local DRR activities, "the Hyogo Disaster Management Leader Training Course" is held for a total of 12 days within a half year. In 2020, the course focused on "how to deal with sudden natural disasters" and "how to deal with infectious diseases at the citizen level". In addition to lectures delivered by leading instructors in the field of DRR, the course provides practical programs that the local communities, including local DRR voluntary groups, can implement by their own initiatives in order to be ready for sudden disasters. Various activities are also included such as developing district DRR plans, creating "My evacuation card", playing an evacuation training game, training evacuation procedures and evacuation facility opening and operation under the COVID-19 situation, implementing various workshops utilizing maps and GIS, and lectures on Basic First Aid.

(3) Functions of the Local Meteorological Office

In 2020, the instructor was dispatched from the local meteorological office to deliver the lecture below.

- Date: 21 November 2020
- Instructor: Disaster Prevention Meteorology Officer from the Kobe local meteorological office
- Theme: The Occurrence Mechanism of Storms and Flood Disasters and Their Countermeasures
- Venue: Hyogo Prefectural Emergency Management and Training Center

1.3 Tokyo Regional Headquarters, JMA

(1) Training Kit of EEW[49]

1) Background

During the latter half of 2011 to 2012, the EEW response training was conducted by the Tokyo Regional Headquarters of JMA (hereinafter referred to as "the Tokyo local meteorological office")

[48] https://www.fire-ac-hyogo.jp/leader/

[49] http://www.jma-net.go.jp/tokyo/fukyu/eew/manual.html, https://www.kyoiku.metro.tokyo.lg.jp/static/safety/kyozai.html

in 20 elementary schools and 6 junior high schools. However, due to limitations of individual support, the Tokyo local meteorological office decided to create a training kit after consultation with the Tokyo Metropolitan Board of Education at the end of 2013.

2) Summary

The Tokyo local meteorological office and Tokyo Metropolitan Board of Education collaboratively created a material for learning the EEW in accordance with the Safe Education Program of the Tokyo Metropolitan Board of Education. It can be utilized for earthquake evacuation training and other related purposes. This material (i. e., training kit) was provided to 2,423 public schools in Tokyo by the Tokyo local meteorological office in April 2014. Versions of the training kit are as follows:

- **Browser ver.:** Users can listen to the actual sound of the EEW delivered from mobile phones (Sound source: NTT DOCOMO, INC.)
- **PPT ver.:** Data for Microsoft PowerPoint/ the sound of the EEW is not included.
- **CD ver.:** "Training Kit" CDs were distributed to all public schools (kindergartens, elementary schools, junior high schools, high schools, and schools for special needs education) in April 2014. This CD includes the sound of the EEW delivered via TVs by NHK.

3) Functions of the Local Meteorological Office

The training kit was developed in collaboration with the Tokyo local meteorological office and the Tokyo Board of Education through the following processes.

From April to August 2013, three types of training kits were created: version for lower grades in elementary school; version for upper grades in elementary school; and version for junior high school. These kits adopted illustrations and photographs utilized in the DRR education textbook "Earthquakes and Safety" created by the Tokyo Metropolitan Board of Education. During the creation period, the Tokyo local meteorological office had meetings with the education agency (four times) regarding the content of the training kit, and revised it based on the comments from the agency (e.g., specific contents for Tokyo, contents in accordance with the guidance of Tokyo Metropolitan Government) and in consideration of the consistency with other materials of said agency.

In October 2013, the training kit was tested in Safe Education promoting schools (kindergarten and 6th grade of elementary school). Then, the local meteorological office revised it based on the results of interviews with the teachers who conducted the training in these schools (e.g., un-continuous concentration of the students in kindergarten, need for more illustrations). Additionally, the participating schools checked the consistency of the contents of the training kit with schools' instructions.

In December 2013, the local meteorological office reported the revised content of the kit to the education agency and discussed the method of its dissemination. Also, the meteorological office obtained permission from NHK to utilize diagrams and sounds of the EEW that NHK shared in the training kit (free of charge). After completion, the Tokyo Metropolitan Government sent a document regarding the distribution of the training kit to public schools (2,423 schools) in Tokyo first. Then, the local meteorological office provided the training kit to each of the schools in pril 2014.

(2) Other collaborative activities for improving people's awareness

Other collaborative activities between the Tokyo local meteorological office and other institutions are as follows:

For schools

- Dispatch of lecturers to DRR classes
- Implementation of DRR classes in collaboration with the Japanese Red Cross Society
- Implementation of DRR workshops in collaboration with the Board of Education and other agencies

- Creation and provision of materials so that schools can conduct workshops by themselves

For local people and communities

- Implementation of on-site lectures
- Dispatch of lecturers to community disaster prevention groups
- Implementation of DRR lectures
- Participation in DRR drills

For/with media

- Implementation of regular meetings with media
- Implementation of explanatory meetings when improving DRR-related information
- Implementation of press conferences at the time of a remarkable phenomenon

1.4 Sendai Regional Headquarters, JMA

(1) Radio broadcast - FM Iwanuma "Weather and Earthquake Encyclopedia"

1) Background

After the 2003 Tokachi-Oki Earthquake, the Sendai Regional Headquarters, JMA (hereinafter referred to as "the Sendai local meteorological office") had visited coastal municipalities in Miyagi Prefecture to disseminate and share the knowledge about DRR, specifically on earthquakes and tsunamis. At that time, due to the established relationship between the Sendai local meteorological office and the city officers in Iwanuma City, a radio program called "Weather and Earthquake Encyclopedia" was set up in FM Iwanuma. The city has participated in the management of the 15-minute program once a week from March 2005. This program targets broadcasting stations in Miyagi Prefecture. Thus, the program basically shares topics related to the prefecture when introducing regional content.

2) Summary

With the cooperation of community FM stations in Miyagi Prefecture (FM Iwanuma, FM Bay Area, Sendai Izumi FM, FM Aozora, Osaki FM, Natori Disaster FM), knowledge regarding meteorology and earthquakes as well as the appropriate utilization of DRR meteorological information is broadcast in an easy-to-understand way every week by the local meteorological office staff and FM station announcers in dialogue format. In relation to the radio program, the Sendai local meteorological office also held or supported exhibitions so that visitors can enjoy learning about the weather and earthquakes through simple experiments. These exhibitions are shown below:

- Exhibition of the Weather and Earthquake Encyclopedia – "Let's learn the mechanism of weather and earthquakes"
- Exhibition at the Academic City "Sendai Miyagi" Science Day

3) Functions of the Local Meteorological Office

The Sendai local meteorological office decides the program schedule of the year and its allocation to each division of the office in the annual meeting. Each content of the program is freely decided by each division. An example of the program is shown below.

- Date: Thursday, 4 February 2021
- Broadcaster: Ms. Tomoe Ogawa (The Division of Global Environment and Marine, Department of Meteorological and Disaster Management, Sendai Regional Headquarters JMA)
- Theme: About the winter climate in the Tohoku Region
- Content:
  - Temperature for several years in the Tohoku Region
  - Changes in winter temperature in the Tohoku Region due to the effects of global warming (1.4 degrees in 100 years)

- Explanation of the effects of global warming such as the increasing number of heavy rainy days and non-rainy days
- Announcement of the impacts of global warming and future prediction such as the increase of the frequency of heavy rains
- Introduction of the climate change in the Tohoku Region in the Meteorological Office website.

(2) Radio broadcast - Tohoku Region Community FM Association "Meteorological Office in daily life"[50]

1) Background

With the coordination of the Yamagata Community FM "Radio Monster" (Yamagata City), which is the secretariat of the Tohoku Community FM Association, the Sendai Local Meteorological Office has cooperated with said association in the conduct of activities to disseminate DRR knowledge, such as broadcasting spot programs at the beginning of the EEW in October 2007 and the Emergency Warning in August 2013. Due such cooperation, the local office and the association had thought of a regular program for the purpose of dissemination of the knowledge on weather and DRR. Consequently, in May 2013, the radio program started to be produced by the Radio Monster station as a 5-minute program twice a month and broadcast by each affiliated station of the association. The program deals with topics related to the Tohoku Region in general. Therefore, when names pertaining to places in the region are mentioned in the program, a detailed explanation is given so that the listeners can understand what part of the prefecture is being discussed.

2) Summary

Tohoku Region Community Broadcasting Association (JCBA Tohoku Region) and the Sendai local meteorological office collaboratively broadcast meteorological information and trivia related to daily life. With the cooperation of JCBA Tohoku Region, FM stations affiliated with it broadcast knowledge regarding meteorology and earthquakes, as well as the appropriate utilization of DRR meteorological information, twice a month in an easy-to-understand way for residents. Two programs with their schedules are as follows:

- Radio BAY WAVE (Shiogama City) at 9:45-10:00 on Tuesdays and Thursdays
- Nato-Radi 801 (former name "Natori Disaster FM") at 8:15-8:20 on Tuesdays

3) Functions of the Local Meteorological Office

This program is cooperatively planned by the local meteorological office and the affiliated stations of JCBA Tohoku Region. Specifically, the program is produced by the Yamaguchi Community FM (Radio Monster), which is the secretariat of the association, and provided to each station. In the program, while broadcasters of Radio Monster deliver the content by reading manuscripts, the program content including titles of each episode and manuscripts are planned and written by the local meteorological office. Furthermore, approximately once a year, the local meteorological office visits the broadcasting stations to exchange thoughts about the programs. As with the case of the program at FM Iwanuma, the local meteorological office decides the program schedule for the year and its allocation to each division of the office during the annual meeting. Each content of the program is freely decided by each division.

(3) Other activities of DRR education and in raising people's awareness

Other collaborative activities between the Sendai local meteorological office and other institutions are as follows:

[50] http://www.bay-wave.co.jp/timetable.html#mokukin

1) For schools[51]

The local meteorological office advises the Miyagi Prefectural Board of Education on the preparation of the "*Miyagi Disaster Prevention Education Textbook*", and the Sendai City Education Center on the preparation of the "*New Disaster Prevention Education Textbook Toward the future from 3.11*", as well as dispatches instructors to workshops for teachers who are in charge of disaster prevention in their schools. Furthermore, the local meteorological office, as an expert, participates and provides advice during workshops regarding heavy rains which are held by schools.

2) For local people and communities[52]

The local meteorological office supports disaster prevention education through the creation of "Kamishibai (storytelling with pictures) on disaster prevention" in collaboration with the Tohoku Branch of the Certified and Accredited Meteorologists of Japan and Miyagi branch of Japan Bousaisi Society. These collaborative organizations hold sessions of the Kamishibai for kindergarten children. The local meteorological office uploads the Kamishibai sessions on their website so that users can create stories by themselves and read them to kindergarten children at a convenient time.

3) For/with media

The local meteorological office and NHK Sendai promote strengthening of cooperative relationship by having once-a-year meetings for exchanging opinions with residents, and find out their requests to protect lives and properties and ensure their safety and security from natural disasters. Specifically, the local meteorological office exchanges opinions with NHK Sendai so that it can understand DRR-related information announced by JMA, and make appropriate calls to local residents when disasters occur. In addition, the local meteorological office and NHK Sendai are developing appropriate call statements according to the risk levels of heavy rains and floods. Through exchanging opinions, it is expected that NHK Sendai will be able to make appropriate calls to local residents in response to disasters, which consequently leads to appropriate evacuation of the residents. This meeting is managed by both institutions alternately, and the facilities of each are also visited.

[51] https://www.jma.go.jp/jma/kishou/know/jma-ws/index.html
[52] https://www.data.jma.go.jp/sendai/knowledge/kyouiku/kamisibai.html

Chapter 4 JICA's Support for Indonesia in the Field of Weather and Disaster Information Transmission

From June 2019 to February 2020, RC Solution Co. conducted a survey funded by JICA to make a feasible business plan by analyzing needs, prioritizing potential customers, and selecting a local partner to be ready for the launching of "Bosai Cloud" developed by RC Solution Co. in Indonesia[53]. This chapter explains background of the introduction of the system, as well as the system overview according to the mentioned survey report.

4.1 Background

4.1.1 Expectations for the "Bosai Cloud"

In Indonesia, residents' lack knowledge on disaster, and they experience delays in the transmission of disaster information from responsible agencies, which have caused serious damage. Even if DRR and disaster information websites are provided in the internet, constantly checking them and searching for the necessary information in a huge amount of information resources will need a lot of time and effort. Furthermore, the effect to residents will be limited if information transmission will be uniformly done in a traditional way. Therefore, in order to promote appropriate evacuation and consequently achieve disaster risk reduction, it is crucial to provide individuals in each place with specialized information, as well as to distribute information by push notification. Specifically, since the number of international tourist is large in the country, distribution of warning information to individuals is also significant to continually develop the tourism industry.

"Bosai Cloud" (proposed and analyzed in the survey) is a system expected to solve these issues through promptly distributing disaster-related information from private companies and public authorities to residents. This system was developed by RC Solution Co., which is a leading company in the market of DRR-related information transmission service in Japan with the top-class technics of rapid information transmission.

4.1.2 Summary of the function of "Bosai Cloud"

"Bosai Cloud" is a system introduced in Japan to provide clients (e.g., private companies and local governments) with necessary disaster-related information by utilizing the earthquake early warning and weather warning issued by JMA. Target markets are public agencies (e.g., local governments and public transportation agencies) and private companies (e.g., hotels and commercial facilities) which are required to rapidly gain disaster-related information and provide these to residents and their clients. The system can be utilized to display disaster occurrence information together with the operational status of transportation for railway and bus companies, or together with evacuation routes at facilities and in areas for hotels and shopping mall management companies. This service can rapidly and specifically provide individuals with necessary information, therefore, it is highly demanded and introduced in a lot of agencies in Japan.

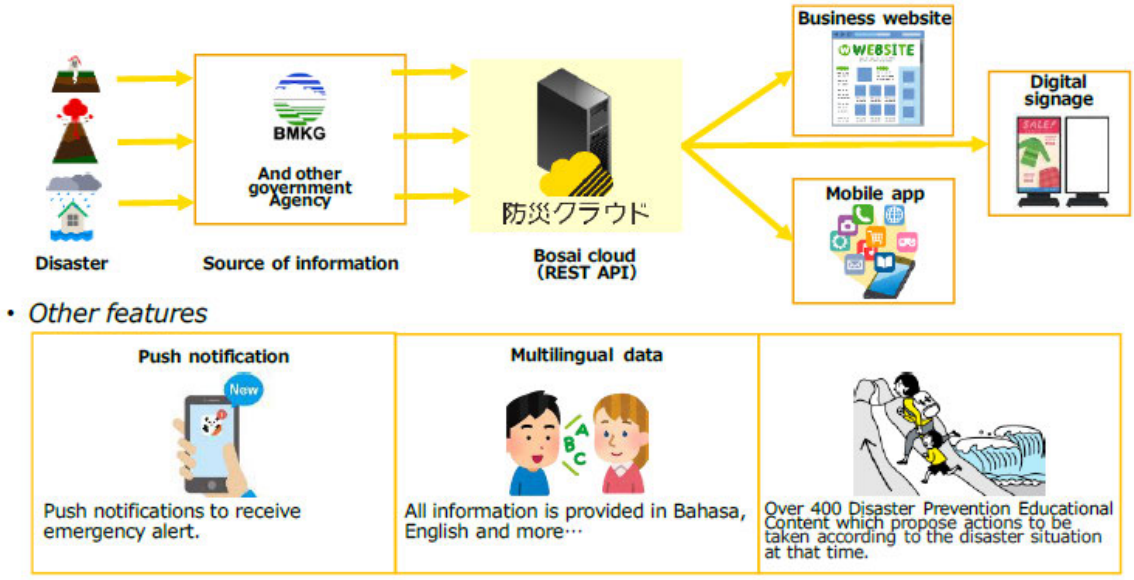
4.2 System overview of "Bosai Cloud" for information transmission in Indonesia

Disaster-related information have been individually managed by different government agencies in Indonesia, such as BMKG being in charge of information on earthquake, tsunami, and abnormal weather; and PVMBG dealing with information on volcanic eruptions. Consequently, "Bosai Cloud" will enable the provision of disaster-related information in a unitary way. The system can collect, process and distribute all disaster information, including those for earthquakes, tsunamis and volcanic eruptions, as well as weather information.

Expected devices that RC Solutions Co. will provide with the information include websites operated by clients, digital signage and mobile apps. Since the information data that BMKG can provide are in XML

[53] "Small and Medium-size Enterprise (SME) Partnership Promotion Survey for Information Provision Business for Disaster Prevention in Indonesia." https://openjicareport.jica.go.jp/pdf/1000042397.pdf

format, clients who are not familiar with this type of data do not have technical knowledge and know-how on how to display information on their websites and apps. “Bosai Cloud” can process this XML data into a format that is easy for each client to handle (JSON format which can be utilized for passing data between various software and programming languages), and transmit information to websites operated by each client, digital signage and mobile apps by push notification. Furthermore, it can be possible also to provide added value according to the clients’ request such as information transmission in multiple languages, including Indonesian, and provision of educational content.



Source: “Small and Medium-size Enterprise (SME) Partnership Promotion Survey for Information Provision Business for Disaster Prevention in Indonesia”[54]

Figure 4.2.1 System image of “Bosai Cloud”

4.3 Current status of introducing “Bosai Cloud” in Indonesia

According to the report “Small and Medium-size Enterprise Partnership Promotion Survey for Information Provision Business for Disaster Prevention in Indonesia” (RC Solution Co., 2020), RC Solution has already agreed with BMKG regarding the acquisition of information and has been allowed to access the data server owned by BMKG, which stores earthquake, tsunami, and meteorological information. In addition, a BMKG-approved mobile app developed by RC Solution for receiving disaster-related information had been released in October 2018. Also, there is a cooperative relationship between the company and government agencies, as the company also obtained assurance of cooperation to the project from PVMBG and Regional Disaster Management Agency. The Report states that “Bosai Cloud” is scheduled to be launched in 2021 at full-scale, and planned to expand its application in Jakarta in 2022.

[54] https://openjicareport.jica.go.jp/pdf/1000042397.pdf

Chapter 5 Conclusion

The survey articulates the framework of information dissemination from JMA based on the viewpoint of means of communication, roles of stakeholders, and content of the information. The current system underlies the concept of securing the redundancy of information source and awareness raising of the receiver of the information.

(1) Redundancy of transmission of DRR- related information to residents

The ultimate goal of disaster information dissemination is to deliver the information at the earliest timing and maximum number of people.

As for the format of communication, JMA and JMBSC provide various format of information so that DRR-related agencies in both public and private sectors can disseminate the information by utilizing various means of communication such as media, wireless network, mobile application, SNS and so on. Editable format of information provided by JMA enables DRR-related stakeholders to generate visually understandable information to residents through their accessible devices.

JMA and legal transmission agencies establish redundant means of communication (such as landline, wireless network and satellite communication) to be prepared for the damage of communication system in case of large-scale disaster. JMA and JMBSC provide various disaster-related information by different means and types so that they can maximize the number of public and private stakeholders that can convey the information to the residents.

(2) Awareness Raising for the Receivers of Disaster Information

Disseminating disaster information become effective once the receivers correctly understand the messages and take necessary actions to mitigate the damage of disaster. JMA defines itself as a DRR agency, and contributes to raise the awareness on disaster information, even though the Meteorological Service Act does not stipulate it as an agency with such function.

Since the risks of disaster varies in each region, JMA strengthens the partnership with local government through its local meteorological offices by dispatching experts to schools, municipal DRR self-help group trainings, and media. These collaborations contribute to accumulate the awareness and perception of local population toward disaster, and improve the countermeasures for disaster based on lessons learned from the interaction with local population.

(3) Effective involvement of private sector

Making disaster information available to the private sector contributes to enhance the accessibility of the disaster information to residents by permitting certificated businesses to be profitable. This will encourage the private sector to be involved as providers of disaster information, and contribute to disseminate information to more people than just relying on administrative communication. As previously mentioned, providing editable information creates business opportunities for the private sector, such as developing mobile applications, websites, and information service provision for municipality, private firms, and individuals who think that accurate and prompt disaster information are worth paying for premium. If the private sector realizes that accurate and prompt disaster information, quality and convenience of web services and app for subscription will be improved in Indonesia, it can replicate the experience of Japanese private businesses who have tailor-made the services in response to the needs of the users who can afford to pay for the information. This market has not matured in Indonesia as government agencies operate their own apps and websites.

(4) Utilization of Social Networking Service (SNS)

In Japan, various kinds of SNS and mobile applications are available developed not only by government agencies but also by the private sector. Increasing the number of developers of apps or that of information providers of SNS will contribute to increasing the access to disaster information. It should be noted that providing the information via SNS may cause misunderstanding the information that may end up

underestimating the damage or risk of disaster. Specifically, the information tends to have brevity when using SNS. Awareness by the residents of "how to read the information" should be considered when posting information by SNS, or the app should have the function to access the meaning of information provided.

Appendix: Catalog of smartphone applications and websites utilizing information issued by JMA

List of smartphone applications and websites utilizing warning information issued by JMA

No.	App/ Web	Title of App and Website	Category
1	App	Koto City Bosai Map	Public (Local government in Tokyo Metropolis)
2	App	Adachi City Disaster Prevention Navi	Public (Local government in Tokyo Metropolis)
3	App	Kokoshiru Shinagawa	Public (Local government in Tokyo Metropolis)
4	App	Tokyo Metropolitan Government Bosai App	Public (Prefecture level)
5	App	Wakayama Prefecture Bosai Navi	Public (Prefecture level)
6	App	Shizuoka Prefecture Bosai	Public (Prefecture level)
7	App	Kawasaki Bosai App	Public (City level)
8	App	Sapporo City Disaster Prevention App – Sonae	Public (City level)
9	App	Niihama Info	Public (City level)
10	App	Fujikawaguchiko Town Bosai	Public (Town/Village level)
11	App	Kihoku Town Bosai Navi	Public (Town/Village level)
12	App	Oiso Bosai・Gyosei Navi	Public (Town/Village level)
13	App	Yahoo! Bosai-Sokuho	Private
14	App	NHK News Bosai	Private
15	App	Tokumu kikan NERV Bosai	Private
16	App	goo Disaster Prevention App	Private
17	App	PREP (New version of “Yure-kuru Call”)	Private
18	App	KOKODAYO – DRR for families and Earthquake early warning App	Private (Specialized in earthquakes)
19	App	Newsflash and Earthquake early warning - News Digest	Private (Specialized in earthquakes)
20	App	Japan Earthquake Information Lite	Private (Specialized in earthquakes)
21	App	(Earthquake early warning) Earthquake Now!	Private (Specialized in earthquakes)
22	App	Quake and Tsunami Community	Private (Specialized in earthquakes) *Paid app (300 yen/month)
23	Web	Yahoo! Weather・Disaster	Private
24	Web	NHK NEWS WEB Weather and Disaster Information	Private
25	Web	Google Disaster Information	Private
26	Web	tenki.jp	Private
27	Web	Weathernews	Private

1	Title of App (Users)	Koto City Bosai Map (10,000+ installed from Google Play)

General Information

Category	Public (Local government in Tokyo Metropolis)
Responsible Agency/Developer	Koto City, Tokyo/ Shobunsha Publications, Inc.

Content/User Interface

Other Functions: Flashlight, Buzzer, etc.

Meteorological and disaster-related information notified by the App

Disaster-related information notified by the City is introduced on the city's website as follows:

Information issued by JMA
- Seismic Intensity
- Earthquake early warning
- Tsunami information (Advisory, Warning)
- Meteorological information (Advisory, Warning)
- Flood information (Advisor, Warning), etc.

Information issued by Cabinet Secretariat
- Civil Protection Information

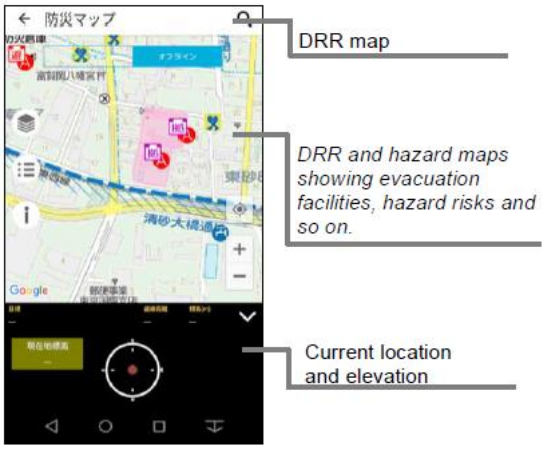
Information issued by Koto City
- Evacuation information, etc.

Features	● Search evacuation facilities and display evacuation routes from one's location to there ● Display current opening status of evacuation shelters and other temporary accommodation facilities ● Push notification in an emergency to support evacuation ● Content in 4 languages, available offline
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.mapple.android.koto&hl=ja&gl=US

Screenshots of the content

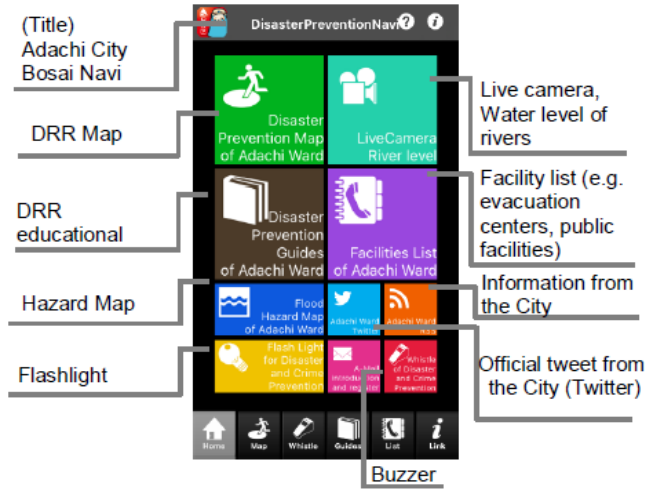
Example of Emergency notification

Example of Educational content



2	Title of App (Users)	**Adachi City Disaster Prevention Navi** **(10,000+ installed from Google Play)**

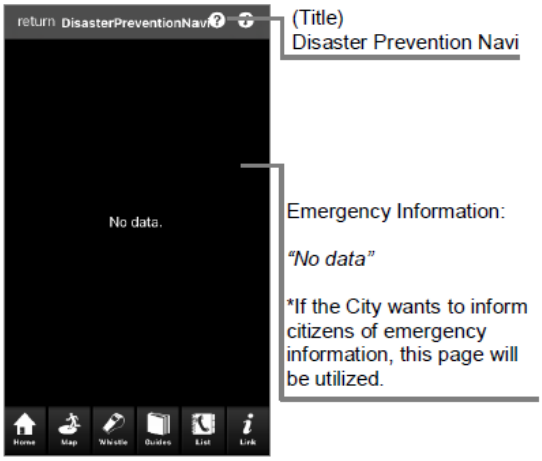
General Information	
Category	Public (Local government in Tokyo Metropolis)
Responsible Agency/Developer	Adachi City, Tokyo/ Comnet System Corporation

Content/User Interface	**Meteorological and disaster-related information notified by the app**
	**<u>Information issued by river management offices</u>** • Water levels of rivers, and other information **<u>Information issued by Adachi City</u>** • Disaster-related information

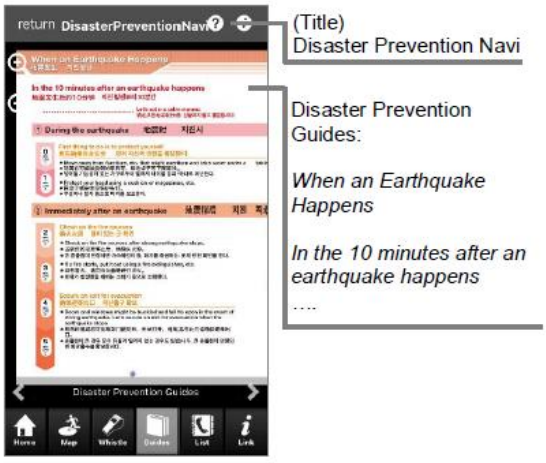
Features	● Integrated useful functions in the app such as DRR maps, live camera shot of rivers, new announcements from the City, flashlight, and buzzer ● Content in 4 languages ● Available offline for DRR maps, DRR guide, evacuation facility list, etc.
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.comp.android.bousai.adachi

Screenshots of the content

<u>Example of Emergency notification</u>



<u>Example of Educational content</u>

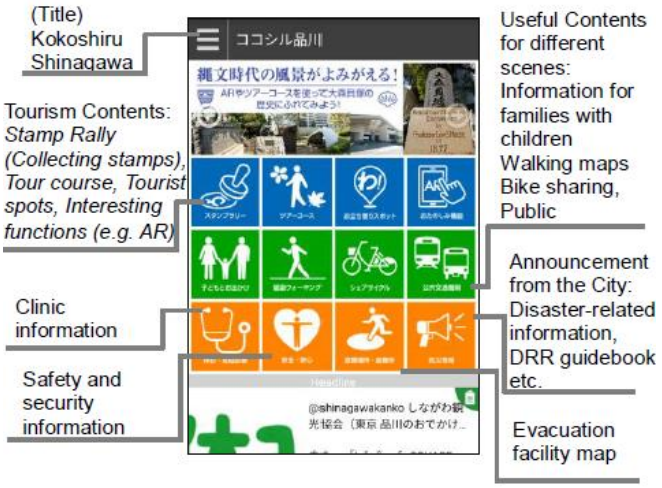


3	Title of App (Users)	Kokoshiru Shinagawa (50,000+ installed from Google Play including all “Kokoshiru” users)

General Information

Category	Public (Local government in Tokyo Metropolis)
Responsible Agency/Developer	Shinagawa City, Tokyo/ UC Technology Corporation

Content/User Interface



Meteorological and disaster-related information notified by the App

Information issued by river management offices
- Water levels of rivers, etc.

Information issued by JMA
- Meteorological information

Information issued by Adachi City
Safety and security information

Information issued by other agencies
- Safety and security information
- Other DRR-related information

Features	● Include interesting tourism content ● Enhanced function for transmitting emergency and disaster-related information ● Push notification in an emergency to support evacuation
URL (Google or Apple)	https://play.google.com/store/apps/details?id=com.uctec.ucdroid&hl=ja

Screenshots of the content

Example of Emergency notification

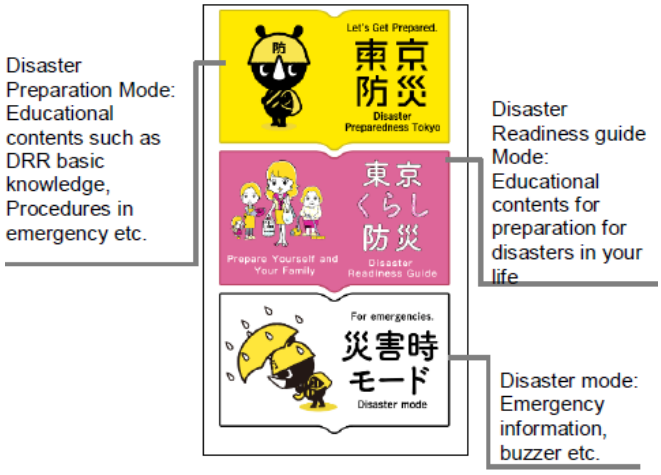
Example of Educational content

4	Title of App (Users)	**Tokyo Metropolitan Government Bosai App (100,000+ installed from Google Play)**

General Information

Category	Public (Prefecture level)
Responsible Agency/Developer	Tokyo Metropolitan Government/ Studio Spoon Inc.

Content/User Interface



Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological information
- Earthquake information
- Tsunami information
- Volcano information

Information issued by local governments
Evacuation information (Advisory, Warning, etc.)

Features	● Push notification in an emergency to gain emergency information ● Various educational contents for disaster preparedness such as disaster response quiz, Checklist for disaster emergency, etc. ● Content in 4 languages (Japanese, English, Chinese, Korean)
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.tokyo.metro.tokyotobousaiapp

Screenshots of the content

Example of Emergency notification

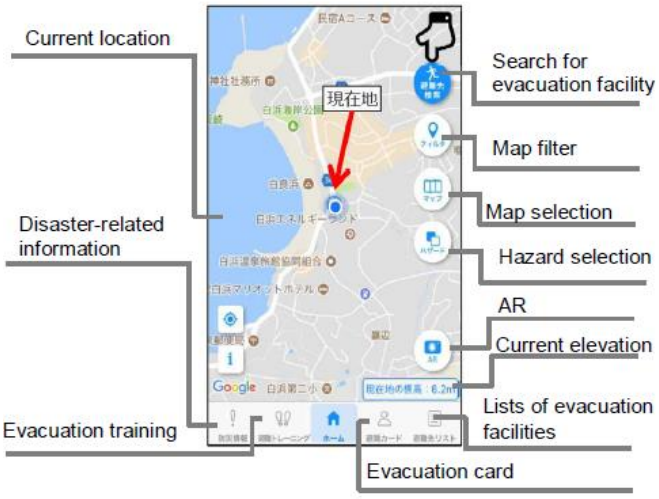
Example of Educational content

5	Title of App (Users)	**Wakayama Prefecture Bosai Navi** **(10,000+ installed from Google Play)**

General Information

Category	Public (Prefecture level)
Responsible Agency/Developer	Wakayama Prefecture/ Cyberlinks Co.,Ltd.

Content/User Interface



Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological information (Advisory, Warning)
- Landslide alert information
- Earthquake information
- Wind watch hazard
- Tsunami information (Advisory, Warning)
- Flood information (Advisor, Warning, etc.)
- Volcanic eruption warnings, etc.

Information issued by Cabinet Secretariat
- Civil Protection Information

Information issued by local governments
- Evacuation information
- Evacuation facilities information
- Announcement from local governments

Features	● Search easily for evacuation facilities and their safety status ● Display the fastest way to the evacuation facility on a map ● Push notification in an emergency to gain emergency information for the current location ● Display locations of family members on a map in an emergency if family groups are registered.
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.cyberl.wakayama&hl=ja

Screenshots of the content

Example of Emergency notification

Wakayama city: Evacuation instructions and recommendation 10:49 Jun 30, 2017

Wakayama city: Evacuation instructions

Issued Evacuation instruction In Hirose district

Issued by Disaster Prevention Planning Division, Wakayama General Affairs Department Risk management bureau, Wakayama Prefecture

Example of Educational content

(Sub-Title) Evacuation training

Evacuation time to be taken from your previous locations

Pause / Evacuated

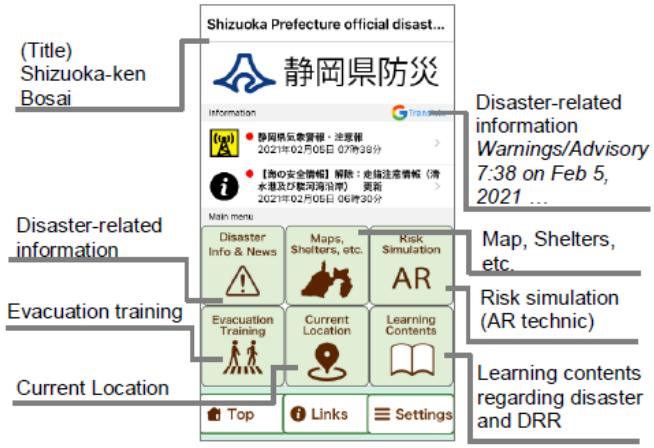
Map illustrating expected routes to an evacuation center.

6	Title of App (Users)	Shizuoka Prefecture Bosai (10,000+ installed from Google Play)

General Information

Category	Public (Prefecture level)
Responsible Agency/Developer	Shizuoka Prefecture/ (no information)

Content/User Interface



Meteorological and disaster-related information notified by the app

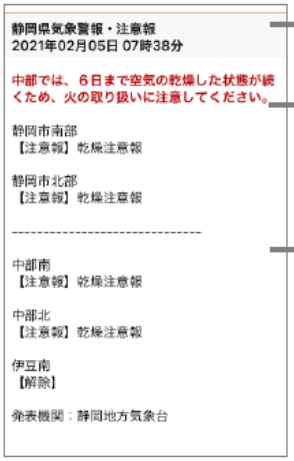
Information issued by JMA
- Meteorological information (Advisory, Warning)

Information issued by local government
- Evacuation information
- Evacuation facility information

Features	● Search easily for evacuation facilities near one's current location ● Support one's evacuation through AR camera and compass function ● Display disaster-related information and hazard information in relation to one's location ● Push notification and display all notification about disaster-related information
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.shizuoka.pref.bousai&hl=ja&gl=US

Screenshots of the content

Example of Emergency notification



(Title)
Shizuoka Prefecture
Meteorological Warning
and Advisory
7:38 Feb 5, 2021

"In the Central area, since dry air will continue until Feb 6, please pay attention to handling of the fire.

Shizuoka city
Southern area
[Advisory] Dry Air Advisory
Northern area
…..

Central South
[Advisory] Dry Air Advisory
Central North …..

Example of Educational content

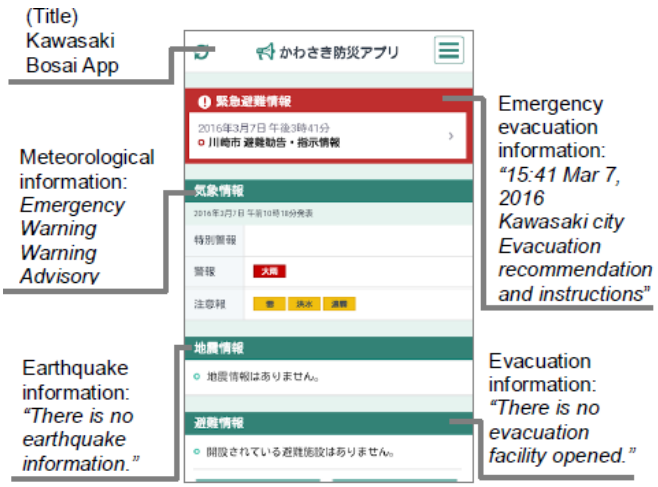
(Title)
Learning Contents

1. For safe evacuation

"(4) Meteorological warning etc.

In order to help DRR-related agencies to appropriately response to disasters and citizens to make a decision of voluntary evacuation, Emergency Warning, Warning or Advisory is issued by JMA depending on significance and possibility of disasters."

7	Title of App (Users)	Kawasaki Bosai App (10,000+ installed from Google Play)
General Information		
Category		Public (City level)
Responsible Agency/Developer		Kawasaki City, Kanagawa / Fujitsu Limited
Content/User Interface		**Meteorological and disaster-related information notified by the app**



Information issued by JMA

- Meteorological information (Advisory, Warning)
- Earthquake information
- Landslide alert information
- Wind watch hazard
- Tsunami information (Advisory, Warning)
- Flood information (Advisory, Warning), etc.

Information issued by local government

- Evacuation information
- Evacuation facilities information
- Announcement from local governments

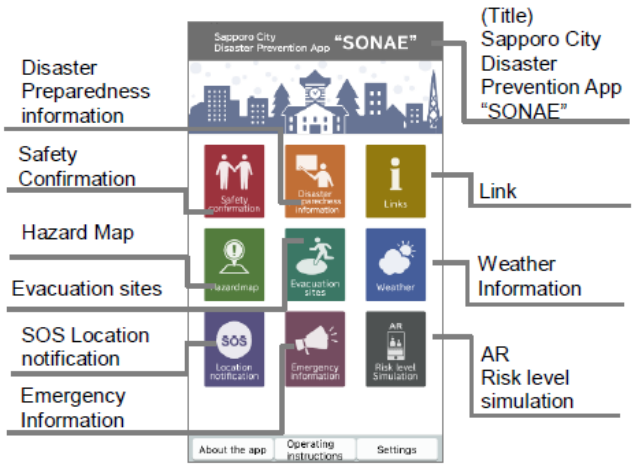
Features	● Display useful information in an emergency such as disaster-related information, meteorological warnings, and evacuation facilities that are open ● Display hazard maps including landslide and flood hazard maps ● Push notification in an emergency to provide emergency information
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.kawasaki.city.kawasakiapp.disaster

8	Title of App (Users)	Sapporo City Disaster Prevention App – Sonae (10,000+ installed from Google Play/ 53,969 users as of Nov. 2019)

General Information

Category	Public (City level)
Responsible Agency/Developer	Sapporo City, Hokkaido/ (no information)

Contents/User Interface



Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological information (Advisory, Warning)
- Earthquake information, etc.

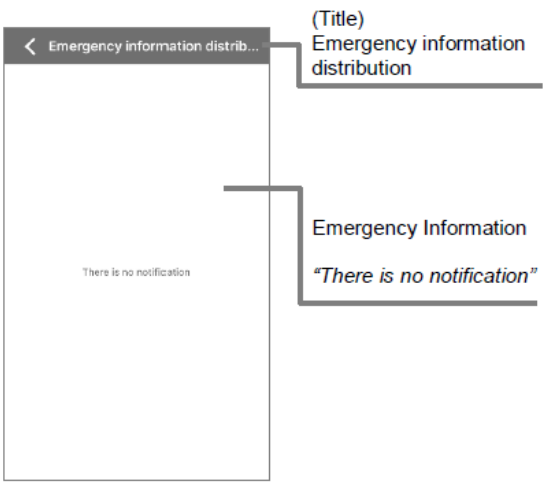
Information issued by Cabinet Secretariat
- Civil Protection Information

Information issued by local government
- Evacuation information
- Evacuation facilities information

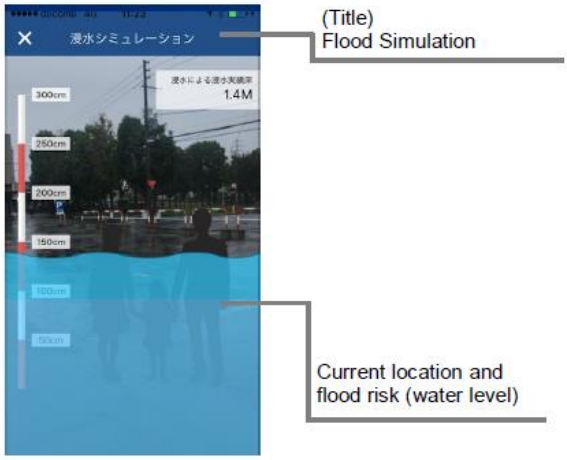
Features	● Display the designated evacuation facilities for each disaster near one's current location by utilizing GPS ● Push notification in an emergency to provide disaster-related information including meteorological information ● Send SOS message and one'sr location to the registered email address ● Content in 4 languages ● Available offline for displaying evacuation facilities
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.bousai.sapporo

Screenshots of the content

Example of Emergency notification



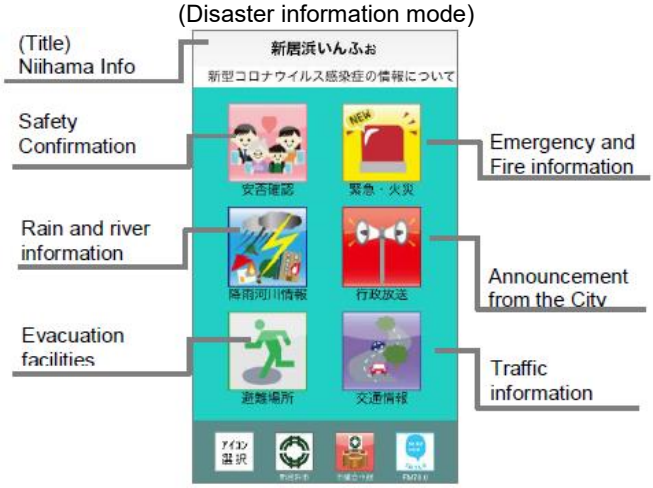
Example of Educational content



9	Title of App (Users)	**Niihama Info** **(5,000+ installed from Google Play/13,106 users as of Apr. 2019)**

General Information

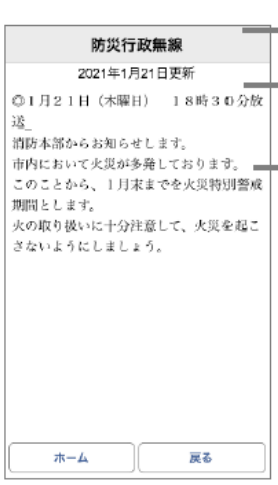
Category	Public (City level)
Responsible Agency/Developer	Niihama City, Ehime/ Heart @ network Co., Ltd (Cable TV company)

Contents/User Interface	**Meteorological and disaster-related information notified by the app**
(Disaster information mode)  	**<u>Information issued by JMA</u>** • Meteorological information (Advisory, Warning) • Landslide alert information • Earthquake information • Tsunami information (Advisory, Warning) • Flood information (Advisory, Warning), etc. **<u>Information issued by local governments</u>** • Evacuation information • Fire information • Announcement from local government **<u>Information issued by Cabinet Secretariat</u>** • Civil Protection Information **<u>Information issued by others</u>** • Water levels in rivers (Link to websites)

Features	● Display emergency information issued via J-ALERT ● Available offline in emergency ● Navigate to evacuation facilities with a map by utilizing GPS ● Display useful life information such as event information, calendar showing garbage collection, traffic information, etc.
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.mcast.m3.LocalInformationNiihama&hl=ja&gl=US

Screenshots of the content

<u>Example of Emergency Notification</u>



(Title)
Administration radio system for disaster prevention

Updated on Jan 21, 2021

"© Announced at 18:30 on Jan 21

Announcement from the fire department. There are a lot of fire occurrences within the city. Therefore, the period until the end of January is designated as "Special fire precaution period". Please pay attention to handle the fire and prevent fire accident."

