

# Great East Japan Earthquake

(GLIDE: EQ-2011-000028-JPN)

## Preliminary Observations



Asian Disaster Reduction Center (ADRC)



International Recovery Platform (IRP)

May 2011

# 1. The Great East Japan Earthquake<sup>1</sup>

## Earthquake

Date and Time: 11 March 2011 at 14:46 JST (5:46 UTC)

Type of earthquake: Plate-boundary earthquake on or near the Japan Trench subduction zone between the Pacific and North America plates

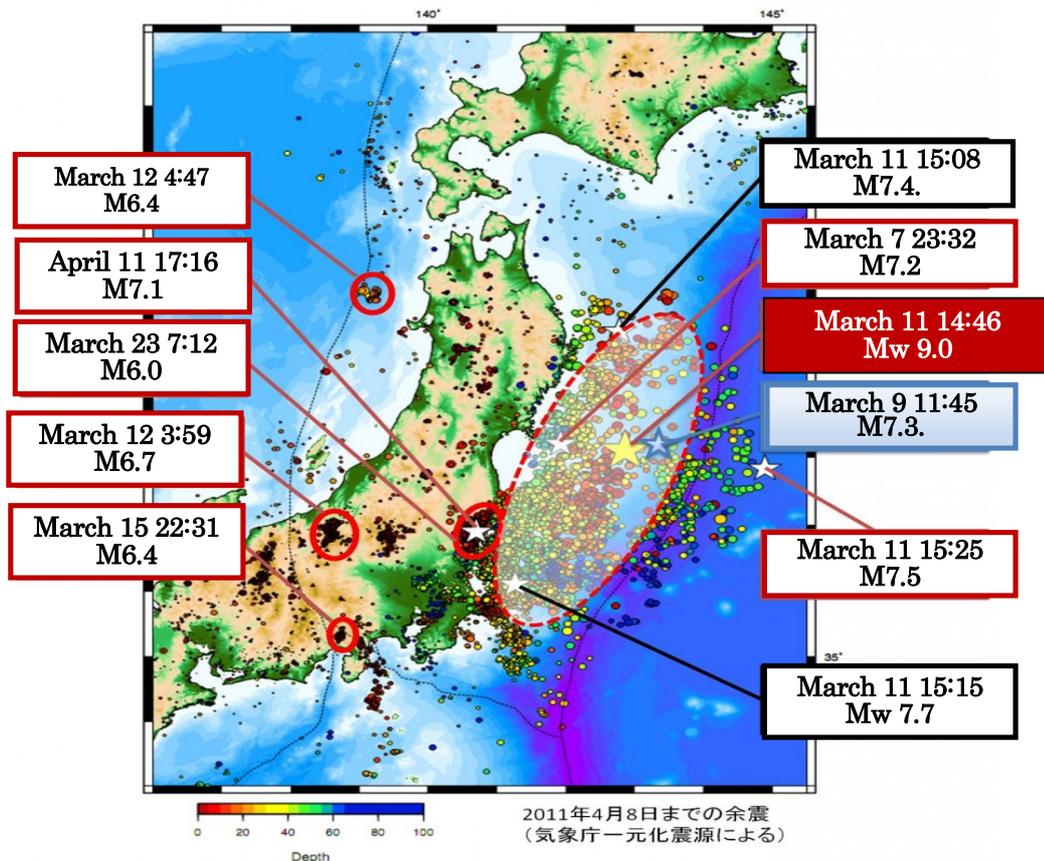
Hypocenter: 130km off the Pacific coast of the Tohoku region, 24 km deep

Magnitude: Mw 9.0 (interim value, the fourth largest in the world since 1900 and largest in Japan since recording started 130 years ago)

- cf. 1960 Chile Earthquake Mw9.5
- 1964 Alaska Earthquake Mw9.2
- 2004 Sumatra Earthquake Mw9.2



Fig. 1 Major earthquakes before and after March 11



Source: USGS and ERI, University of Tokyo

<sup>1</sup> The “Great East Japan Earthquake” is the official name of the March 11 disaster following the decision made by the Cabinet Office on April 1. Other names, such as the “Tohoku Region Pacific Coast Earthquake” or “Tohoku Earthquake”, were used earlier.