10	Title of App (Users)	Fujikawaguchiko Town Bosai (500+ installed from Google Play)

General Information	
Category	Public (Town/Village level)
Responsible Agency/Developer	FujiKawaguchiko Town, Yamanashi/ (no information)

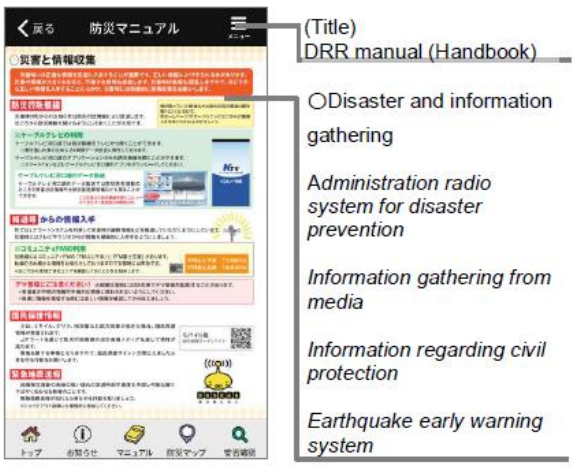
Content/User Interface	Meteorological and disaster-related information notified by the app
	Information issued by JMA • Warning information (Advisory, Warning) • Earthquake information, etc. **Information issued by Cabinet Secretariat** • Civil Protection Information **Information issued by local governments** • Fire information • Evacuation facility information • Announcement from local governments, etc.

Features	● Display latest disaster-related information and push notification ● Search easily for evacuation facilities on a DRR map ● Display the content of the DRR Handbook for Disaster Preparedness ● Available offline in 3 languages
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.visor.machiyell.fujikawaguchiko.production&hl=ja&gl=US

Screenshots of the contents

Example of Emergency notification

Example of Educational content



11	Title of App (Users)	Kihoku Town Bosai Navi (500+ installed from Google Play)

General Information

Category	Public (Town/Village level)
Responsible Agency/Developer	Kihoku Town, Mie/ (no information)

Content/User Interface

Meteorological and disaster-related information notified by the app

Information issued by JMA

- Meteorological information (Advisory, Warning)
- Earthquake information
- Wind watch hazard
- Tsunami information (Advisory, Warning)
- Flood information (Advisory, Warning, etc.)

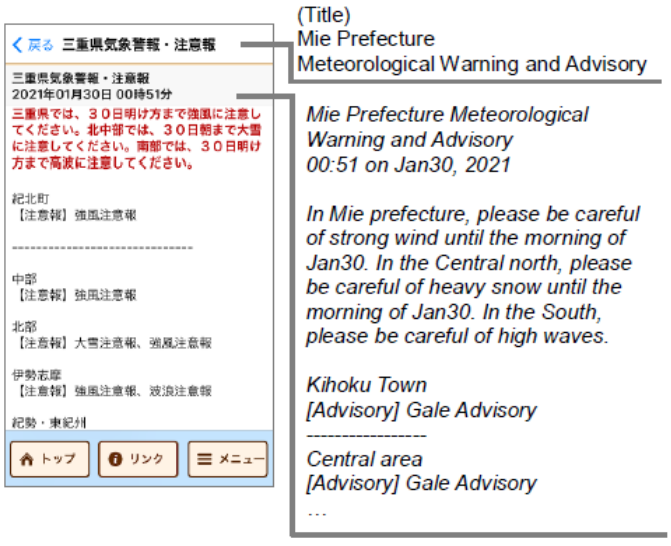
Information issued by local government

- Evacuation information
- Announcement from local government, etc.

Features	● Display evacuation facilities and their information, and support for one's evacuation by AR camera and compass functions ● Display hazard map information on a map in order to understand disaster risk at the current location ● Push notification to provide emergency information ● Available offline for some functions
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.lg.mie_kihoku.town.bousainavi&hl=ja

Screenshots of the content

Example of Emergency notification



<table>
<tr><td colspan="2">12 Title of App (Users)</td><td colspan="2">Oiso Bosai・Gyosei Navi
(Lifevision App 10,000+ installed from Google Play)</td></tr>
<tr><td colspan="4">General Information</td></tr>
<tr><td colspan="2">Category</td><td colspan="2">Public (Town/Village level)</td></tr>
<tr><td colspan="2">Responsible Agency/Developer</td><td colspan="2">Oiso Town, Kanagawa / Denso Corporation</td></tr>
<tr><td colspan="3">Content/User Interface</td><td>Meteorological and disaster-related information notified by the app</td></tr>
<tr><td colspan="3">(Title)
Oiso Bosai (DRR)
Gyosei (Government administration) Navi

Announcement
Oiso police department information 10:10 on Feb2, 2021

COVID-19 information 9:00 on Jan30, 2021

Date
Friday, Feb 5</td><td><u>Information issued by JMA</u>
• Meteorological information (Advisory, Warning)
• Landslide alert information
• Earthquake information
• Wind watch hazard
• Flood information (Advisory, Warning, etc.)

<u>Information issued by Cabinet Secretariat</u>
• Civil Protection Information

<u>Information issued by local government</u>
• Evacuation information
• Evacuation facilities information
• Announcement from the local government</td></tr>
<tr><td colspan="2">Features</td><td colspan="2">● Search easily for evacuation facilities and AED kit near one's current location on a map
● Display and play information announced by the disaster prevention administrative radio system for disaster prevention anywhere and anytime
● Display hazard maps, evacuation facility lists, evacuation tips</td></tr>
<tr><td colspan="2">URL (Google or Apple)</td><td colspan="2">https://play.google.com/store/apps/details?id=jp.co.denso.lv.basic.app&hl=ja</td></tr>
</table>

13	Title of App (Users)	Yahoo! Bosai-Sokuho (18,000,000 users)

Basic Information

Category	Private (Covering various disasters)
Responsible Agency/Developer	Yahoo Japan Corp.

Content/User Interface

Other Functions: Hazard maps, Evacuation facility list, etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological information (Advisory, Warning)
- Earthquake information
- Heavy rain forecasts
- Landslide alert information
- Tsunami information (Advisory, Warning)
- Flood information (Advisor, Warning, etc.)
- Volcanic eruption warnings
- Heatstroke information, etc.

Information issued by Cabinet Secretariat
- Civil Protection Information

Information issued by local governments
- Evacuation information
- Emergency information

Information issued by other agencies
- Emergency information on utilities
- Security information, etc.

Features	● Display information on 12 types of disasters ● Push notification in an emergency such as occurrence of earthquake, tsunami, and heavy rains to support evacuation ● Display emergency notification regarding registered three areas
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.co.yahoo.android.emg

Screenshots of the content

Example of Emergency notification

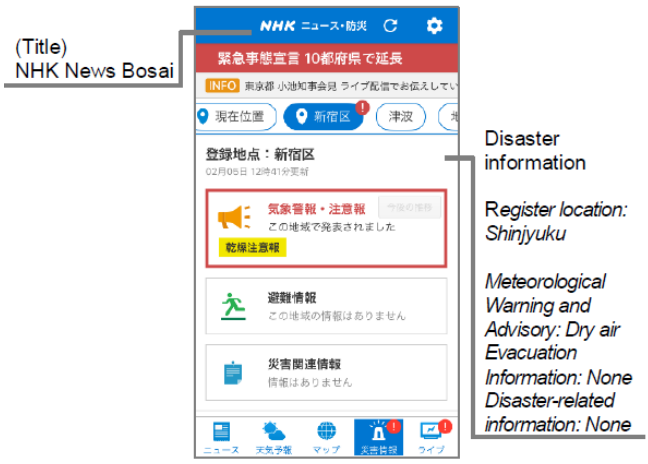
Example of Educational content

14	Title of App (Users)	NHK News Bosai (5,000,000+ installed from Google Play)

Basic Information

Category	Private (Covering various disasters)
Responsible Agency/Developer	NHK (Japan Broadcasting Corp.)

Content/User Interface



Other Functions: News, weather forecast, map, News Live, etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA

- Meteorological information
- Warning information (Advisory, Warning)
- Earthquake information
- Tsunami information
- Landslide alert information
- Flood information
- Heat illness, etc.

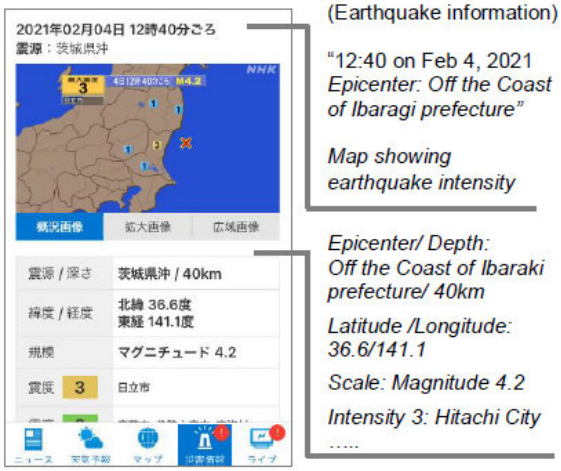
Information issued by local governments

- Evacuation information
- Emergency information

Features	● Push notification of various information including the latest news, disaster information depending on one's current location by utilizing GPS ● Display live information on weather ● Provide meteorological explanation with video by news anchor
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.or.nhk.news&hl=ja&gl=US

Screenshots of the contents

Example of Emergency notification



Example of Educational content

15	Title of App (Users)	Tokumu kikan NERV Bosai (100,000+ installed from Google Play)

Basic Information

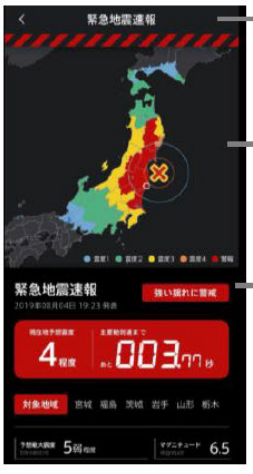
Category	Private (Covering various disasters)
Responsible Agency/Developer	Gehirn Inc.

Content/User Interface	**Meteorological and disaster-related information notified by the app**
(Current and Registered area) Shinjyuku City *Shinjyuku City, Tokyo Meteorological Warning and Advisory* Dry Air Advisory *"Please pay attention to handle the fire."* Other Functions: Emergency information timeline, Rain radar, Weather forecast, etc.	**Information issued by JMA** • Earthquake Early Warning • Meteorological information (Advisory, Warning) • Earthquake information • Tsunami information • Landslide alert information • Flood information • Volcanic eruption warnings, etc. **Information issued by Cabinet Secretariat** • Civil Protection Information (J-ALERT)

Features	● Push notification of various emergency information including disaster risk of heavy rains depending on one's current location or registered areas ● Promptly display the optimized disaster-related and meteorological information owing to the directly connected line with JMBSC
URL (Google or Apple)	https://play.google.com/store/apps/details?id=app.nerv

Screenshots of the content

Example of Emergency Notification



(Title)
Earthquake Early Warning

Map showing expected earthquake intensity and affected areas

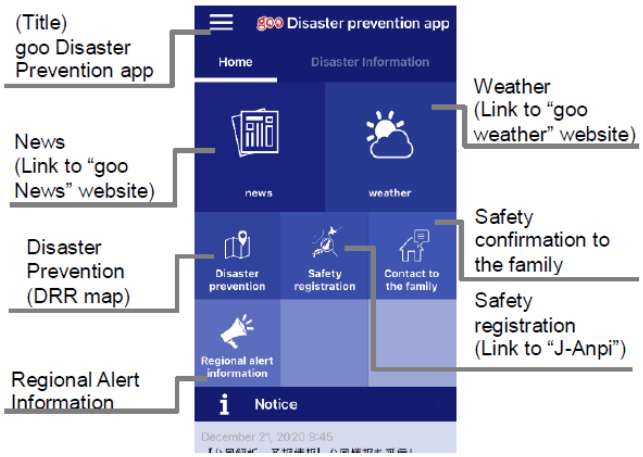
Earthquake Early Warning
"Be careful of destructive shaking"
Expected earthquake intensity: 4
Expected arrival of earthquake: 003.77sec
Expected areas: Miyagi, Fukushima…
….

16	Title of App (Users)	goo Disaster Prevention App (100,000+ installed from Google Play)

Basic Information

Category	Private (Covering various disasters)
Responsible Agency/Developer	NTT Resonant Incorporated

Content/User Interface



Other Functions: Disaster Information (e.g., Disaster Preparedness Handbook, medical dictionary), SNS link to disaster-related government agencies), etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological information (Advisory, Warning)
- Other warnings and advisory information

Information issued by Cabinet Secretariat
- Civil Protection Information

Information issued by local governments
- Evacuation information
- Evacuation facility information
- Information on establishment of Disaster Management Headquarters
- Announcement from the local government

Features	● Display disaster-related information regarding three designated regions and one's current location ● Communicate with family members and confirm their safety by utilizing "J-anpi" safety confirmation website. ● Push notification in an emergency, content in 4 languages ● Substantial disaster education content for disaster preparedness and for evacuation simulation.
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.ne.goo.bousai.bousaiapp

Screenshots of the content

Example of (Emergency) Notification

(Title)
Information

2:29 on Dec 21, 2020

[Tsunami prediction]
Tsunami prediction (and a little movement of sea surface) is issued

[Issued time]
2:29 on Dec 21, 2020

[Caution, additional comments]
"Although a little movement of sea surface is predicted, please do not worry about damage by the tsunami."

Example of Educational content

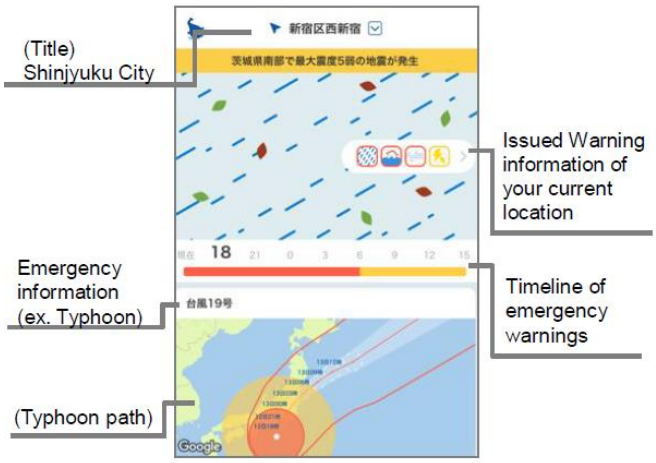
(Title)
Preparation for earthquake

(DRR handbook contents)
"10 Tips for earthquake safety
Quake! Protect yourself first.
Make sure you have ways out: Open Doors and windows" …..

"10 Ways to Prepare for an earthquake
Keep furniture from falling or moving.
Keep informed about disasters. ….

17	Title of App (Users)	PREP (New version of "Yure-kuru Call") (6,000,000 users officially announced from the developer)

Basic Information	
Category	Private (Specialized in Earthquake -> Covering various disasters)
Responsible Agency/Developer	RC Solution Co.

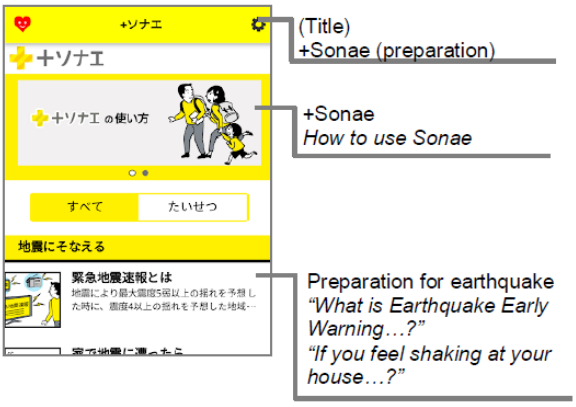
Content/User Interface	Meteorological and disaster-related information notified by the app
	**Information issued by JMA** • Earthquake information (Earthquake Early Warning) • Tsunami information • Volcanic eruption warnings • Heavy rain forecasts • Flood information • Typhoon information • Landslide and flood risk information • Wind hazard information (e.g., tornado) • Thunderstorm information, etc. **Information issued by local governments** • Evacuation information

Features	● Display expected earthquake intensity and arrival time in one's registered place before occurrence of shaking ● Display real-time disaster information related to one's current location ● Support one's evacuation in an emergency by displaying a course of appropriate actions which oneself have decided before the occurrence of disaster
URL (Google or Apple)	https://apps.apple.com/jp/app/%E3%82%86%E3%82%8C%E3%81%8F%E3%82%8B%E3%82%B3%E3%83%BC%E3%83%AB/id398954883

Screenshots of the contents

Example of Emergency Notification
(Yure-kuru Call ver.)

Example of Educational content
(Yure-kuru Call ver.)



18	Title of App (Users)	KOKODAYO – DRR for families and Earthquake early warning App (100,000+ installed from Google Play)

Basic Information

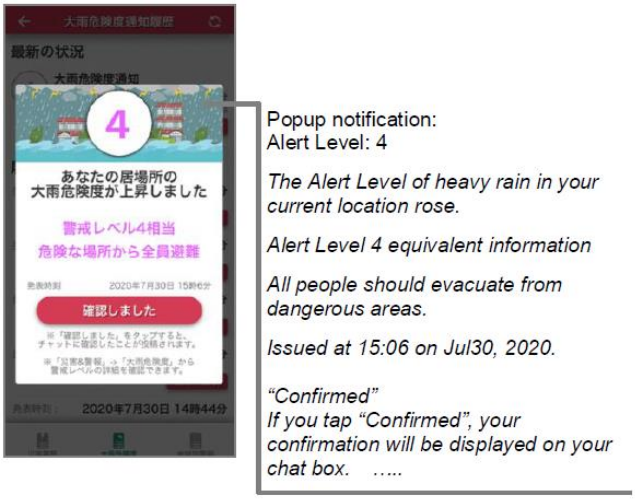
Category	Private (Covering various disasters, specialized in earthquakes)
Responsible Agency/Developer	GENETEC CORPORATION

Content/User Interface	**Meteorological and disaster-related information notified by the app**
 Other Functions: Provision of weather information and forecast, notification of warnings, evacuation facility list and maps, etc.	**Information issued by JMA** • Earthquake Early Warning • Meteorological warning and advisory (e.g., heavy rains, landslide, flood, heavy snow, heavy wind) **Information arranged by MLIT* and GSI**** • Evacuation facility information MLIT*: Ministry of Land, Infrastructure, Transport and Tourism GSI**: Geospatial Information Authority of Japan

Features	● Promptly display earthquake early warning and show the previous information after the shaking ● Quickly share one's safety confirmation and location with your family ● Display evacuation facility list near one's current location and provide detailed information about the facility with a map ● Navigate one's route to evacuation facilities
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.cocodayo.consumer.android&hl=ja&gl=US

Screenshots of the content

Example of Emergency Notification



19	Title of App (Users)	Newsflash and Earthquake early warning- News Digest (6,000,000 users officially announced from the developer)

Basic Information

Category	Private (Covering various disasters, specialized in earthquakes)
Responsible Agency/Developer	JX PRESS Corporation

Content/User Interface	**Meteorological and disaster-related information notified by the app**
 Other functions: Display of newsflash, safety and security map, etc.	**<u>Information issued by JMA</u>** • Earthquake early warning • Meteorological warning information (e.g., heavy rains, flood, tornado, volcanic eruption warnings) • Other disaster-related information **<u>Information issued by other agencies</u>** • Earthquake early warning overseas (Over M6.0) • Transportation operation status

Features	● Fast delivery of newsflash and earthquake early warning ● Push notification in an emergency, including during occurrence of earthquake
URL (Google or Apple)	https://play.google.com/store/apps/details?id=jp.newsdigest&hl=ja&gl=US

Screenshots of the content

<u>Example of Emergency notification</u>

<table>
<tr><td>20</td><td>Title of App (Users)</td><td colspan="2">Japan Earthquake Information Lite
(Only for Apple users, no information on DL numbers)</td></tr>
<tr><td colspan="4">Basic Information</td></tr>
<tr><td colspan="2">Category</td><td colspan="2">Private (Specialized in earthquakes)</td></tr>
<tr><td colspan="2">Responsible Agency/Developer</td><td colspan="2">EJing</td></tr>
<tr><td colspan="3">Content/User Interface</td><td>Meteorological and disaster-related information notified by the app</td></tr>
<tr><td colspan="3">(Sub-title)
Earthquake information list

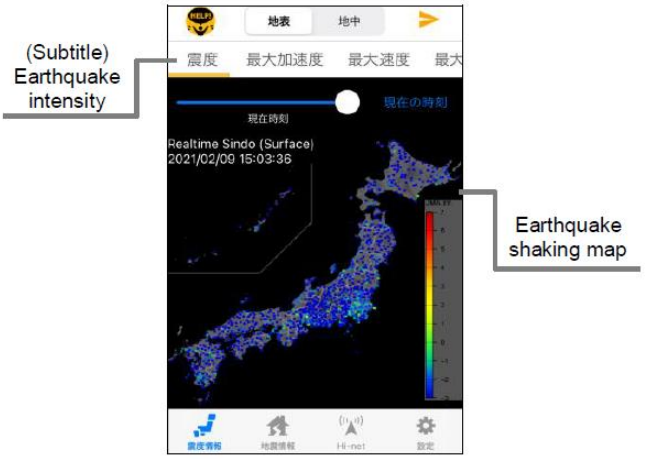
(List of earthquake)
Occurrence time: 19:32 on Oct 25, 2012
Max intensity: 5-
Epicenter: Off the Coast of Miyagi prefecture
Latitude /Longitude: 38.3/141.9
Depth: 50km
Affected areas: Miyagi prefecture…
Other Information: Earthquake map showing epicenter and magnitude of the earthquake, list of earthquake intensity, etc.</td><td><u>Information issued by JMA</u>
• Earthquake information
• Earthquake early warning</td></tr>
<tr><td colspan="2">Features</td><td colspan="2">● Promptly display the list of earthquake information issued by JMA with the specific color codes, depending on the maximum intensity of the earthquake
● Notify earthquake early warning regardless of ones current location
● Content available in 3 language</td></tr>
<tr><td colspan="2">URL (Google or Apple)</td><td colspan="2">https://apps.apple.com/jp/app/earthquake-information-lite/id412784885?l=en</td></tr>
</table>

21	Title of App (Users)	【Earthquake early warning】Earthquake Now! (Earthquake information, Earthquake intensity information) (Only for Apple users, no information on DL numbers)

Basic Information

Category	Private (Covering various disasters, specialized in earthquakes)
Responsible Agency/Developer	Hidehiko Aihara

Content/User Interface



Meteorological and disaster-related information notified by the app

Information issued by JMA
- Earthquake information

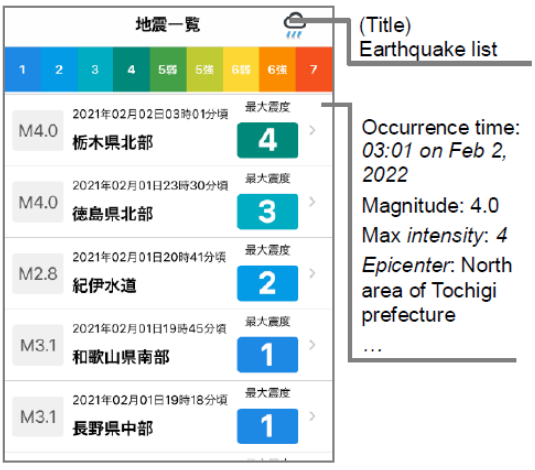
Information issued by NIED*
- Earthquake information

* National Research Institute for Earth Science and Disaster Resilience, Information from High Sensitivity Seismograph Network Japan

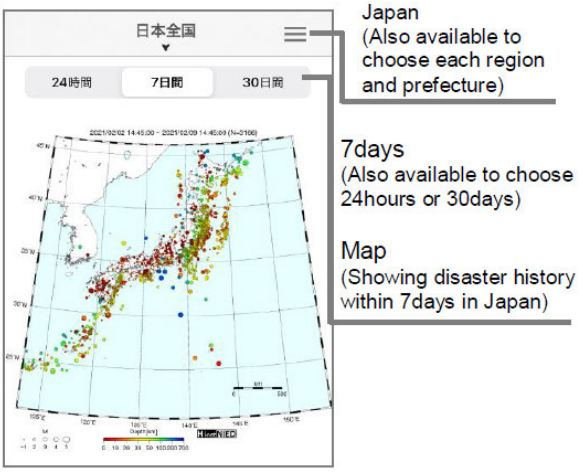
Features	● Display real-time earthquake information ● Display the list of previous earthquakes and their information (e.g., occurrence time, epicenter, earthquake intensity) ● Share one's location address and picture with family and friends
URL (Google or Apple)	https://apps.apple.com/jp/app/%E5%9C%B0%E9%9C%87%E9%80%9F%E5%A0%B1-%E9%9C%87%E5%BA%A6now-%E5%9C%B0%E9%9C%87%E6%83%85%E5%A0%B1-%E9%9C%87%E5%BA%A6%E6%83%85%E5%A0%B1/id1185234444

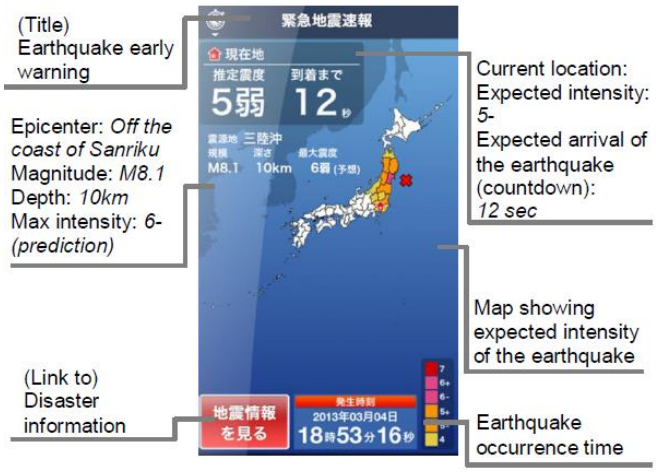
Screenshots of the content

Example of (Emergency) Notification



Example of Educational content



<table>
<tr><td>22</td><td>Title of App (Users)</td><td colspan="2">Quake and Tsunami Community
(50,000+ installed from Google Play)</td></tr>
<tr><td colspan="4">Basic Information</td></tr>
<tr><td colspan="2">Category</td><td colspan="2">Private (Specialized in earthquakes), Paid app (300 yen/month)</td></tr>
<tr><td colspan="2">Responsible Agency/Developer</td><td colspan="2">Weathernews Inc.</td></tr>
<tr><td colspan="3">Content/User Interface</td><td>Meteorological and disaster-related information notified by the app</td></tr>
<tr><td colspan="3"> 

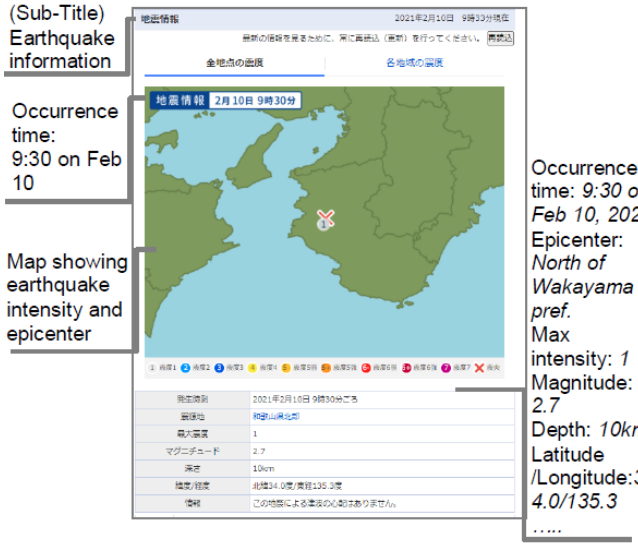
Other Functions: Tsunami radar investigating tsunami every 2 seconds, Announce from the Weathernews meteorological center, DRR column etc.</td><td><u>Information issued by JMA</u>
• Earthquake early warning
• Earthquake information
• Tsunami information
<u>Original information by the company</u>
• DRR and disaster information from Weathernews Meteoroidal Center</td></tr>
<tr><td colspan="2">Features</td><td colspan="2">● Promptly display the earthquake early warning and the countdown of the arrival of the shaking
● Display abundant earthquake information, including expected intensity of earthquakes, their epicenters, magnitudes, etc.
● Display areas in which JMA issues tsunami warning on a map</td></tr>
<tr><td colspan="2">URL (Google or Apple)</td><td colspan="2">https://play.google.com/store/apps/details?id=com.weathernews.l10s&hl=ja&gl=US</td></tr>
</table>

23	Title of Website	Yahoo! Weather・Disaster

Basic Information

Category	Private
Responsible Agency/Developer	Yahoo Japan Corp.

The top page of earthquake information



Other contents: Weather news (e.g., weather forecast and map, meteorological satellite, rain radar), disaster information, landslide and flood map, evacuation facility map, disaster history calendar, DRR Handbook, disaster damage information, etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA
- Warnings and advisories
- Typhoon information
- Earthquake information
- Tsunami information
- Volcanic eruption warnings
- Heatstroke information etc.

Information issued by Cabinet Secretariat
- Civil Protection Information

Information issued by local governments
- Evacuation information
- Emergency information
- Water levels of rivers

Information from other agencies
- Evacuation facility information
- Emergency information on utilities, etc.

Features	● Provide promptly and comprehensively on its website various weather-related and disaster-related information issued by different agencies
URL	https://weather.yahoo.co.jp/weather/

Screenshots of the contents

Example of (Emergency) Notification

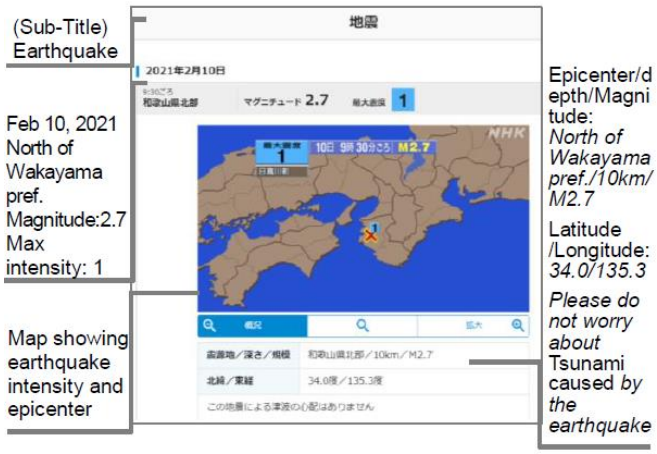
Example of Educational content

24	Title of Website	NHK NEWS WEB Weather and Disaster Information

Basic Information

Category	Private
Responsible Agency/Developer	NHK (Japan Broadcasting Corp.)

The top page of earthquake information



Other contents: Meteorological information (e.g., weather forecast, temperature, rain and wind conditions, satellite), the current status of warnings and advisories nationwide, lifeline utility information related to disasters, etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA
- Meteorological warnings and Advisories
- Tsunami information (warnings and advisories)
- Earthquake information, etc.

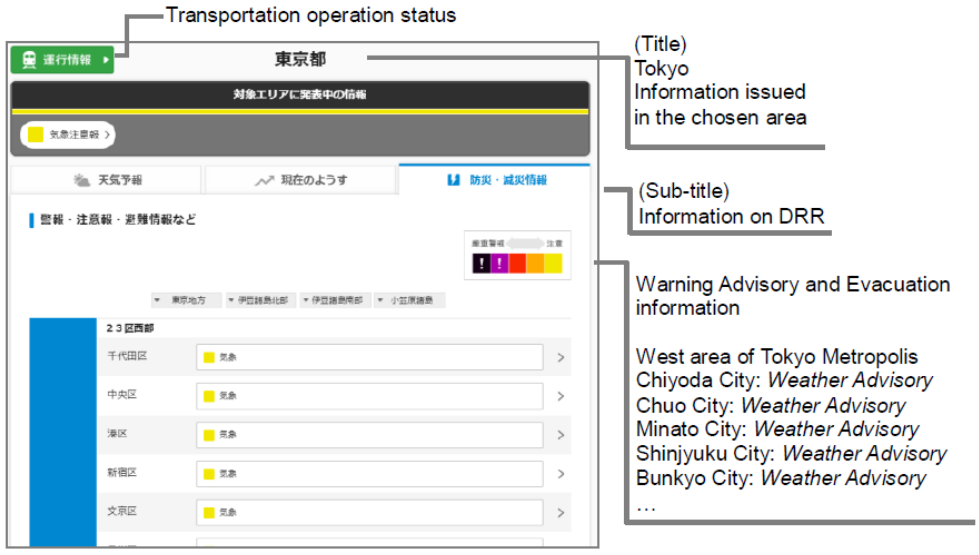
Information issued by local governments
- Evacuation information

Information from other agencies
- Emergency information on utilities, etc.

Features	● Provide news and information relevant to disaster, early warning, and DRR as well as weather forecast, radar, satellite, and international weather
URL	https://www3.nhk.or.jp/weather/disaster/index.htm

Screenshots of the content

Example of (Emergency) Notification



25	Title of Website	Google Disaster Information

Basic Information		
Category	Private	
Responsible Agency/Developer	Google.org	
The top page of earthquake information		**Meteorological and disaster-related information notified by the app**

Dry Air Advisory: Saitama Pref.
Issued 6hours ago
Since the dry air will continue until Feb 11 in Saitama, *please pay attention to handling of the fire.*

In terms of "Dry Air Advisory"
This Advisory will be issued when there is a risk that disasters may occur due to dry air. Specifically, it will be issued when it is predicted to reach the conditions with a high risk of fire.

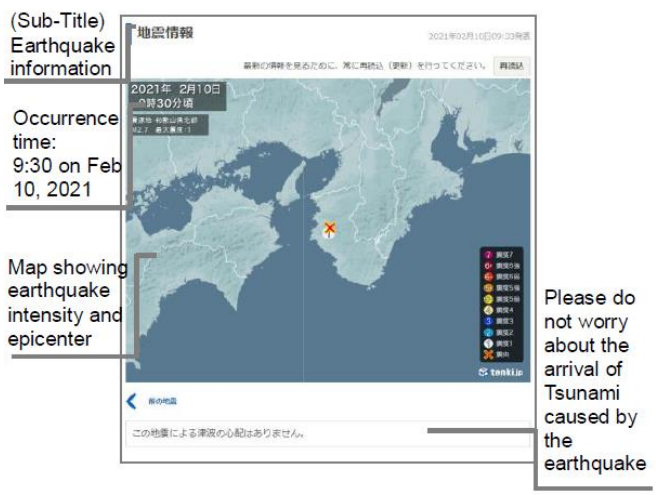
Other contents: Map showing areas in which JMA issued warnings and advisories, typhoon path, traffic conditions, etc.

<u>Information issued by JMA</u>
- Typhoon path (map)
- Earthquake and tsunami information (Information of epicenter is from USGS.)
- Meteorological information
- Meteorological warnings and advisories, etc.

Features	● Display warnings and advisory information, map showing areas where the warning information have been issued, and relevant information according to the issuance of advisories and warnings from official agencies
URL	https://google.org/crisismap/japan

26	Title of Website	tenki.jp

Basic Information	
Category	Private
Responsible Agency/Developer	Japan Weather Association (JMA)

The top page of earthquake information	**Meteorological and disaster-related information notified by the app**
 Other contents: Weather forecast (e.g., Japan's weather, international weather, rain radar), DRR information (e.g., warnings and advisories, earthquakes and tsunamis), weather map, etc.	**Information issued by JMA** • Warnings and advisories • Earthquake information • Tsunami information • Volcanic eruption warnings • Typhoon information, etc.

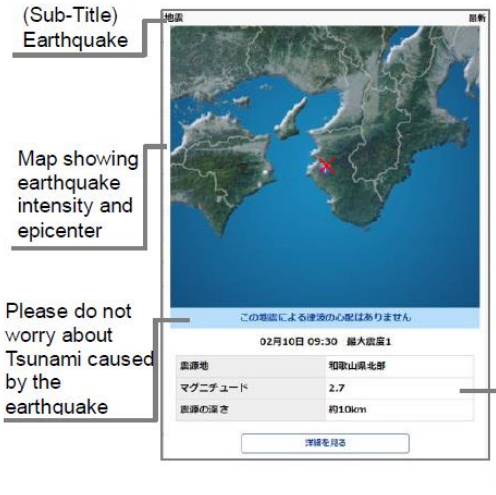
Features	● Provide not only weather forecast in each region, but also specialized meteorological information and disaster-related information, including those for earthquakes and tsunamis
URL	https://tenki.jp/bousai/warn/

27	Title of Website	Weathernews

Basic Information

Category	Private
Responsible Agency/Developer	Weathernews Inc.

The top page of earthquake information



Other information contents: Weather news (e.g., weather forecast and map, meteorological satellite, rain radar), DRR information, nature and season-related information (e.g., dry air, heat illumes, hay fever risk information), etc.

Meteorological and disaster-related information notified by the app

Information issued by JMA

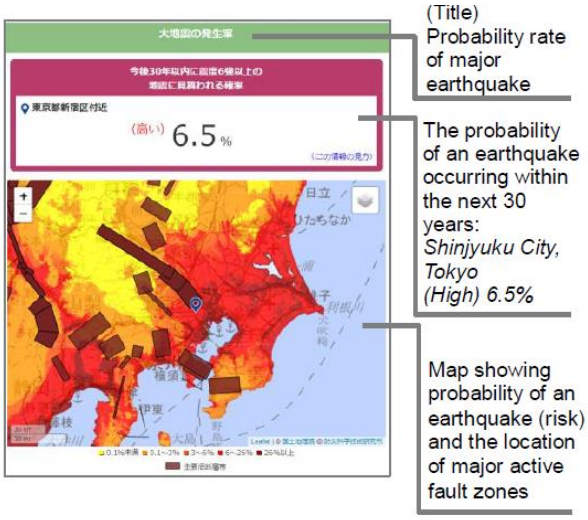
- Earthquake information
- Tsunami information
- Typhoon information
- Warnings and advisories
- Volcanic eruption warnings
- Heavy rain information, etc.

Features	● Promptly deliver new and abundant meteorological information for both daily and emergency purposes ● Provide useful educational content for DRR such as disaster history database (report), disaster risk levels (flood, landslide, earthquake)
URL	https://weathernews.jp/

Screenshots of the content

Example of (Emergency) Notification

Example of Educational content



APPENDIX 8-16

A Survey on Transmission and Dissemination of Lessons Learned from Past Earthquakes and Tsunamis Leading to Evacuation Behavior of Residents

A Survey on Transmission and Dissemination of Lessons Learned from Past Earthquakes and Tsunamis Leading to Evacuation Behavior of Residents

The Project for Capacity Development on

Operation of Earthquake and Tsunami Analysis and

Warning Dissemination

June 2021

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
Japan Meteorological Business Support Center
Pacific Consultants Co., Ltd.

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Abbreviations

Abbreviation	English
AHA Center	Asean Coordinating Center for Humanitarian Assistance on Disaster Management
BIG	Badan Informasi Geospatial/Geospatial Information Agency
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika/ Meteorological, Climatological, and Geophysical Agency
BNPB	Badan Nasioanal Penanggulangan Bencana /National Agency for Disaster Management
BPBD	Badan Penanggulangan Bencana Daerah/Regional Agency for Disaster Management
BPPT	Badan Pengkajian dan Penerapan Teknologi/ Agency for the Assessment and Application of Technology
CAO	Cabinet Office
COVID-19	Coronavirus Disease 2019
DRR	Disaster Risk Reduction
Destana	Desa Tangguh Bencana/ Disaster Resilient Village
FDMA	Fire and Disaster Management Agency
GDPC	Global Disaster Preparedness Center
GEJE	Great East Japan Earthquake
GHAE	Great Hanshin-Awaji Earthquake
GSI	Geospatial Information Authority of Japan
IDR	Indonesian Rupiah (Indonesian currency)
JA	Japan Agricultural Cooperatives
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
LIPI	Lembaga Ilmu Pengetahuan Indonesia/Indonesian Institute of Sciences
LPBI NU	Lembaga Penanggulangan Bencana dan Perubahan Iklim Nahdlatul Ulama/Disaster Management and Climate Change Institute-Association of Moslem Scholars)
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MIC	Ministry of Internal Affairs and Communications
MoHA	Ministry of Home Affairs
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
NGO	Non-Governmental Organization
NPO	Non-Profit Organization
PLTD	Pembangkit Listrik Tenaga Diesel/Diesel-fueled Power Plant
PMI	Palang Merah Indonesia/Indonesian Red Cross
RENSTRA	Rencana Strategis/Strategic Plan
SLG	Sekolah Lapang Geofisika/Geophysical Field School
SPAB	Satuan Pendidikan Aman Bencana/Disaster Safe Education Unit
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	U.S. Agency for International Development

Chapter 1 Introduction

1.1 Background

In order to improve the evacuation behavior of residents at the community and Regency/Municipality levels, it is important to strengthen the capacity of DRR-related organizations to improve the communication flow and communication chart of the information disseminators of tsunami warnings, as well as to ensure that the residents who receive the information take correct evacuation actions based on lessons learned from past disasters.

The additional survey previously conducted by JICA Expert Team envisaged the differences in the information sources for evacuation between Indonesian and Japanese residents, but there were similarities in the evacuation behavior.

In Japan, the folklore of "tsunami tendenko" saved many lives when the Great East Japan Earthquake occurred in 2011. And what was initially a local tradition and effort has been taken up in disaster prevention education throughout the country as an effective tool learned from the Great East Japan Earthquake.

In Indonesia, the results of the survey by JICA Expert Team conducted in June 2020 revealed several cases where lessons learned from past earthquakes and tsunamis affected the evacuation behavior of the residents in Central Sulawesi Province.

For instance, residents evacuated to higher places when the earthquake occurred, even government warning on tsunami did not reach them. They decided to evacuate based on the sea level change, and advised others to evacuate as well. In addition, the results of the interview survey indicated that the lessons learned from the Indian Ocean earthquake and tsunami affected the evacuation behavior of the people in Central Sulawesi Province.

During past disaster prevention education activities conducted by another JICA-funded project in Central Sulawesi Province, it was confirmed that there were residents in the affected areas who adhered to folklore about disasters in the past. The project also found out the case of the Sunda Strait tsunami, specifically, the tsunami triggered by a volcanic eruption whose story had been handed down for more than 100 years. The participants of the disaster prevention education activity showed high interest in the case of the Indian Ocean earthquake and tsunami, and that of the Sunda Strait tsunami, where adhering to local folklore saved the lives of residents. Therefore, it is considered that introducing the adoption of local traditions/wisdom regarding disasters is one of the useful ways to raise the awareness of the residents in Indonesia for the education of earthquake and tsunami evacuation.

1.2 Objective of the Review

In addition to the case studies identified in the previous survey, this survey will conduct a broad survey on the lessons learned from past earthquake and tsunami disasters in Indonesia, as well as their transmission and dissemination methods, in order to understand the position and role of disaster transmission in Indonesia.

The survey will also compile the prospects for raising awareness on disaster prevention among local residents, creating related educational materials, and effectively disseminating them in Indonesia, taking into account the current status of disaster transmission in the country.

Chapter 2 Local Wisdom for Disaster Mitigation in Indonesia

Indonesia is located at the confluence of several plates in the world, which makes the country highly vulnerable to disasters. The Indonesian government has realized this and responded by issuing regulations on disaster mitigation learning in schools, and educating the public as well.

After the Indian Ocean earthquake and tsunami in 2004, there were findings that the Smong local wisdom had provided valuable knowledge for the community to survive the disaster. Smong tradition of indigenous knowledge of tsunami risk had successfully alerted people in the island of Simeulue, Aceh Region on the 2004 tsunami. This tradition evolved based on the recorded experiences of the Simeulueans through oral stories which have been passed down from generation to generation.

As part of disaster mitigation learning and awareness-raising, an inventory of indigenous culture similar to Smong is needed since the local wisdom has been preserved in the Indonesian communities across many regions, including Java and Central Sulawesi. The Indonesian government has initiated the efforts of recognition, utilization, and dissemination of local wisdom through the enactment of a Presidential Regulation in December 2019. This momentum is reflected through the initiatives and disaster prevention education activities currently being implemented in Indonesia.

In this Chapter, firstly, the most significant local wisdom about disasters in Indonesia are inventoried and summarized. After that, the perception of the public toward local wisdom on disaster is described by undertaking a literature review of the opinions of archeologists, religious leaders, university researchers and lecturers mostly in the context of sociocultural field. Secondly, the utilization and dissemination of local wisdom on disaster are explored by identification of legal and planning framework, followed by detailing policies and activities that promote the utilization of disaster local wisdom. Thirdly, the utilization and dissemination of local wisdom on disaster are explored among selected publications and websites. Finally, disaster prevention education and awareness-raising activities such as the development of disaster monuments and/or museums are presented in detail.

2.1 Most Significant Local Wisdom on Disaster in Indonesia

2.1.1 Local Wisdom by Types of Disaster

According to the research by Afrian *et al.* (2017), disaster mitigation and prevention learning can be absorbed perfectly when taken in the context close to the community such as local wisdom. An inventory of local culture relevant to disaster mitigation is, therefore, needed so that these can be adopted and enhanced as alternative in disaster mitigation education and awareness-raising[1]. Furthermore, the research by Syafwina (2014) concludes that the story of *Smong* (means "tsunami" in *Devayan* language) passed on from generation to generation since 1907 has saved the Simeulueans as it naturally becomes the basis of an early warning system anytime an earthquake occurs in the island[2]. Besides the famous Smong local wisdom in Simeulue, in the research conducted by Sirajuddin (2020), it was found that Indonesia has local wisdom and religious views that thrive and are preserved in the communities across many islands. Some examples related to earthquake and tsunami disasters are described in succeeding sections.

Central Sulawesi Region

The *Kaili* tribe, one of the tribes that live in the island of Sulawesi, in Central Sulawesi, has a unique local wisdom. An interesting part of the tribe's local wisdom is the practice in organizing and designing harmonious settlements since ancient times. The customary rules adopted are intended to maintain balance and harmony of life between humans and the environment, and humans with nature's rulers so that the *Kaili* community and other groups who are part of their

[1] Afrian *et al*. 2017. Local culture inventory for disaster mitigation learning. IOP Conf. Series: Earth and Environmental Science 412 (2020) 012017 IOP Publishing doi:10.1088/1755-1315/412/1/012017.
[2] Syafwina. 2014. Recognizing indigenous knowledge for disaster management: Smong, early warning system for Simeulue Island, Aceh. Procedia Environmental Sciences 20 (2014): 573 – 582.

society can coexist with their environment to avoid disaster[3].

According to an article in *lokadata.id* (2019)*, Kaili* community that lived in a small village named *Kinta* had been saved from the liquefaction disaster during the Palu earthquake and tsunami, because the members believed in the folklore that their ancestors had passed on from generation to generation. It is said that the *totua* (elders) chose to stay in *Kinta* village, but never in Petobo and Balaroa (the areas close to *Kinta* village which were totally damaged and disappeared due to the liquefaction). Their ancestors considered the *Kinta* to be a safe land, while the Petobo and Balaroa areas were disaster-prone swamps of sago palm and coconut trees. Therefore, the native Palu who had memories of *nalodo* (liquefaction) chose not to live in Petobo and Balaroa because of the history of liquefaction disasters decades ago[4].

Java and Bali Region

Another form of local wisdom in disaster mitigation carried out by Hindus in Bali is the use of *saput poleng* (cloth) in large trees which is believed can indirectly save the Balinese people from flooding, landslides and drought[5].

Besides Bali, Sundanese communities of West Java also apply local wisdom in disaster mitigation such as the Naga village community in Garut Regency. People in this village always adhere to values: 1) discipline and honesty, 2) religious, 3) compliant, 4) mutual assistance and togetherness, 5) simple living, friendly and independent. The values of local wisdom provide communities with disaster-based environmental management. The Sundanese are aware that a disaster will occur if their environment lives in disrepair. One of the awareness takes the form of traditional myths and rules in the building of bamboo houses.

The research by Suparmini *et al.* (2014) cited that in addition to Naga village, there is another community that practice local wisdom in disaster mitigation. Specifically, the *Baduy* community in West Java has oral traditions based on customary provisions known as *pikukuh.* According to this wisdom, thecultivation of crops and building homes should maintain the sustainability of forest and water resources. *Baduy* community also has wisdom related to mitigating earthquake disasters, landslides, floods, and fires which is reflected in cultivation tradition that considers land use. This has kept the members of the community safe from landslides and fires. Furthermore, the practice in building houses that requires the use of flexible natural materials and to place the houses in accordance with the contours of the land they occupy. This practice minimizes the impacts of landslides and floods. Another local wisdom is the practice of dividing the forest zones into three areas as a manifestation of ecosystem conservation and mitigation of landslides, floods, erosion, and other disasters[6].

Aceh Region

The Acehnese community also has traditional buildings that are resistant to earthquakes called *Rumoh* (house) Aceh. According to Meutia (2017), the construction process of *Rumoh* Aceh that does not use nails but uses joined wooden elbows has made the building resistant to shock. The vibration will be distributed through cracks of wood following the pattern of the building. In addition, *Rumoh* Aceh is also resistant to flooding because of its high platform[7]. However, as written in an article by the Acehnese Indigenous Community Network (2012), nowadays this kind of building construction has been abandoned by many people, especially those around Banda Aceh City. As a consequence, many houses were destroyed during the 2004 tsunami[8]. The design of the Aceh Tsunami Museum (see Section 2.2. in details) which was built after the disaster has

[3] Sirajuddin, Z. 2020. Local wisdom as a planning strategy and sustainable settlement development in Kaili traditional settlement. Central Sulawesi, Indonesia. Review of European Studies, Vol.12, No.2. ISSN 1918-7173.
[4] https://lokadata.id/artikel/petunjuk-bencana-dari-leluhur. 2019.
[5] Suda, I. 2010. The Ideology of Environmental Conservation Behind the Use of Saput Poleng on Large Trees in Bali. Journal Bumi Lestari, Vol.10, No.8.
[6] Suparmini *et al*. 2014. Disaster Mitigation Based on Local Wisdom of the Baduy Community. Journal of Humanities Research, Vol.19, No.18
[7] Meutia, E. 2017.Mapping the structural system of Aceh traditional house construction in responding to the earthquake. Journal of Koridor,8(1), 65-72. https://doi.org/10.32734/koridor.v8i1.1330
[8] https://www.jkma-aceh.org/rumoh-aceh-dalam-perspektif-kearifan-lokal/

been inspired by *Rumoh* Aceh's architecture.

Banten and Sunda Strait Region

In the Sunda Strait, the story of a tsunami triggered by a volcanic eruption has been passed down for more than 100 years. An article in one of the biggest online newspapers written in 2019 mentions that beside storytelling by word of mouth, evidence of a large tsunami can be seen from the existence of a giant rock by the side of the road near the Anyer lighthouse in Banten. In a number of other places in the area, there are also large rocks, which indicate the force of the tsunami that was able to knock the rocks onto the ground. There is a village named Sindang Laut (meaning the "the sea water has reached") located on a high land in Carita Beach about 100 meters above sea level. According to a 97-year-old local resident who heard the story from his father, the origin of the village's name reflects the enormity of the tsunami due to the volcanic eruption at that time. Until now, the local people in that village run to a higher place in case of an earthquake[9]. In an article written after the tsunami in 2018, there was a story by local residents that a crocodile from the sea was seen crawling onto land an hour-and-a-half before the tsunami. Half an hour later, the residents received news that the area close to the beach had been hit by the tsunami. By remembering the past experience told by their ancestors, the local people ran to the hill not far from their settlement[10].

In the Banten and Sunda Strait region, some ancient manuscripts were found and these revealed the occurrence of natural disasters. Banten society is described through ancient manuscripts as comprising of people who are accustomed to interpreting signs of nature. According to their belief, the tsunami and earthquake events occur every 170 years. Not only that, there are several events and signs of the emergence or threat of disaster which are contained in ancient texts.

Table 2.1.1 shows examples of local wisdom about disasters in Indonesia categorized into types of disasters (earthquake, earthquake and tsunami, liquefaction, volcanic eruption-induced tsunami, and whole natural disasters). The table includes examples of local wisdom introduced previously. Their sources were identified such as ancient manuscripts, poems, songs, lyrics, and oral literature.

[9] https://regional.kompas.com/read/2019/10/09/10220031/pesan-siaga-bencana-di-indonesia-kisah-nyi-roro-kidul-hingga-syair-kuno?page=all

[10] https://banjarmasin.tribunnews.com/2018/12/26/tingkah-aneh-buaya-sebelum-tsunami-banten-dan-tsunami-lampung-firasat-tsunami-selat-sunda

Table 2.1.1 Local Wisdom Including Those in Oral History and Ancient Manuscripts by Disaster Type

Type of Disaster	Title of Local Wisdom	Area	Overview
Earthquake and Tsunami	*Takwil gempa* (Takwil earthquake) -ANCIENT MANUSCRIPT-	Zawiyah Tanoh Abee, Aceh Besar	The manuscript written in Arabic and Malay called the earthquake as *takwil.* It tells the signs and consequences of an earthquake and tsunami such as the one which hit Aceh on December 26, 2004.
	Takwil gempa (Takwil earthquake) -ANCIENT MANUSCRIPT-	Lubuk Ipuh dan Malalo,West Sumatera	The term *takwil*, which has the same meaning as it is used in Aceh Besar, also tells about earthquake and tsunami phenomena.
	Gempa (earthquake) & tsunami -ANCIENT MANUSCRIPT-	Bengkulu	The old manuscript containing records of the big earthquake and tsunami that occurred on the west coast of Sumatra on 3 November 1823.
	Babad Buleleng and *Babad Ratu Panji Sakti* (History of Buleleng and Queen Panji Sakti) -ANCIENT MANUSCRIPT-	Bali	The recorded history is about the earthquake and tsunami that happened in 1815.
	Nandong Smong (Smong Song) -SONG-	Simeulue, Aceh	The lyrics of the traditional Simeulue *nandong* (song) says what happened started with an earthquake, followed by *smong* (huge waves/tsunami), drowning the whole village all of a sudden. If the earthquake is strong, and then the water recedes, immediately seek refuge in a higher place. The song was created based on the mechanism of the tsunami in 1907, starting with an earthquake and followed shortly after by receding seawater as a sign of an impending tsunami. Although not all earthquakes will cause tsunamis and not all tsunamis start with a low tide signal, in the events of the 1907 tsunami and 2004 tsunami, the mechanism of the earthquake and the processes that follow it are relatively the same. The song 'Nandong Smong' is usually sung by the local people during traditional weddings, circumcision rite, or other events in Simeulue Island, western of Aceh. Hundreds of years ago, Aceh's westernmost island was often hit by natural disasters. This oral tradition emerged because of a series of earthquakes and tsunamis in 1883 and 1907. Likewise, when Aceh was shaken by an earthquake with a magnitude of 9.3 on the Richter scale, followed by a tsunami reaching a height of 30 meters on December 26, 2004. Because of community awareness through adherence to nandong smong folklore, the victims who died in Simeulue were only seven people. Nandong Smong can be considered local wisdom for the community's early warning system against tsunami threat.
	Linu (earthquake) and *Bombatalu* (high wave/tsunami) -VERBAL STORY TELLING AND POEM-	Kaili Tribes, Palu Area, Central Sulawesi	The older generation of the *Kaili* Tribe, the ethnic group that inhabits the Palu Valley, has a tradition of *tutura* (story telling). This tradition can take the form of poetry, known as *kayori* (words). The words that are spoken with a certain tone of voice and character tell about things that really happen. The *kayori* poem about the shaking and sinking village describes the earthquake and tsunami in 1938. This poem was found in an old record belonging to the *Kayumalue* indigenous people in Palu City[11].
Tsunami	*Ie Beuna* (High wave) -FOLKLORE AND ANCIENT MANUSCRIPT-	Aceh	*Ie Beuna* is a vocabulary from the Aceh language which means “tsunami”. The word *ie* means “water”, while *beuna* means “true”. In delivering this information, it is common for parents to tell a story about a black wall of water crashing into the beach after an earthquake. *Ie Beuna*'s words were less popular among the people of Aceh before the earthquake and tsunami in 2004. Unlike Smong which often hummed (nandong) by mothers when lulling their children, *ie beuna* does not have a standard pattern or method of delivery. This made the knowledge of the earthquake and tsunami among the Acehnese people on the mainland of Sumatra Island before the 2004 tsunami event less popular. The lack of dissemination of knowledge on the earthquake and tsunami through ie *beuna* resulted in inaccurate reactions from the Acehnese on the mainland in reacting to the tsunami phenomenon which resulted in the high number of casualties caused by the tsunami.
Earthquake	*Ramalan Gempa* (earthquake prediction) -ANCIENT MANUSCRIPT-	Jakarta	There is an ancient manuscript about earthquake prediction stored in the national library in Jakarta.
	Atu Belah (Rock Split) -FOLKLORE-	Central Aceh	The story of *Atu Belah* is a folklore known to the Gayo community around Central Aceh, Bener Meriah, and Gayo Lues districts in Aceh Province. *Atu* is a Gayo language which means “stone”, and *Belah* means “splitting”. This story, known since hundreds of years ago, is about a child who disobeyed his mother's order so that his mother got angry and went to the big rock. The mother asked that the stone be split open so that she could enter the rock. Instantly, nature responded to the request and the stone split open. Then the mother went into the rock and the stone closed swallowing her. At the time of the splitting and closing of the rock, it is said that the earth shook violently. The split rock is currently located in Penurun Village in Central Aceh District, about 35 km from Takengon City. The mechanism of the rock splitting rapidly and recapping may be related to the ground motion caused by the earthquake. It is difficult to prove if the story is true, so that until now it is still considered a folklore and is still told by parents while sending their children to sleep. The moral of the story is for the children to always obey their parents.
	Sang Latura Dano -FOLKLORE-	Nias, North Sumatera	*Latura Dano* is the name of the ancestor of Nias that transformed into a large snake. When humans did bad things, then *Latura Dano* would shake his body so that an earthquake would occur on the mainland of Nias Island. Nias people will shout "*Biha Tuh*a! *Biha Tuha*!" which means "*Grandma enough*! *Grandma enough*!". The word *Biha Tuha* was voiced loudly as if asking *Latura Dano* to forgive the mistakes that humans had done and stop shaking his body which caused the earthquake. Stories like this can still be heard in several places in North and West Nias. This was the way people in Nias Islands interpreted earthquake mechanisms long before the existence of modern tools to identify them. However, very few young people now in Nias Island know this story.
	Laomaru's story -FOLKLORE-	Nias, North Sumatera	The *Laomaru* legend tells of a magician who lived in Nias Island with his son. They lived in a cave believed to be located not far from Gunung Sitoli City and on the edge of the ocean. One day, *Laomaru* intended to attract Nias Island to join the mainland of Sumatra Island. At that time, he asked his son to help out and warned him never to look back. *Laomaru* and his son then pulled Nias Island while walking toward the open sea. *Laomaru* was able to uncover the seawater when he heaved Nias Island. However, the boy then disobeyed his father and curiously looked back. Then, the sea that had been parted met again and Nias Island failed to be united with Sumatra Island. Earth activities as told in the *Laomaru* legend may also mean that an earthquake occurred and a tsunami engulfed Nias Island, although no one can really tell what happened. Until now, *Laomaru* cave can still be seen on the side of the road and its mouth is almost covered by grass and rock ruins so it is difficult to identify.
	*Naskah (*manuscript) Gembong, Naskah Kalembak, Naskah Kasunyatan, Naskah Lempuyang -ANCIENT MANUSCRIPTS-	Banten	The Gembong manuscript was found in the area of Gembong village, Jayanti District, Balaraja Regency, Banten. One of the contents of this manuscript states that before a natural disaster occurs, it can be marked by the appearance of a solar eclipse in the month of Muharram, and it will be followed by a leachate or earthquake event. The Kalembak manuscript was found in Caringin Pandeglang, Banten. In this text, the prediction of a catastrophic natural disaster is revealed, which is the eruption of Mount Krakatau. This prediction was written approximately 40 years before the disaster. Kalembak manuscript was written in 1843, and the writing had been based on stories passed down ancestors. The Kesunyatan manuscript was found in the State Museum of Banten, Banten. It contains the Banten chronicle and an explanation that natural disasters had occurred in Banten. It also revealed that the belief was that the occurrences of earthquakes and hurricanes are signs that a wise person would come to rule the country. The Lempuyang manuscript found in Lempuyang village, Tanara Serang subdistrict, Banten reveals the possibility of the existence of writings about natural disasters.
	Manuscripts of *Palinduran*, *Cilinaya*, *Takepan Doyan Nada*, *Takepan Suwung*, *Babad Lombok*, and *Dewi Anjani.* -ANCIENT MANUSCRIPTS-	West Nusa Tenggara	The six texts contain teachings on how to deal with earthquakes and earthquake predictions, as well as lessons on the importance of keeping a promise and the willingness to appreciate local wisdom by doing positive things.
Liquefaction	*Nalodo* (suction soil or swallowed by the mud) -VERBAL STORY TELLING-	Palu, Central Sulawesi	The earthquake was accompanied by liquefaction (melting of soil) in Petobo and Balaroa. It turned out that in that area, there is an oral culture that mentions liquefaction as *nalado*. In the manuscript, it is said that if an earthquake occurs in the afternoon before *maghrib* (Moslem’s time for prayer), it is a sign that an area will be moving (nalado). Liquefaction is a phenomenon in which a village is rolled up, moving it several kilometers, such as what happened in Petobo and Balaroa.
Volcanic	*Hikayat* (History) of *Nakhoda Asik* and *Hikayat* (History) of *Merpati Mas*	Jakarta	In Jakarta, there are 19th-century manuscripts entitled *Hikayat Nakhoda Asik* and *Hikayat Merpati Mas* by Muhammad Bakir written in 1887 using the Arabic-Betawi letters. The manuscripts recorded the story about the flood that happened in Jakarta due to the earthquake and eruption of Mount Krakatau in 1883.

[11] https://www.mongabay.co.id/2019/02/26/cerita-kampung-mamboro-dan-tsunami-yang-berulang/

Type of Disaster	Title of Local Wisdom	Area	Overview
induced earthquake and tsunami; Flood	-ANCIENT MANUSCRIPTS-		
	Syair (poem/lyric) *Lampung Karam* -ANCIENT MANUSCRIPT-	Lampung and Banten	A manuscript was found about the massive eruption of Mount Krakatau on August 27, 1883, which caused an earthquake and tsunami as high as 40 meters[12].
Whole Natural Disasters	*Syair* (Lyric) *Nagari Taloe Tarendam* (Submerged of a region) -POEM-	West Sumatra	The text states the importance of the role of the *ulama* (religious leaders) in the social life of the community, especially aspects related to natural disasters. When natural disaster occurs, people are taught to be patient, do something good, be disciplined, have good social attitude, and uphold religious teachings. If they disobey, the natural disaster would happen again.
	Sundanese *Karuhun* (Ancestor) -ANCIENT MANUSCRIPT-	West Java	The manuscript states that natural disasters are God's will, but ancestral lands must be preserved. Therefore, nature must not be overexploited. The harmony of nature must be maintained, so that disasters do not occur.
	Naskah (The Script) of *Kedutan* -ANCIENT MANUSCTIPT-	Banten	Before a disaster occurs, there are signs from animal behaviors and people feel anxious. So, there is the tradition of *tolak bala/ruwatan* (refusing reinforcements).
	Bunga Rampai Manuscript -ANCIENT MANUSCRIPT-	Cirebon, West Java	The manuscript contains disaster mitigation narratives. The text states that the north coast of Java is more peaceful. However, the southern coast of Java is more prone to natural disasters, and many people choose to become farmers in the highlands.
	Lontarak Pangissengeng Manuscript -ANCIENT MANUSCRIPT-	South Sulawesi	This is an ancient manuscript of the Bugis people that mentions the relationship between the occurrence of earthquakes and other natural disasters and bad human behavior.

Source: JICA Expert Team (References: Footnotes 13 and 14)

[12] https://edukasi.kompas.com/read/2008/08/31/10515861/~Sains~Arkeologi
[13] https://news.detik.com/x/detail/intermeso/20201008/Jejak-Mitigasi-Tsunami-dalam-Manuskrip-Kuno/
[14] https://siagabencana.com/post/5-naskah-kuno-yang-menguak-bencana-alam

As described in previous sections and in Table 2.1.1, there are local wisdom about various types of disasters in Indonesia. However, as mentioned in the introduction in this section, communities in Indonesia do not fully recognize local wisdom. For instance, *Kaili* tribe has their own folklore about tsunamis (*bombatalu*) and earthquakes, but the values embedded in this indigenous knowledge were not heeded at all during the last tsunami occurrence, though there were few people who adhered to this knowledge. This is probably due to migration of community members so that the local stories are not passed down to the next generation anymore. Moreover, local wisdom from all over the archipelago is not well documented[15].

Therefore, it has become a challenge for the government and Indonesian people to find ways so that future generation of local residents be handed down of local wisdom about disaster experience which can be utilized as powerful tool for disaster risk reduction. Adoption of lesson learned in Japan described in Chapter 3 can be one alternative for Indonesia in finding solutions to mainstream local knowledge.

2.1.2 Perception of the Public Toward Local Wisdom on Disaster

There are various views and opinions about disasters that evolved in Indonesian society. These are compatible with the level of education and individual or community's understanding on disasters[16]. Some perceptions assume that disaster is a curse or God's wrath as a result of humans' disobidience to His will. Thus, a disaster cannot be overcome or resisted because everything is according to destiny. Another view ascribes that disaster is a natural phenomenon caused by human activity that exploits nature, causing an imbalance to the environment, which eventually trigger the disaster. Over time, local wisdom has emerged in the Indonesian community as a manifestation of understanding and knowledge gathered from long processes and experiences resulting from interactions between the community and the surrounding environment in responding to disaster. Local wisdom for disaster mitigation is now seen as very valuable and has benefits in community life. This section describes perception toward local wisdom by professionals in Indonesia and that of the people, and recommendations for improving public perception.

(1) Perception of Professionals in Indonesia Toward Local Wisdom on Disasters

An archaeologist of the City Museum of Palu

An archaeologist of the City Museum of Palu has the perception that several communities in the Palu, Donggala area survived when the tsunami occurred, even though they did not have technology-based electronic equipment that could warn them of the imminent disaster. At that time, they only applied disaster mitigation based on local knowledge that was disseminated through storytelling of parents from generation to generation. Unfortunately, this kind of knowledge has begun to be forgotten or is no longer shared so that when a disaster occurs many residents do not know that such knowledge that could tell them what to do exists.

Religious leaders of Nahdlatul Ulama (NU)

Religious leaders of Nahdlatul Ulama (NU) have the perception that local wisdom about disaster should become an integral part of people's lives for them to become familiar with cultural signs before and when disasters happen[17]. By taking Smong and Baduy's local wisdom as examples, the religious leaders believe that the utilization of local knowledge has saved the community from past disasters, and this will save them as well in the future.

A Christian scientist

It is interesting to find out an opinion written by a Christian scientist on the website of The Church

[15] https://www.umy.ac.id/pemerintah-harus-lebih-perhatikan-local-wisdom-untuk-menyelesaikan-konflik.html
[16] Suparmini *et al*., 2013. Disaster mitigation based on local wisdom in Baduy community. Research report of State University of Yogyakarta.
[17] lpbi-nu.org/kearifan-lokal-dalam-pengurangan-resiko-bencana-sebagai-sains/

of Masehi Injili in Kupang, East Nusa Tenggara. He took an example that happened in Flores in East Nusa Tenggara, where the Christianity religion is practiced by majority of the population. He cited that within years after the 1992 earthquake and tsunami, there have been no initiatives to preserve the environment and to mitigate future disasters, for example, imposition of building code for house construction that takes into account the risk of seismic failure. The church, as a religious institution, and its leader, do not see disaster risk reduction instruments for the pastoral area and people. Consequently, there have been no recommendations coming from the church for disaster awareness raising. Therefore, the writer of the article highly recommends that religious institutions, such as churches, start preparing anticipatory steps to protect their followers from disaster risk through religious activities[18].

A university researcher

A researcher of Sunan Kalijaga University in Yogyakarta writes that almost every time a disaster occurs in Indonesia, religious discourses always emerge or intentionally done for the interest of certain elite or religious groups. The discourses link disasters with God's doom, or utilize religious beliefs or doctrines as basis of the reluctance of people to evacuate and even those who refuse relocation after the disaster event. Experiences from past disasters require a wiser solution. The approach that tends to be in the same direction and only considers the "scientific" aspect, sometimes triggers the increasing resistance of people who have the potential to be affected by disasters. The case of the death of *Mbah Maridjan* (the elder leader) and several of his followers in the Merapi eruption disaster in 2010, for example, could be a valuable lesson that disaster mitigation process only relies on one aspect, in this case, an explanation from the government, which is then rigidly socialized without touching aspects of wisdom in the community around the slopes of Merapi, it did not work well[19].

An architect and the governor of West Java Province

Ridwan Kamil, an architect as well as the Governor of West Java Province, has adopted in the design of Tsunami Aceh Museum the concept of Rumoh Aceh that is resistant to earthquake because of its structure[20]. He believes that this local knowledge should be preserved, as currently, this building concept has been abandoned by many people, especially those around the city of Banda Aceh so that during the 2004 tsunami, many houses were destroyed[21].

(2) Perception of the People Toward Local Wisdom on Disaster

Current status of adherence to local wisdom among people

According to a journalist of one of the biggest digital media in Indonesia, people's knowledge of local wisdom is currently decreasing due to minimal socialization and guidance, so that increasing awareness and community empowerment are absolutely necessary[22]. In line with this note, an article of indonesia.go.id (2021) states that the exploration of local wisdom is necessary because it provides understanding and guidance within the scope of local traditions on how to live daily life, including knowledge of the characteristics of disasters and the prohibition of carrying out activities that damage the environment or balance of the ecosystem[23].

Value of local wisdom

According to Hermainingrum and Junining (2016) in a social-cultural article, the value of local wisdom is believed to be the basis for disaster mitigation efforts, which aim to explore all cultural traditions, seek sociocultural relationships in disaster mitigation, and empower disaster-aware communities. Traditional local wisdom values to build a system of human sociocultural behavior

[18] https://sinodegmit.or.id/teologi-bencana-yang-emansipatif/
[19] Arifin, A.Z. 2019. Reconstructing the role of religion in the disaster mitigation process. Volume 2 Issue 3 – 2019 TALENTA Conference Series: Local Wisdom, Social, and Arts (LWSA). DOI 10.32734/lwsa.v2i1.580.
[20] https://www.esdm.go.id/en/media-center/news-archives/museum-tsunami-aceh-rumoh-aceh-escape-hill-karya-ridwan-kamil
[21] https://acehkita.com/desain-museum-tsunami-ridwan-kamil-kuras-air-mata/
[22] https://nasional.okezone.com/read/2011/08/08/337/489220/menguji-ketangguhan-indonesia-menghadapi-bencana
[23] https://indonesia.go.id/kategori/komoditas/2367/kearifan-lokal-sumber-mitigasi

so that it becomes an integral part of the environmental ecosystem. Local wisdom is a practice and method developed by community groups to include an understanding of the local environment that is orally passed down from generation to generation[24].

Another study by Nurbayani and Utami (2019) about disaster mitigation implementation by using a social capital approach reveals that disaster management requires the participation of community. Indigenous peoples have legal ties and solidarity, so they have strong trust, cooperation and social networks. Social capital in indigenous peoples makes a community as a social organization that facilitates action and cooperation for mutual benefit. Therefore, the social capital owned by indigenous peoples is based on approaches and strategies of local knowledge in handling disaster mitigation. Local wisdom becomes a solid foundation for the community to protect the environment. Local wisdom makes people have a sense of collectivism, solidarity and tolerance which is embedded in the daily life practices of society in the context of disaster mitigation efforts. One of the roles of local wisdom is to empower the community to participate in disaster risk reduction. Therefore, local wisdom is considered a traditional asset for management in the development of community-based disaster management systems, especially at the disaster mitigation stage[25].

Perceptions on local wisdom utilized in the educational sector

According to the study conducted by Yusutria *et al.* (2018), the values of local wisdom contained in the disaster-based geography module on faith have been introduced in education institutions. The modules are developed to address and provide information to students and their communities surrounding them about natural disaster prevention and mitigation. However, the absorption is still low which is reflected through the low level of understanding in dealing with disasters[26].

According to the study by the lecturers of Udayana University in Bali, communities have local wisdom to read natural phenomena which are practiced and inherited over generations through folklores or poems. The study concludes that local wisdom can be used as a reference for disaster preparedness education[27]. In line with the opinion of Udayana University's lecturer, other researchers introduce local wisdom-based education. It is an education that teaches students to always be close to the concrete situations they face every day. Local wisdom-based education is an example of education that has high relevance for life development skill[28]. Local wisdom integrated in the curriculum is believed to provide appropriate education to handle disasters. Local culture-based education will explain the relationship between humans and the natural environment with that of the surrounding cultural environment, so that local culture-based learning can provide students with the ability and skills, as well as knowledge about the area, that are useful for themselves and the community in general[29]. In addition, students also have the ability to adapt in an environment similar to the conditions from which the local culture originates. The natural disaster has made many parties realize that, since ancient times, their ancestors and parents had taught about disaster mitigation based on events that had occurred in the past.

2.2 Utilization and Dissemination of Local Wisdom on Disaster

In the National Coordination Meeting in 2021, the National Agency for Disaster Management

[24] Hermainingrum, S.,&Junining,S. 2016. Socio-cultural of Kelud People in connecting with traditional mitigation effort based on local wisdom. International Journal of Social and Local Economic Governance, 2(2), 127-135

[25] Nurbayani, S., & Utami, L. 2019. Social capital based on local wisdom in disaster mitigation. LWSA Conference Series 02. Available online at https://talentaconfseries.usu.ac.id/lwsa.

[26] Yusutria *et al*., 2018. Local wisdom values in facing natural disasters on module of geographic planning subject based on faith. International Journal of Progressive Sciences and Technologies, Vol.10 No.2, pp. 231-234.ISSN: 2509-0119.

[27] Agusintadewi, N. 2019. Developing a disaster response culture based on local wisdom in Indonesia. Seminar Nasional Arsitektur dan Tata Ruang (SAMARTA), Bali-2019, ISBN 978-602-294-397-6. https://www.researchgate.net/publication/344888873

[28] Nadlir. 2014. Urgensi pembelajaran berbasis kearifan lokal. Jurnal pendidikan agama Islam, Vol.2, p.300-330.

[29] Desfandi, M. 2014. Urgensi kurikulum pendidikan kebencanaan berbasis kearifan lokal di Indonesia. Jurnal Sosio Didaktika: Social Science Education Journal, Vol.1

(BNPB) states that local wisdom can be a part of the information system for early warning of potential disasters which must be maintained and improved in each region. Disaster mitigation efforts and the implementation of an early warning system cannot only rely on infrastructure built with modern technology. There needs to be an understanding of the community, a wisdom which later becomes a culture[30]. In line with the statement of BNPB, the Meteorological, Climatological, and Geophysical Agency (BMKG) also emphasizes the need of local wisdom to be well articulated, utilized, and disseminated to the community. The early warning system based on modern technology is not sufficient for disaster mitigation. The utilization and dissemination of local wisdom are believed to encourage the community to become independent during self-evacuation. The following sections describe some activities of utilization and dissemination of disaster wisdom including legal and planning framework, publication and website creation, disaster prevention education and awareness, and establishment of historical monuments for raising disaster awareness. The official information source of the organizations establishing frameworks and implementing activities are mainly indicated in the footnotes of each title below.

2.2.1 Legal and Planning Framework to enable the Utilization of Disaster Local Wisdom

(1) Tsunami Master Plan in 2012 (BNPB)[31]

The Master Plan articulates the importance of increasing public awareness through the adoption of local wisdom, and has been identified by taking samples in Bali and East Nusa Tenggara provinces. In Bali province, increasing public awareness is carried out through the establishment of the Bali Disaster Risk Reduction (DRR) Forum to secure early warning equipment through integration with the Coastal Protection Agency (*Bala Wisata)* which is active in addressing and observing hazards, and increasing knowledge and risk assessment by the government and non-governmental organization (NGO). DRR in Bali province includes ceremonial activities once every six months in all community levels to ask the ocean god not to send disaster, the use of *kentongan* (a device function as an alarm), storytelling of *Naga Gombang Legend* which is related to the occurrence of earthquakes, and adoption of *Tri Hita Karana* values which maintain the harmony among humans, God, and nature. The utilization of local wisdom was also found in tsunami early warnings in East Nusa Tenggara province, such as the storytelling of *Edo* (water rises) in Maumere regency; and *Kami Latu* and *Ami Norang* in Sikka regency which means "We are there/We exist".

Furthermore, the plan in disaster risk reduction also encourages the importance of community and religious leaders' involvement in increasing public understanding of disaster management through the formulation of the concept and implementation of outreach.

(2) Presidential Regulation No. 93 (2019): Strengthening and Developing Earthquake and Tsunami Early Warning Information System[32]

Summary of the regulation

In the recent regulation stipulated in December 2019, by taking into account Law No. 24/2007 on Disaster Management andLaw No. 31/2009 on Meteorology, Climatology, and Geophysics, the central government considers that the earthquake and tsunami early warning information systems have a strategic and important role in anticipating and mitigating earthquake and tsunami disasters to improve safety of life and property of the Indonesian people. Arrangements are needed to create a synergy between institutions in managing and utilizing earthquake and tsunami early warning information systems. Besides BMKG as the lead institution, other institutions/agencies are to work together including: Geological Agency (*Badaan Geologi*), Agency for the Assessment and

[30] https://bnpb.go.id/berita/rakornas-pb-bnpb-2021-kepala-bmkg-kearifan-lokal-harus-dikuatkan-sebagai-sistem-peringatan-dini-bencana

[31] BNPB. 2012. Tsunami Master Plan.

[32] The Presidential Regulation No. 93 (2019) Regarding Strengthening and Developing Earthquake and Tsunami Early Warning Information System.

Application of Technology (*Badan Pengkajian dan Penerapan Teknologi*/BPPT), Geospatial Information Agency (*Badan Informasi Geospasial*/BIG), Ministry of Home Affairs (MoHA), Ministry of Education, Ministry of Research and Technology, Ministry of Public Works and Settlements, Ministry of Transportation, Ministry of Communication and Informatics, Ministry of Marine and Fisheries, Ministry of Agriculture and Spatial Planning, BNPB, and Indonesian Institute of Sciences (*Lembaga Ilmu Pengetahuan Indonesia*/LIPI).

Components in the regulation

There are three components mentioned in the regulation: structural, cultural, and self/independent evacuation. The structural components are ministries/agencies that coordinate and synergize in carrying out a series of activities to provide and disseminate earthquake information and tsunami early warnings. The cultural component comprised of ministries/agencies and local governments that coordinate and synergize in implementing a series of activities which constitute efforts to reduce disaster risk or mitigate and prepare for potential earthquakes and tsunamis, including in the delivery of earthquake information and tsunami early warnings to the community. On the other hand, independent evacuation is an effort to independently rescue residents from the earthquake and tsunami disasters without having to wait for the given early warnings.

Capacity building as referred to in Article 15 includes community preparedness education, strengthening of earthquake and tsunami disaster literacy, safe space campaign and local wisdom, implementing the disaster-safe education unit program, earthquake and tsunami preparedness drills (including independent evacuation drills), and planning for management training.

Therefore, this regulation strongly encourages the utilization and dissemination of local wisdom for disaster risk reduction in Indonesia. The following subchapters will discuss more details about the policies and activities utilizing and disseminating local wisdom on disaster by assigned institutions/agencies such as those mentioned in the regulation.

2.2.2 Policy and Activities Utilizing Local Wisdom on Disaster

(1) BMKG[33]

Following the mandates in Law No. 31/2009 [34] that meteorological, climatological, and geophysical information has a strategic role in improving the safety of life and property, economy, as well as defense and security, BMKG has been continuously fulfilling itsr role and supporting the implementation of disaster risk reduction in Indonesia.

As part of disaster mitigation, BMKG encourages the utilization of local wisdom that has existed for a long time in the Indonesian community[35]. This is due to the fact that local wisdom has been proven to save Simeulue residents from the tsunami disaster in 2004. Besides local wisdom, BMKG has been supporting also the implementation of disaster education for awareness-raising through several formulated programs such as BMKG Goes to School[36].

After the enactment of Presidential Regulation No. 93/2019, BMKG continues to support and improve disaster preparedness and education through collaboration with other assigned ministries/agencies. Additionally, in the Strategic Plan (*Rencana Strategis*/RENSTRA) 2020-2024[37], BMKG has referred to Presidential Regulation No. 93/2019 to accommodate the needs of the community and stakeholders for a fast, precise, accurate, wide-reaching, and easy to understand meteorological, climatological, and geophysical information.

[33] https://www.bmkg.go.id/
[34] The Law Number 31 Year 2009 About Meteorological, Climatological, and Geophysical
[35] https://mediaindonesia.com/humaniora/246210/kearifan-lokal-dan-peran-pemda-penting-untuk-mitigation-bencana
[36] https://www.bmkg.go.id/tag/?tag=bmkg-goes-to-school&lang=ID
[37] Rencana Strategis Badan Meteorologi Klimatologi dan Geofisika 2020-2024 (Strategic Plan of Meteorological Climatological and Geophysical Agency 2020-2024

(2) BNPB[38]

By referring to the Regulation of the Head of BNPB No. 1 of 2012 concerning Guidelines for Disaster Resilient Villages, BNPB carries out the formation and development of Disaster Resilient Villages (*Desa Tangguh Bencana*/Destana)[39]as a manifestation of the government's responsibility to provide protection to the community from the threat of disaster. The village communities are considered as the ones closest to the local wisdom or can be said as the origin of local knowledge.

Furthermore, BNPB encourages local wisdom to be incorporated in the installation of tsunami early warning system and other disaster-based technology[40]. The reason is that the rapid development of science and technology does not seem to always solve the problem. On the other hand, the greatness of thought and cultural values in local wisdom, is, in some cases, able to answer the existing challenges, especially in natural disaster management. The combination of the two knowledge can be the key to solving problems faced by humans[41]. Recently, in April 2021, after attending a friendly meeting forum with the people of Simeulue Island, the Head of BNPB asked other regions in Indonesia to imitate what these people have and care for about local wisdom in dealing with "*smong*". By considering that natural phenomena (such as earthquakes and tsunamis) are recurring events, local wisdom becomes important to be known by all levels of society. It is expected that information about natural signs that can trigger disasters can be disseminated to the public in order to minimize risks[42].

In RENSTRA BNPB 2020-2024[43], it is acknowledged that community participation has been formed through local wisdom, such as the existence of Destana and disaster volunteers. BNPB claims that as one of its main strengths in achieving vision and mission in the future. Therefore, in April 2021, while observing earthquake victims in Ampelgading District, Malang Regency, BNPB reminded the community about the risk at the southern coast of Java Island. BNPB suggested that the residents utilize local wisdom to anticipate earthquakes that have the potential to cause tsunami. Local wisdom is essential for the community members to remember so that they will no longer wait for instructions from the local government or related parties to evacuate independently[44].

(3) Agency for the Assessment and Application of Technology (*Badan Pengkajian dan Penerapan Teknologi*/BPPT)[45] and Indonesian Institute of Sciences (*Lembaga Ilmu Pengetahuan Indonesia*/LIPI)[46]

In the website kabarsultengbangkit.id (2019), a number of experts from the Agency for the Assessment and Application of Technology (BPPT) and the Indonesian Institute of Sciences (LIPI) said that apart from improving natural disaster early warning technology, disaster mitigation education based on local wisdom is also important for people living in disaster-prone areas. In the case of Palu, Sigi, and Donggala of Central Sulawesi region, the local knowledge about earthquake, tsunami, and liquefaction existed. However, it was not fully understood and utilized yet during Palu earthquake 2018. Therefore, BPPT emphasizes that in the future, there must be a massive education of disaster mitigation for residents, especially based on local

[38] https://www.bnpb.go.id/
[39] BNPB.2012. Regulation of the Head of BNPB Number 1 Year 2012 regarding General Guidelines for Disaster Resilient Villages.
[40] https://news.detik.com/berita-jawa-tengah/d-4533352/bnpb-saatnya-pembangunan-selalu-berorientasi-pada-kebencanaan
[41] https://nasional.okezone.com/read/2011/08/08/337/489220/menguji-ketangguhan-indonesia-menghadapi-bencana
[42] https://www.bnpb.go.id/berita/kepala-bnpb-minta-daerah-lain-tiru-kearifan-lokal-simeulue-guna-kesiapsiagaan-dan-mitigasi-bencana-
[43] Rencana Strategis Badan Nasional Penanggulangan Bencana 2020-2024 (Strategic Plan of National Agency for Disaster Management 2020-2024)
[44] https://nasional.okezone.com/read/2021/04/11/337/2392965/doni-monardo-beri-mitigasi-bencana-gempa-dengan-kearifan-lokal
[45] https://www.bppt.go.id/
[46] http://lipi.go.id/

wisdom[47].

(4) Regional Agency for Disaster Management (*Badan Penanggulangan Bencana Daerah*/BPBD)

1) BPBD Banten Province[48]

In the website of BPBD Banten Province, it is stated in the guideline that local wisdom must become the basis for disaster management in each region because the pattern of countermeasures is carried out such that the public knows about potential disasters and understands natural signs that indicate the imminent disaster[49]. Based on the policy, as written in banten.antaranews.com, local government and BPBD Banten Province invite the community to jointly explore the values of local wisdom to maintain the balance of nature as well as to know what should be done in the event of a disaster[50]. Moreover, community members are taught to map their area, create an evacuation route to save themselves in the event of a disaster, where safe points to gather are located, and which agencies should be contacted in anticipation ofdisasters in the future.

2) BPBD Central Sulawesi Province[51]

Following the regulation of BMKG about earthquake and tsunami information, BPBD Central Sulawesi Province in its website gives a clear instruction on important things to do in case of earthquake and tsunami[52]. It emphasizes the use of local knowledge to know the signs of an imminent tsunami, especially after an earthquake (earthquake intensity is long and feels strong, seawater recedes, rumbling sounds from the middle of the ocean, lots of fish floundering on low tide beaches, and other natural signs). The BPBD instructs that the local knowledge should be introduced to the members of the community through many ways, including listening to the storytelling of ancestors. Another instruction is to monitor information from various official media regarding the potential of a tsunami after an earthquake, and to quickly run to a high place and stay there for a while. Furthermore, BPBD reminds the importance of immediately staying away from the beach and avoiding to see a tsunami coming or catch fish on the beach due to low tide. The last instruction is for community members to learn about the vulnerability level of their residence to tsunami hazards and the quickest evacuation route to higher ground.

3) BPBD Banda Aceh City[53]

In its website, in accordance with the policy on main tasks and function, BPBD Banda Aceh City has considered local wisdom in the formulation of policies for disaster prevention, mitigation, preparedness and early warning, as well as community empowerment. By taking into account the success of "*smong*" story in saving people's lives during 2004 Aceh tsunami, BPBD Banda Aceh City adopts the role of local wisdom on disaster such as the one applied by the Simeulueans in disaster mitigation and risk reduction planning and activities[54].

4) BPBD Bogor Regency[55]

In an article published in the website of BPBD Bogor Regency, local wisdom that exists in Indonesia is considered as a wealth that must be preserved in this modern era. A combination of modernization and local wisdom will be an effective step to minimize the impact of disasters that occur in Indonesia. Therefore, BPBD highly recommends to adopt local wisdom in disaster management practices[56].

47 https://kabarsultengbangkit.id/pentingnya-mitigasi-bencana-berbasis-kearifan-lokal/
48 https://bpbd.bantenprov.go.id/
49 https://bpbd.bantenprov.go.id/read/berita/163/Kearifan-Lokal-Harus-Jadi-Basis-Penanganan-Bencana.html
50 https://banten.antaranews.com/berita/23804/gubernur-penanganan-bencana-harus-berbasis-kearifan-lokal
51 http://bpbd.sultengprov.go.id/
52 https://pusdalops-bpbdsulteng.com/c_utama_auth/detail_tips/TP00004
53 http://bpbd.bandaacehkota.go.id/
54 http://bpbd.bandaacehkota.go.id/organisasi/tupoksi/
55 http://bpbd.bogorkab.org/v3/index.php
56 https://bpbd.bogorkab.go.id/kearifan-lokal-budaya-indonesia-dalam-mitigasi-bencana/

5) BPBD Central Java Province[57]

In the study conducted in 2014 based on the Hyogo Frameworks for Action, BPBD Central Java Province has initiated the utilization of local wisdom in implementing disaster management in the former residence of Semarang City. The community as the main actor is considered as the component who knows best of the condition of the area and has a variety of local wisdom. By taking the case of the Simeulueans as example, the study concludes that local knowledge, though it is very diverse with traditional terms and ways, should be seen as a potential in disaster mitigation planning. Therefore, the BPBD Central Java Province strongly recommends to treat local wisdom as an asset to be incorporated into disaster risk reduction implementation in the region[58].

6) BPBD Lampung Province[59]

BPBD Lampung Province has conducted a field study on rehabilitation and reconstruction after the tsunami in Sunda Strait in 2018. In the field study, a post-disaster recovery needs assessment was adopted as the approach for the preparation of a comprehensive rehabilitation and reconstruction plan which considered social and cultural aspects. In the social aspect, the recovery is focused on restoring community wisdom and traditions, restoring intercultural and religious relations, and reviving community sociocultural life. Restoring the function of the environment, such as through forest and spring revegetation as well as waste management, has been identified for the implementation activities on disaster risk reduction[60].

(5) Ministry of Education and Culture[61]

In September 2019, the Ministry of Education and Culture enacted Regulation No. 33/2019 about Disaster Safe Education Unit (*Satuan Pendidikan Aman Bencana*/SPAB) program[62]. The program considers the provision of protection and safety for students, educators, and education personnel from disaster risk through increasing preparedness and disaster mitigation within the education unit. One of the important activities carried out by the ministry is to integrate education materials related to disaster prevention and management in the national school curriculum.

(6) Ministry of Home Affairs (MoHA)[63]

The Ministry of Home Affairs emphasizes that the role of local government is no less important in minimizing the impact and casualties when a disaster occurs. The vulnerability level of the community in an area to the threat of disasters will be reduced if capacity of the community is strengthened. It is important to enhance this in a disaster-prone area, including those where local wisdom exists, for disaster risk reduction[64]. Furthermore, through MoHA Regulation No. 101/2018[65] about basic technical services concerning disasters, it is emphasized that the government should give basic services like the provision of disaster information such as warning signs, conducting disaster preparedness drills or simulations, and evacuation of victims when a disaster occurs. As regulated by the central government, disaster-prone areas are prioritizing budgets for disaster services. Following this, local governments and BPBDs are undertaking activities to utilize and adopt local wisdom for disaster management practices in the region.

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57 https://bpbd.jatengprov.go.id/aksi/

58 https://bpbd.jatengprov.go.id/PPID/FILE%20DOWNLOAD/Daftar%20Penelitian/1%20Eks%20Semarang_kearifan%20lokal.pdf

59 https://bpbdkotabandarlampung.id

60 Maryanti *et al*., 2020. Field study of rehabilitation and reconstruction after tsunami in Sunda Strait 2018 by BPBD Lampung Province. Journal of Disaster Managementa Vol.6, no.2, November 2020.

61 https://www.kemdikbud.go.id/

62 Ministry of Education. 2019. Regulation of Minister of Education Number 33 Year 2019 Concerning Disaster Safe Education Program.

63 https://www.kemendagri.go.id/

64 https://www.kemendagri.go.id/berita/baca/28945/pemda-kunci-dalam-penanganan-bencana

65 Ministry of Home Affairs Regulation Number 101/2018. Basic Technical Services Concerning Disasters for District/Regency.

(7) Local Government

Local Government of Central Sulawesi Province[66] in responding to the Palu earthquake and tsunami 2018 disaster, has enacted the Regulation of Governor Central Sulawesi Province No. 10/2019 about Post-Disaster Rehabilitation and Reconstruction Plan[67]. In the annex, it is clearly instructed that preserving cultural heritage, both customs, traditions and artistic activities is a must. Such activities include rebuilding evidence of community history through post-disaster building debris (disaster warning monuments), optimizing community functions in building communication and networks in preparedness and early warning systems, and preserving the local culture in its delivery of disaster threats that can be accepted by the community. For example, the city's name "Palu" comes from the word *Topalu'e* which means "raised land"; or the people of Central Sulawesi recognize liquefaction as *nalodo*.

Disaster Risk Reduction (DRR) Forum of Sigi Regency[68], Central Sulawesi assessed that the 2018 natural disaster had raised mutual awareness on the importance of future development efforts based on disaster risk reduction. At the community level in rural areas, they generally have local wisdom that can support disaster mitigation efforts. This can be seen from the customary rules governing spatial use[69]. As a forum that involves the community and the government of Sigi Regency, DRR Sigi will prioritize a community-based local wisdom approach in an effort to facilitate disaster mitigation activities in the region.

2.2.3 Research and Publications Related to Local Wisdom on Disaster

It is difficult at this time to find specific publications and websites which disseminate information and procedures to utilize local wisdom for disaster mitigation in Indonesia. However, the following collected information might be useful to give an insight on how the values of local wisdom are being identified and explored for disaster risk reduction practices in Indonesia.

(1) The Role of Local Wisdom and Social Capital in Disaster Risk Reduction and Coastal Development (in Indonesian Language)[70]

Marfai (2015) published a book regarding the role of local wisdom and social capital in disaster risk reduction and coastal development. This publication seeks to describe the identification of local wisdom from the process of community behavior and culture over a long period of time. Apart from that, this book also seeks to identify the social capital that exists in the community in relation to environmental management and efforts to reduce disaster risk. The publication provides various information and data to local governments related to local wisdom and the social capital of traditional communities for sustainable development planning. In addition, the writing of this book is also important for the development of methods in integrated multidisciplinary research.

(2) The Integration of Indigenous Knowledge for Disaster Risk Reduction Practices through Scientific Knowledge: Cases from Mentawai Islands, Indonesia[71]

Zulfadrim *et al*. (2019) conducted a research in terms of the integration of indigenous knowledge in disaster risk reduction practices in Mentawai Island. Highlights are as follows:

This study explores the importance of indigenous knowledge for everyday practices of

[66] https://www.sultengprov.go.id/

[67] Regulation of Governor of Central Sulawesi Province Number 10 Year 2019 About Post Disaster Rehabilitation and Reconstruction Plan, 159 pages. Enacted in Palu, 12th April 2019.

[68] https://sigikab.go.id/

[69] https://www.voaindonesia.com/a/museum-kampanyekan-mitigasi-bencana-berbasis-kearifan-lokal-melalui-pameran-sejarah-alam-dan-kebencanaan-sulteng/5118291.html

[70] Marfai, M. 2015. The role of local wisdom and social capital in disaster risk reduction and coastal development. Gajah Mada University Press

[71] Zulfadrim, Z., Toyoda, Y., and Kanegae, H. 2019. The integration of Indigenous Knowledge for Disaster Risk Reduction Practices through Scientific Knowledge: Cases from Mentawai Islands, Indonesia. International Journal of Disaster Management, Vol .2. No.1(2019), pp.1-12.

disaster risk reduction and response. Many existing studies have highlighted the need to integrate such knowledge with modern science. Based on ethnographic research in indigenous communities in the Mentawai Islands of Indonesia, this study explores the categorization of indigenous knowledge in the integration process. To that end, primary data were collected through in-depth interviews while secondary data were collected from relevant documents, including books, articles, websites, and government and NGO reports. The findings indicate that indigenous knowledge is acquired through long observation and interaction with disasters. Although some of this knowledge is based on successes in other localities, some indigenous knowledge is completely local, homogenous, and shared among community members. It was also concluded that indigenous knowledge can be meaningfully organized into a number of categories and that indigenous knowledge of a technical nature is more likely to be integrated with scientific knowledge. The research was exploratory and approached indigenous knowledge issues from the point of view of indigenous communities themselves. This approach should be replicated and expanded in other indigenous communities.

(3) Adoption of Local Wisdom in Disaster Management in Indonesia[72]

Hutagalung and Indrajat (2020) conducted research regarding adoption of local wisdom in disaster management in Indonesia. This publication explores the values of local knowledge for the people that can contribute to disaster management in the country. The study also includes the identification of the potential and relevance of local wisdom for institutional disaster management through data collection from reliable sources such as local government leaders and leaders of the indigenous communities. The result of the study describes the model of local wisdom integration into the local government programs for disaster response.

(4) Local Wisdom in Disaster Mitigation of Baduy Tribe, Banten Province (in Indonesian Language)[73]

Permana *et al*. (2011) conducted qualitative research in terms of local wisdom in disaster mitigation of the indigenous *Baduy* community. Data were collected by observation and depth interview methods, and the analysis was conducted by descriptive-analytical method. This study aims to gain knowledge and traditional ways of *Baduy* society that have been passed down from generation to generation. The results showed that (a) cut-and-burn system utilized by *Baduy* people in forests to open fields for dry rice cultivation does not cause forest fires; (b) *Baduy* settlements that are close to the river are safe from flooding, (c) houses and buildings made of combustible materials (wood, bamboo, thatch, and palm fiber) are safe from fires, and (d) even though *Baduy* territory is in the earthquake-prone areas of West Java, their structure do not sustain damage due to earthquake. These results have proved that the *pikukuh* (customary rules) as guideline and direction for thinking and acting are successfully applied by *Baduy* people. Moreover, *pikukuh* has been adopted as the basis of traditional knowledge that believes in wise and prudent behaviors to avoid disasters.

(5) Strengthening of Community Resilience to Disasters Introduced on the Website of BNPB[74]

The website of BNPB states that it commits to strengthening community resilience to disasters which has been the mainstream in disaster management since the beginning. When a disaster occurs, it is the community who becomes the victim and the party who suffers the most, so it is necessary to increase the capacity of members so that they are able to respond to disasters quickly and appropriately. One of the efforts is by utilizing local disaster knowledge that evolves in the

[72] Hutagalung, S. and Indrajat, H. 2020. Adoption of local wisdom in disaster management in Indonesia. International Journal of Scientific & Technology Research Volume 9, Issue 03, March 2020. ISSN 2277-8616.
[73] Permana *et al*. 2011. Local Wisdom of Disaster Mitigation in Baduy Tribe. Social Humaniora, Vol.15, No.1, July 2011: 67-76.
[74] https://siaga.bnpb.go.id/hkb/

community.

(6) Local Wisdom in Disaster Risk Reduction as a Science Introduced on the Website of Moslem Religious Nahdatul Ulama[75]

Nahdlatul Ulama (literally translated as "Revival of the Moslem Religious Leader", abbreviated as NU) is a traditionalist Ash'ari movement in Indonesia following the Shafi'i school of jurisprudence. NU was established on January 31, 1926, in Surabaya as a response to the rise of al-Aṯharīya in Saudi Arabia and Islamic modernism in Indonesia. NU is basically one of the biggest associations of Moslem scholars in Indonesia engaged in religious, educational, social and economic fields[76]. On the website, NU campaigns for local wisdom in disaster risk reduction, which is based on the faith that people can understand the signs of imminent disaster as a cultural message. Furthermore, the website explains the experience of disaster management in Japan and shows that disaster risk reduction in Japanese culture is a strategic aspect that is institutionalized to all people from an early age. So, when disaster occurs, they succeed in reducing the number of victims and shortening the emergency response period. Natural signs of disasters in Japanese culture are used as practical guidelines and have become official references in forecasting disasters.

(7) Local Wisdom as a Source of Disaster Mitigation Introduced on the Website of Indonesian Information Portal[77]

The article published in the website of Indonesian Information Portal (indonesia.go.id), states that the attitude of preparedness in responding to disasters is usually formed from behaviors that have been maintained from generation to generation. So, it is important to preserve and maintain local knowledge such as *smong* as a way to mitigate tsunami disaster. Due to risk of earthquake, the *Baduy* people work on the application of local knowledge by making customary rules or *pikukuh,* and certain prohibitions in building houses. Furthermore, the website states that "*the combination of local wisdom, regional spatial planning, and the sophistication of the early warning system is expected to strengthen mitigation*" in Indonesia.

(8) Local Wisdom About "Smong" for Disaster Mitigation Introduced on the Website of the Local Government of Aceh[78]

The website of the local government of Aceh introduced stories about Smong, and these are as follows:

> *Smong's stories are conveyed to the younger generation including children on various occasions, such as harvesting cloves. Simeulue used to be famous for its cloves, children often helped their parents when harvesting cloves. [...] Smong is also a lullaby for children to sleep at night. The parents talked about Smong while waiting for their baby to fall asleep. All parents did the same thing, until finally Smong became the local wisdom of the Simeulue people which was passed on through various means. The elders believe that one-day Smong will come again, although they really hope that the incident would never happen again.*

(9) Local Wisdom and Disaster Knowledge "Smong" That Saved Simeuleu Introduced on the Affiliated Website of BNPB[79]

The affiliated website of BNPB introduced the story of "*Smong"* that has been kept as one of the local cultures of the Simeulue community. It conveys the story of the 1907 tsunami and tells of required action to be taken to rapidly move away from coastal areas or save oneself by going to

[75] http://lpbi-nu.org/kearifan-lokal-dalam-pengurangan-resiko-bencana-sebagai-sains/
[76] https://www.nu.or.id/
[77] https://indonesia.go.id/kategori/komoditas/2367/kearifan-lokal-sumber-mitigasi
[78] https://dishub.acehprov.go.id/aceh-transit/smong-kearifan-lokal-untuk-mitigasi-bencana/
[79] http://www.siagabencana.com/kearifan-lokal-amp-pengetahuan-bencana/post/legenda-smong-yang-menyelamatkan-simeulue

higher places such as a hill. Furthermore, the basic supplies such as rice, sugar, salt, matches, and clothes are advised to be prepared in advance for survival while in the temporary refugee camp.

2.2.4 Disaster Prevention Education and Awareness

Since the aftermath of the Indian Ocean earthquake and tsunami in December 2004, disaster prevention education and awareness initiatives have been increasing in Indonesia. However, school communities have still limited disaster education opportunities and knowledge. This can imply a low level of disaster awareness.

In 2019, President Joko Widodo gave directives during the National Coordination Meeting for Disaster Management that disaster education must be started and should be focused on schools in disaster-prone areas through teachers, and in the community through religious leaders[80]. Since then, the implementation of Disaster Education program has relatively progressed. The government's commitment has also increased, which is marked by the issuance of various policies both at the national and regional levels. At the same time, collaboration between the Ministry of Education and Culture and BNPB, with the support of various nongovernmental organizations, has also increased.

According to BNPB, disaster education activities in Indonesia are basically associated with local wisdom that exists in the community[81]. Although the opened documentations of activities that explicitly focus on local wisdom in promoting preparedness and self-awareness on disaster risk are few, BNPB and its affiliates have put efforts to implement measures that are familiar to the community and closely related to its wisdom. For instance, in the developed national school curriculum by the Ministry of Education and Culture in 2013, local wisdom-based disaster education was implemented through the identification first of the local wisdom and the development of the learning materials utilizing it (See Figure 2.2.12 for an example of disaster teaching module based on the 2013 curriculum)[82]. Furthermore, following the directive of the President of the Republic of Indonesia and the provision of local-wisdom based disaster education by the Ministry of Education and Culture in 2019, BNPB started to organize disaster mitigation education program for students in disaster-prone areas by incorporating materials on local wisdom in the implemented activities. The Tsunami and Earthquake Division at BMKG also continues its disaster education programs, such as BMKG Goes to School and Geophysics Field School, which have similar aims with the BNPB's program[83]. As indicated in these programs, after the stipulation of Presidential Regulation in 2019, the utilization of local wisdom for disaster education can have more exposure. The following sections illustrate ongoing disaster prevention education and awareness activities in Indonesia.

(1) BMKG Goes to School Program

Summary of the Program

In order to strengthen the duties and functions of the BMKG as stipulated in Law No. 31 of 2009 and Government Regulation No. 11 of 2016, concerning the obligation to provide meteorological, climatological and geophysical services, the BMKG Goes to School activities are intended to provide simulation of information related to meteorology, climatology and geophysics and also as a disaster early warning education effort for the public[84].

The general objective of this activity is to make the participants better understand the natural phenomena that occur around their respective residential areas, especially those related to meteorology, climatology and geophysics. Participants are also expected to be more concerned,

[80] https://setkab.go.id/peresmian-pembukaan-rapat-koordinasi-nasional-bnpb-dan-bpbd-seluruh-indonesia-2-februari-2019-di-jx-international-exhibition-surabaya-jawa-timur/
[81] https://bnpb.go.id/berita/taman-edukasi-bencana-1
[82] Mustofa & Handini. 2020. Disaster education based on local wisdom in strengthening the character of disaster preparedness. Journal Kajian Ilmu dan Pendidikan Geografi GEODIKA, 4(2), p.200-209. DOI: 10.29408/geodika.v4i2.2776
[83] https://www.bmkg.go.id/tag/?tag=bmkg-goes-to-school&lang=ID
[84] https://www.bmkg.go.id/berita/?p=bmkg-goes-to-school-oleh-stamet-biak&lang=ID&tag=berita-daerah

more prepared and responsive in dealing with potential disasters.

Public literacy education on the risk of disasters, especially for elementary and high school students, is very important because the introduction of natural disaster mitigation caused by weather, climate, and especially earthquakes and tsunamis need to be instilled from an early age so that they know what needs to be done when these occur[85].

This Goes-to-school activity has been carried out by BMKG Public Relations Team in several schools, from elementary to high school, in the Greater Jakarta area such as Binus Elementary School, Santa Ursula Elementary School, Lazuardi Elementary School, and Cakra Buana School. According to one of the students of these schools, self-rescue activities during earthquakes are very important so that early elementary school students can understand and be able to properly save themselves during earthquakes.

Activity Report from West Java

In September 2018, BMKG Public Relations Team conducted a Goes to School activity at Lazuardi Global Islamic Primary School located in Depok, West Java[86]. This activity was carried out to increase knowledge and understanding of early level primary school students related to weather, climate, earthquakes and tsunamis, and teach them how to evacuate or carry out early rescue when an earthquake occurs as an initial step to mitigate or reduce risks during a disaster. This earthquake simulation was attended by 250 students from levels 4 to 6. They were very enthusiastic about doing the activities and the response given by the teachers was very encouraging. One of the teachers commented that early rescue activities during earthquakes are very important because there is no actual practical knowledge of procedures like this integrated in the curriculum, and she hoped that through this Goes to School activity early elementary school students can understand and be able to properly save themselves from earthquakes.

Source: BMKG

Figure 2.2.1 BMKG's Goes to School Activity in Lazuardi Global Islamic Primary School in Depok, West Java (Year 2018)

In March 2021, the Geophysics Station Bandung held a BMKG Goes to School activity at Pangandaran beach area, West Java. The purpose of the activity was to simulate the conditions of the Pangandaran area from a disaster perspective, especially the potential for seismicity and tsunamis, as well as provide education in dealing with these disasters. With this learning activity, it is hoped that students will be able to recognize potential disasters in their area and existing local wisdom, and increase their capacity in dealing with these disasters[87].

[85] https://www.kompasiana.com/ririnbmkg/5bc9a360aeebe177ae2d8462/bmkg-goes-to-school-tanggap-bencana-untuk-keselamatan-dini
[86] https://www.bmkg.go.id/berita/?p=goes-to-school-kenalkan-penyelamatan-dini-gempabumi&lang=ID
[87] https://www.bmkg.go.id/berita/?p=sosialisasi-dan-edukasi-potensi-kebencanaan-lewat-bmkg-goes-to-school&lang=ID

Source: BMKG

Figure 2.2.2 BMKG's Goes to School Activity in a Senior High School in Pangandaran Beach Area, West Java (Year 2021)

(2) BMKG's Geophysical Field School (Sekolah Lapang Geofisika/SLG)

In March 2021, BMKG held a Geophysical Field School (SLG) in Yogyakarta as an effort to educate the community on disaster preparedness especially for earthquake and tsunami occurrences[88]. The location in Yogyakarta was chosen because it is directly facing the Indian Ocean and the Megathrust Zone.

In addition to building a strong attitude and utilizing local culture in communities and schools in earthquake- and tsunami-prone areas, SLG is aimed at strengthening coordination between BMKG Geophysical Stations in the regions as extension of the Central BMKG with various related parties in their respective areas, and strengthen the role of BPBD in disseminating correct information and direction to communities regarding tsunami early warning.

Source: BMKG

Figure 2.2.3 BMKG's Geophysical Field School in Yogyakarta (Year 2021)

Besides Yogyakarta, BMKG also planned to implement SLG nationally in 29 other locations in 2021, such as in Pidie and Singkil in Aceh, Nias, South Tapanuli, Central Tapanuli, West Pasaman/ Padang Pariaman, Jambi, Pesisir Barat, Cilegon, Cianjur, Purworejo, Malang Regency, Sumenep, Jembrana, Karangasem, Mandalika Central Lombok, Labuan Bajo, Lembata, West Sumba, Penajam Paser Utara, Likupang North Minahasa, Tolitoli, Jeneponto, Bau-Bau, Tual South-East Maluku, South Halmahera, Jayapura Regency, Sarmi and Nabire.

[88]https://www.bmkg.go.id/berita/?p=wujudkan-masyarakat-siaga-gempabumi-dan-tsunami-bmkg-gelar-sekolah-lapang-geofisika-di-yogyakarta&lang=ID&tag=sekolah-lapang-geofisika

(3) Palu Urban Forest Kamboana: Moving the Crowd Trauma Healing (Palu, Central Sulawesi)

The 2018 Palu earthquake and tsunami accompanied by liquefaction, did not only devastated residential areas, but also destroyed coastal tourism areas along Palu Bay. Spots that were mostly visited by Palu residents to spend the weekend with family and relatives had been damaged by the tsunami. Located around the hills of Jabal Nur, Talise Village, Matikulore District, the Palu Urban Forest Kamboana was developed for trauma healing purpose[89]. Previously, this location was a reforestation area and rarely visited by people.

In this area, people of Kaili tribe in Palu have implemented forest conservation since long time ago because they believe that forest conservation can save them from disaster[90]. It means that they have prohibition mechanisms in the community in order to sustain the forest and mitigate disasters. Therefore, the development of Palu Urban Forest is highly relevant, not only for recreational purpose after the tsunami disaster but also for sustainable forest conservation and in nurturing the tradition of local wisdom.

Currently, the Palu Urban Forest Kamboana becomes one of the main tourist attractions in Palu[91] that serves as a green space and recreational place that facilitates sports activities.

Sources: Radar Sulteng(left), Tribun Palu.com (right)

Figure 2.2.4 Palu Urban Forest Kamboana

Source: sultengterkini.com

Figure 2.2.5 Kamboana Food Stall

(4) Disaster Mitigation Based on Local Wisdom Featured in Historical and Natural Disaster Exhibition Activities

Held for six days in October 2019, the Special Exhibition of Natural History and Disaster in Central Sulawesi organized by the Central Sulawesi Cultural Park and Museum succeeded in

[89] https://www.sultengterkini.com/?s=hutan+kota+palu
[90] Saleh, S. 2013. Local Wisdom of Kaili Tribes in Central Sulawesi. Journal Academia Fisip University of Tanduloko, 05 (2) p.1126-1134. ISSN 1441-3341
[91] https://metrosulawesi.id/2020/01/11/hutan-kota-kaombona-palu-jadi-destinasi-wisata-bersama-keluarga/

attracting 10,000 visitors. The exhibition sought to campaign for natural disaster mitigation based on local wisdom[92]. One form of local wisdom of people in the past was through tautonymy, or naming a place associated with a natural disaster in their local language. In this event, visitors can watch documentation photos of the impact of natural disasters and a documentary film containing the explanation of earthquake, tsunami and liquefaction phenomena. The visitors can also read the explanation of liquefaction that happened during the Central Sulawesi disaster.

Source: voaindonesia.com

Figure 2.2.6 Special Exhibition of Natural History and Disaster in Central Sulawesi

(5) Series of Geological Seminars on Earthquake and Tsunami Preparedness Coordinated by Religious Organization (Fellowship of Church in Indonesia, NU, BNPB, BMKG, LIPI, National and Foreign University, NGO)

To commemorate the 50th anniversary of the Church of Jesus Christ in Indonesia, the Church worked with its old partner, the Nahdlatul Ulama Disaster Management and Climate Change Institute (LPBI NU) in holding a series of Geological Seminars for Earthquake and Tsunami Disaster Preparedness[93].

[92] https://www.voaindonesia.com/a/museum-kampanyekan-mitigasi-bencana-berbasis-kearifan-lokal-melalui-pameran-sejarah-alam-dan-kebencanaan-sulteng/5118291.html
[93] https://news-id.gerejayesuskristus.org/article/gereja-menggelar-seminar-geologi-siap-siaga-bencana-gempa-dan-tsunami

Source: gerejayesuskristus.org[94]

Figure 2.2.7 Geological Seminars on Earthquake and Tsunami Preparedness by a Religious Organization in Indonesia (Year 2019)

This activity was carried out in three cities in Indonesia. Highlights of these seminars are reported in a website[95] and described below.

The first and second geological seminars

The first seminar was held on 25 November 2019 in Malang City, East Java with the theme "Increasing Community Resilience in Facing Disasters and Tsunamis through Education and Awareness". In collaboration with the Islamic University of Malang, the seminar presented a number of speakers from Brigham Young University Utah, Malang Geophysics Station, BNPB, and BPBD Malang Regency. The Rector of the Islamic University of Malang explained that Indonesia is located in disaster-prone area, especially for earthquakes and tsunamis. By holding this seminar, it was hoped that participants and students could be motivated to carry out the task of protecting the environment and reducing disaster risks. A speaker from BMKG (Dr. Daryono) shared a number of new paradigms in viewing disasters: "*First is understanding disaster risk, the second is risk management, the third is investing by strengthening building structures, and the last is improving preparedness with simulation and disaster evacuation drills. The simulation disaster evacuation drills will strengthen the instincts to save ourselves*." On November 27, 2019, the second geological seminar was held in Palu City, Central Sulawesi.

The third geological seminar

The third geological seminar was held in Jakarta on 29 November 2019. The speaker from BNPB (Ir. B. Wisnu Widjaja) pointed out that *"Human arrogance always blames nature by making the term 'natural disasters', even though the earth is always moving, that is its nature."* He emphasized the need to be focused in finding a solution so as to minimize the number of disaster victims. He further explained that to do this, there is a need to understand the disaster, and strengthen risk governance.

Furthermore, another speaker (Dr. Eko Yulianto from LIPI) shared this insight: "*Local wisdom can help overcome the effects of the earthquake."* He further explained, "*Through local wisdom, our ancestors noted ways to overcome disasters, one of which is by building earthquake-resistant houses, namely houses on stilts.*" He compared these with houses and buildings that are made of bricks of a quality that is not earthquake resistant. *"Oftentimes it is not the earthquake that causes many victims, but the result of falling houses that have collapsed*," he explained. One of the solutions offered is to campaign for an independent evacuation site. "*This is a place in the house that is safe for family gatherings when a disaster occurs, for example in the bathroom, because this space has minimal furniture*," he concluded. Finally, the speaker from the NGO Save the Children (Mr. J. Victor Rembeth) closed the seminar by inviting participants to learn together and realize that disasters are caused by human behavior. He also

[94] https://www.gerejayesuskristus.org/
[95] https://news-id.gerejayesuskristus.org/article/gereja-menggelar-seminar-geologi-siap-siaga-bencana-gempa-dan-tsunami

appealed to all to change their attitude and be ready to cope with disasters.

(6) Development of Fun Digital Learning: TANAH, the Tsunami and Earthquake Fighter

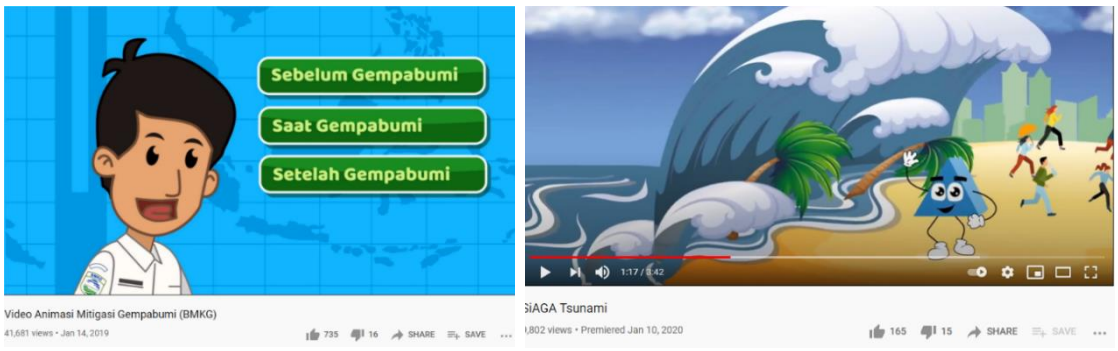
Through collaboration among the Global Disaster Preparedness Center (GDPC), UNESCO-Bangkok, and USAID with the assistance of Indonesian Red Cross (PMI), and Asean Coordinating Center for Humanitarian Assistance on Disaster Management (AHA Center), a disaster preparedness educational mobile app was developed by Thai-based software company Opendream. This mobile app launched in December 2015 was designed for kids and other family members, and enable them to play a game wherein players follow heroine Tanah who learns to prepare and save herself from earthquakes and tsunamis. Through the game, players can enhance their awareness on hazards, as well as learn key concepts on disaster risk reduction. This free app is available in English, Indonesian language and Thai[96].

Note:10,000+ installs in the Google Play
Source: Google Play

Figure 2.2.8 The Tsunami and Earthquake Fighter Game

(7) Development of Video Animation on Earthquake and Tsunami Mitigation by BMKG and BNPB

There are several video animations developed by BMKG and BNPB. These explain what people should do before, during and after an earthquake and be ready for an imminent tsunami if people are in an earthquake- and tsunami-prone area. BMKG introduces the utilization of local knowledge for recognizing potential earthquake and tsunami hazards in the area where people live. BNPB also gives guidelines for mitigating tsunami such as by adhering to the local culture that exists in community and surrounding areas.



Sources: Youtube uploaded by BMKG (left); Youtube uploaded by BNPB (right)

[96] https://www.preventionweb.net/educational/view/47238

Figure 2.2.9 Video Animation Earthquake and Tsunami Mitigation

(8) Development of Guidelines and Posters on Earthquake and Tsunami Mitigation by BNPB

As mandated in the Regulation of Head of BNPB No. 4/2008[97] regarding Guidelines for Disaster Management Plan, several activities are encouraged for disaster prevention, mitigation, and awareness such as the development of guidelines and the creation of posters/leaflets/brochures.

Govt Guidelines (BNPB, 2012)

Govt Poster (bnpb.go.id)

Source: BNPB

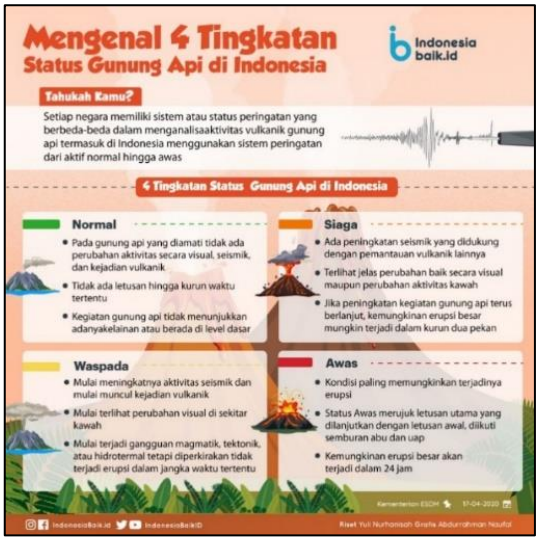
Figure 2.2.10 Earthquake and Tsunami Guideline and Posters Developed by BNPB

[97] BNPB. 2008. The Regulation of Head of BNPB Number 4 Year 2008 Regarding Guideline for the Formulation of Disaster Management Plan

(9) Development of Poster and Other Disaster Awareness Materials by the Ministry of Communication and Information

The Ministry of Communication and Information has managed the website "Indonesiabaik.id" as one of the efforts to stimulate the spirit toward a better Indonesia. The vision is to showcase what Indonesia has, and to convey and disseminate them for public, especially the children, knowledge and awareness. The contents range from information about Indonesia, the services of the ministry, and the development of the nation.

There is no specific information in the website regarding direct utilization of local wisdom mentioned. However, it introduces basic information about the level of volcanic activities and promotes the utilization of a traditional tool (*kentongan)* which is very popular within Indonesian community as part of disaster early warning system.



Source: Indonesiabaik.id

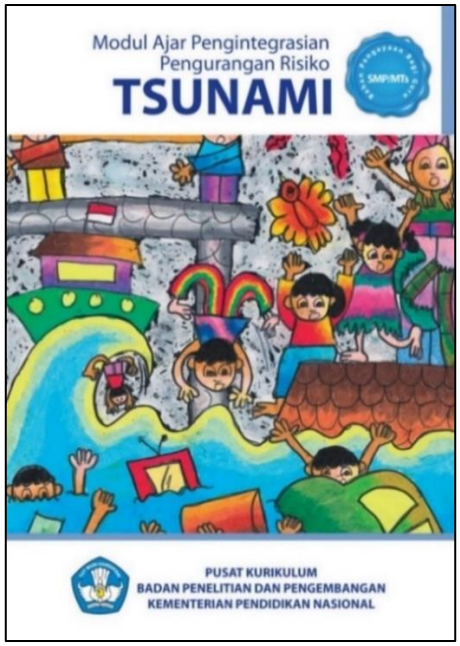
Figure 2.2.11 Infographic of Volcanic Activities

Source: Indonesiabaik.id

Figure 2.2.12 Poster About the Importance of Disaster Early Warning System

(10) Development of Teaching Module for Integrating Tsunami Risk Reduction by the Ministry of Education and Culture

Following Regulation No. 33 Year 2019, the Ministry of Education and Culture has implemented SPAB in various regions which is carried out by multiple parties, including local governments, NGOs, Scouts, PMI, and many other institutions. The Ministry of Education commits to promoting disaster-resilient education and has put efforts to create a comprehensive child-centered education through the development of a school curriculum which includes local wisdom-based disaster education and provision of disaster mitigation materials[98].



Source: Ministry of Education and Culture

Figure 2.2.13 Teaching Module for Tsunami Risk Reduction

(11) Nationally Mandated Program: Disaster-Resilient Villages (*Desa Tangguh Bencana*/*Destana*) by BNPB

Disaster-resilient villages (Destana) is a government program to train villages/subdistricts throughout Indonesia to be self-sufficient during disasters by developing the mindset to adapt, mitigate, and recover[99].

Destana outputs include strengthening mitigations, mapping disaster-prone regions, creating mitigation rules and regulations, strengthening people's local knowledge about disasters and mitigations, and encouraging active participation from villagers.

[98] Ministry of Education. 2019. Regulation of Minister of Education Number 33 Year 2019 Concerning Disaster Safe Education Program.
[99] BNPB. 2012. Regulation of the Head of National Agency for Disaster Management Number 1 Year 2012 Regarding Village Resilience Program.

Sources: aceh.tribunnews.com[100] (left), jateng.tribunnews.com[101] (right)

Source: jabarekspres.com[102]

Figure 2.2.14 Destana Programs in Aceh, Central Java, and West Java

(12) Tsunami Education for the Public and Schools

Tsunami education programs have been continuously held by coordination of BNPB and local government[103]. According to Rafliana (2011) [104], the most recent disaster events in the nation have been a major wake-up call for giving more attention to disaster education. As one of the strategies aiming at reducing disaster risks, disaster education activities were introduced to residents and schools with the hope that they can be catalysts for influencing community's disaster preparedness.

Sources: radarnusantara.com (left), bnpb.go.id (right)

Figure 2.2.15 Tsunami Education for the Public and Schools

[100] aceh.tribunnews.com
[101] jateng.tribunnews.com
[102] jabarekspres.com
[103] Khaerunnisa, 2020. Tsunami Awareness in Indonesia
[104] Rafliana, I. 2011. Disaster education in Indonesia: Learning how it works from six years of experience after Indian Ocean Tsunami in 2004. Journal of Disaster Research, Vol.7 No.1, 2012

(13) Other Development Activities Post 2004 Tsunami in Relation to Disaster Prevention Education and Awareness

After the Indian Ocean earthquake and tsunami, there have been disaster risk reduction activities such as the development of Tsunami Escape Building, construction of the Aceh Besar breakwater, mangrove planting in Cermin Beach, and establishment of Madani Foster Home. Disaster risk reduction is a key element of the process of disaster recovery and reconstruction in order to ensure communities to mitigate future disasters, and be as prepared as possible.

The 2006 Progress Report of "Aceh and Nias Two Years After the Tsunami" (2006)[105] argues that one of the specific concerns in the reconstruction program is to develop good quality structures in the appropriate locations such as coastal areas. In some cases, communities with conducting partners have rebuilt the area near the coast due to condition that they did not own land elsewhere and considered that they had little choices. However, an appropriate disaster risk management process through activities such as community-based mapping offers an opportunity for identifying safe resettlement sites, improving evacuation routes and enhancing disaster awareness[106].

(1) Tsunami Escape Building

(2) Aceh Besar Breakwater

(3) Mangrove Planting in Sedang Bedagai

(4) Madani Foster Home in Deli Serdang

Sources: national.tempo.co (1), antarafoto.com (2), goodnewsfromindonesia.id (3), and facebook.com (4)

Figure 2.2.16 Other Development Activities Post 2004 Tsunami

2.2.5 Educational Facilities for Awareness Raising Initiatives

According to the Tsunami Catalog by BMKG (2010), in the last two decades there have been at least ten catastrophic tsunami events in Indonesia. Nine of them were destructive tsunamis and caused casualties and material losses, namely, the tsunami in Flores (1992); Banyuwangi, East Java (1994); Biak (1996); Maluku (1998); North Sulawesi (2000); Aceh (2004); Nias (2005); West Java (2006); Bengkulu (2007); and Mentawai (2010). About 170 thousand people died due to the tsunamis[107].

The survey conducted by Central Connecticut State University in the US (2016) revealed that Indonesia is in the second last rank of 61 countries with the lowest literacy level[108]. In the context of disaster mitigation, literacy is not just reading, but understanding materials on disaster

[105] BRR and Partners. 2006. Aceh and Nias Two Years After the Tsunami 2006 Progress Report. Advance Release Version.
[106] https://reliefweb.int/sites/reliefweb.int/files/resources/8F7E4BD64414C4C449257252001DDD68-Full_Report.pdf
[107] BMKG. 2010. Tsunami Catalog.
[108] https://www.thejakartapost.com/life/2016/08/29/indonesia-ranks-second-last-in-reading-interest-study.html

education. The impact of weak literacy in Indonesia makes many people do not fully aware/comprehend that Indonesia is prone to earthquakes and tsunamis, especially in Aceh, where there was a tsunami disaster that occurred in the past. Another example is Talise Village, East Palu, Central Sulawesi where the village was wiped out due to the tsunami that hit the coast of Palu on September 28, 2018. Tsunamis had occurred in the area long before. However, experience was not able to save the community when the tsunami hit the coast of Central Sulawesi in September 2018. Even though there were still many living witnesses who had experienced past tsunamis and listened to the folklore from their ancestors, most of the residents seemed not to care much about disaster knowledge that could have saved many lives.

According to the research conducted by Sugimoto (2018) in the country, the weakness in Indonesia is the lack of media in terms of conveying knowledge about earthquakes and tsunamis. The infrastructure built for disaster is not enough, but community awareness must be developed, one way of which is through the establishment of tsunami monuments. A monument that marks an area ravaged by a tsunami is significant to remind future generations of past disaster and be reminded of the experience and/or lessons learned. Therefore, if a tsunami occurs again, casualties can be reduced[109].

As realized by the government of Indonesia as well as through the encouragement of international researchers, the following monuments have been mainly built to commemorate past disasters and for purposes of raising awareness and preparedness in the future. They are introduced in several information sites in the country.

(1) Monuments Built to Commemorate Disasters

1) Flores 1992 Tsunami Monument (Maumere Tsunami Monument)

An earthquake with a magnitude of 7.5 triggered a 25-meter high tsunami in Flores in December 1992[110]. By considering enormous suffering, loss of lives and materials in Flores due to the disaster, the Presidential Decision No. 66 Year 1992 has stipulated that the natural disaster in Flores be considered as a national disaster. Hence, the Flores Tsunami Monument was built in Maumere City Park to commemorate the devastation caused by the tsunami event in 1992 and to symbolize the community's resilience after the disaster[111].

Source: thevoiceofflores.com[112]

Figure 2.2.17 Maumere Tsunami Museum

2) Java Tsunami 2006 Monument at Widarapayung Beach, Cilacap, Central Java

On July 17, 2006, a magnitude 7.0 earthquake triggered 3- to 8-meter high tsunami that hit the south coast of West and Central Java. BNPB explained that the Java tsunami monument at Cilacap, Central Java was built to commemorate the earthquake and tsunami event in 2006[113].

[109] https://kumparan.com/zuhri-noviandi1515408418019/lemahnya-literasi-kebencanaan-di-indonesia-1545896699980048097/full
[110] BMKG. 2019.Tsunami Catalog per Region 2nd Edition
[111] https://www.thevoiceofflores.com/home/maumeretsunami
[112] https://www.thevoiceofflores.com/home/maumeretsunami
[113] https://www.siagabencana.com/post/monumen-tsunami-indonesia

Source:siagabencana.com

Figure 2.2.18 Tsunami Monument at Widarapayung Beach, Cilacap, Central Java

3) Banyuwangi Tsunami 1994 Monument at Pancer Village, Banyuwangi, East Java

The Banyuwangi Tsunami Monument was built to commemorate the tsunami disaster in Pancer village, Banyuwangi, in1994. BNPB mentioned that the tsunami had claimed lives due to the absence of early warning, preparation, and local knowledge. In commemoration of the event, the monument was built to remind future generations of lessons learned, so that they will always remember and be alert of tsunami event[114].

Source:siagabencana.com

Figure 2.2.19 Banyuwangi Tsunami Monument at Pancer Village, East Java

4) Tsunami Monument in Desa Gampong Pasir Lhok Aron, West Aceh

The tsunami monument in Lhok Aron, Aceh was built to commemorate the tragedy in 2004. This monument displays the list of victims and symbolizes the 7-meter tsunami that ravaged the area[115].

[114] https://siagabencana.com/post/monumen-tsunami-banyuwangi
[115] https://www.antaranews.com/berita/603622/monumen-tsunami-gampong-pasir-aceh-barat-diresmikan

Source: antaranews.com

Figure 2.2.20 Tsunami Monument in Lhok Aron, West Aceh

5) Monument Krakatau, Lampung

The powerful eruption of Mt. Krakatau in 1883 was followed by a 40-meter-high tsunami had claimed 36,000 casualties and affected around 12,000 people in Lampung and Banten regions[116]. To commemorate the devastation of the natural disaster, the Krakatau Monument was built 45 km away from Mt. Krakatau in Teluk Betung City, Lampung. The main building of the Krakatau Monument is a lighthouse which is a silent witness to the enormity of the tsunami. The lighthouse, which is about 2 meters high with a diameter of 1.5 meters and weighs up to half a ton, was also wiped out into the ocean by the 40-meter-high tsunami[117].

Source: liputan6.com

Figure 2.2.21 Monument of Mt. Krakatau Eruption at Lampung

6) Pidie Tsunami Museum, Aceh

The Pidie Tsunami Museum is located in Kuala Pidie, Sigli City District, Pidie Regency, Aceh Province. When visitors arrive at the museum, they first see a golden globe on the lawn. In addition, there are gold carvings of verses of the Al-Qur'an which are beautifully engraved on the walls. The 6-meter high curved wall is very unique. Next to the wall, there is an alley with walls on which inscribed the names of tsunami victims in Pidie and Pidie Jaya Regencies in 2004[118].

[116] Center for Excellence in Disaster Management & Humanitarian Assistance. 2015. Indonesia Disaster Management Reference Handbook
[117] https://siagabencana.com/post/mengenang-ingatan-letusan-krakatau-1883-melalui-monumen-krakatau
[118] https://mediaaceh.co/2016/12/26/melihat-museum-tsunami-di-kota-sigli/

Source: acehtourism.travel

Figure 2.2.22 Pidie Tsunami Museum in Pidie Regency, Aceh

Inside the museum, visitors can see many photos that illustrate how devastating the Aceh tsunami was. These photos are neatly displayed and protected by a layer of glass. By looking at these photos, visitors can get a glimpse of the condition of Pidie and Pidie Jaya Regencies when they were devastated by the tsunami. The collection in Pidie Tsunami Museum is not as extensive as that in Aceh Tsunami Museum in Banda Aceh. There are no replicas or dioramas like the ones in Aceh Tsunami Museum. However, through many exhibits in this museum, visitors can learn about tsunami disaster[119]. Pidie Tsunami Museum now appears to be lacking in maintenance and requires intervention from the local government to revive it[120].

[119] https://acehtourism.travel/en/destination/12/2019/tsunami-museum-in-the-city-of-sigli/
[120] https://waspada.id/aceh/monumen-tsunami-sigli-riwayatmu-kini-terabaikan/

7) "Thanks to The World" Monument, Blang Padang, Aceh

The Monument "Thanks to The World", located in Blang Padang, is a symbol of Aceh's gratitude to volunteers, NGOs, higher state institutions, national and international companies, civilians and military who have participated in the development of Aceh after the 2004 tsunami disaster. The white structure located at the north of the field is shaped like a tsunami which reminds anyone who sees it that Aceh had been hit by a huge tsunami. The monument indicates that the Aceh government is indeed determined to maintain in the memory of the Acehnese the devastation caused by the 2004 earthquake and tsunami, and so that the next generation of Acehnese children can find out about this part of history and events in their place of birth[121].

Source: bandaacehkotamadani.wordpress.com

Figure 2.2.23 "Thanks to The World" Monument in Blang Padang, Aceh

8) Tsunami Height Poles – A Lesson Learned from Japan Disaster Experience

According to Sugimoto *et al*. (2010), in order to keep disaster awareness in the area where the Indian Ocean tsunami caused enormous damage in 2004, 85 tsunami height poles were erected in Banda Aceh City in 2007 with funds from Grassroots Grant Assistance for Human Security of the Japanese government. These monuments have the same height as the tsunami that ravaged each location. The aim of the height poles is to let the next generation visualize past disaster and enable the residents to remember its impact for a long period of time[122].

Source: Sugimoto *et al*. (2010)

Figure 2.2.24 Tsunami Height Poles in Banda Aceh City, Aceh

Sugimoto further explained that many tsunami memorial monuments have been constructed in Japan (see Section 3.2.5 for details) to hand down disaster experiences to future generations, and

[121] https://bandaacehkotamadani.wordpress.com/2012/08/27/thanks-to-the-world-monument/

[122] Sugimoto, M., Iemura, H., Shaw, R. 2010.Tsunami height poles and disaster awareness. Memory, education and awareness of disaster on the reconstruction for resilient city in Banda Aceh, Indonesia. Disaster Prevention and Management Vol.19 No.5, pp.527-540. Emerald Group Publishing Limited. DOI 10.1108/09653561011091869

improve understanding and awareness of people on disasters. Without such monuments, people can forget lessons from disaster experiences, since storytellers, such as grandmothers handing down the *Smong* story, will not be forever around to share the disaster knowledge to the next generation. The poles in Aceh are expected to continuously hand down disaster experience and to be utilized for disaster education to improve people's awareness regarding disaster occurrences in the area.

(2) Tsunami Education Park, Aceh

Tsunami Education Park is located in Punge Blang Cut, Banda Aceh City. It is the first tsunami educational park in Indonesia, covering an area of 4,500 m^2. For purposes of disaster education, there are tsunami simulation equipment, photos of destruction brought about by tsunami, open theater, and playground in it. This tsunami education park greatly contributes to make the younger generation understand tsunami phenomenon and its impact on individuals, families, communities, culture and the environment[123].

Source: nelva-amelia.blogspot.com

Figure 2.2.25 Tsunami Education Park in Punge Blang Cut, Banda Aceh City, Aceh

(3) Aceh Tsunami Museum

The Aceh Tsunami Museum, established in Banda Aceh in 2009 with the cost of approximately IDR70 billion[124], is a museum designed as a symbolic reminder of the 2004 Indian Ocean earthquake and tsunami disaster, as well as an educational center and an emergency disaster shelter in the area[125]. The building of the museum adopts the traditional design of uplifted Rumoh Aceh, and it resembles a ship with protruding funnel[128]. The concept of Rumoh Aceh is introduced in the book *Tajul Muluk* as an earthquake-resistant structure, including the consideration of the wind direction, structure position, construction techniques and house motifs[126].

The museum building consists of two floors. At the entrance on the first floor, visitors can find "Lorong Tsunami (Tsunami Alley)", which is a dark and narrow pathway flanked by 40 meters (131 feet) high walls and filled with flowing water with scary rumbling sound effect. This was

123 https://nasional.kompas.com/read/2008/04/30/14003785/~Regional~Sumatera
124 https://www.indonesia.travel/jp/en/destinations/sumatra/banda-aceh/the-aceh-tsunami-museum
125 https://museumtsunami.id/tentang-kami/
126 https://www.aa.com.tr/en/asia-pacific/aceh-tsunami-museum-serves-as-memorial-to-tragedy/1561326

designed to replicate the victims' fear of the tsunami and to remind of its devastation. There are also several sections on the first floor which display collections of relics and debris recovered after the disaster; pictures and dioramas of conditions before, during, and after the tsunami; actual materials from the area, including fishing boats damaged by the tsunami; and a picture of the Diesel-fueled Power Plant (Pembangkit Listrik Tenaga Diesel/PLTD) Apung Ship which was swept away by the tsunami and came aground at Punge Blang Cut in Banda Aceh City. The museum also has a room called "Sumur Doa" (Well of Prays) where the names of the victims and survivors are inscribed on the walls. The second floor has a library, an electronic simulation of the tsunami, and a souvenir shop. In front of the museum, visitors can find the wreck of trucks retrieved after the tsunami.[128] [130]

(1) Aceh Tsunami Museum

(2) Tsunami Alley of Aceh Tsunami Museum

(3) Aceh Tsunami Museum Interior

(4) Aceh Tsunami Museum Exterior

(5) Visitors of Aceh Tsunami Museum

Sources: dialeksis.com (1); urbane.co.id (2) and (3); kumparan.com(4); and cnnindonesia.com(5)

Figure 2.2.26 Aceh Tsunami Museum

This museum is well-known to both domestic and international tourists. Before the COVID-19 pandemic, *Jejak Langkah Sejarah* (*Jelajah*), a group that encourages people to understand Indonesian history, reported that it had been the country's most popular museum based on the high number of visitors. According to an article by Anadolu Agency (2019) [130], more than 2,000 people visited the museum on weekdays, while the number of visitors on weekends could be up to 6,000. The group also introduced the aspect of the museum as an educational facility. Since the museum is expected to provide disaster education, especially to younger people, it had become the venue for disaster mitigation campaigns, such as the briefing on disaster preparedness done by 600 junior high school students who assembled in the area[130].

Chapter 3 Local Wisdom for Disaster Mitigation in Japan

Like Indonesia, Japan is prone to natural disasters and has experienced numerous disasters in the past. The experiences and lessons learned from these disasters have been handed down from generation to generation as local wisdom in each region.

After the Great East Japan Earthquake (hereinafter referred to as "GEJE") in 2011, news spread across the country about incidents in which lessons learned from past disasters were applied and enabled the survival of a lot of people in areas hit by the disaster. Subsequently, legal framework and a national policy indicated the direction in which disaster lessons and local wisdom should be utilized for disaster mitigation. Currently, various initiatives and disaster prevention education are being implemented across Japan adopting lessons learned from past disasters and local wisdom. Educational facilities in disaster-affected areas have also been developed to provide visitors the opportunity to learn about Japan's past disaster experiences.

In this Chapter, firstly, an inventory and summary of the most significant local wisdom in Japan is presented, followed by the people's perceptions regarding local wisdom. After that, utilization and dissemination of local wisdom are explored, which include legal and planning framework as well as national and local policies and activities. Then, research and publications related to disaster local wisdom are reviewed. Finally, initiatives in disaster prevention education for raising people's awareness, including educational programs and facilities, are summarized.

3.1 Most Significant Local Wisdom on Disaster in Japan

3.1.1 Local Wisdom by Types of Disasters

As Japan has experienced numerous disasters which have caused massive damages in many places, lessons learned from these disasters have been handed down from generation to generation in various forms of documents, drawings, stories, and proverbs in each region. Based on these lessons, there is diversity in local wisdom in Japan. Some examples of these that are related to earthquake and tsunami disasters are as follows:

Wisdom that informs of the threat or disaster risk of earthquake and tsunami

- Do not build your house on low ground.
- Be cautious of a tsunami when an earthquake occurs.
- A tsunami can occur even if there is no earthquake (the earthquake happened in other countries).

Wisdom that can be useful in determining actions during disasters

- Open the door immediately after an earthquake.
- Evacuate to higher ground when an earthquake occurs
- Tsunami tendenko (Run for your life to the top of the hill and never mind others or even your family when the tsunami comes.[127])
- Be cautious for at least an hour after a slow, long and massive shaking due to an earthquake.

Other sayings and proverbs related to signs of disasters

- If a mackerel sky is seen, an earthquake might occur.
- If a pheasant crows, an earthquake might occur.
- Fish might jump out of the water before an earthquake.
- If well water runs out, a tsunami might occur.

Table 3.1.1 shows examples of local wisdom including those in oral history and ancient manuscripts by disaster type (earthquake, earthquake and tsunami, and tsunami induced by volcanic eruption). Since there are numerous disaster histories and local wisdom throughout the country, examples that have the following characteristics were selected: their sources are clearly identified such as old documents and stone monuments; in particular, disaster lessons for future generation of local residents that have been handed down in various ways; and the handed-down stories are relatively highly recognized.

[127] Kodama S. 2015. Tsunami-tendenko and morality in disasters. J Med Ethics 2015; 41. Pp.361-363.

Table 3.1.1 Local Wisdom Including Those in Oral History and Ancient Manuscripts by Disaster Type

Type of Disaster	Title of Local Wisdom and/or Name of the Disaster	Area	Overview
Earthquake	Mikawa earthquake	Kota Town, Aichi	**Summary of the disaster story that has been handed down** On January 13, 1945, an inland earthquake – the Mikawa earthquake (Mg. 7.1) occurred. The depth of the epicenter was less than 10 km. The earthquake caused great damage mainly in Nishi-Mikawa (especially, in Fukozu and Sakasagawa, Nukata-gun, Kota Town). **Local wisdom and lessons learned from the disaster/method of handing down the story** The earthquake fault which was created by the Mikawa earthquake was named "The Fukozu Fault", and was designated as a natural monument by Aichi Prefecture on December 26, 1975. The area around the fault is open to the public for tours and being utilized as a place for learning about threat of an earthquake. The forms of the handed down data are documents and photographs which are posted on the town website. In addition, the earthquake hazard map of the town introduces the damage caused by a past earthquake that hit the area, and explains the vulnerable areas in the town by showing the distribution map of the earthquake[128]. **Sources** • Kota Town, Aichi. 1964. Kota-cho shi (History of Kota Town). Pp.53-57. • Kota Town website (description and pictures)
Earthquake and Tsunami	"Inamura-no-Hi (the fire of rice sheaves)"/Ansei earthquake and tsunami	Hirogawa Town, Wakayama Prefecture	**Summary of the disaster story that has been handed down** On November 5, 1854, the Nankai earthquake (Mg. 8.4, 5 m tsunami in coastal areas) occurred. Immediately after the earthquake, Goryo Hamaguchi let the evacuation of residents in Hiro Village to higher ground in order to save their lives from an imminent tsunami. An embankment was also built by Goryo and others after the tsunami with their private funds. **Local wisdom and lessons learned from the disaster/method of handing down the story** Goryo's anecdote was published as "Inamura-no-Hi (the fire of rice sheaves)" in the nationally designated school textbook before World War II, and distributed throughout the country. This story teaches the importance of early evacuation, the necessity of quick decisions and actions during natural disasters, giving high priority to saving people's lives, and so on. In order to hand down these stories and the town's culture on disaster mitigation to future generations, the town holds the tsunami festival in November 5, and the Inamura-no-Hi festival in October every year as well as developed and distributed a walking map to introduce places related to Goryo Hamaguchi[129]. Furthermore, a constructed embankment and other relevant sites has been designated as a *Japan Heritage* in May 2018[130] with the title of "*Eternal Relief - Heritage of Disaster Prevention Through the Memories of Tsunami and Recovery in Hirogawa*". Also, the Inamura-no-Hi no Yakata, which consists of the Hamaguchi Goryo Archives and the Tsunami Educational Center, inform visitors of the lessons from the anecdote Inamura-no-Hi. After the 2004 Sumatra earthquake, a disaster educational material introducing "Inamura no Hi" was developed and distributed to eight Asian countries in nine languages, including English, Thai, and Indonesian. The lessons from Inamura-no-Hi have been passed down across the globe[131]. **Sources** • Hirogawa Town, Wakayama. March 1974. Hirogawa-cho shi (Journal of Hirogawa Town). • Sugimura, K. April 1934. Hamaguchi Goryo Shoden (A short biography of Goryo Hamaguchi). • Sugimura, K. December 1937. Hamaguchi Goryo den Honyaku shu (Translation of the Biography of Goryo Hamaguchi). • Hamaguchi Goryo Monuments, Portrait, Hiro Village embankment • Illustrations showing actual situations of the Nankai earthquake and tsunami
	"Tsunami Tendenko"/ Meiji Sanriku Earthquake and Tsunami)	Iwate Prefecture	**Summary of the disaster incident which has been handed down** On June 15, 1896, the Sanriku earthquake (Mg.8.5) occurred. The entire coast of Iwate Prefecture was damaged by it. The maximum tsunami height in the coastal areas was 38 meters. **Local wisdom and lessons learned from the disaster/method of handing down the story** Since no one was able to predict the tsunami due to prior weak shaking caused by the earthquake, the area suffered great damage. There were so many cases wherein parents who were trying to save their children, and vice versa, consequently died together. The lesson from the experience led to the local wisdom "tsunami tendenko[132]", which was applied in the evacuation during the earthquake and tsunami in the Showa period. Besides that, there are other local wisdom related to earthquake and tsunami in Iwate Prefecture, including "Evacuate to higher ground if there is an earthquake"; "Do not build your house in a low ground"; "Run to higher ground when the tide recedes after an earthquake"; "Be cautious for at least an hour after a slow, long and massive shaking caused by an earthquake"; Tsunami can occur even the earthquake happened in another country, and so on. **Source** • Iwate Komonjyo Kenkyu Kai (Iwate paleography Research Group). 1999. Meiji Sanriku Daikaisho kanren bunsho (Meiji Sanriku tsunami-related document). Iwate Paleography Vol.5. Pp.9-160.
	Sanriku Earthquake and Tsunami (Meiji and Showa period)	Kesennuma City	**Summary of the disaster story that has been handed down** On June 15, 1896, the Meiji Sanriku earthquake occurred. In Kesennuma City, especially in the Hajikami district, after a weak shaking due to an earthquake with intensity 2-3, a huge tsunami said to be approximately 10 meters high hit the coastal area. The coastal villages of the city were almost completely destroyed with 442 victims. **Local wisdom and lessons learned from the disaster/method of handing down the story** Since the earthquake, the local wisdom "Be careful of a tsunami when an earthquake occurs" has been handed down from generation to generation and helped to mitigate the damage caused by the Showa Sanriku earthquake and tsunami in 1933. The forms of the handed down data include documents such as "the history of Kesennuma City" and inscriptions such as the large tsunami memorial monument at Iwaisaki, Kesennuma City, etc. **Summary of the disaster story that has been handed down**

[128] https://www.town.kota.lg.jp/soshiki/7/1378.html
[129] https://www.mlit.go.jp/common/001230612.pdf
[130] https://japan-heritage.bunka.go.jp/en/stories/story063/index.html#ancTabArea
[131] http://www.bousai.go.jp/kohou/kouhoubousai/h26/76/special_01.html
[132] "Tsunami Tendenko" is a traditional evacuation concept handed down in the Sanriku region where tsunami disasters have often occurred. It means "*run for your life to the top of the hill and never mind others or even your family when the tsunami comes*" (Cited from: Kodama S. Tsunami-tendenko and morality in disasters. J Med Ethics 2015;41:Pp.361-363.)

Type of Disaster	Title of Local Wisdom and/or Name of the Disaster	Area	Overview
			On March 3, 1933, the Showa Sanriku earthquake occurred. In Kesennuma City, especially in the Hajikami district, after an earthquake with an intensity of around 5, a massive tsunami hit the coastal area. In the city, 66 people died and more than 300 houses were swept away. **Local wisdom and lessons learned from the disaster/method of handing down the story** In relation to the earthquake and tsunami, there are local wisdom and lessons learned from the disaster such as “Be careful of a tsunami when an earthquake occurs” and “A huge tsunami will come when a strong earthquake occurs”. Also, there is local disaster folklore saying that a “dong” sound is heard in some places before a tsunami comes. Considering that the coastal areas of the Sanriku region have had a lot of tsunami disasters since ancient times, a monument was constructed in the tsunami-affected area after the Showa earthquake and tsunami. The forms of handed-down data include literary materials and inscriptions. **Source** • Kesennnuma City. 1993. Kesennuma-shi shi (The History of Kesennuma City). P.212-222. * including photographs of inscriptions
	1960 Chile Earthquake and Tsunami	Minamisanriku Town	**Summary of the disaster story that has been handed down** On May 24, 1960, an earthquake (Mg.9.5) occurred off the coast of Chile in South America, which was the strongest earthquake ever recorded. At that time, although JMA was able to observe the earthquake and the disaster situation in the Hawaiian Islands, it was not able to predict the impact to Japan and did not issue tsunami advisory and warnings. As a result, in Minamisanriku Town, the tsunami induced by the Chile earthquake caused 41 deaths, 500 injured, 319 houses lost and 1,023 houses collapsed or partially destroyed. **Local wisdom and lessons learned from the disaster/method of handing down the story** People had adhered to the saying "Be cautious of an imminent tsunami when there is an earthquake” since the Sanriku earthquake and tsunami hit the area in 1933. But a tsunami hit without the occurrence of an earthquake. Since an abnormal ebb tide was observed as a sign of the tsunami, the local wisdom "Beware of a tsunami if you see an abnormal ebb tide” emerged and added to the lessons learned from past earthquake and tsunami disasters. In order to commemorate the disaster experience, the town holds tsunami disaster prevention drill every May 24. The forms of the handed down data include literary materials, inscriptions of monuments, and photos showing the tsunami damage. **Sources** • Shizugawa Town (currently in Minamisanriku Town).1989. Shizugawa-Cho-shi II “Seikatsu no Yorokobi (Shizugawa Town Magagine “Joy of Life”. Pp.344-368. • Shizugawa Town 1990. Shizugawa-Cho Chile Jishin Tsunami Saigai 30 shunen kinen-shi(Shizugawa Town Commemoration of the 30th Anniversary of the Chili earthquake and tsunami disaster)
	1993 Hokkaido Nansei-oki Earthquake	Okushiri Town, Hokkaido	**Summary of the disaster story that has been handed down** On July 12, 1993, an earthquake (Mg. 7.8) occurred off the southwest coast of Hokkaido. The depth of the epicenter was 34 ㎞. The maximum height of the tsunami induced by the earthquake was 29 m. The tsunami damaged 60 municipalities in Hokkaido Prefecture. **Local wisdom and lessons learned from the disaster/method of handing down the story** Okushiri Island, which is close to the epicenter of the earthquake, was hit by the Central Sea of Japan Earthquake on May 26, 1983. 83 houses and other buildings were damaged by the tsunami (over 4 m tsunami hit the Aonae district in Okushiri Town). Based on this experience, immediately after the earthquake, the residents made their own decisions to evacuate to higher ground with only the barest necessities. That means, lessons learned from the past disaster experience were utilized. However, as the tsunami arrived very quickly and was much larger than expected, numerous people failed to evacuate and lost their lives. Besides the local wisdom “Evacuate to higher ground when an earthquake occurs”, there are several other lessons handed down in the town, such as “Checking your evacuation routes should be a daily watchword”; and “Open the door immediately after an earthquake". **Sources** • Okushiri Town. March 1996. *Hokkaido Nansei-oki Jishin Okushiri Kirokusho (Okushiri Town record of the 1993 Hokkaido Nansei-oki Earthquake)*. • Hokkaido Prefecture. March 1995. Heisei 5nen (1993) *Hokkaido Nanseioki Jishin Saigai Kiroku (Disaster record of the 1993 Hokkaido Nansei-oki Earthquake).*
Tsunami Induced by Volcanic Eruption	Landslide and Tsunami caused by Kansei Shimabara Chihen	Nagasaki Prefecture	**Summary of the disaster story that was handed down** In 1791, Mt. Fugen-dake in Unzen erupted. Amidst the frequent earthquakes and cracks in the ground, a strong earthquake (Mg. around 6.4) occurred on April 1, 1792 (in the old calendar). As a result, a part of Mt. Bizan on the west side of Shimabara City collapsed and damaged the southern part of Shimabara Castle area by landslide. The landslide reached the Ariake Sea and caused a tsunami, which damaged not only the Shimabara area but also the Ariake Sea coast, including Higo on the opposite shore killing 15,000 people. It was known as "Shimabara Taihen Higo Meiwaku” (meaning Shimabara eruption, Higo affected)". **Local wisdom and lessons learned from the disaster/method of handing down the story** The eruption of Mt. Fugen-dake shed viscous lava. As people were used to volcanic eruption, they went to watch it such that the feudal lords banned going near the site. In March 1792, a large number of residents including feudal lords were evacuated due to the frequent occurrence of strong earthquakes. When evacuees began to return because the earthquakes weakened, a collapse of Mt Bizan occurred and caused a catastrophe. For this reason, a lot of people still fear the collapse of Mt. Bizan whenever an eruption or earthquake occurs. Meanwhile, the local governments learned lessons from this disaster about the timing of evacuation and its cancellation. In the eruption in the Heisei period, governments utilized the lessons that gave them utmost caution. **Sources** • Shimabara City, Nagasaki. 1972. *Shimabara no rekishi <hansei hen> (the History of Shimabara <Feudal system edition>)*. .Pp.139-146. • Shimabara City, Nagasaki. 2002. *Fukamizo seiki (Fukamizo Century) vol.16.* Pp.25-41. • Memorial tower, monument, etc. (photos are filed in the City’s Board of Education)
		Kumamoto Prefecture	**Summary of the disaster story that has been handed down** On April 1, 1792, the eruption of Mt. Bizan on the Shimabara Peninsula in Nagasaki caused a major collapse that triggered a large tsunami in the Ariake sea, which had high tide at that time. The tsunami reached Kumamoto Prefecture and caused enormous damage to the coastal areas of the Ariake Sea, as well as in the Kumamoto Plain, the Uto Peninsula, and the Amakusa area. The height of the tsunami was 10 to 20 m, with a maximum height of 30 m. The death toll in Kumamoto Prefecture was approximately 4,600. **Local wisdom and lessons learned from the disaster/method of handing down the story** In Kumamoto Prefecture, there are 43 memorial towers, 5 stone monuments, 16 tombstones, and other ancient documents related to the Kansei Tsunami, which show the devastation and threat of the disaster. One of them describes the 23 m high tsunami. **Source**

Type of Disaster	Title of Local Wisdom and/or Name of the Disaster	Area	Overview
			• Kansei Otsunami 200 nen Jikko Iinkai (Executive committee of the 200 year anniversary of Kansei tsunami). August 1991. *Kansei Otsunami kara 200 nen – Unzen saigai (200 years since the Kansei Tsunami - Unzen Disaster)*
	Hokkaido's Mt. Komagatake eruption and tsunami	Hokkaido Prefecture	**Summary of the disaster story that has been handed down** On July 31, 1640, Mt. Komagatake in Hokkaido erupted on a massive scale. The mountain violently rumbled and the summit partially collapsed around noon. Due to that, an avalanche of debris flowed onto Onuma and Uchiura Bay, which triggered a tsunami that killed more than 700 people along the coast. After collapsed, the mountain violently spewed ash and volcanic debris until August 2, and caused volcanic ash and pyroclastic flows. These activities continued until the end of August. This volcanic eruption created Dekima-zaki, and formed Lake Onuma and Konuma almost as they appeared today. The eruption was recorded in many historical documents such as "Shinra-no-kiroku", "Matsumae Nennen-ki" and "Kiji Hirokata Oboegaki". **Local wisdom and lessons learned from the disaster/method of handing down the story** The 1640 eruption was the oldest recorded eruption in Hokkaido Prefecture and most extensive ever recorded at Mt Komagatake. Numerous historical documents recorded the eruptions and damages such as the sudden collapse of the mountain landform on July 31, 1640, whose debris flowed into the sea and induced a tsunami; a tsunami reached the Nyorai-do at Zenkoji in Usu on the opposite bank; approximately 100 ships were destroyed at Uchiura Bay (Eruption Bay). Furthermore, it is also recorded that there was significant mountain rumbling before the tsunami, while no signs of the eruption were recorded. **Sources** • Japan Meteorological Agency. "Mt. Komagatake, Hokkaido - Volcanic activity since prehistoric times"[133] • Appendices of Komagatake Volcanic Eruption inter-municipal disaster management plan[134]
	Oshima Island eruption and tsunami	Hokkaido Prefecture	**Summary of the disaster story that has been handed down** On August 18, 1741, Mt Nishi in Oshima Island erupted. From August 25, daylight darkened in Esashi district due to the ash fall. On August 29, 1741, a huge tsunami hit the coast from Kumaishi to Matsumae in Oshima Peninsula and caused 1,467 deaths in Hokkaido and Tsugaru, and 791 houses were washed away. (The island is currently uninhabited, although there had been seasonal residents who gathered seaweeds in the area.) That was one of the largest tsunamis ever formed in the Sea of Japan. The damage records in various areas are collected in the Earthquake Data (Monbu sho Shinsai Yobou Hyogikai (Council for the Disaster Prevention, Ministry of Education 1943). The volcanic eruption in Oshima was recorded not only in the Oshima coast, but also in the Tsugaru region across the strait. **Local wisdom and lessons learned from the disaster/method of handing down the story** There are two memorial towers to commemorate 120 deaths caused by the tsunami in Esashi village. One of the tsunami monuments at Shogakuin describes that the tsunami was accompanied by a sea rumbling and a luminous phenomenon at sea, and that several tsunamis swept ashore with such violent force as they rolled up stones on the beach (Tanaka 1936 cited by Hatori 1979). **Sources** • Japan Meteorological Agency. "Mt. Oshima Island, Hokkaido - Volcanic activity since prehistoric times"[135] • Matsumae City. 1997. Kanpo large tsunami caused by the eruption of Oshima Island, Historical Chronology, The History of Matsumae Town. • Hatori, T. 1979. "Memorial monument for the Hokkaido Oshima Island Tsunami (1741). Bulletin of the Earthquake Research Institute Vol.54 (1979). Pp.343-350[136]
	Sakurajima An-ei eruption and tsunami	Kagoshima Prefecture	**Summary of the disaster story that has been handed down** On November 8, 1779, Mt. Sakurajima erupted. Before the eruption, there were frequent earthquakes for several days. During mornings, wells on the coast had boiling water and flowing out, and the seawater turned purple. At about 14:00 in November 8, the mountain exploded with black smoke from the middle of the south side of it, and soon erupted from the middle of the northeast side. From the early morning of the next day, lava flowed out. In the evening, a submarine eruption started off in the northeast coast. A tsunami caused by submarine eruptions occurred in September and October 1780. On April 11, 1781, another eruption occurred off the coast of Komen and triggered a tsunami that caused the death of 8 people, 7 missing and 1 injured, and 6 ships perished. In May, another submarine eruption occurred. Between 1779 and 1782, the death toll was over 150. **Local wisdom and lessons learned from the disaster/method of handing down the story** At the Taisho eruption on January 12, 1914, since Sakurajima was considered a dormant volcano, the warning of the volcanic eruptions and the observation system were weak. Fortunately, a local legend of the An-ei eruption had been handed down among residents. Thus, a lot of residents who felt fear from the abnormal phenomena, such as change in well water, in the Island evacuated in advance, which led to the minimized number of victims even though there was great eruption[137]. The reason for the low death toll of 25 during the eruption occurrence, which was said to be the strongest eruption in Japan in the 20th century, is believed to be due to the residents' voluntary evacuation and quick rescue activities of residents and local governments. A monument showing the lessons of the eruption says: "Residents should not trust theories (or rely on theories alone), and if you notice anything unusual, it is important to prepare for evacuation before an eruption occurs" [138]. **Sources** • Japan Meteorological Agency. "Sakurajima, Volcanic Activity since prehistoric times. [139] • Ishihara, K. 2013 "20-Seiki saidai no Sakurajima Taisho Funka to sono kyokun – Sakurajima no Funka no Rekishi (The Sakurajima Taisho Great Eruption in the 20th Century and Its Lessons: The History of Sakurajima's Eruptions - 1[140]

Source: JICA Expert Team (References: FDMA[141], JMA[142])

[133] https://www.data.jma.go.jp/svd/vois/data/sapporo/113_Komagatake/113_history.html
[134] https://www.town.hokkaido-mori.lg.jp/docs/2015030900013/files/kanmatushiryo.pdf
[135] https://www.data.jma.go.jp/svd/vois/data/sapporo/115_Osimaosima/115_history.html
[136] https://repository.dl.itc.u-tokyo.ac.jp/?action=repository_action_common_download&item_id=33110&item_no=1&attribute_id=19&file_no=1
[137] http://www.bousai.go.jp/kyoiku/kyokun/kyoukunnokeishou/rep/1914_sakurajima_funka/pdf/09_owarini.pdf
[138] https://www.nhk.or.jp/sonae/column/20130809.html
[139] https://www.data.jma.go.jp/svd/vois/data/fukuoka/506_Sakurajima/506_history.html
[140] https://www.nhk.or.jp/sonae/column/20130809.html
[141] https://www.fdma.go.jp/publication/database/item/database009_01_01.pdf
[142] https://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/kaisetsu/volcano_disaster.htm

Since the descriptions of the disaster history and local wisdom in Table 3.1.1 were based on traditional information from the sources, the disaster and location names may differ from the historical facts, or may not represent the actual disaster situations and records. Therefore, it is necessary to understand these local histories and the wisdom as the strong desire of ancestors to hand down the experiences of past disasters to the future generation, and focus on the facts contained in the stories that have been handed down in the region.

As shown in the table, disaster histories, as well as local wisdom and lessons related from disasters, have been handed down to future generations through stone and memorial monuments in the local areas. There are also some cases that municipalities or national governments designated disaster-related sites or remains as significant disaster remains, cultural properties, and natural monuments with local lessons learned from past disasters. They also established disaster educational centers together with the disaster remains and, comprehensively and continuously, have managed the areas with ensured budgets. Furthermore, some municipalities create hazard maps with photos of past disasters to raise people's awareness, while others organize events and disaster drills in relation to the local disaster history, and local wisdom and lessons learned from the disasters. Through these ways, the disaster histories and local wisdom have been handed down from generation to generation in the regions. Indeed, there are actual cases that local wisdom has been handed down and effectively utilized during disasters. For example, according to a survey conducted by Sato *et al*. (2017)[143] in 2016 on 1,560 households (357 valid responses) in Rikuzentakada City, which was a disaster-affected area, many of the residents who evacuated from the tsunami during the GEJE had heard about the facts and lessons learned from the Showa Sanriku earthquake and tsunami that hit the same area, through oral traditions and mass media, and they had opportunities to discuss how to respond to and prepare for disasters with their family members.

3.1.2 Perception of the Public Toward Local Wisdom on Disaster

After the GEJE, various researchers, mass media, and local governments have conducted surveys and research on the perception of handing down disaster lessons and local wisdom among citizens. This section describes the perception on local wisdom at the citizen's level by presenting the review of two research results. These survey results revealed that more people recognized local wisdom on disaster after the GEJE, and that numerous respondents currently want to hand down disaster lessons and local wisdom to the future generation.

(1) Perception of the Public Toward Local Wisdom on Disaster Before and After GEJE

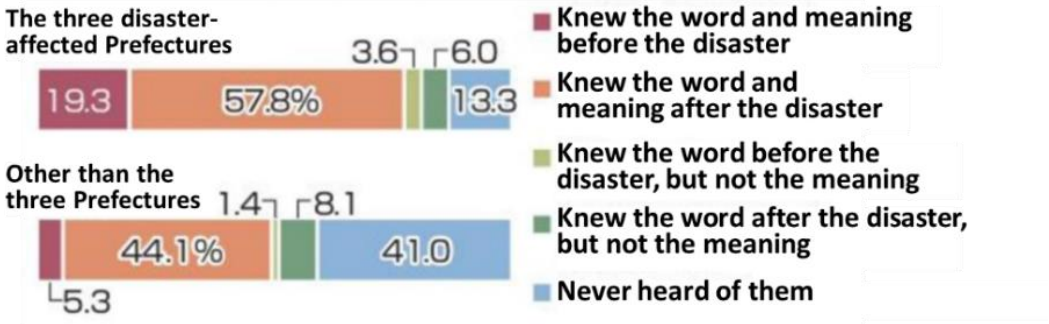
A local wisdom "tsunami tendenko[144]," which has been handed down from generation to generation in the Sanriku region, led to the "The Miracle of Kamaishi"(see 3.2.4 for details). This experience was featured in various media. Currently, the disaster prevention slogan is recognized by more people than before the disaster. Indeed, according to a joint survey conducted by 15 local newspapers[145], including Kahoku Shimpo Publishing Co., more than 40% of the people nationwide learned the word (phase) and its meaning after the disaster. In the three disaster-affected prefectures of Iwate, Miyagi, and Fukushima, the percentage was 57.8%, which was higher than the survey's national average. When combined with the 19.3% of respondents who said that they had known the word and its meaning before the disaster, the figure reached approximately 80%. Therefore, the perception of the public toward local wisdom has been

[143] Sato, S., Hirakawa, Y., Shinka, A. and Imamura, F. 2017. Did Disaster Tradition Activities Promote Tsunami Evacuation Behavior? : Case Study Using Questionnaire Survey in Rikuzentakada City, Iwate Prefecture: *Journal of social safety science* 31:69-76.

[144] "Tsunami Tendenko" is a traditional evacuation concept handed down in the Sanriku region where tsunami disasters have often occurred. It means "*run for your life to the top of the hill and never mind others or even your family when the tsunami comes*" (Cited from: Kodama S. Tsunami-tendenko and morality in disasters. J Med Ethics 2015;41:Pp.361-363.)

[145] The research was conducted through utilizing the free communication application "LINE" and other tools to connect reporters of 15 local newspapers nationwide including the Kahoku Shimpo with readers, as a part of an "on-demand investigation reporting" program aiming to solve questions about daily life and local issues. This collaborative project received answers from 1,699 people in 40 prefectures. Of these, 166 respondents were from the three disaster-affected prefectures of Iwate, Miyagi, and Fukushima. Note that this was different from general surveys of public opinions.

affected by the GEJE. On the other hand, while 44.1% of the respondents outside the three prefectures learned the phrase and its meaning after the disaster, 41.0% had never heard them. Therefore, there is still a difference between disaster-affected prefectures and others.



Source: Kahoku Online News (Mar. 5, 2021)[146] (Translated by JICA Expert Team)

Figure 3.1.1 Perception on "Tsunami Tendenko"

(2) Perception of the Public Toward Handing Down Disaster Stories in the Tohoku Region

In Japan, perception of the public toward handing down disaster stories has been also revealed by surveys and studies conducted by researchers and local governments. For instance, Sendai City conducted a questionnaire survey in 2020 targeting 5,000 citizens of the city aged 16 or older (1,969 valid responses)[147]. According to the result, relatively many respondents answered that they are "already handing down or preserving" (37.7%) and "eventually want to hand down or preserve" (37.2%) the disaster lessons of the GEJE, which means that 74.9% of the respondents wanted to hand them down. In terms of effective activities for children who have not experienced an earthquake to increase their awareness on disaster prevention, the most popular responses were "Participating in evacuation drills at schools or in the communities" (62.9%), followed by "Visiting disaster-related facilities (e.g., disaster memorial facility - the Arahama Elementary School, the tsunami evacuation tower)" (48.9%), and "Listening to storytellers and people who have experienced the GEJE" (45.5%). This indicates that citizens in Sendai City are aware of the effectiveness of handing down disaster lessons and local wisdom in raising people's awareness on disaster prevention.

3.2 Utilization and Dissemination of Local Wisdom on Disaster

Although disaster wisdom in Japan has been handed down at the local level, it is expected to be utilized for enhancing public awareness on disaster prevention. Indeed, the FDMA collected information on disaster histories and wisdom nationwide from 2004 to 2006, and has opened the information to the public through its website. Specifically, after the GEJE in 2011, the government reviewed the Basic Act on Disaster Management and stipulated that citizens are responsible for handing down the lessons on disasters, and that disaster management agencies – including the national and local governments and private agencies – should strive to implement disaster prevention education[148]. In response to the government policy, there are initiatives being actively implemented by private organizations and academic institutions, as well as activities carried out through the collaboration of government, industry, and academe for disseminating disaster histories and lessons. This section describes legal and planning framework to enable the utilization of local wisdom on disaster, and provides detailed examples of related initiatives and activities.

[146] https://kahoku.news/articles/20210305khn000025.html
[147] Sendai City. 2020. Bosai ni Kansuru Shimin Ishiki Anke-to Chousa Houkokusho (The Report on a questionnaire survey on citizens' awareness of disaster prevention
[148] Act on Partial Amendment of the "Basic Act on Disaster Management (Act No. 41 of 2012) enacted in June 2013

3.2.1 Legal and Planning Framework to enable the utilization of Disaster Local Wisdom

This section summarizes the administrative principles and policies that have been developed and announced in the wake of the GEJE. In Japan, the national government revised the Basic Act on Disaster Management, and newly stipulated the "enhancement of disaster awareness through handing down lessons learned from past disasters and strengthening disaster prevention education" in the Act. In addition, the "Principles for Reconstruction" issued two months after the GEJE in May 2011 clearly states these principles scientifically analyzing the records of the disaster, handing down the lessons to the next generation, and disseminating them both domestically and internationally. It also regards the handing down of local wisdom as a primary function of reconstruction.

(1) First Revision of the Basic Act on Disaster Management: The Enhancement of Disaster Awareness Through Handing Down Lessons Learned from Past Disasters and Strengthening Disaster Prevention Education

Based on the lessons learned from the GEJE, the first revision of the Basic Act was submitted to the House of Representatives on May 18, 2012, during the 180th session of the National Diet of Japan, and this was enacted on June 20, 2012. The revised Act clearly stipulated that it is the responsibility of residents to hand down lessons learned from disasters, and that each disaster prevention-related agency, including the national and local governments and private agencies, shall endeavor to implement disaster prevention education in order to raise the people's awareness on disaster prevention.

> ***(Responsibilities of Residents)***
> ***Article 7 (3)*** *(...), local residents must endeavor to (...) contribute to disaster management by voluntarily participating in disaster reduction drills and any other disaster management activities, and handing down lessons learned from past disasters, and any other challenges.*
>
> ***(Exercising of Care in the Interest of Disaster Management in Enforcing Measures)***
> ***Article 8 (2)*** *In the interest of preventing a disaster from occurring and of preventing the spread of a disaster that has occurred, the State and local governments must particularly endeavor to carry out the following matters:*
> ***(xiii)*** *(...) matters on the encouragement of the citizens to engage in voluntary disaster management activities such as (...), supporting activities to hand down lessons learned from past disasters, (...) ;*

Source: The Basic Act on Disaster Management[149]

Figure 3.2.1 Articles Related to Handing Down Disaster Lessons in the Basic Act on Disaster Management

In terms of handing down disaster lessons, it is assumed that various materials (including the results of research and analysis, and videos on large-scale disasters) will be widely collected, organized, appropriately stored, and be accessible to the public. Regarding disaster prevention education, it is envisaged that textbooks and manuals will be distributed to staff of various disaster prevention-related agencies and that training on disaster prevention will be provided for them in cooperation with educational institutions[150].

(2) Reconstruction Design Council's "Toward Reconstruction - Hope Beyond the Disaster" and the Establishment of the Basic Policy on Disaster Reconstruction

One month after the GEJE, the Reconstruction Design Council, an advisory panel of intellectual figures, has been set up by the Government of Japan. In response to the massive disaster that occurred, it developed the "Seven Principles for the Reconstruction Framework" followed by "Toward Reconstruction – Hope Beyond the Disaster", as reconstruction policies for the GEJE

[149] http://www.japaneselawtranslation.go.jp/law/detail/?id=3322&vm=&re=
[150] https://www.sangiin.go.jp/japanese/annai/chousa/rippou_chousa/backnumber/2013pdf/20131001125.pdf

impacts at the national level.

Principle 1 of the "Seven Principles for the Reconstruction Framework" announced in May 2011 cites that "*we shall record the disaster for eternity, including through the creation of memorial forests and monuments, and we shall have the disaster scientifically analyzed by a broad range of scholars to draw lessons that will be shared with the world and passed down to posterity.*"[151] Hence, the panel regard the handing down of disaster lessons to the next generations as a primary function of reconstruction. Furthermore, Principle 2 states that "*we shall make community-focused reconstruction the foundation of efforts toward recovery. The national government shall support that reconstruction through general guidelines and institutional design*"[137], which makes it clear that the local communities are the main actors in the reconstruction process, while the national government is the one supporting it. The policy "Toward Reconstruction – Hope Beyond the Disaster", which was decided upon in the following month after 14 meetings of the Reconstruction Design Council and 8 review subcommittees, includes the following statements. It can be seen that great significance has been placed on handing down disaster lessons.

- *(…) disaster prevention education, etc. needs to be promoted with the participation of a wide range of residents and which draws on the characteristics of the communities.*
- *In order to prevent damage of a similar nature in the future, we must share the lessons learned from the Great East Japan Earthquake with all regions and generations.*
- *Japan should record and preserve the lessons of what it has learned from the earthquake, tsunami and nuclear disasters by first creating a core facility and then establishing solid links between that facility and entities such as local governments and universities. Furthermore, a structure for preservation and disclosure of records should be developed, utilizing public-private consortiums.*
- *Japan must promptly gather information materials and tsunami heritage information and develop a system to allow anyone, whether they be in Japan or abroad, to access, store, and use this information in an integrated manner.*

Source: The Reconstruction Design Council in Response to the Great East Japan Earthquake[137]

Figure 3.2.2 Remarkable Statements Related to Handing Down Disaster Lessons

After the establishment of "Toward Reconstruction – Hope Beyond the Disaster", the "Basic Reconstruction Policy" was formulated in 2011, and it had been updated in 2016 and 2019. In the updated basic policy, approved by the Cabinet in 2019, the description about the utilization of the network and know-how of various organizations was added to the parts that apply to disaster prevention tradition. In addition, the description about cooperation between several disaster educational facilities was also clarified.

3.2.2 Policy and Activities to Utilize Local Wisdom on Disaster

The GEJE led to an awareness of the importance of handing down disaster lessons and local wisdom for disaster preparedness at the national level, which resulted in the development of legal framework and principles. Following that, the government has been promoting activities related to handing down the disaster lessons and local wisdom, including the development of specific policies and plans contributing to handing-down practice at each level. In particular, the Cabinet Office (CAO), and FDMA of the Ministry of Internal Affairs and Communications (MIC) have developed their specific policies and implemented concrete activities regarding handing down disaster lessons. Some local governments affected by the GEJE also developed their policies and plans in order to promote related activities and projects. This section provides some specific examples below.

(1) Central Disaster Management Council, CAO

In accordance with the Basic Act on Disaster Management, the Central Disaster Management Council stipulated the policy and activity related to handing down disaster lessons in the Basic

[151] http://www.cas.go.jp/jp/fukkou/english/pdf/report20110625.pdf

Disaster Management Plan, as described in Figure 3.2.3.

4. Passing on disaster lessons

- *In order to ensure that disaster lessons learned from past massive disasters and disaster culture will be passed on to the next generation, the national government (CAO, GSI, each ministry, National Diet Library, National Archives of Japan, etc.) and local governments shall endeavor to widely collect and organize various materials, including the results of surveys and analyses of large-scale disasters and video images, as archives, appropriately store them, and make them available to the public through mapping them and other methods. In addition, they shall endeavor to correctly convey to future generations the meanings of stone monuments and monuments related to disasters.*
- *[…]. In addition to raising awareness of the importance of passing on disaster lessons, the national government (CAO, etc.) and local governments shall support the activities of local residents to pass on disaster lessons by collecting, storing and disclosing various materials […].*

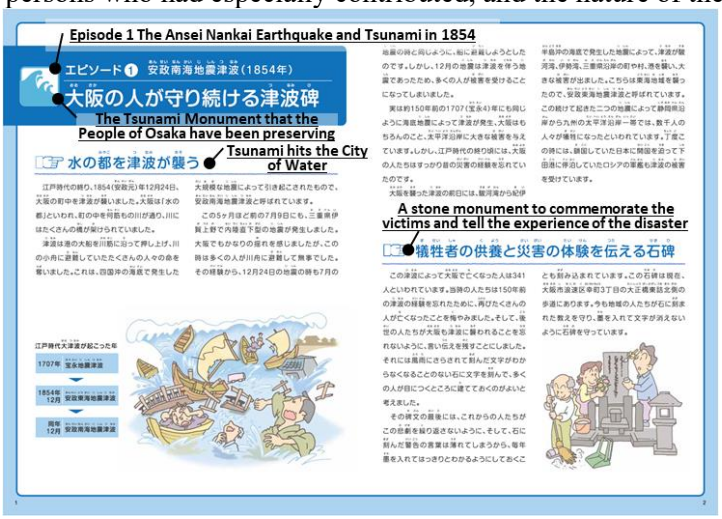
Source: The Basic Disaster Management Plan[152] (Translated by JICA Expert Team)

Figure 3.2.3 Description Regarding Handing Down Disaster Lessons in the Basic Disaster Management Plan

Indeed, even before the GEJE, CAO has been promoting activities related to passing on of disaster lessons. One of these activities was the establishment of the Expert Committee on Disaster Lessons and the development of related learning materials. In 2003, the Central Disaster Management Council established the "Expert Committee on Disaster Lessons" at the Central Disaster Management Council, with the aim of accurately handing down the experience and wisdom of past disasters by systematically collecting information on the disaster damage, government response, impact on people's livelihoods, and socioeconomic impacts, in order to raise public awareness on disaster prevention, and contribute to future disaster response[153].

The committee compiled the records and lessons learned from past disasters in a structured and systematic manner, and organized them as a report and a learning textbook, bearing in mind the following points. These data are available on its website.

- To be organized by types of disasters such as earthquake, volcanic eruption, tsunami, flood, and so on.
- To include the situations of disaster damage, government's response, impact on people's lives and the persons who had especially contributed, and the nature of the contribution



Source: Cabinet Office (2012)[154] (Translated by JICA Expert Team)

[152] http://www.bousai.go.jp/taisaku/keikaku/pdf/kihon_basicplan.pdf
[153] http://www.bousai.go.jp/kyoiku/kyokun/kyoukunnokeishou/index.html
[154] http://www.bousai.go.jp/kyoiku/kyokun/kyoukunnokeishou/pdf/saigaiwokataritsugu_a3_201203.pdf

Figure 3.2.4 Brochure on Handing Down Disaster Lessons

(2) Fire and Disaster Management Agency (FDMA) of the MIC

FDMA, which is an external agency of MIC, also stipulates in its Disaster Management Operation Plan that it will provide advice to the activities of local governments to pass down lessons learned from disasters[155]. In terms of practical activities, FDMA compiles records, drawings, stories, proverbs, etc. in relation to disasters throughout the country, which were collected through surveys from 2004 to 2006 with the cooperation of prefectures and municipalities. These are accessible to the public through its website and serve as the national information on handing down disaster histories. This database is expected to be utilized as a disaster educational material, as well as to lead individuals to recognize lessons learned from past disasters and raise people's disaster awareness. In particular, the following information is listed on the website.

- "Disasters" that have been handed down to the present
- "Folklore" (handed-down disaster experience) related to disaster prevention
- Individual activities for disaster prevention
- Organization's activities for disaster prevention
- Exhibitions and educational facilities related to disaster prevention

Furthermore, based on the experience from the GEJE, FDMA launched a storytelling project called "The 10-Year Project of Passing Down Disaster Lessons"[156]. Under the project, registered storytellers, including local government officials, firefighters, and community disaster prevention group members engaged in activities in disaster-affected areas, have been dispatched to various municipalities in Japan to deliver lectures and other activities. The project is expected to strengthen the capability on disaster response of municipalities and raise awareness on disaster prevention among local residents.

(3) Geospatial Information Authority of Japan (GSI) of the MLIT

MLIT also states in the Disaster Management Operation Plan that it shall develop materials on disaster prevention education through organizing past disaster records and passed-down disaster experiences in regions. One of the activities implemented by the Ministry and related external agencies is a memorial monument mapping activity. The Geospatial Information Authority of Japan (GSI), which is an external agency of the MLIT, adds the locations of disaster monuments, which were established by ancestors to show disaster lessons, nationwide on GSI maps that can be accessed on its website. In Japan, while there are cases that residents utilized disaster lessons written on monuments to save their lives, numerous valuable messages on these monuments are not being fully utilized in regions. In consideration of this situation, through the activity, GSI aims to appropriately pass down past disaster lessons to residents and, based on these, mitigate disaster damage by the residents' preparedness[157]. The web-based map is expected to be utilized for the following purposes:

- To be utilized as a learning material in primary and junior high schools to enable understanding of the disaster histories in the regions
- To be utilized as a target site when setting up a walking tour course in order to create an opportunity for participants to naturally know past disasters while walking around the area
- To be utilized as a material for students to create original disaster prevention maps through hands-on experience, including field surveys

[155] https://www.fdma.go.jp/laws/laws/items/bousaigyoumukeikaku.pdf
[156] https://www.fdma.go.jp/publication/hakusho/h30/chapter4/para1/38341.html, https://www.fdma.go.jp/relocation/10yearsproject/
[157] https://www.gsi.go.jp/bousaichiri/denshouhi.html

Source: Geospatial Information Authority of Japan[158]

Figure 3.2.5 GSI Web-Based Map Showing Locations of Natural Disaster Monuments

(4) Miyagi Prefecture

In the fiscal year 2017, Miyagi Prefecture established the "Expert Committee to Study Handing Down Disaster Memories and Lessons Learned from the GEJE" consisting of experts including academia to discuss the prefecture's approach, contents of the activities, and implementation system of handing down memories and lessons from the earthquake. Subsequently, in 2021, the prefecture developed the "Basic Policy on Handing Down the Memories and Lessons of the GEJE", which clearly states the direction of activities for handing down disaster memories and lessons, as well as the policies for steadily implementing such activities.

This Basic Policy has the following basic principles: "1- Continuing to hand down the experience of the GEJE, the process of recovery and reconstruction, and the lessons learned from it to the present and the future generations. 2- Creating a society where every individual can protect his/her precious life and "take actions to save her/his own life during disasters." Based on these principles, the following pillars of activities were established: 1) Accumulation and dissemination of memories and experiences on the disaster; 2) Development of human resources regarding passing down disaster records and disaster prevention and mitigation, as well as promotion of disaster prevention education; 3) Promotion of handing down disaster memories and lessons through cooperation among various organizations. For each of these pillars, specific activity policies are outlined. In addition, in accordance with the Basic Policy, the prefecture established a specific division of the Reconstruction Support and Passing Down Disaster Records in the Reconstruction and Crisis Management Department within the prefectural government to promote the initiative[159], and in implementing 18 projects in the fiscal year 2021[160]. Examples of major projects are shown below.

Accumulation and dissemination of memories and experiences of the disaster

- **Project for disseminating information on the area affected by the GEJE:** Creating records and videos related to the period of the development of the Prefectural Disaster Reconstruction Plan, archiving the information of disaster reconstruction and making it available to the public, etc.
- **Passing on the 3.11 disaster record and disaster mitigation project:** Displaying panels to raise awareness on disaster prevention and to disseminate the current state of reconstruction from the disaster, etc.

Development of human resources for passing down disaster records and disaster prevention and mitigation

[158] https://maps.gsi.go.jp/#12/35.690959/139.745750/&base=english&ls=english%7Cdisaster_lore_all&disp=11&lcd=disaster_lore_all&vs=c1j0h0k0l0u0t0z0r0s0m0f0&d=m
[159] https://www.pref.miyagi.jp/uploaded/attachment/844116.pdf
[160] https://www.pref.miyagi.jp/uploaded/attachment/844120.pdf

- Project for promoting the development of local disaster prevention leaders: Organizing training courses and follow-up courses, and dispatching advisors
- Training project by visiting disaster-affected areas: Conducting training for teachers and staff through visiting the disaster-affected areas

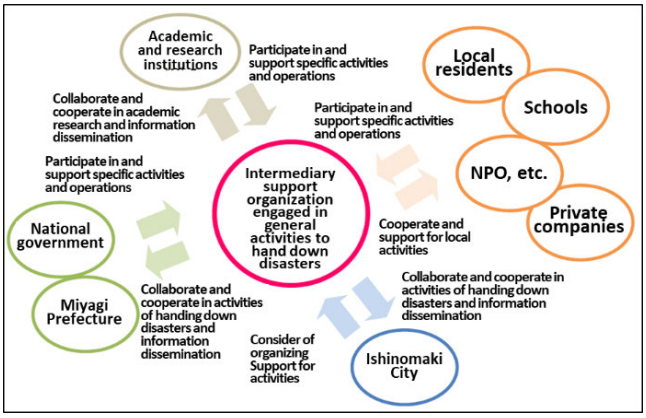
Promotion of handing down disaster memories and lessons through cooperation among various organizations.

- Project for promoting handing down the GEJE experience: Promoting the cooperation of various organizations engaged in handing down disaster memories and lessons, setting up the specialists who will do the promotion activities.
- Reconstruction activity support project: Support activities of the reconstruction workers, which can be done by sharing information on the current situation and issues in the disaster-affected areas and examples of reconstruction support activities to private organizations and Non-Profit Organizations (NPOs) which work for reconstruction support

(5) Ishinomaki City, Miyagi Prefecture

Ishinomaki City, Miyagi Prefecture developed the "Ishinomaki City Plan for Disseminating Earthquake Disaster Record" in June 2017, based on discussions during the meeting of the "Review Council for Disseminating Earthquake Record" composed of academic experts, local residents, NPO, and governmental organizations[161]. The basic policies of the Plan are: (1) to promote the continuous collection and utilization of materials, (2) to create opportunities for learning about the disaster (disaster prevention), (3) to disseminate the experience and lessons learned from the disaster domestically and internationally, (4) to develop a place for commemoration and remembrance, (5) to develop a place for activities of handing down disaster lessons, and (6) to establish a promotion system to support sustainable activities. The Plan indicates the policy to implement specific projects by utilizing the reconstruction financial resources and so on.

In order to implement the Plan, the city clearly outlines a concrete image of the promotion system that will enable various actors (e.g., the national government; Miyagi Prefecture; academic and research institutions; other organizations involved in handing down disaster lessons) to share the importance of passing down disaster lessons and obtain their commitments as leaders of these activities, as well as to sustainably implement their activities. This is based on the perspective that it is necessary to have a stable system that can support their activities, as well as have a flexible and specialized organization that can expand activities and disseminate them to the world. The system also aims to promote collaboration between industry, academia, governments, and private sectors, as well as to develop human resources in the community, centering on the "intermediary support organizations engaged in general activities to hand down disaster lessons"[162].



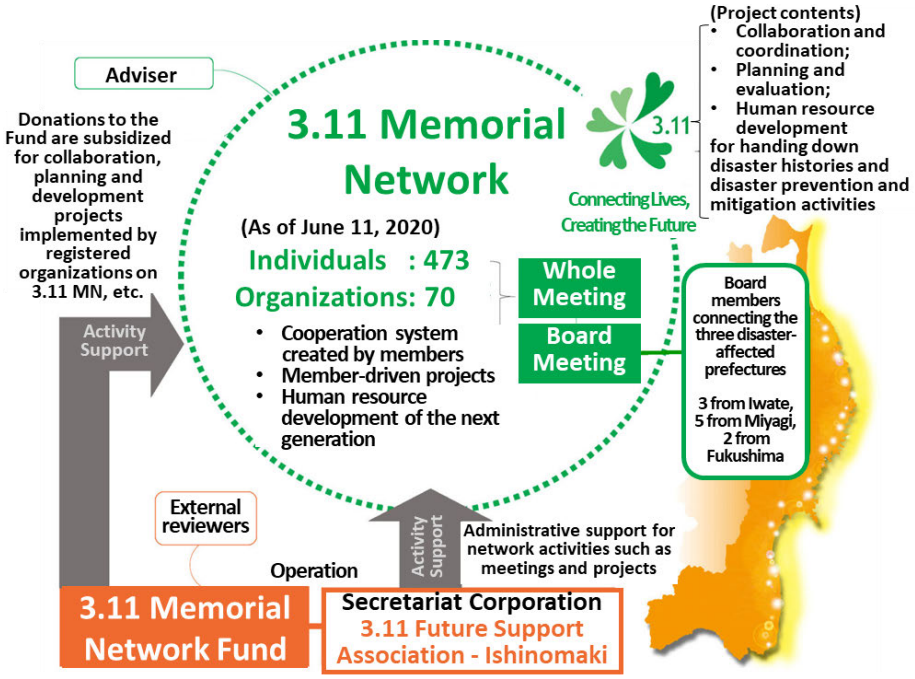
[161] https://www.city.ishinomaki.lg.jp/cont/10051100/9003/20170608155535.html
[162] https://www.city.ishinomaki.lg.jp/cont/10051100/1002/04_betten1.pdf

Source: Ishinomaki City (2017)[148] (Translated by JICA Expert Team)

Figure 3.2.6 Promotion System comprised of Intermediary Support Organizations

(6) Private Agencies and Networks (3.11 Future Support Association)

In addition to initiatives led by government agencies, there are also activities implemented by private agencies and created networks which are composed of multiple private or public agencies. One of them is the 3.11 Memorial Network, which is a network of individuals and organizations involved in handing down activities in Iwate Prefecture, Miyagi Prefecture, and Fukushima Prefecture, established by 3.11 Future Support Association. The network aims to create a society in which no lives are lost in disasters, and in which disaster victims and disaster-affected areas can alleviate their hardships and move toward reconstruction, through creating a network of individuals, organizations, and facilities involved in passing down disaster lessons across regions and generations, and sharing the awareness of facing the past experiences and preparing for the future throughout Japan and around the world[163]. The network offers programs on handing down disaster histories such as story-telling and guided vehicle tours, as well as establishes and manages a disaster exhibition with a socializing space. Furthermore, it also conducts these activities in foreign languages to pass down disaster experiences to foreigners[164].



Source: 3.11 Future Support Association[150] (Translated by JICA Expert Team)

Figure 3.2.7 Operational Structure of 3.11 Memorial Network

[163] https://311mn.org/aboutus
[164] https://311support.com/assist/311network

Source: 3.11 Future Support Association[165]

Figure 3.2.8 Some Activities of 3.11 Memorial Network

3.2.3 Research and Publications Related to Local Wisdom on Disaster

In Japan, numerous local governments have recorded past disaster experiences in the form of a document and video, and uploaded them on their websites. The information can be utilized as teaching materials for local disaster education. This section shows examples of research conducted and managed by the national and local governments, and publications.

(1) Disaster Record Book (Fukushima Prefecture)

Numerous local governments throughout Japan compile records of disasters that have occurred in each region in book form (commonly referred to as "Record Book"), and let the public access this on their respective websites. Regarding GEJE records, many municipalities in the Tohoku Region and the Kanto Region created them. For example, Fukushima Prefecture created Disaster Record Books divided into three editions: an overview of the damage; an initial response to the disaster; and recovery and reconstruction. The Kansai Region, Hyogo Prefecture, on the other hand, produced a record book called "The Great East Japan Earthquake: One Year Support from Hyogo", which is available on its website.

Source: Fukushima Revitalization Station[166] (Translated by JICA Expert Team)

Figure 3.2.9 Disaster Record Books on the GEJE Experience Created by Fukushima Prefecture

(2) Disaster Videos (Miyagi Prefecture)

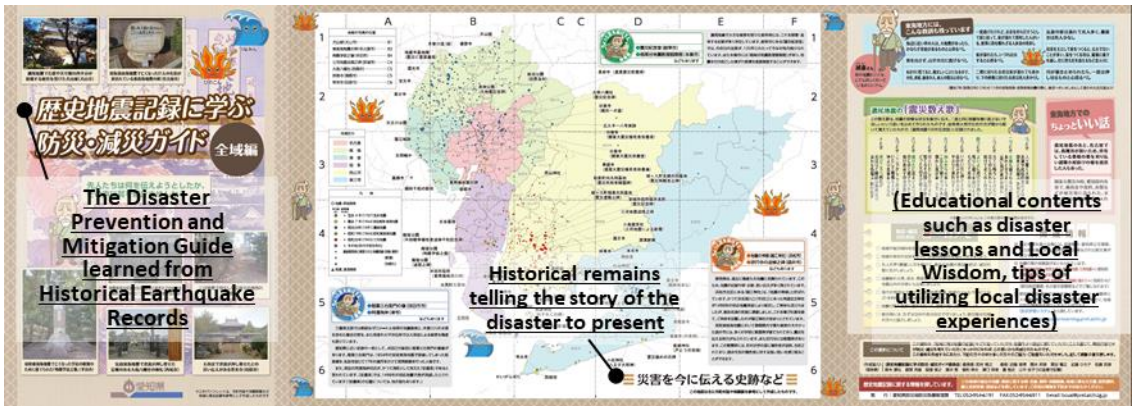
In terms of video recording, Miyagi Prefecture produced "The Great East Japan Earthquake: The

[165] https://311mn.org/everyone
[166] https://www.pref.fukushima.lg.jp/site/portal-english/

Record of Miyagi Prefecture", which is available on its website and DVD rent free to the residents. Miyagi Prefecture also created a video of its recovery and reconstruction activities. In relation to the GEJE experience, Chiba Prefecture also produced a DVD in April 2013 titled "Passing Down to the Future – The Record of the Great East Japan Earthquake in Chiba Prefecture", and this is available on its website. The DVD form is also available rent free to residents of the prefecture. Tottori City also produced a DVD about earthquake experience, called "Passing Down the Memory of the Earthquake - What We Learned from the Tottori Great Earthquake" and rents this out to residents.

(3) Guidebook Illustrating Historical Disaster Records and Remains (Aichi Prefecture)

Aichi Prefecture compiles and organizes records of past earthquakes in the prefecture as part of the "Project on Creating a Disaster Prevention and Mitigation Guidebook Based on Historical Earthquake Records and Raising Public Awareness", and created the disaster prevention and mitigation guidebook with 7 types of maps (one map for each of the 6 regions and 1 for the whole prefecture). This guidebook is available on its website, and it is also distributed in 71 venues in the prefecture by its team for handing down the disaster histories and memories. In addition, the prefecture implements various activities to raise disaster awareness of the residents such as displaying panels, showing DVDs on earthquake disaster prevention, playing picture-story shows on disaster prevention, implementing a simulation game for preventing furniture from falling over, and conducting questionnaire surveys[167].



Source: Aichi Prefecture (2014)[168] (Translated by JICA Expert Team)

Figure 3.2.10 Disaster Prevention and Mitigation Guidebook of Aichi Prefecture

3.2.4 Disaster Prevention Education and Awareness

In Japan, disaster prevention education is conducted in elementary and junior high schools by utilizing not only textbooks of social studies and science, but also moral and safety supplementary materials. Some materials created at the prefectural level introduce examples of disaster histories and local disaster lessons. In addition, each school level has disaster educational program and this is being carried out across the country, including awarding activities. This section summarizes examples of disaster prevention education and awareness, utilizing disaster wisdom and disaster lessons.

(1) Tsunami Disaster Prevention Education Based on the principle of "Tsunami Tendenko" (Kamaishi City, Iwate Prefecture)

Even before the GEJE, Kamaishi City in Iwate Prefecture had been conducting tsunami disaster prevention education based on the principle of "tsunami tendenko", which means that in the event of a tsunami, residents should separately flee at once to high places, prioritizing their own safety

[167] Takeda, F., Takeuchi K. and Mizuyama, T. 2017, A Study on Local Governments' Efforts to Hand Down Lessons Learned from Disasters in Japan. *GRIPS Discussion Paper 17-02*
[168] https://www.pref.aichi.jp/bousai/densho/pdf.html

than that of others, even if they are separated from family members. The principle is handed down in the Sanriku Region.

Through creating maps of evacuation centers and attending evacuation drills, local children had learned how to evacuate even by themselves, and can tell where they can evacuate and where to meet with their families so that they can evacuate adhering to the "tendenko" (separate) principle during an emergency.

During the GEJE disaster, students of Unosumai Primary School and Kamaishi Higashi Junior High School, located near the coast in the Unosumai district, immediately started evacuating to the school's designated evacuation site in accordance with what they learned from tsunami disaster prevention education. Even after they arrived at the evacuation site, once they recognized that it was unsafe due to the collapse of the cliff behind the site, they moved to a nursing care and welfare facility located on higher ground, which was a designated tsunami evacuation site. At the facility, due to the huge tsunami coming over the school building, they ran farther up to a stone shop along Route 45 on higher ground, and saved their lives[169].

Unosumai Primary School and Kamaishi Higashi Junior High School were located outside the inundation area on the tsunami hazard map. However, the students recognized that their locations were close to the coast and they were still at risk from tsunami. They were able to save their lives by themselves through their disaster prevention education, including evacuation trainings and high awareness on disaster prevention based on the principle of "tsunami tendenko"[170].

Based on the lessons learned from the experience, Iwate Prefecture and the Research Center for Disaster Prevention in the Extended Tokyo Metropolitan Area in Gunma University collaboratively developed the Kamaishi City Tsunami Disaster Prevention Education Guide for elementary and junior high school students in Kamaishi City, which includes the curriculum of the tsunami disaster prevention education, teaching materials and examples of activities from each school.

(2) Supplementary Material for Disaster Prevention Education ("Never Forget 3.11") by the Tokyo Metropolitan Board of Education

The Tokyo Metropolitan Board of Education developed and distributed a supplementary disaster prevention education material called "Never Forget 3.11" to elementary and junior high school students in January 2012. This is being utilized across all subjects to promote disaster prevention education, and to develop human resources who can first protect their lives, then help those close to them, and further contribute to the community. In April 2012, based on the revision of the damage estimates of a major earthquake directly striking the Tokyo Metropolis and other earthquakes, The Tokyo Metropolitan Board of Education developed a new edition of the supplementary material in December of the same year in order to prepare for earthquakes directly striking the metropolitan area. Since then it has been promoting disaster prevention education by utilizing the material throughout the year in public elementary and junior high schools, secondary schools and Special Needs Schools in Tokyo[171]. In the supplementary material, as shown in the figure below, the records of past disasters and the teachings of Japanese ancestors taken from classical literature are compiled and organized as lessons and utilized for disaster prevention education.

[169] http://iwate-archive.pref.iwate.jp/tokusen/kodomo/

[170] https://www.pref.iwate.jp/_res/projects/default_project/_page_/001/012/174/13_teigen.pdf

[171] https://www.kyoiku.metro.tokyo.lg.jp/school/study_material/safety/files/reference2016/gaiyou.pdf

Elementary school ver.	Key features of the materials	Junior high school ver.
○ "Self-aid" and "Mutual-aid" for elementary school students ○ How to protect yourself during disasters (e.g. earthquake, typhoon) ○ Participation in local disaster drills, etc.	Fostering a spirit of self-aid and mutual-aid	○ Evacuation procedures during major earthquakes, based on various scenarios ○ Disaster Prevention measures at home ○ Volunteer activities by junior high school students during disasters, etc.
○ Activities of the Fire Rescue Task Forces of Tokyo Fire Department ○ Activities of "Bond Team" of Tokyo Metropolitan Police Department, etc.	Understanding the function of public assistance	○ Interview with the Fire Rescue Task Forces of Tokyo Fire Department ○ Received "Prince of Asturias Awards" (Spain) ○ Dispatch of staff and teachers from Tokyo Metropolitan Government to disaster-affected areas
○ How to use a fire extinguisher ○ How to use CPR and AED ○ How to call 119 ○ Let's research, learn about and feel disaster prevention	Learning first-aid and firefighting skills, etc.	○ How to Operate a Class D portable fire pomp ○ The Basics of First-Aid (Triangular bandage, AED) ○ Rescue training ○ Let's go to the disaster prevention centers
○ Letters and drawings by children in Higashi matsushima City, Miyagi Pref. ○ Essay by children in Rikuzentakata City and Otsuchi Town, Iwate Pref. and Iwaki City, Fukushima Pref.	Learning from the thoughts of children in the disaster-affected areas	○ Letters and essays by students of Kesennuma City and Natori City, Miyagi Pref., Iwaki City, Fukushima Pref. ○ Holding a summit by junior high school students in Ishinomaki City, Miyagi Pref., etc.
○ Major Natural Disasters in chronical order ○ The Great Kanto Earthquake and subsequent reconstruction, etc.	Learning from past disasters	○ Major Natural Disasters in chronical order ○ The Great Kanto Earthquake and subsequent reconstruction, etc. ○ The Great Hanshin-Awaji Earthquake, etc.
○ "Ogura Hyakunin-isshu" ○ "Heike Monogatari" ○ "Inamura-no Hi" ○ Seasonal word "Shinsai Ki" ○ "Tsunami Tendenko", etc.	Learning from ancient literature and the wisdom of our ancestors	○ "Ogura Hyakunin-isshu" ○ "Houjyou Ki" ○ "Heike Monogatari" ○ "Inamura-no Hi" ○ "Tsunami Tendenko" ○ Nami Yoke Hi (Monument of disasters), etc.
○ The front page of the morning newspapers on March 12, 2012 ○ Handwritten Newspaper of Ishinomaki Hibi Shimbun ○ Collecting information during earthquakes to protect your safety	Thinking about the proper collection of information and its appropriate use	○ Evaluation of the Japanese response to the GEJE by foreign newspapers ○ Collection and usage of the information during earthquakes ○ Information morals during disasters (uncertain information during past disasters)

Source: Tokyo Metropolitan Board of Education (2017)[172] (Translated by JICA Expert Team)

Figure 3.2.11 Contents of the Supplenetary Education Material called "Never Forget 3.11"

(3) 1.17 Disaster Reduction Future Award "Bousai Koshien" (Hyogo Prefecture, etc.)

Bousai Koshien is a project sponsored by the Hyogo Prefecture, the Mainichi Newspapers Co., Ltd., and the Hyogo Earthquake Memorial 21st Century Research Institute (Disaster Reduction and Human Renovation Institution). It awards children and students who are engaged in disaster prevention education and disaster prevention activities in schools and communities in order to hand down to future generations the experiences and lessons from the Great Hanshin-Awaji Earthquake that occurred on January 17, 1995. There are several awards, and one of them is given to "outstanding activities which are implemented in disaster-affected areas after the earthquake, based on the experiences and lessons learned from the disaster". In 2020, the award was given to an elementary school that organized a lecture conducted by a local government official who experienced disasters, and taught the students to create a disaster prevention map.

Source: Bousai Koshien website[173]

Figure 3.2.12 Scene of the Activities That Made the Elementary School Won the "Bousai Koshien" Award

[172] https://www.kyoiku.metro.tokyo.lg.jp/school/study_material/safety/files/reference2016/gaiyou.pdf
[173] http://bousai-koushien.net/383-2/

(4) Initiative for the establishment of "Day of Disaster Prevention Education and Passing Down Past Disaster Records and Memories"

With the aim of designating March 11, the day that the GEJE occurred, as "Day of Disaster Prevention Education and Passing Down Past Disaster Records and Memories" by 2022, a group of university professors specializing in disaster prevention intends to gather supporters through the internet and other means, and request the designation from the government[174]. Through the establishment of the commemoration day, it is hoped that regional disparities in disaster prevention education and local wisdom will be addressed, and that activities in various areas will be shared to encourage further practice of disaster prevention education and handing down of disaster history and local wisdom[175]. Through these activities, it is expected that the significance of disaster prevention education and handing down disaster lessons and local wisdom will be more widely understood by the public.

3.2.5 Educational Facilities for Awareness Raising Initiatives

In Japan, there are numerous monuments and facilities constructed in disaster-affected areas for purposes of telling lessons learned from past disasters to future generations. For instance, after the GEJE, 41 sites and facilities in 23 disaster-affected municipalities had been left[176]. In order to mitigate disaster damage by natural disasters, it is crucial to hand down the lessons learned from past disasters to the next generation through maintaining these disaster remains. Furthermore, since these monuments and facilities are located close to local communities in many cases, they provide opportunities to learn about local disasters[177]. This section introduces the purposes, contents, and usage status of monuments and facilities that hand down stories telling the extent of disaster damage and lessons learned from the GEJE and other earthquakes and tsunamis in Japan. It is noted that, according to the website of MLIT, the elements of the disaster remains are facilities that 1) convey fear of disasters and awe of nature, 2) convey the lessons from disaster experience, 3) contribute to disaster prevention for future disaster occurrences, 4) have historical and academic value in disaster, or 5) introduce the actual situation of disasters and lessons learned from past disasters[178].

(1) Facilities to Hand Down the GEJE Experience

1) Kesennuma City Memorial Museum (Kesennuma City, Miyagi Prefecture)

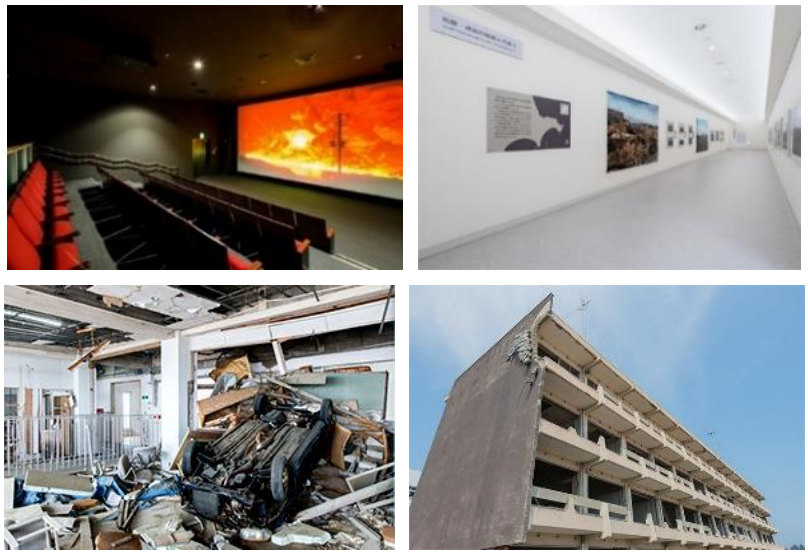
The massive tsunami and fires caused by the GEJE on March 11, 2011 caused one of the greatest tragedies in Kesennuma City, with 1,152 dead and 214 missing. The Kesennuma City Memorial Museum was established on March 10, 2019 by Kesennuma City, with the aim of preserving the memories and lessons of the disaster for future disaster mitigation. It will serve as "visible evidence" to continue the ringing of alarm bells, contributing to the Kesennuma City's initiative to achieve the target of "zero tsunami deaths".

This Museum is composed of two parts: Memorial Museum and Disaster Ruins (the former Kesennuma Koyo High School building). In the Memorial Museum, there is a video theater (with a 300-inch large screen) where visitors can see the video showing the time of the disaster as well as an exhibition illustrating the threat of the earthquake and tsunami, the state of the evacuation center after the disaster, the life of the survivors in the temporary housing, and the history of restoration and reconstruction in the area. At the Disaster Ruins, the former school building of Kesennuma Koyo High School, which was destroyed by the tsunami up to the 4th floor, has been left as it was at the time of the disaster. Visitors can also see the cars swept up to the 3rd floor by the tsunami, which will enable them to understand the actual power of it. In addition, local people

[174] https://www.jiji.com/jc/article?k=2021021300467&g=soc
[175] https://www.bousai-edu.jp/info/saigai-denshou/
[176] https://www.jiji.com/jc/graphics?p=ve_soc_earthquake-higashinihon20180304j-02-w680
[177] http://www.bousai.go.jp/kaigirep/hakusho/h28/honbun/1b_1s_01_05.html
[178] https://www.thr.mlit.go.jp/shinsaidensho/sisetsu.html

affected by the disaster provide guide to the facility as storytellers[179].

Although the number of visitors from 2019 to 2020 exceeded the target with approximately 87,000 visitors for that period, the burden of the maintenance and management costs is increasing. The number of visitors has been decreasing due to the impact of COVID-19 pandemic and the seemingly decline in interest to see the museum.



Source: Kesennuma City Memorial Museum Official website[180]

Figure 3.2.13 Kesennuma City Memorial Museum

2) Taro Kanko Hotel (Miyako City, Iwate Prefecture)

Before the GEJE, the Tarou Kanko Hotel, which was built in 1986, had been loved by citizens and tourists. It was fully damaged by the tsunami that was said to be over 17 meters high, sweeping away everything up to the second floor, leaving only the pillars. The fourth floor of the hotel was also filled with water. The structure remained in its form after the tragedy without collapsing. Miyako City decided to maintain it as a tsunami ruin and carried out facility maintenance in order to pass down the memory of the devastation of the tsunami to future generations without letting it fade away[181].

At the facility, visitors can see the damage in the exterior of the hotel and can feel the destructive power of the tsunami. They can also enter the inside of the facility under the "Learning Disaster Prevention" guided tour[182], which aims to raise awareness on disaster prevention. Inside the facility, visitors can watch the tsunami video taken at the hotel on the day of the earthquake[183]. Through visiting the facility and taking a guided tour, visitors can learn about the threat of natural disasters and raise their awareness on disaster prevention[184].

[179] https://kesennuma-memorial.jp/about/
[180] https://www.kesennuma-memorial.jp/
[181] https://www.city.miyako.iwate.jp/kanko/tsunamiikoutaroukankouhotel.html
[182]"Manabu Bosai (Learning Disaster Prevention)" program is run by the Miyako Tourism Association with the aim of raising participants' awareness of disaster prevention through communicating the actual situation during the GEJE in Taro area which was severely damaged by the earthquake. (Reference: https://www.kankou385.jp/bousai/)
[183] https://www.city.miyako.iwate.jp/kanko/miyako_tarokankouhotel.html
[184] https://www.thr.mlit.go.jp/shinsaidensho/facility/iwate-3-001.html

Source: MLIT[185]

Figure 3.2.14 Taro Kanko Hotel and Bosai (Disaster Prevention) Tour

3) Takatamatsubara Memorial Park and Iwate Tsunami Memorial Museum (Rikuzentakata City, Iwate Prefecture)

"Takatamatsubara Memorial Park for Tsunami Disaster" in Rikuzentakata City was established by the national government, Iwate Prefecture and Rikuzentakata City. It started operating in September 2019 in order to hand down the memories and lessons learned from the disaster to future generations, to provide a place for memorial and reflection on those lost in the disaster, as well as to domestically and internationally convey the strong desire for reconstruction[186][187]. There are valuable earthquake memorial facilities in this park, namely: "Tapic 45 (for Michi-no-Eki Takatamatubara)", "Kesen Junior High School", "The Miracle Pine Tree[188]", "Rikuzentakata Youth Hostel, "Shimojyuku Settlement Promotion Housing"[189], and the Iwate Tsunami Memorial Museum. These facilities are integrally maintained in the area[190] and lead to understanding of the threat of tsunami such as the extent of disaster damage it can bring and its destructive power.

Iwate Tsunami Memorial Museum was constructed by Iwate Prefecture and opened in September 2019 with the aim of passing down the actual situation after the tragedy and lessons from the earthquake and tsunami experience to future generations. It also communicated the extent of reconstruction, domestically and internationally, in order to prevent a repeat of the tragedy brought about by the GEJE. The facility shares the lessons and teachings learned from the realities of the GEJE and tsunami experience with people around the world, serving as gesture of gratitude for all the support that the prefecture had received[191].

The facility has a guidance theater and four exhibition zones with the theme "Protecting lives, and living together with the ocean and earth". The first zone is called "Tracking history" where visitors can understand tsunami disasters from a historical and scientific perspective. The second zone is "Learning the facts" where visitors can understand the realities of the GEJE and tsunami experience through viewing damaged items, photos of the disaster-affected sites, and the profile of the victims. The third zone is "Learning lessons" where visitors can learn the lessons from the disaster. The fourth zone is "Moving towards restoration together" where visitors can understand the reconstruction in the disaster-affected areas. Through the exhibitions and video presentations, visitors are able to understand the destructive power and threat of the earthquake and tsunami, recognize disasters as a personal matter and learn lessons to save their lives. Education programs, including workshops are also conducted in the seminar room of the facility[192][193].

In March 2021, as the number of visitors to the facility reached 300,000, numerous people from

[185] https://www.thr.mlit.go.jp/shinsaidensho/facility/iwate-3-001.html
[186] https://iwate-tsunami-memorial.jp/images/leaflet_en.pdf
[187] https://takatamatsubara-park.com/
[188] The pine survived the massive tsunami and has become a symbol of hope and recovery for the region.
[189] https://iwate-tsunami-memorial.jp/images/r03_leaflet_en.pdf
[190] https://www.city.rikuzentakata.iwate.jp/material/files/group/39/koukai-siryou.pdf
[191] https://iwate-tsunami-memorial.jp/images/leaflet_en.pdf
[192] https://www.thr.mlit.go.jp/shinsaidensho/facility/iwate-3-015.html
[193] https://www.pref.iwate.jp/_res/projects/default_project/_page_/001/031/037/r2.6_zigyohoukoku.pdf

Japan and abroad have visited the facility[194]. It is also often utilized for educational tours by schools inside and outside the prefecture and sightseeing tours for those from the Tokyo metropolitan area[195].

Source: MLIT[196]

Figure 3.2.15 Iwate Tsunami Memorial Museum

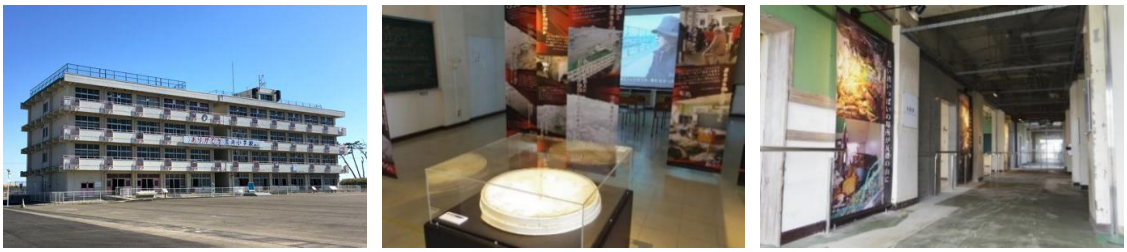
4) Arahama Elementary School (Sendai City, Miyagi Prefecture)

Arahama area is located on the Pacific coast, about 10 km east of central Sendai. During the GEJE, the huge tsunami damaged the first and second floors of the four-story school building, but 320 students, school teachers and local residents were able to evacuate to the rooftop and escaped the disaster. In order to raise awareness on disaster prevention and mitigation among visitors, and to prevent loss of life due to future tsunami, the city maintained what remained from the school building. It opened to the public in April 2017 as the first earthquake disaster memorial site in the Prefecture[197]. The school building clearly leaves traces of the disaster, and exhibits the situation immediately after the disaster to provide visitors the opportunity to experience the power and threat of tsunami.

Around the school building and on the first and second floors, visitors can see the school building as damaged by the tsunami in the original site, as well as photos showing the situation immediately after the tsunami. These contents lead them to feel the threat of the tsunami. On the fourth floor, visitors can look back at the various phases of the disaster, from the occurrence of the earthquake to evacuation, the tsunami occurrence, and rescue with photos and videos (approximately 17 minutes), and learn about disaster preparedness. On the rooftop, visitors can view the entire Arahama area and compare the scenery before and after the disaster, through photos that were taken before the earthquake[198].

After its opening to the public, 77,000 people visited the facility in the 1st year[199]. In July 2018, the total number of visitors reached over 100,000. More than 70% of the visitors were from outside the city, and some were from abroad[200].

[194] https://iwate-tsunami-memorial.jp/4144/
[195] https://www.pref.iwate.jp/_res/projects/default_project/_page_/001/031/037/r2.6_zigyohoukoku.pdf
[196] https://www.thr.mlit.go.jp/shinsaidensho/facility/iwate-3-015.html
[197] Kadokura et al, 2019. A Survey on Current Situation and Visitors Evaluation of Disaster Reconstruction Memorial Facilities in Sendai City - Sendai 3.11 Memorial Community Center and Ruins of the Great East Japan Earthquake: Sendai Arahama Elementary School - (https://www.jstage.jst.go.jp/article/jisss/35/0/35_191/_pdf)
[198] https://www.city.sendai.jp/kankyo/shisetsu/documents/brochure202004.pdf, https://www.city.sendai.jp/sesakukoho/gaiyo/shichoshitsu/kaiken/2017/04/documents/pamphleta.pdf
[199] https://www.city.sendai.jp/kankyo/shisetsu/arahama_elementaryschool003.html#:~:text=%E9%9C%87%E7%81%BD%E9%81%BA%E6%A7%8B%E4%BB%99%E5%8F%B0%E5%B8%82%E7%AB%8B%E8%8D%92%E6%B5%9C%E5%B0%8F%E5%AD%A6%E6%A0%A1%E3%81%AF%E6%98%A8%E5%B9%B44,%E5%8D%83%E4%BA%BA%E3%81%A8%E3%81%AA%E3%82%8A%E3%81%BE%E3%81%97%E3%81%9F%E3%80%82
[200] https://www.city.sendai.jp/shinsaifukko/chushin/documents/1st_07_coastarea.pdf



Source: Sendai City[201]

Figure 3.2.16 Arahama Elementary School

5) Kadonowaki Elementary School (Ishinomaki City, Miyagi Prefecture)

The GEJE caused massive damage to Ishinomaki City and destroyed the Kadonowaki Elementary School. The city decides to preserve the school building and plans to open it to the public by March 2022 as an earthquake and tsunami memorial site. This is because the building is the only facility that retains traces of both the tsunami damage and the tsunami fire which occurred in many disaster-affected areas in the Tohoku region. Furthermore, the facility has a story to share, specifically when school survivors were able to evacuate to Hiyoriyama Hill to escape the raging fire. The city expects that this site will become the main facility of an earthquake disaster memorial area where the Ishinomaki Minamihama Tsunami Recovery Memorial Park and Hiyoriyama Hill are located[202].

Source: Asahi Shimbun (September 30 2020)[203]

Figure 3.2.17 Kadonowaki Elementary School

6) Outdoor Clock at the City Public Gymnasium (Ofunato City, Iwate Prefecture)

The outdoor clock in front of the Ofunato Civic Gymnasium was donated to Ofunato City by the Japan Agricultural Cooperatives (JA) Ofunato before the earthquake, and served the gymnasium, tennis courts, and other sports facilities in the area. The clock hands had stopped at 2:46 P.M., which is the time of GEJE occurrence. After the earthquake, the City decided to preserve the original clock as a disaster remain[204]. The facility is located near the Ofunato Civic Gymnasium.

[201] https://www.city.sendai.jp/kankyo/shisetsu/ruin_arahama_elementaryschool.html
[202] https://www.pref.miyagi.jp/uploaded/attachment/374738.pdf
[203] https://www.asahi.com/articles/ASN9Y6W4YN9BUNHB00K.html
[204] https://www.thr.mlit.go.jp/shinsaidensho/facility/iwate-2-001.html

Source: MLIT [25]

Figure 3.2.18 Outdoor Clock at the Ofunato City Public Gymnasium

Like the clock shown above, numerous disaster remains (including small ones) have been preserved and maintained in each disaster-affected area in the Tohoku region. They help inform about the damage and the threat of disasters as well as the necessity of disaster risk reduction. However, due to the number of memorial facilities, it would be possible that the visitors dispersed, which could make facility managers face the difficulty of attracting visitors, especially for single facilities. In view of the situation, the Disaster Memorial Network Council was established with the aim of promoting cooperation for creating a network to more effectively and efficiently hand down the lessons of the disaster, and contributing to strengthening the disaster resilience of the community in addition to the promotion of social interaction and regional revitalization[205]. The council registers the disaster remains and exhibition facilities in the GEJE-affected areas as "disaster memorial facilities" and introduces them on the internet with a facility map and information signs. It also implements various initiatives and activities related to disaster prevention and disaster mitigation, based on the facilities and the network[206]. Tour plans are also developed and enable participants to visit multiple disaster remains and facilities. This is being done as a form of tourism initiative in cooperation with private agencies.

Source: 3.11 Densho Road Promotion Organization[207]

Figure 3.2.19 Brochure of 3.11 Densho Road and the Map of the Disaster Memorial Facilities

The report presented by 3.11 Future Support Association[208] shows the increase in the number of

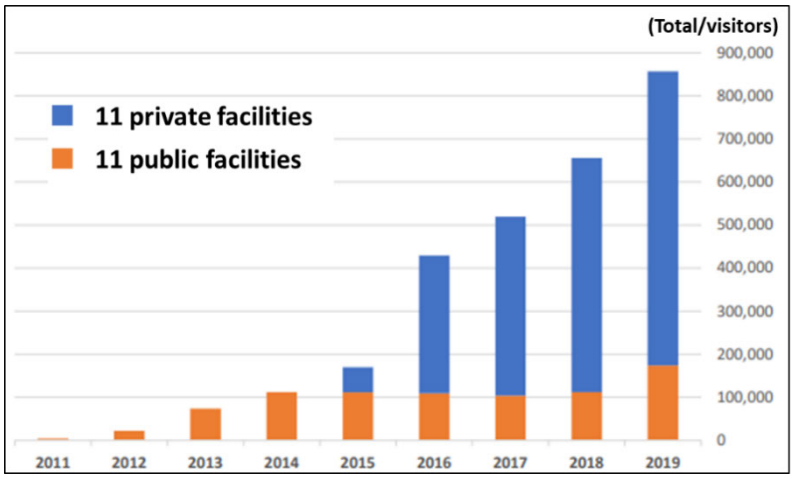
[205] The Earthquake Disaster Heritage Network Council registers memorial parks located in the disaster-affected areas including Iwate Prefecture, Miyagi Prefecture and Fukushima Prefecture, as well as disaster remains in the areas including Aomori Prefecture, Iwate Prefecture, Miyagi prefecture, Fukushima Prefecture and Sendai City. The organization of the Council consists of officials from Tohoku Regional Development Bureau - MLIT, Aomori Prefecture, Iwate Prefecture, Miyagi Prefecture, Fukushima Prefecture and Sendai City. (Reference: http://www.thr.mlit.go.jp/shinsaidensho/network.html)

[206] https://www.311densho.or.jp/profile/index.html, https://www.thr.mlit.go.jp/shinsaidensho/index.html

[207] https://www.311densho.or.jp/en/introduction/index.html?no=0

[208] 3.11 Future Support Association. 2020. *2019 Survey Report on Activities to hand down disaster lessons of the Great East Japan Earthquake.*

visitors of disaster memorial facilities[209] constructed in three disaster-affected prefectures in the Tohoku region from 2011 to 2019, and this can be partly attributed to an increase in the number of facilities funded by the reconstruction budget.



Source: 3.11 Future Support Association[210] (Translated by JICA Expert Team)

Figure 3.2.20 Number of Visitors of Disaster Memorial Facilities by Year

(2) Facilities Related to Other Past Earthquake and Tsunami Disasters in Japan

1) Okushiri Tsunami Memorial Museum (Okushiri Town, Hokkaido Prefecture)

Okushiri Tsunami Memorial Museum was constructed by the national government, Hokkaido Prefecture and Okushiri Town in 2001 as a facility that serves to pass down the memories of the great tsunami that hit Okushiri Island on July 12, 1993, immediately after the Hokkaido earthquake (The Hokkaido-Nansei-Oki Earthquake). It plays a role in conveying the memories and lessons learned from the disaster, and the gratitude for the reconstruction assistance received from all over the country. The facility is currently managed by the Town Board of Education.

Inside the facility, there are seven exhibition spaces by theme, which illustrate the state of the disaster and the reconstruction process that was carried out. The main contents of the exhibition space include monument "198 Hikari" in memory of 198 people who died in the disaster, memorial plates, and photographs of the disaster-affected area, among others. In addition, visitors can watch the documentary “Saigai no Kiroku” (the Memory of Disaster) at the Video Hall (available for 50 people) and understand the mechanism of the earthquake, the scale of the disaster and the reconstruction process with realistic images and sound effects.

In Okushiri Town, there are disaster prevention learning programs that target junior and high school students who visit the island. Since 2005, over 1,000 students mainly from schools located in Hokkaido have visited disaster prevention-related facilities within the island, especially the museum[211]. After the GEJE, due to the increased attention to tsunami experience because of the 1993 Hokkaido earthquake, the number of visitors to the island had significantly risen. Since the number of visitors of the facility depends on the number of people who come to the island, providing comprehensive package tours to visit multiple attractive points in the area regarded as aneffective strategy.[212]

[209] The results are based on 22 facilities that cooperated with the survey in the three prefectures. However, it should be noted that the survey included facilities that held earthquake-related exhibitions in parts of spaces in communication centers and halls, and that the visitors were counted regardless of the purposes of their visit. Thus, it cannot be said to be an objective figure that directly contributes to handing down disaster lessons and local wisdom.

[210] https://311support.com/wp2/wp-content/uploads/2020/08/311DisasaterEducationReport2019.pdf

[211] http://www.bousai.go.jp/kohou/kouhoubousai/h26/78/leader_01.html

[212] Inagaki, S. 2014. Exhibition of Tsunami Disaster Record in Okushiri Town : Progression and Prospect. Bulletin of the Natural Disaster Science Data Center, Hokkaido 27:49-55

Source: Okushiri Town[213]

Source: Okushiri Tourism Association[214] Source: CAO[215]

Figure 3.2.21 Okushiri Tsunami Memorial Museum

2) The Great Hanshin-Awaji Earthquake Memorial Museum (Hyogo Prefecture)

The Great Hanshin-Awaji Earthquake (GHAE) Memorial Museum (Disaster Reduction and Human Renovation Institution) was established in April 2002, seven years after the GHAE that occurred on January 17, 1995. It was funded by Hyogo Prefecture with support from the national government. The institute provides exhibits, practical disaster management research and training for young disaster management specialists, data collection and preservation, local disaster response assistance, training for disaster response specialists, guidance in forming networks. The exhibits provide accessible information on experiences and lessons learned from the GHAE with the help and cooperation of many people. The mission of the facility is to pass down the experience and lessons learned from the GHAE to future generations, thereby contributing to the formation of a culture of disaster prevention, improvement of local disaster prevention capacities, support for the development of disaster prevention policies, and the establishment of a safe and secure society where citizens can work together to reduce disaster risks.

There are several floors in the facility, which include “Relive the Earthquake”; “Earthquake Memories”; “Disaster Management and Mitigation Activities”, “Guidance Room”, a library, and a theater. On the floor of the Disaster Management and Mitigation Activity, there is the Disaster Info Station where visitors can learn about natural disasters that happen all over the world, and can gain practical knowledge about disaster management and mitigation through activities and games. On the floor of Earthquake Memories, stories are shared and earthquake-related artifacts from donors are displayed. Visitors also see texts and visuals telling what life in the city was like in the earthquake’s aftermath and during the reconstruction process. On the floor of Relive the Earthquake, there is a big screen called 1/17 Theater with powerful visuals and sound, which lets visitors experience the earthquake’s dreadful devastation. Furthermore, visitors can also experience the earthquake’s aftermath by walking through in the realistically reproduced city streets (called “Streets After the Quake”). The facility also provides an opportunity to hear the experiences shared by survivors[216].

[213] https://www.town.okushiri.lg.jp/hotnews/detail/00003668.html,
https://www.town.okushiri.lg.jp/hotnews/detail/00001049.html
A memorial monument (photo on the right) stands near the museum. The hollow of the monument which is made of black granite faces the southwest coast where the epicenter of the earthquake was located. If visitors stand in front of the monument facing the sea on July 12 which is the day of the earthquake, they can see the sun setting into the hollow.
[214] http://unimaru.com/?page_id=82
[215] https://kokkyo-info.go.jp/791/
[216] https://www.preventionweb.net/files/55978_finalsmallerversionworldtsunamimuse.pdf

Approximately 500,000 people visit the facility each year, mainly from schools and disaster management offices of local governments. Although the number of visitors exceeded 7 million in July 2016[217], the number has significantly dropped in 2020 due to the COVID-19 pandemic[218].

Source: DRI[219]

Figure 3.2.22 The Great Hanshin-Awaji Earthquake Memorial Museum

3) Inamura-no-Hi no Yakata[220] (Hirogawa Town, Wakayama Prefecture)

"Inamura-no-Hi no Yakata" was established in April 2007 in order to learn from and hand down the achievements, spirit, and lessons of Goryo Hamaguchi. He was a businessman who guided and saved numerous people by setting his harvested rice sheaves on fire at the time of the great tsunami following the Ansei Nankai earthquake on November 5, 1854. He also initiated the construction of a large embankment for improving community resilience[221]. The facility is managed by Hirogawa Town. The anecdote of the "Inamura-no-Hi (The fire of rice sheaves)" has spread around the world as a lesson for tsunami preparedness. Then, in 2015, the United Nations designated November 5th as World Tsunami Awareness Day to promote a global culture on tsunami awareness, based on the anecdote[222].

The facility consists of two parts: the Tsunami Educational Center and Hamaguchi Goryo Archives. In the Tsunami Educational Center, visitors can learn the mechanism of tsunami through watching a mini tsunami simulation, experience the huge intensity of a tsunami at the theater, and prepare for an imminent tsunami through games and videos. There is also an exhibition about Inamura no Hi and a section introducing the "Aceh Tsunami Museum" in Indonesia, which is a sister museum of Inamura-no-Hi no Yakata[223]. In the Hamaguchi Goryo Archives, visitors can learn about the great achievements, lessons, and episodes reflecting the personality of Goryo through seeing exhibits and watching a visual presentation on Goryo's life in the space dedicated for him. There is also a beautiful garden that resembles the one that Goryo cherished.

Since the GEJE, numerous people who are interested to know about tsunamis have visited the museum. The total number of visitors reached 250,000 in October 2014. As the facility accepts

217 https://www.sankei.com/region/news/160722/rgn1607220010-n1.html
218 https://www.yomiuri.co.jp/local/kansai/news/20210107-OYO1T50025/
219 https://www.dri.ne.jp/exhibition/field-trip/, https://www.dri.ne.jp/exhibition/guide/
220 "Inamura no Hi" is a story of a man who noticed a precursor of a large tsunami at the earliest stage and led village inhabitants to high ground by burning harvested rice sheaves. (https://www.adrc.asia/publications/inamura/phase1.php)
221 https://www.town.hirogawa.wakayama.jp/inamuranohi/
222 https://current.ndl.go.jp/node/30554 , https://en.unesco.org/commemorations/tsunamiday
223 "Inamura-no-Hi no Yakata" has cemented a partnership with Aceh Tsunami Museum in Indonesia since January 2016 in order to promote disaster risk reduction of tsunami. (reference: https://www.pref.wakayama.lg.jp/prefg/011600/soumu/sekaitunaminohi/top_d/fil/h27.pdf)

visitors from all over Japan and other countries, it plays a role as an international information dissemination facility (Sakiyama 2015[224]). Also, the museum serves the secondary purpose as an evacuation center in case of tsunami occurrence. In relation to the facility, the Inamura-no-Hi Festival is conducted annually by local communities, and this gathers around 600 people that include students from elementary and junior high school.

Source: Museum official website (Hirogawa Town)[225]

Figure 3.2.23 Tsunami Educational Center (Inamura-no-Hi noYakata)

(3) Monuments

In addition to facilities and museums, disaster-related monuments are constructed in areas that suffered from natural disasters, in order to hand down the disaster experience and share lessons learned from past disasters to future generations. These monuments are expected to be useful in understanding the actual situation during times of disaster and in raising the awareness of local residents about disaster prevention in each area. For instance, stone monuments in Osaka City and Sakai City illustrate the disaster damage and lessons of the Ansei Nankai Earthquake and tsunami (December 24, 1854) as shown in Figure 3.2.24.

Inscription on the stone monument "Daijishin Ryokawaguchi Tsunami-ki" (Osaka City)

"During the earthquake, since people were afraid of being trapped under their houses, they evacuated by boats. However, a few hours later, a tsunami struck, swept the boats, destroyed the bridges, and killed approximately 350 people. When a similar earthquake occurred 148 years ago in the Hoei period, many people died after evacuating to their boats. We failed to make use of the past experience of our ancestors. We will pass it down to our descendants. There will be other earthquakes in the future. When this time comes, do not try to evacuate by boats. Please ink and pass down the words on this monument every year so that it can be always read."

Inscription on the stone monument "Yougo-ji" (Sakai City)

"After an earthquake, a large tsunami engulfed the area. While bridges, some houses, and boats were damaged or destroyed, many people in Sakai City gathered and evacuated to the shrine, and no one got injured. They knew the legend that many people died when trying to evacuate by boat during the Hoei earthquake."

Sources: FDMA[226] (doc.), Sakai City (photo)[227]

Figure 3.2.24 Stone Monuments and Inscriptions

The stone monument in Osaka City is designated as a tangible cultural property by the city, and it is washed and inked every year by the Monument Preservation Committee of the local community[228]. The local community also established a guideboard explaining the inscription and

[224] https://f-gakkai.net/wp-content/uploads/2020/09/13-1-6SAKIYAMA.pdf
[225] https://www.town.hirogawa.wakayama.jp/inamuranohi/tunami.html,
https://www.town.hirogawa.wakayama.jp/inamuranohi/tunami_1f.html,
https://www.town.hirogawa.wakayama.jp/inamuranohi/tunami_3f.html
[226] https://www.fdma.go.jp/publication/database/item/database009_01_01.pdf
[227] https://www.city.sakai.lg.jp/smph/kanko/rekishi/bunkazai/bunkazai/shokai/bunya/rekishi/yougoji.html
[228] https://www.city.osaka.lg.jp/kyoiku/page/0000009171.html

maintains the monument[229].

Source: Ichioka High School, Osaka Prefectural Education Center[230]

Figure 3.2.25 Inking activity at the monument by local high school students

[229] Nagao, T. 2015. The Memorial Service for Victims on the 50th Anniversary of the 1854 Ansei Nankai Earthquake Tsunami: At the Monument of "Ohjishin Ryokawaguchi Tsunamiki" in Osaka City. *Historical Earthquakes*, 30 (2015): 159-167.
[230] https://www.osaka-c.ed.jp/blog/ichioka/kocho/2013/08/19-032012.html

Chapter 4 Conclusion

(1) Institutionalization of preserving and passing down local wisdom on disaster

Historically, Japan has reconfirmed the importance of local wisdom after the occurrence of major catastrophic disasters. Especially after the GEJE, the Government of Japan legalized through the Basic Act on Disaster Management (First Revision), the holding of activities related to passing down records of past disasters, as well as the establishment of Expert Committee on Disaster Lessons.

Meanwhile, Indonesia also has various types of local wisdom on disaster from across the country, yet these are not fully recognized and utilized for disaster education or awareness raising. In fact, in a disaster-stricken area of Central Sulawesi, the JICA Study Team of the Project for Developing Regional Disaster Risk Resilience Plan in Central Sulawesi confirmed the case of an elderly person who was aware of past disaster lessons from his grandparents because they informally told him about it. Meanwhile, majority of the villagers in the same area did not know about them.

The Government of Indonesia is aware of the importance of local wisdom to mitigate the damage of disasters. Presidential Regulation No. 93/2019 for tsunami early warning has been enforced with the involvement of multiple DRR-related agencies. As of now, each agency stated the intention to initiate the utilization of local wisdom in their areas of work. In order to realize the initiatives of each agency, there is a need to stipulate the national level plan and regulation that enable government agencies to raise funds to conduct events, and maintain the facilities to pass down records of disasters in the long term.

It is recommended that the Government of Indonesia, especially BNPB in collaboration with DRR-related agencies, legalize the Presidential Regulation or incorporate its contents in the National Disaster Management Strategy to provide legal backbone to lead the local level and line ministries of the abovementioned initiatives in actual projects, programs or activities.

(2) Multistakeholder engagement for passing down and utilizing local wisdom on disaster

As mentioned in the previous section, legalization and institutionalization will be especially effective to mobilize human resource and budget of the public sector. In addition, in order to disseminate the importance of passing down past records of disaster to the public, involvement of the private sector, NGOs, academia, among others are indispensable. Currently, major stakeholders of DRR education and awareness raising related to local wisdom on disaster in Indonesia are the public sector, mainly the DRR-related agencies.

In Japan, various stakeholders that include the government, academia, private sector, and NGOs strive to preserve intangible local wisdom in a variety of ways. This framework and methodology can be applicable to Indonesia, to increase the stakeholders to preserve and disseminate local wisdom on disaster. For example, operating awareness-raising facilities are often done through a collaboration of the public sector, private sector including media, and NGOs. These facilities function as community gathering space, educational space for children, as well as preserving the records of past disasters in a region. Another good practice is the promotion of local disaster wisdom as a tourism resource, to be done in collaboration with local government, academia, NGO and community groups. Even if the government raises funds for such initiatives (e.g. preservation of past disaster records and its awareness raising activities) securing sustainable financial sources by collecting entrance fees from visitors and sponsorship fees will strengthen the operational body of the awareness raising initiatives. Furthermore, attracting more visitors is another aspect in making people least likely to forget past disasters, which is a challenge for both Japan and Indonesia.

APPENDIX 8-17

Lecture on “Aimed Picture of Earthquake and Tsunami Analysis and Warning Dissemination System”

2021.May.25,27

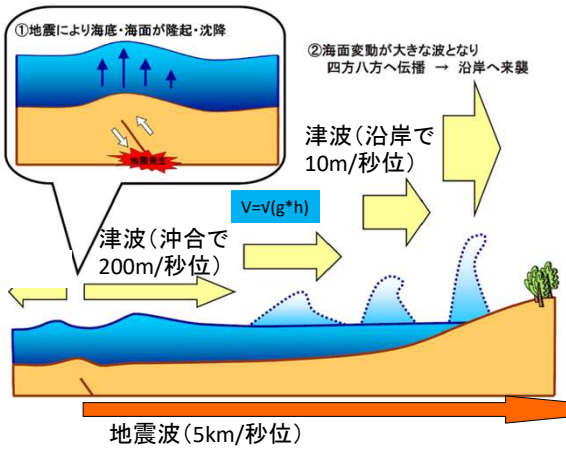
「途上国における地震津波観測・警報発出に関わる目標像」説明資料

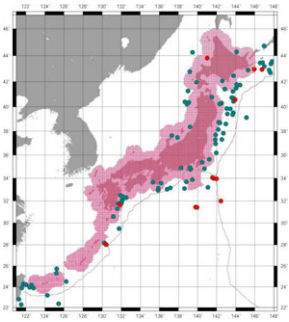
JMBSC　上垣内　修

1

津波警報の原理

津波のほとんどは地震に伴って発生





日本周辺の、津波による被害が発生した地震及び津波予報を行った地震のうち約４割は、沿岸に20分以内で津波が来襲する領域（ピンク）で発生している。

避難に充てられる時間を最大限確保するためには、
地震波の解析結果に基づき津波警報（第１報）発出要。
その後地震や津波の観測データ（沖合のものを含む）等により必要に応じ更新。

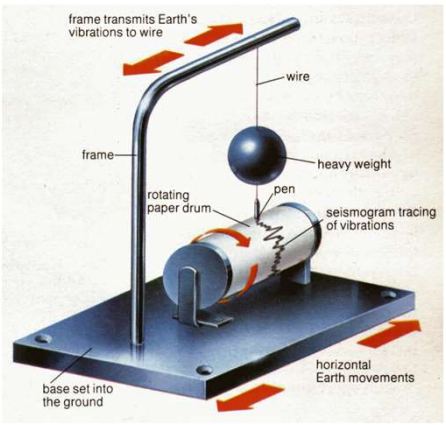
津波警報の原理　＝　地震波と津波の伝播速度の差（一桁以上）を利用。
地震波の解析から津波の規模を予測。

2

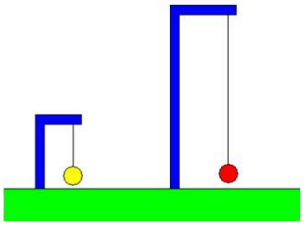
「地震計」とは

地面の揺れを「正確に」観測する測器。
→ 地震計の開発（19世紀後半）

振り子により「不動点」を造り出し、それに対する地面の揺れを観測する。

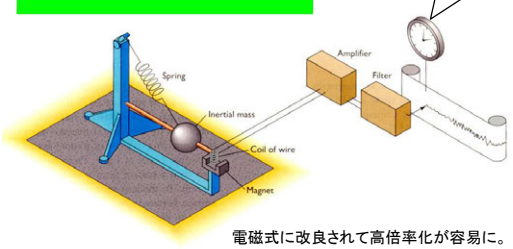


機械式地震計の原理

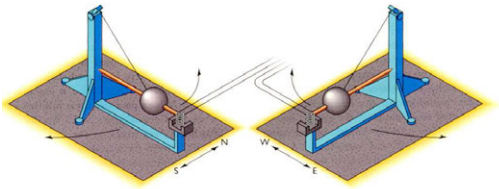


振り子の「固有周期」よりも短い周期の揺れに対して、重りは「不動点」となる。

正確な時計も必須！



電磁式に改良されて高倍率化が容易に。



たがいに直交する3方向の揺れを記録する地震計3台一式で、地面の三次元的揺れを記録できる。

3

揺れの強さ

各種地震計の観測可能範囲

強震計

生の出力信号を演算処理して回路にフィードバックすることで、広ダイナミックレンジ化・広帯域化が可能となった。

広帯域強震計

広帯域地震計

（磁場の中を運動するコイルの出力信号そのままのシンプルな型）

短周期地震計

揺れの周波数

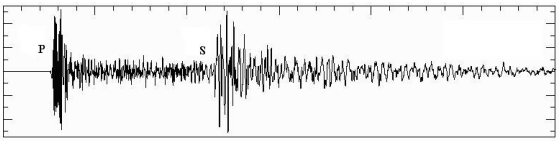
気象庁松代地震観測所坑道内の広帯域地震計
STS-1（奥側ガラス容器内×3）、STS-2（緑）

気象庁地震観測点の外観

気象庁地震観測点の短周期地震計（左）と強震計（右）

4

地震の観測記録の例（短周期地震計）



19世紀半ばには、弾性体力学の理論で、P波とS波が存在することがわかっていた。

地殻上部の代表的な値λ≒μ=3×10^{11}dyne/cm^2（堅さ）、ρ=2.6gram/cm^3（密度）を下式に代表すると、

Vp=5.9km/sec（P波の速度）、
Vs=3.4km/sec（S波の速度）　となる。

$$Vs=\sqrt{\mu/\rho} \quad < \quad Vp=\sqrt{(\lambda+2\mu)/\rho}$$

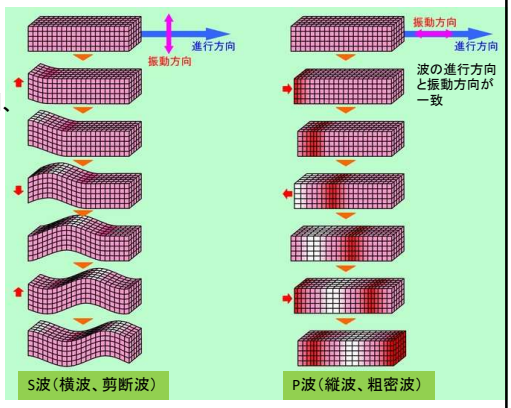
記録から読み取れる情報と、わかること

1) 波の到着時刻
→ 震源（どこで地震が発生したか）位置と地震発生時刻、地球の内部構造

2) P波の初動（上下成分）の押し引き
→ 断層の形状（向き、傾き、ずれ方向）
& 震源に働いた力の向き

3) 波の振幅
→ 地震の規模（マグニチュード）

最近では、広帯域地震計の波形データを用いることで、断層の形状とマグニチュード(Mw)が同時に推定できるようになった(CMT解析:Centroid Moment Tensor)。



S波は、流体（気体・液体）の中は伝わらない！

5

1)波の到着時刻からわかること
①地震波速度構造を仮定すると、震源の位置・地震発生時刻がわかる。

震源の位置　3点でのS-P時間を利用した震源計算の原理

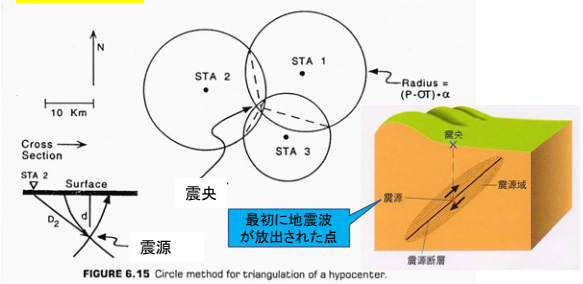
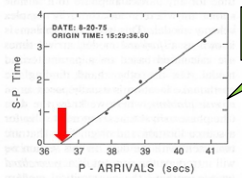


FIGURE 6.15 Circle method for triangulation of a hypocenter.

地震の発生時刻

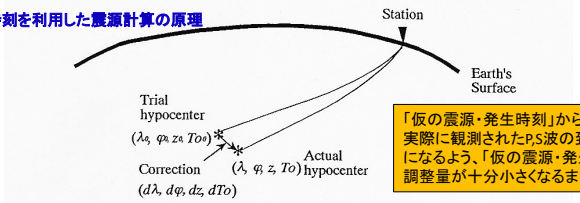


和達ダイアグラムという

FIGURE 6.14 An example of the Wadati diagram method for determining the origin time of a local earthquake. The origin time is given by the intercept with the *P* arrival time axis.

近年はもっと高等な「最小二乗法」を用いた方法が用いられていて・・・

多点でのP時刻、S時刻を利用した震源計算の原理



「仮の震源・発生時刻」から予想されるP,S波の到着時刻と、実際に観測されたP,S波の到着時刻の差の二乗和が最小になるよう、「仮の震源・発生時刻」を微調整。
調整量が十分小さくなるまで、それを繰り返す。

Fig. 3.1 Schematic vertical cross section along the ray path in spherically layered media.

6

その1

2) P波の初動（上下成分）の押し引きからわかること
→ 断層の形状 & 震源に働いた力の向き

その前に・・・

地震後に地表に「断層」が現れることがあることは、わりと古くから知られていたが、二つ説があった。

①断層は強い揺れの結果生じたもの
（地震の原因としては、地下空洞崩壊、地下のガス・水蒸気の膨張・爆発、マグマの陥入等の説があった。）
②断層が地震の原因である（←弾性反発説(1911)）

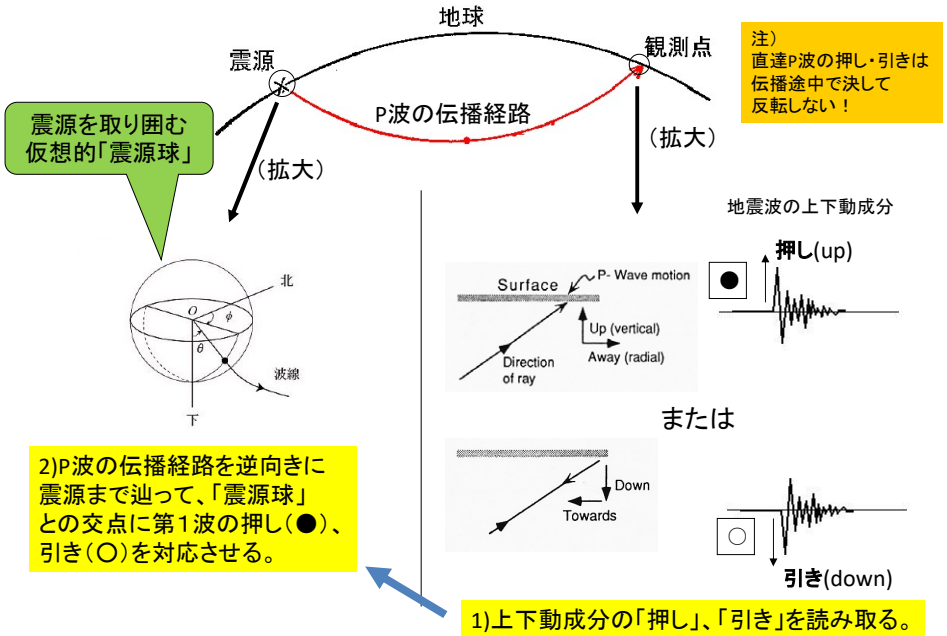
1891年濃尾地震(M8.0)で地表に出現した断層

1995年兵庫県南部地震(M7.3)で地表に出現した断層

7

その2

2) P波の初動（上下成分）の押し引きからわかること
→ 断層の形状 & 震源に働いた力の向き



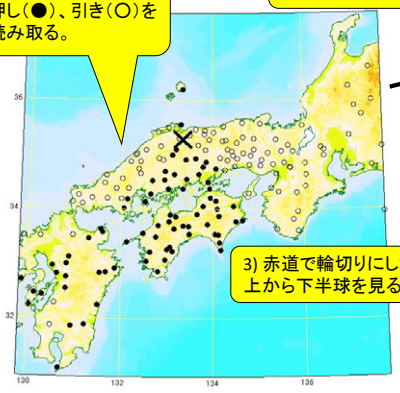
8

その3

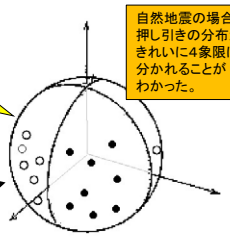
2) P波の初動（上下成分）の押し引きからわかること
→ 断層の形状 & 震源に働いた力の向き

2000年10月6日鳥取県西部地震の例

1) 観測点毎にP波の押し（●）、引き（○）を読み取る。



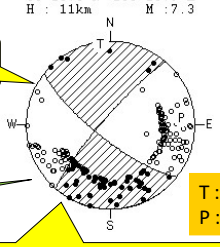
2) 押し、引きを「震源球」まで遡る。



自然地震の場合、押し引きの分布がきれいに4象限に分かれることがわかった。

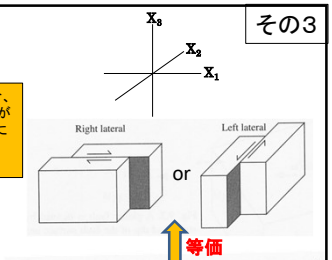
2000/10/06 13:30:18.0
WESTERN TOTTORI PREF
35°16.5'N 133°20.9'E
H : 11km M :7.3

3) 赤道で輪切りにして上から下半球を見る。

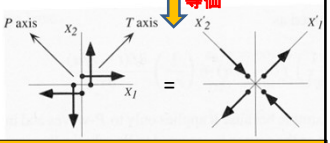


余震の分布も併せると、北西ー南東走向の面が断層面と特定された。

4) 押し引き分布を最も矛盾なく分割するよう節線を引く。
→そのどちらかが断層面に対応。

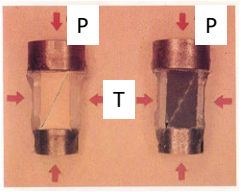


等価



1960年代に日本の地震学者によって、断層ずれと2組の偶力との等価性が証明され、2組の偶力によるP,S波放射パターンと観測が合致することが確認された。→「断層は地震の原因」で決着。

T：張力軸
P：圧縮軸



岩石破壊実験の例

その4

2) P波の初動（上下成分）の押し引きからわかること
→ 断層の形状 & 震源に働いた力の向き

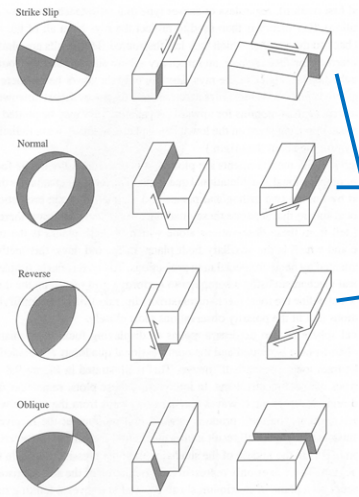
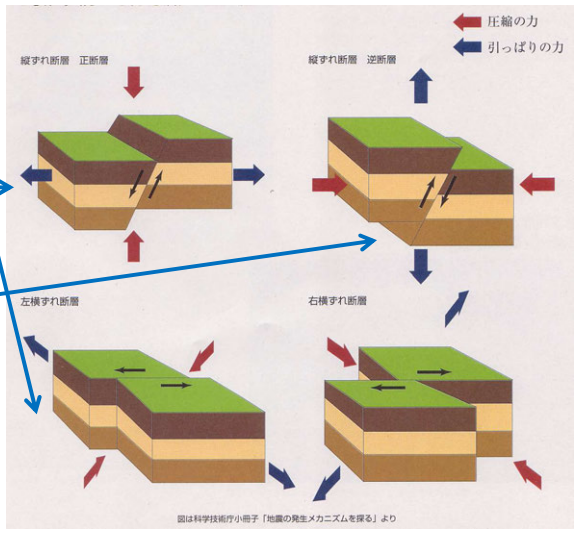


Fig. 9.8. Examples of focal spheres and their corresponding fault geometries. The lower half of the focal sphere is plotted to the left, with the compressional quadrants shaded. The block diagrams on the right show the two fault geometries (the primary and auxillary fault planes) that could have produced the observed radiation pattern.



3) 波の振幅からわかること → 地震の規模（マグニチュード。「M」と表記されることが多い。）

地震のカタログを作成するうえで、発生時刻、震源位置に加えて、「大きさ」を記載したくなるのはごく自然な発想。
→アメリカの地震学者が、1935年（つまり、地震の原因が断層運動であることがわかる以前）に、震源からある距離に置かれた地震計で記録された最大振幅の対数(log)から「マグニチュード」を定義したのが始まり。気象庁マグニチュード(Mj)もその流れに沿ったもの。

対数(log)関数とは‥
その数が10の何乗かを返す関数

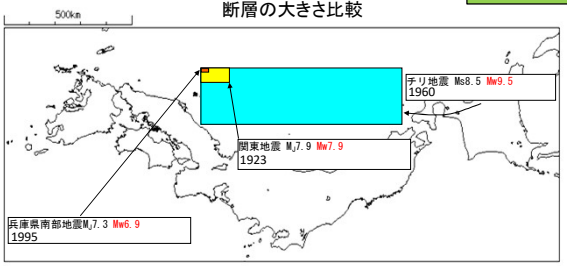
その後、地震の正体が断層運動であることがわかり、より物理的な意味が明確な「モーメント(Mo)」及びそのマグニチュード換算値（モーメントマグニチュード：Mw）が、地震の規模を表す世界標準となりつつある。MjとMwは、8.0以下で概ね一致する。

Mo = （震源における岩石の堅さ：μ）×（断層の面積）×（断層のずれ量）
Mw = (log(Mo) – 16.1) × 2/3

断層の形状は概ね長方形で近似できる

（「スケーリング則」という）

断層の大きさ比較



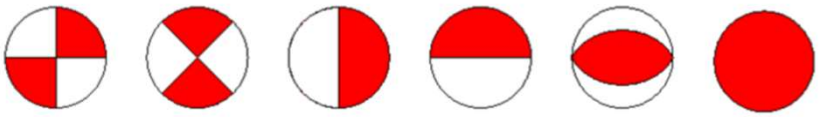
マグニチュードと断層の長さ・ずれ量の関係

M	断層の長さ	断層のずれ量
3.0	0.5km	1.6cm
4.0	1.6km	5.0cm
5.0	5.0km	16cm
6.0	16km	50cm
7.0	50km	1.6m
8.0	160km	5m
9.0	500km	16m

Mjは地震発生から3分で計算できる反面、周期5秒程度の地震波の最大振幅を用いるため、M8を超えるような巨大な地震の規模を正確に推定することができない。
Mwは巨大地震でも正確な規模の推定ができる反面、計算には地震発生から10分程度を要する。また、小さな地震には適用困難。

11

任意の断層は、下の6つの「基本的断層」の重み付き足し合わせで表現できる。



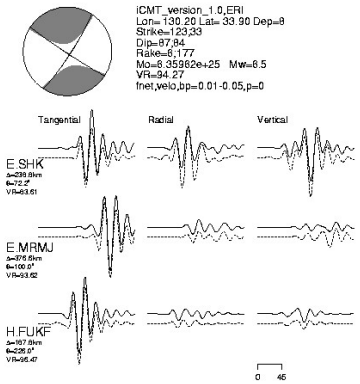
おのおのの「基本的断層」による観測点jにおける理論波形M1j(t),M2j(t),…,M6j(t)を計算しておく。

$\sum_{(j:観測点)}\{Obs.j(t) - Syn.j(t)\}^{**}2$ が最小になるよう、
（ここで、$Syn.j(t) = \sum_{(i=1,6)} Ai*Mij(t)$）係数A1～A6を決定すると、断層形状とMo(→Mw)が同時に求まる。

これを、CMT解(Centroid Moment Tensor解)という。

S波到達前の波形のみを用いたCMT解析を特にW-phase解析と言う。

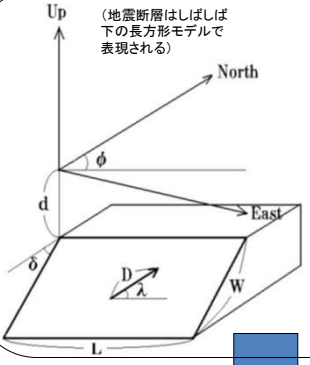
これらは、破壊の大局を代表した発震機構解を与えるため、津波予測には初動極性を用いた方法よりも適している。



観測波形(点線)を最も良く再現する理論波形(実線)（下）と、対応する発震機構解(CMT解)（上）の例。

12

正確な津波予測のために必要な断層パラメータ



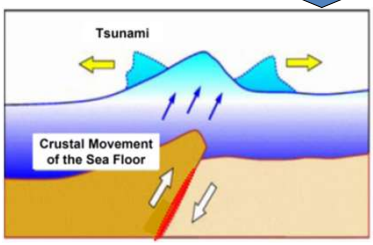
断層モデルを規定するパラメータ

d: Depth ← 震源計算で得られる
L: Fault Length
W: Fault Width
D: Slip Length

断層の大きさ
→相似則から計算可能
log L=0.5M-1.9, W=L/2, log D=0.5M-3.2
(M:ﾏｸﾞﾆﾁｭｰﾄﾞ)

ϕ: Strike Angle
δ: Dip Angle
λ: Slip Angle

断層の形状
→発震機構解(CMT解)が得られるまで不明。
→それ以前は何らかの仮定が必要。



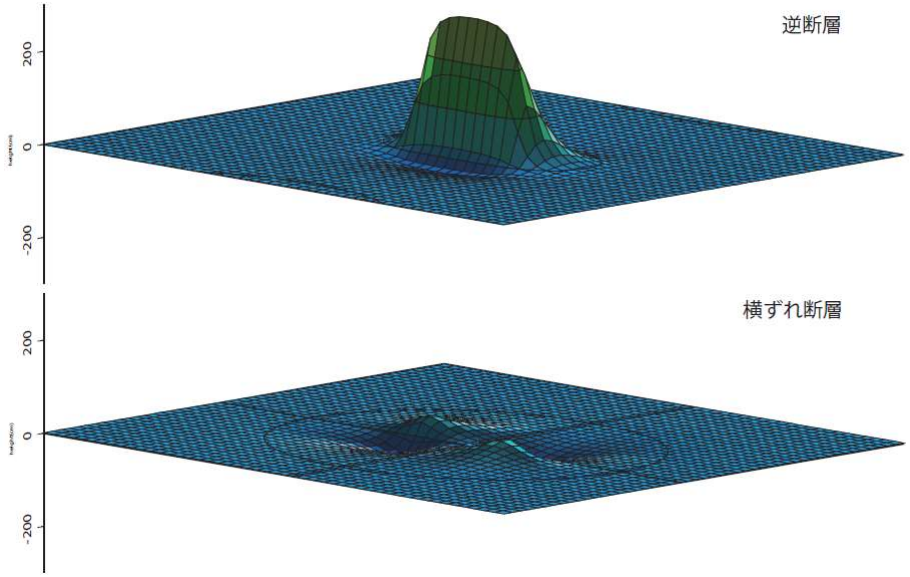
初期津波波源の与え方

- 海底の地殻変動は、与えられた断層パラメタに基づき弾性理論によって計算できる (岡田, 1985)。
- 初期津波波源の形は、海底の地殻変動の形と同じ。

13

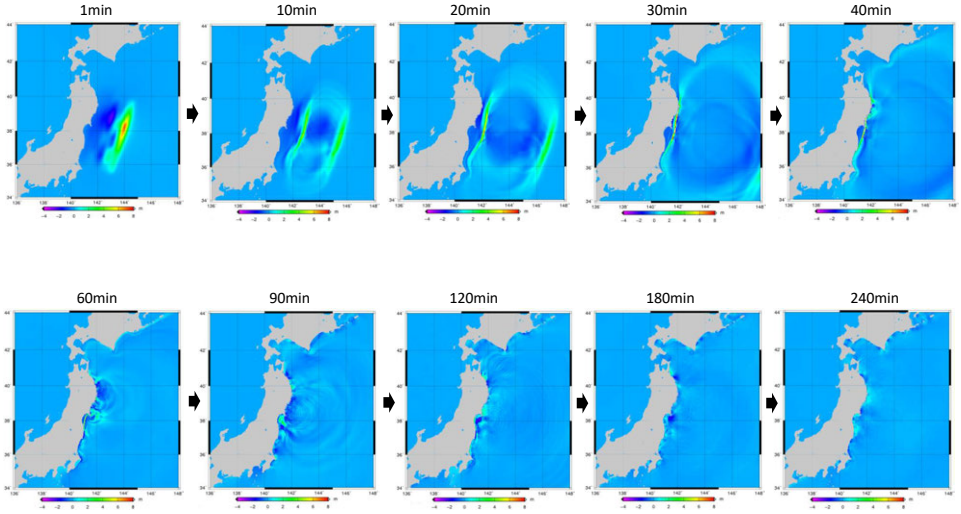
断層の形状（メカニズム）による津波励起量の違い

同じ断層面積・ずれ量、同じ断層上端深さでも、逆断層（上）と横ずれ断層（下）では海底の上下変動（津波励起量と同じ）が大きく異なる！



14

津波伝搬シミュレーションの例 (2011 東北地方太平洋沖地震)



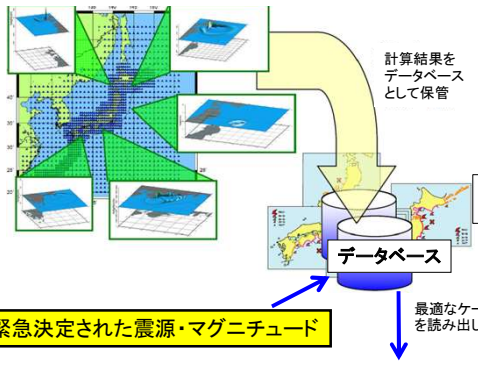
津波伝搬シミュレーションの技術は確立しているので、初期津波波源の形が与えられると、一定の分解能以上の正確な海底地形データに基づき計算実行可能。
ただし、現在の計算機能力をもってしても計算にはある程度の時間が必要。

15

気象庁の津波警報の発表

津波シミュレーションデータベースの構築

様々な震源・マグニチュードの想定地震に対する津波シミュレーションを予め実施



計算結果をデータベースとして保管

3分で発表する第1報では、逆断層を仮定。

緊急決定された震源・マグニチュード

最適なケースを読み出し

予報区毎に予想される最大波高に応じて、津波警報ないしは津波注意報を発表

津波警報・注意報を原則3分以内に発表、
その後のデータ、解析結果に応じて更新発表。

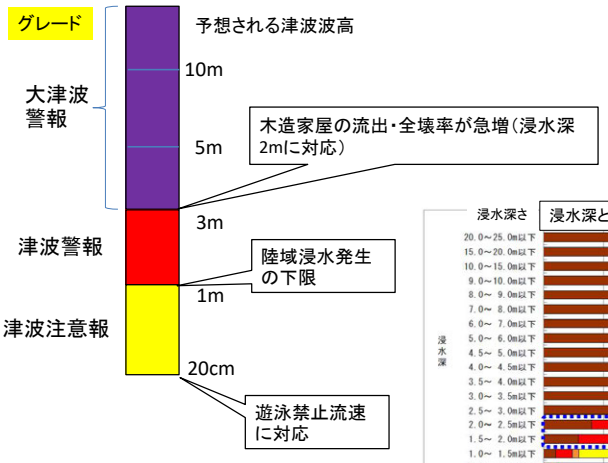
津波予報区

計66予報区
（基本的に、1県1予報区）

16

津波警報の発表基準と津波予報区

津波警報発表基準

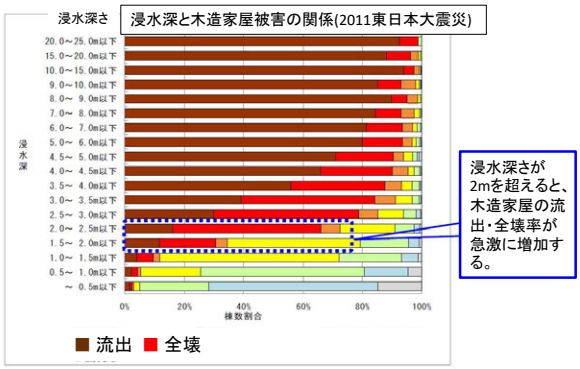


国毎の海岸利用状況や
堤防整備状況等を踏まえて決定。

津波予報区設定にあたって考慮すべき点

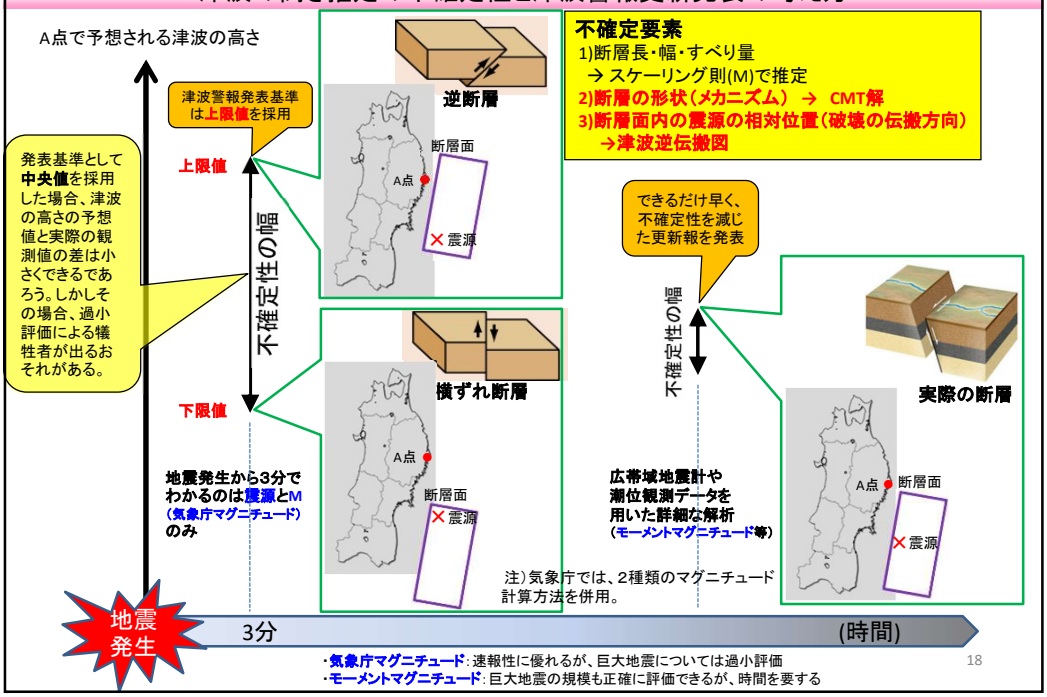
- 行政境界
- 海の分布
- 津波挙動の類似性
- 津波予測精度

自治体等関係防災機関と協議のうえ決定。



17

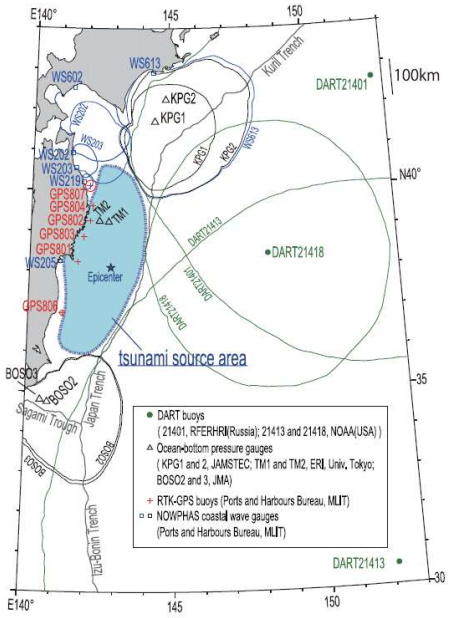
津波の高さ推定の不確定性と津波警報更新発表の考え方



18

津波逆伝搬図を用いた津波波源域の推定

津波逆伝搬図を用いた津波波源域 (薄青)推定例



「津波到達時刻」－「発震時(OT)」＝走時。
津波逆伝搬図とは、津波観測点から走時の時間分、伝搬を遡った閉曲線。この曲線上のどこかから津波が到来した。
いくつかの津波観測点からの津波逆伝搬図を描画することで、その包絡線から津波波源域が推定できる。

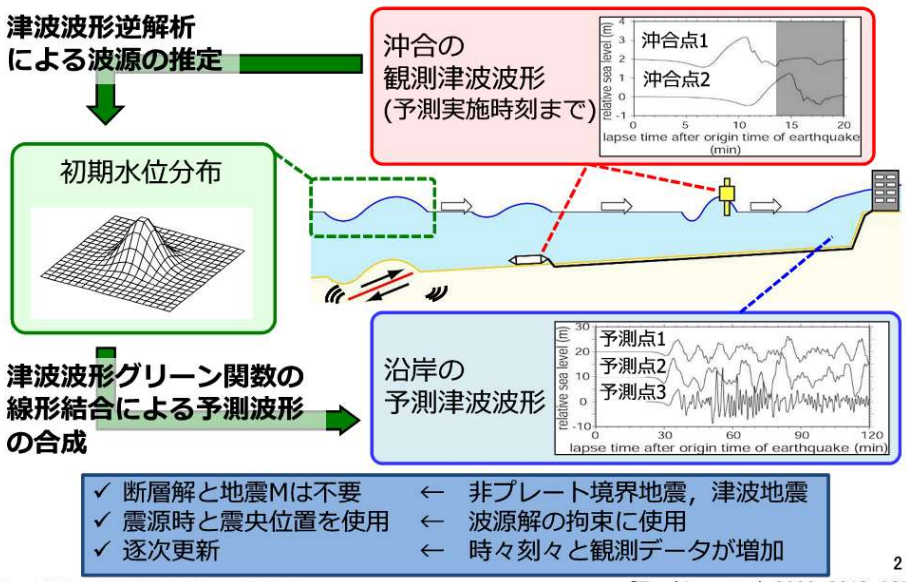
自動決定される余震の震央分布からもある程度津波波源域(≒震源域)を推定できる。

Hayashi et al. (2011)

19

沖合い津波波形逆解析に基づく津波即時予測手法

tsunami Forecasting based on Inversion for initial sea-Surface Height (tFISH)



✓ 断層解と地震Mは不要 ← 非プレート境界地震，津波地震
✓ 震源時と震央位置を使用 ← 波源解の拘束に使用
✓ 逐次更新 ← 時々刻々と観測データが増加

2

津波予測技術に関する勉強会(第14回)資料より

[Tsushima *et al.*, 2009, 2012, JGR]

20

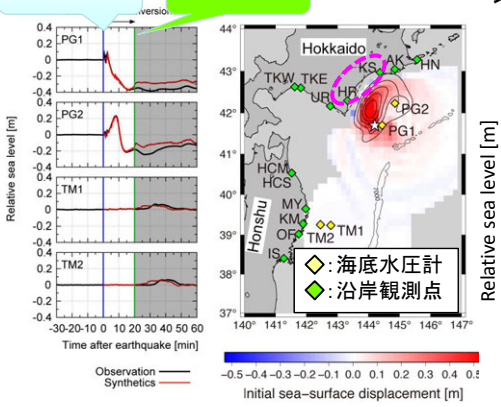
tFISHによる津波予測

2003年十勝沖地震に対する海底水圧計データに基づく津波予測結果

地震発生後20分

地震発生直後ではない！

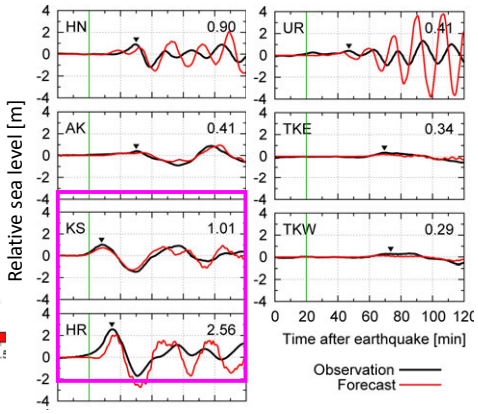
地震発生　予測計算



震源域直上のPG1，PG2にて，
海底変動成分をほぼすべて観測

[対馬，2009]

北海道沿岸での津波波形 (観測，予測)

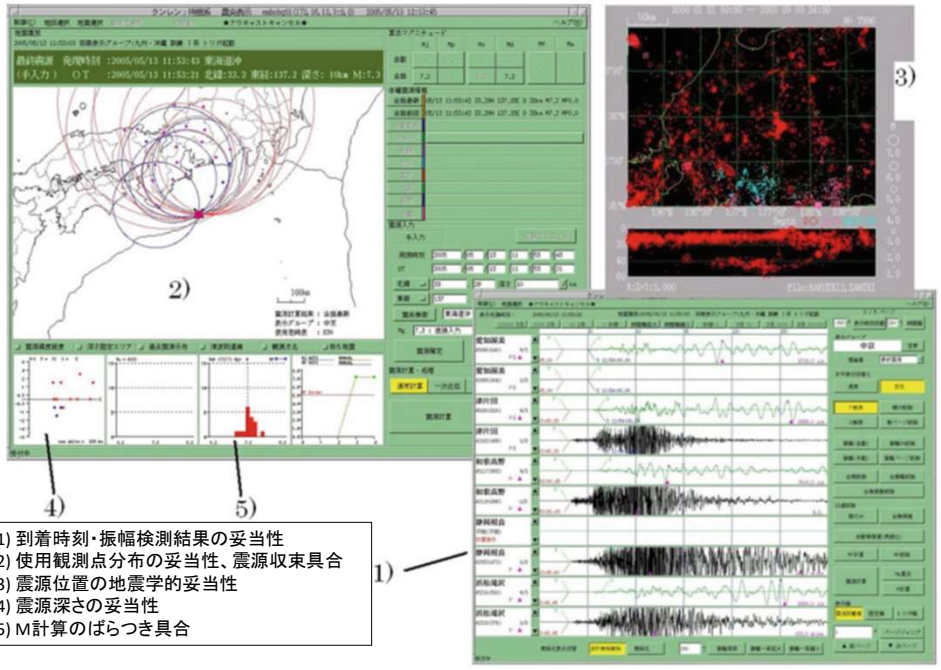


**津波が沿岸へ来る前に
高精度の津波予測が可能**

気象研地震火山研究部資料に加筆

21

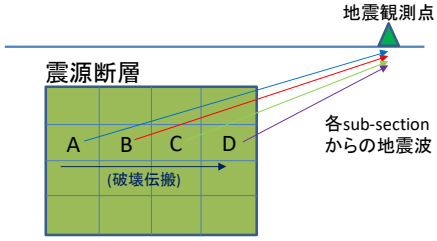
気象庁EPOSの地震波形検測、震源・M計算のMMI

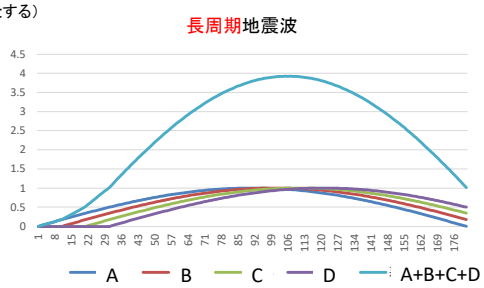


1) 到着時刻・振幅検測結果の妥当性
2) 使用観測点分布の妥当性、震源収束具合
3) 震源位置の地震学的妥当性
4) 震源深さの妥当性
5) M計算のばらつき具合

22

（ある周期帯の最大振幅値に基づく）マグニチュードの飽和



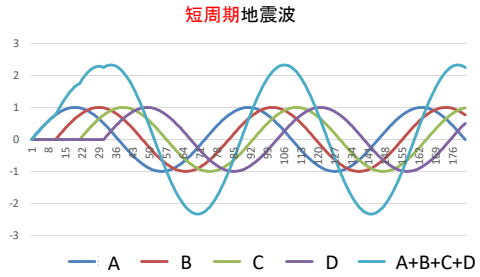


一定速度の破壊伝搬を仮定する。
地震波の到達時刻差(A→B→C→D) は一定。
すべてのsub-sectionは同一の地震波生成能力を持つとする。

長周期(上図) 波は位相が概ねそろっており、各寄与を加算すると大きな振幅となる。

一方、短周期(下図)波は位相がずれており、各寄与を加算しても一部が相殺され、振幅は大きくならない。
（縦軸スケールの違いに注意）

これが時間領域で見た場合のMの飽和。

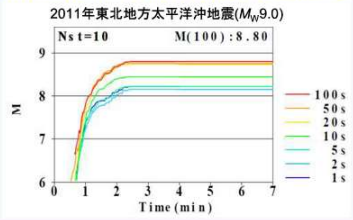


23

気象庁M過小評価可能性チェックツール

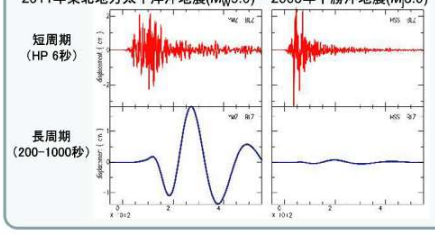
① 様々な周期帯の波形データから推定（M100s）

様々な周期帯の波形データを用いてMwを推定
（この例では、周期100秒帯で約2分20秒後にMw8.8に達する）



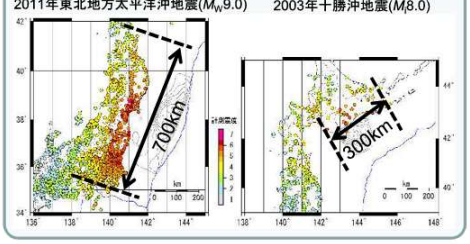
② 長周期成分の波形から推定（長周期モニタ）

長周期波形の振幅から地震規模を推定
（短周期成分と比べ長周期成分では顕著な違いが見られる）



③強震域の広がりから推定

震度観測から強震域の範囲を基に地震規模を推定



計算された気象庁マグニチュードについて、それぞれの手法を用いて過小評価判定を実施

↓

いずれかの手法で過小評価の可能性があると判定

↓

当該海域で想定されている地震の想定断層 または 想定最大のマグニチュードを用いて津波を予測

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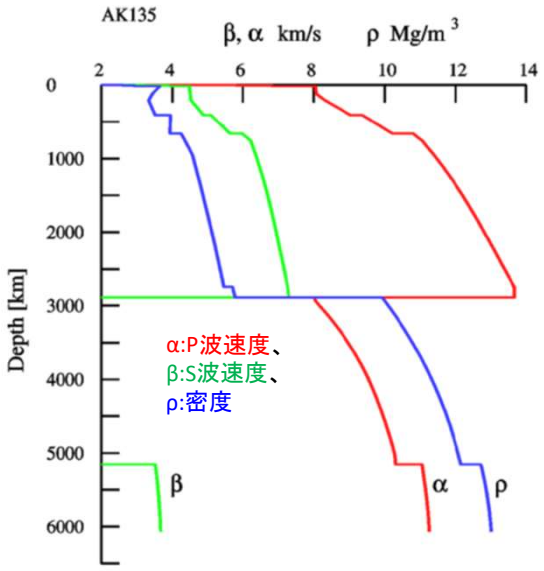
4

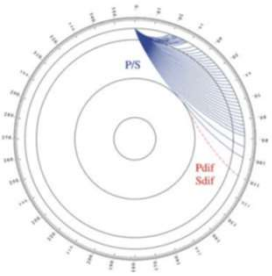
「ローカル地震学」のススメ（その1：速度構造or走時表）①全球モデル



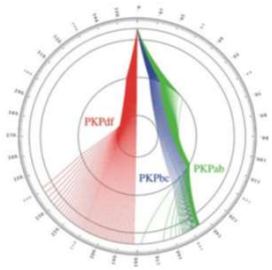
遠地震源計算によく用いられる相の波線

波線は主に深部を通過する

P/S and Pdif/Sdif



PKPab, PKPbc and PKPdf



SeiscomP3等に導入されている全球平均地震波速度構造モデルAK135。遠地の地震の震源決定が主眼に置かれているため、地震波線があまり通過しない浅部の構造の地域性は考慮されていない。

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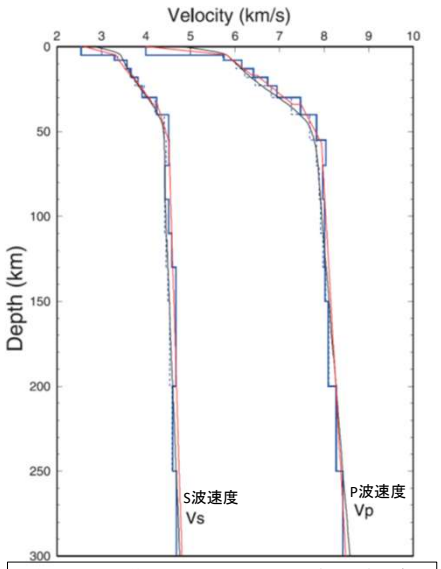
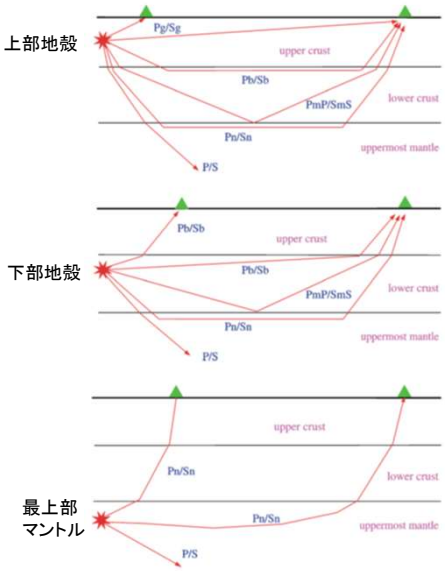
「ローカル地震学」のススメ（その1：速度構造or走時表）②ローカルモデル



気象庁の震源計算に用いられている地震波速度構造モデルJMA2001（黒線）。近地の地震の震源決定が主眼に置かれており、地震波が主に通過する日本列島直下の浅部の構造に適合したモデルになっている。爆破地震学グループの研究成果が用いられている。

近地震源計算によく用いられる相の波線



浅部ほど地域性が大きい

26

「ローカル地震学」のススメ（その2：マグニチュード計算式）

近地で発生する地震に対する津波警報発出が必要な国では、

1）迅速な発表が求められる（e.g. インドネシアでは地震発生から5分以内の津波警報発表が大統領令で定められている）ため、
・近距離に対して当該地域に適合した距離減衰補正項が定義された式であって、
・震源近傍で振り切れない振幅値が得られる強震計データに基づいた式　である必要がある。かつ、

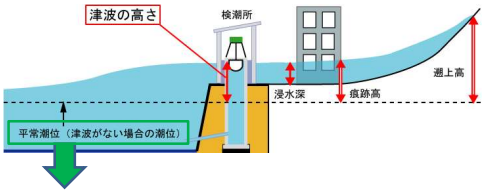
2）比較的高い頻度で発生するM8程度の地震まではマグニチュードが飽和しない式である必要がある。（M8を大きく超える巨大地震についてはW-phase解析が有効であるが、そのためには広帯域強震計の整備が望ましく、その場合であっても計算完了までに10～15分程度を要する。迅速な発表が求められる警報第一報に間に合わせるためには、強震域の広がりとの比較でM飽和（過小評価）の可能性を覚知し、その場合には計算されたM値に＋0.5する、ないしは当該海域で想定される最大M値に置き換える等の措置が別途必要となる。）

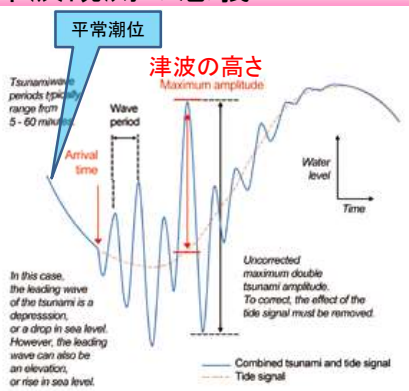
現在、複数の発展途上国津波警報発出責任機関において、独GFZが開発したSeiscomP3が地震データ処理システムとして導入・運用されているが、同システムに採用されているマグニチュード計算式 ML, mb, mb(BB), Ms, Ms(BB), Mwpはいずれも、上記の条件1）、2）のいずれかを満たしていない。

従って、上記1）及び2）を満たす新たなマグニチュード計算式が望まれる。

いくつかの国では強震計観測網が既に整備されているが、リアルタイムの防災情報には活用されておらず、その有効活用（震度情報に加えて、M計算、M過小評価可能性覚知）を図る意味もある。 27

「津波の高さ」の定義と津波観測の意義





= 天文潮位
+ 気象擾乱の影響（気圧、風）
+ 海流の影響
+ その他

津波観測の意義
●「津波検知」の事実を速やかに知らせ、未だ避難を逡巡している住民の避難を促す。
●津波の最新状況を住民に知らせる。 } 情報発表

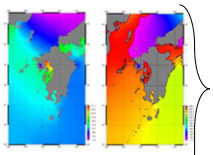
○地震以外の原因による津波発生の覚知
○観測波高/予測波高に基づく津波警報の更新
○津波逆伝搬図を用いた津波波源域の推定（前述）
○津波警報解除の根拠

29

潮位データからの天文潮位＋気象擾乱の影響の除去

気象庁では、「高潮ガイダンス」（沿岸1kmメッシュ毎の、TPから測った擾乱のない海面の高さ）が利用可能

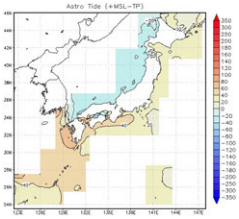
面的調和定数（28分潮）



（M2分潮の振幅・遅角）

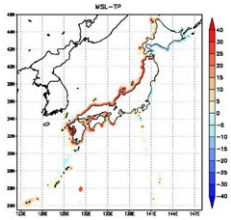
（‥分潮の振幅・遅角）

（日周・半日周潮27分潮
＋長周期潮(Sa)）



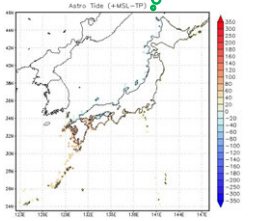
天文潮位（MSL基準）

＋



標高換算値

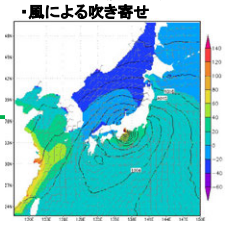
精度10cm
程度



天文潮位（標高基準）

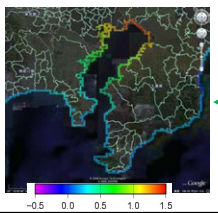
高佐et al(2011)測候時報vol.78特別号

＋



・気圧による吸い上げ
・風による吹き寄せ

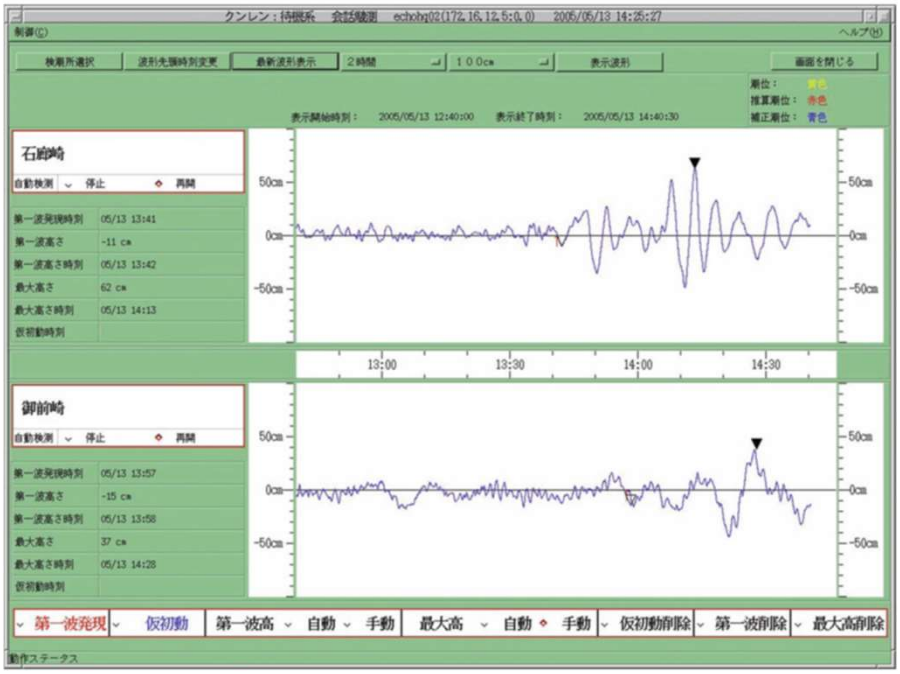
高潮モデル（潮位偏差）



高潮ガイダンス（潮位）

30

気象庁EPOSの潮位波形検測のMMI



31

地震カタログ・津波災害DB作成の効能

○地震カタログ

・後日行う詳細な（緊急時よりも多くの観測点を用いた）地震波形検測及び震源再計算の分析を通じて、観測点毎の波形の特徴（どこを地震波到達時刻として検測すべきか等）や、震源位置毎の最適な観測点の選択に関するノウハウが蓄積され、緊急で実施する震源計算精度の改善に繋がる。

・地域毎の地震活動の特徴が定量的に評価できるようになり、当該地域で地震活動が活発化した場合の、今後の活動の見通しにつき解説が可能となる。

・津波警報業務で使用する津波伝搬シミュレーションデータベースがカバーすべき海域の吟味や、仮定すべき地震のメカニズムにつき改善が図られるとともに、海域毎に想定すべき最大Mに関する知見が得られる。

○津波災害DB

・潮位観測点毎に異なる波形データの特徴が把握され、緊急時における津波到着時刻検測精度の向上に繋がる。

・シミュレーション波形と観測波形との比較により、津波伝搬シミュレーション精度手法そのもの、ないしは仮定すべきメカニズムの改善が図られる。

・同じ海域で同様の地震が発生した場合の、今後の津波の見通し（継続時間等）につき解説が可能となる。

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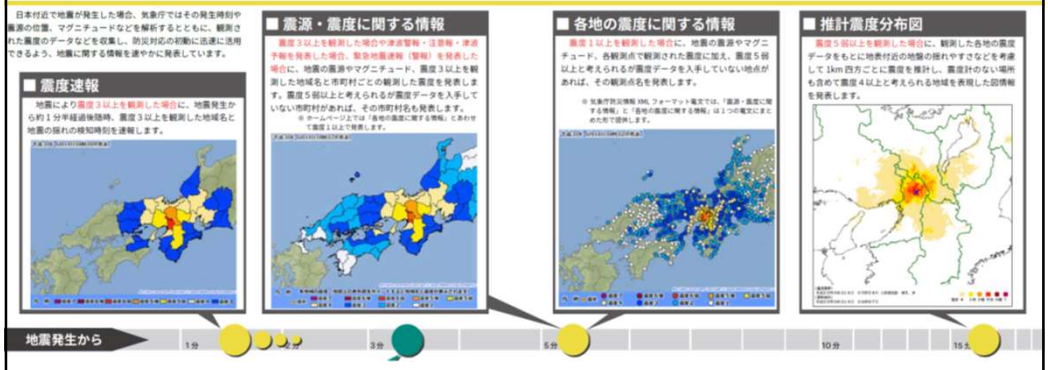
強震動情報

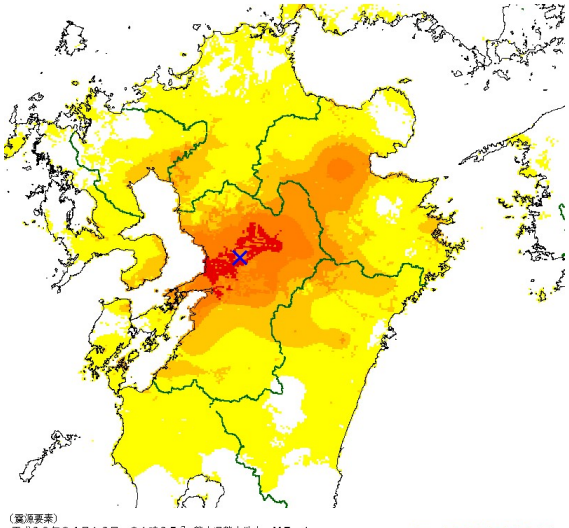
【強震動情報の目的】
強く揺れた地域の迅速な把握による、初動体制の立ち上げ。
つまり、緊急地震速報が「自らの身を守るための情報」（警報）であるのに対し、
下の震度情報等は「人を助けるための情報」。
激甚な強震動災害が発生した可能性を迅速に覚知・共有。



33

推計震度分布図の例

熊本地震（本震）に対する推計震度分布図の例



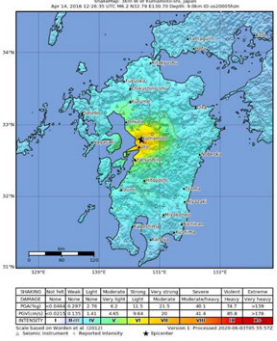
（震源要素）
平成２８年０４月１６日　０１時２５分 熊本県熊本地方　Ｍ７．１
（情報時刻）
平成２８年０４月１６日　０１時４０分

震度 4　5弱 5強 6弱 6強 7

推計震度分布図の作り方

地表での震度観測値（点）
↓
表層地盤の増幅度(1kmメッシュ)で割って
工学的基盤上での値に換算（点）
↓
工学的基盤上で内挿（面）
↓
増幅度を掛けて地表での値に換算（面）

（参考）熊本地震（前震）に対するShakeMapの例



観測データ、
地表増幅度に加えて、
強震動予測式も組み
合わせて計算
（MMI,PGA,PGV,
加速度応答スペクトル）

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APPENDIX 9

Project Design Matrix

(PDM)

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Version 1
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)
Dated 28 July 2022
Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey			
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	・DRR-related policies of Indonesia will not significantly change.		
Outputs 1. Improve acquisition of seismic observation data in proper and timely manner. 2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations. 3. Enhance capacity for operating InaTEWS to issue tsunami warning. 4. Improve dissemination methodologies of earthquake information and tsunami warning.	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (from XX % to XX %). 1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis 1. Revised SOP 2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation 1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural hazards/disasters do not occur.		

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	・Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition ・Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermesures>

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Version 2.0
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)
Dated 31 August 2022
Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey		Not in this term	
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	・DRR-related policies of Indonesia will not significantly change.	Not in this term	
Outputs				Not in this term	
1. Improve acquisition of seismic observation data in proper and timely manner.	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (from XX % to XX %).		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural hazards/disasters do not occur.		
2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations.	1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis				
3. Enhance capacity for operating InaTEWS to issue tsunami warning.	1. Revised SOP 2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation				
4. Improve dissemination methodologies of earthquake information and tsunami warning.	1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials				

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	・Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition ・Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermesures>

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)

Version 3.0
Dated 28 February 2023

Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey		Not in this term	
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	DRR-related policies of Indonesia will not significantly change.	Not in this term	
Outputs					
1. Improve acquisition of seismic observation data in proper and timely manner.	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (from XX % to XX %).		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural hazards/disasters do not occur.	1-1. The SOP is started in the initial actions. 2-1.Small progress was made in term of quality of data processing. 4-1. WG started drafting the updated dissemination flow and communication chart and will continue the coordination with other agencies.	1-1. JICA Expert Team and BMKG agreed to replace the name from “Guidelines/Manual” to “SOP (Standard Operation Procedure)”.
2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations.	1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis				
3. Enhance capacity for operating InaTEWS to issue tsunami warning.	1. Revised SOP 2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation				
4. Improve dissemination methodologies of earthquake information and tsunami warning.	1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials				

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermesures>

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Version 4.0
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)
Dated 31 August 2023
Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey		Not in this term	
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	DRR-related policies of Indonesia will not significantly change.	1. BMKG officials who have been involved in the Project gave presentations on project activities, mainly on the dissemination methodologies of earthquake information and tsunami warning, at a seminar held in May 2023, and shared project activities with the entire BMKG and relevant organizations. The officials who participated the 1st training in Japan in June 2023 shared the findings from the training within the relevant division of BMKG.	
Outputs 1. Improve acquisition of seismic observation data in proper and timely manner. 2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations. 3. Enhance capacity for operating	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (from XX % to XX %). 1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis 1. Revised SOP		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural	1-1.The SOP will start to be developed after the training in October for the PGT and the PSGT. 1-2.WG1 plan to set a review test (pre- and post-test) for the training participants. 2-1.Small progress was made in term of quality of data	1-1.WG1 agreed to replace the name from “Guidelines/Manual” to “SOP (Standard Operation Procedure)”. 1-2.WG1 proposes to change the indicator

InaTEWS to issue tsunami warning. 4. Improve dissemination methodologies of earthquake information and tsunami warning.	2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation 1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials		hazards/disasters do not occur.	processing. 4-1. WG4 drafted the proposed update of the communication chart and will develop the narrative description of the chart for the education and dissemination purpose.	to “Participants number of training and Review test”.

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermeasures> <Issues> Regarding the OP1 activities condition, the Project purchased most of the

communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.			equipment for training purpose in Japan. However, since the insurance of their exemption letter will take 3 months or over. the delivery of them to BMKG HQs has been delayed several months. <Countermeasures> In order to minimize the impact of not having the equipment that has been planned to be used, WG1 rearranged the training plan to conduct the training by temporarily borrowing available equipment from BMKG's laboratory and follow up when the equipment arrives.

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Version 5.0
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)
Dated 29 February 2024
Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey		Not in this term	
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	DRR-related policies of Indonesia will not significantly change.	1. BMKG hosted five events with input from the Project.	
Outputs 1. Improve acquisition of seismic observation data in proper and timely manner. 2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations. 3. Enhance capacity for operating InaTEWS to issue tsunami warning.	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (PGT: from 88% to XX%, PSGT: from 53% to XX%, Baseline is as of May, 2022). 3. Number of training participants who passed the review test (More than 32 persons scored at least 80%) 1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis 1. Revised SOP 2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation 4. Time required to transfer Seismic Intensity information		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural hazards/disasters do not occur.	1-1.SOPs for PGT and PSGT were drafted. 1-2.WG1 plan to set a review test (pre- and post-test) for the training participants. Current participants number is 57. 3-1. BMKG decided NOT to downgrade tsunami advisory/warning just by the decrease of Mw value compared with M value used in the first advisory/warning dissemination considering the occurrence of ocean bottom land slide, and to incorporate hypocentral parameter adequacy examination	

4. Improve dissemination methodologies of earthquake information and tsunami warning.	from PSGT to PGT (within 2 mins) 1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials			process before the tsunami advisory/warning dissemination decision making. 4-1. WG4 drafted the proposed update of the communication chart and will develop the narrative description of the chart for the education and dissemination purpose.	

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermeasures>

tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.			<Issues> Regarding the OP1 activities condition, the Project purchased most of the equipment for training purpose in Japan. However, the delivery of them to BMKG HQs has been delayed several months due to administrative matters on shipping procedure. <Countermeasures> In order to minimize the impact of not arriving the equipment that has been planned to be used in on-the-job training, WG1 rearranged the training curriculum and conducted the training by temporarily borrowing available equipment from BMKG's laboratory and will provide follow-up session when the equipment arrives.

Project Design Matrix

Project Title: Capacity Development on Operation of Earthquake and Tsunami Analysis and Warning Dissemination
Version 6.0
Implementing Agency: BMKG (Agency of Meteorology, Climatology and Geophysics)
Dated 31 August 2024
Target Group: Officials of BMKG and relevant central/local government agencies
Period of Project: 36 months
Project Site: BMKG HQ in Jakarta and seismic observation stations
Model Site: Banten Province and Palu City

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions	Achievement	Remarks
Over Goal Earthquake and tsunami information issued by BMKG is utilized by DRR-related organizations and the public for their DRR activities.	1. Number of actions taken by DRR-related organizations and the public based on the improved BMKG information in the pilot areas. 2. Increased satisfaction rate of DRR-related organizations and the public which receive the improved BMKG information (from XX % to XX %) in the pilot areas.	Public documents by DRR-related organizations Stakeholder survey		Not in this term	
Project Purpose Capacity of BMKG is strengthened for delivering timely and accurate information on earthquake and tsunami to DRR-related organizations and the public.	1. Number of seminars/presentations conducted by BMKG officials on earthquake and tsunami (e.g. earthquake field school). 2. Improved information is reflected in earthquake and tsunami warning/publication/website. 3. Improved information is received by DRR-related organizations in a continuous and stable way.	Project documents with deliverables attached BMKG official document (e.g. Renstral, annual report) BMKG website	DRR-related policies of Indonesia will not significantly change.	1. Six times in total (BMKG hosted seminars, meetings, In-house training, etc.) 2. (1) under development of the system to disseminate seismic intensity information (2) under improvement of the contents of earthquake catalogs and shake maps (3) under improvement of the process of determining hypocenters and issuing tsunami warnings (4) under improvement of the content of information issued from the WRS to realize faster and more accurate earthquake information and tsunami warnings. 3. Under improvement of the communication chart by reflecting the feedback from related organizations through information dissemination drills.	

Outputs					
1. Improve acquisition of seismic observation data in proper and timely manner.	1. Guidelines/Manuals 2. Improved percentage of seismic data availability (PGT: from 88% to 95%, PSGT: from 53% to 88%, Baseline is as of May, 2022). 3. Number of training participants who passed the review test (More than 32 persons scored at least 80%)		・Cooperation among relevant agencies are sustained. ・Priority of the government to deal with earthquake and tsunami remain unchanged. ・Budget for project-related activities of BMKG will be sufficient. ・Serious natural hazards/disasters do not occur.	1-1.SOPs for PSGT have been drafted. 1-2.PGT: 93.9%, PSGT 89.8% as of August 2024. 1-3.Conducted review test of In-house training and 27 of 32 regional offices (84.4%) passed the test. 2-1. The relocation work for EQs from 1930 to 1950 was almost completed. 2-2. PGT's strong-motion data is now shared with PSGT, and a shake map integrating seismic intensity is being piloted. 2-3. The stability of the current CMT solution with W-phase will be checked. 3-1. The process of updating tsunami warnings was improved to prevent the downgrading of tsunami warnings in a short period. 3-2. A new magnitude formula was developed and is being run on SeiscomP on a trial basis. It is achieved to save time and improve accuracy 3-3. Under implementation 3-4. The basic system is ready for rapid sharing and only needs to be implemented. 4-1. The information dissemination was updated and piloted in the drill in Nov. 2023. It is being improved. 4-2. Education materials for government officials and disabilities are being developed .	
2. Strengthen capacity for utilizing seismic observation data for practical use by related organizations.	1. Upgraded national earthquake catalog 2. Upgraded shake maps 3. Guidance materials for W-phase analysis				
3. Enhance capacity for operating InaTEWS to issue tsunami warning.	1. Revised SOP 2. Increased accuracy and reduced time for stabilization of magnitude calculation 3. Increased accuracy of tsunami prediction in contrast with actual tsunami observation 4. Time required to transfer Seismic Intensity information from PSGT to PGT (within 2 mins)				
4. Improve dissemination methodologies of earthquake information and tsunami warning.	1. Upgraded information dissemination flow and communication chart 2. Revised tools and materials				

Activities	Inputs		Important Assumptions
	Japanese Side	Indonesian Side	Raw/numerical observation data necessary for project activities are made available.
1-1. Review the present maintenance system of seismic observation and communication equipment, and identify the issues. 1-2. Develop guidelines/manuals for equipment maintenance to standardize the procedure. 1-3. Conduct on-the-job training on maintenance and replacement of seismic observation and communication equipment. 2-1. Review present conditions on utilizing seismic observation data and identify the issues. 2-2. Conduct consultations with related organizations for utilizing strong-motion seismograph data. 2-3. Improve the analysis, study, and public relations service of the BMKG by organizing and integrating scanned seismograms and various forms of historical data, and improving the National Earthquake Catalog. 2-4. Improve the quality of a shake map by utilizing additional data source. 2-5. Improve the sophistication of W-phase analysis (on long-period earthquake ground motion) for tsunami forecasting operation. 2-6. Conduct training on relocation method to enhance the accuracy of earthquake hypocenter. 3-1. Review present conditions on the operation of InaTEWS including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 3-2. Compare prediction and actual observation of past tsunami events. 3-3. Improve a utilization way of tide data for tsunami early warning. 3-4. Develop a new magnitude formula suitable for local & regional tsunami warning service using strong motion meter waveform data. 3-5. Improve SOP of tsunami early warning. 3-6. Conduct workshops and training to issue advisories or warnings against tsunami generated by specific causes besides a tectonic earthquake. 3-7. Promote the mechanism to dissemination of “seismic intensity information”. 4-1. Review the present local DRR plan and information dissemination on earthquake and tsunami including lessons learned from the Central Sulawesi earthquake and tsunami and the Sunda strait tsunami, and identify the issues. 4-2. Upgrade the contents on earthquake information and tsunami warning. 4-3. Upgrade existing earthquake information and tsunami warning dissemination flow and communication chart. 4-4. Evaluate the revised flow by conducting information dissemination exercise in the model sites. 4-5. Develop/revise tools, methods and materials for public awareness and preparedness to DRR-related organizations and the public.	1. Experts 1) Leader/Chief Advisor 2) Equipment Maintenance 3) Strong motion Analysis 4) Tsunami Simulation 5) Tsunami Warning Procedure 6) Information Dissemination/ Awareness 7) Project Coordinator 8) Other experts if necessity arises. 2. Training(s) 1) Strong motion Analysis and Seismic Data Quality Control 2) Tsunami Simulation 3) Tsunami Warning Procedure 4) Seismology, Earthquake Engineering, and Tsunami Disaster Mitigation (Master's degree program by GRIPS and BRI)	1. Assignment and service of counterpart personnel 1) Project Director 2) Project Managers 3) Working Group Leader for each Output 4) Staff members 2. Cooperation of relevant agencies 3. Office space with facilities necessary for the Project 4. Information and data (raw data if necessary) on earthquake and tsunami for project activities. 5. Running expenses for project activities (salary, travel/daily allowance, supply and replacement of equipment, etc.)	Pre-condition Earthquake and tsunami related data is available through the coordination of BMKG by the beginning of the Project. <Issues and countermeasures> Nothing special.