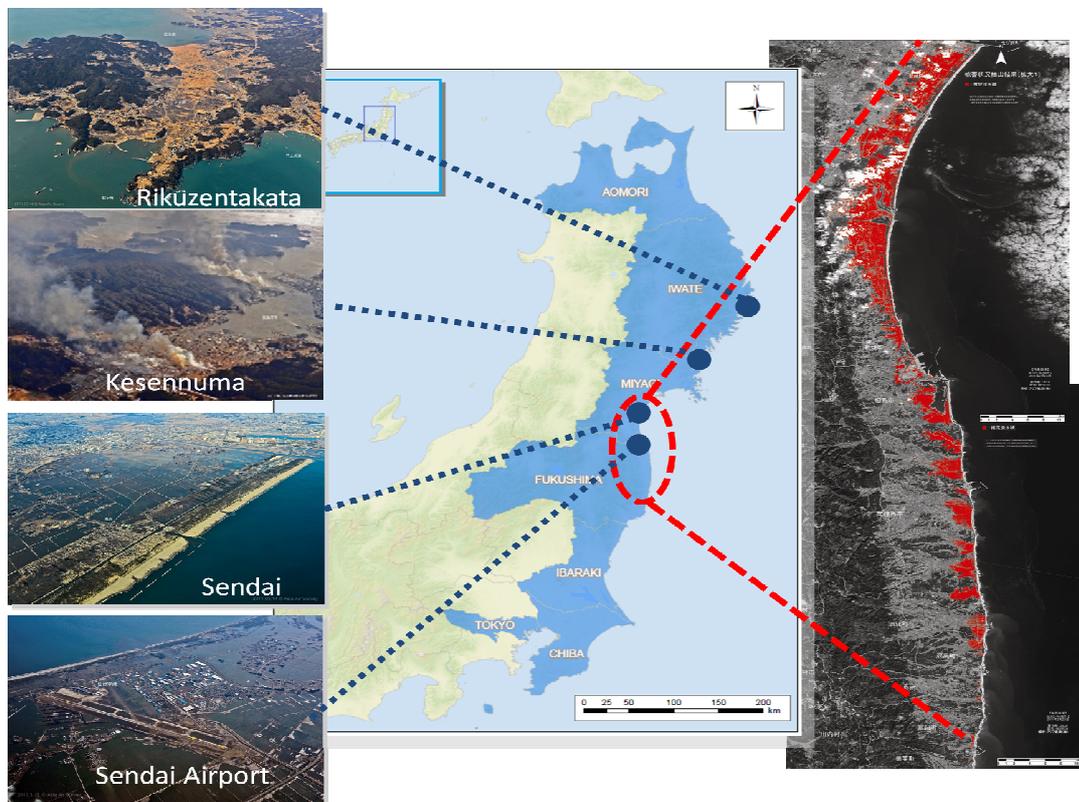
## Tsunami

The Mw. 9.0 earthquake at 14:46 and the series of large-scale earthquakes that followed had resulted in multiple tsunami waves of unprecedented scales at the coastal areas of Hokkaido, Aomori, Iwate Miyagi, Fukui, Ibaraki, and Chiba Prefectures. It has been reported that there were seven tsunami waves over a six hour period. Waves became more turbulent and more powerful upon reaching the inland areas. According to the experts, the fault rupture was about 500 kilometers long in a north-south direction and the tsunami waves hit the coastal areas from different directions, one crossing over the other, explaining the destructive power of the tsunami.

Several scientific investigations are being conducted concerning the scale of tsunami. Initial survey by Tokyo University of Marine Science and Technology found that tsunami waves had reached the heights of 14 meters or 15 meters in many coastal areas, and as high as 38.9 meters in Miyako City, Iwate Prefecture. This is higher than the previous record of 38.2 meters in Ofunato City in the same prefecture during the 1896 Meiji Sanriku Earthquake Tsunami.<sup>2</sup> It is generally believed that timber houses will be destroyed by tsunami waves higher than 2 meters. By contrast, concrete buildings can withstand 4 meters, or so, but will be destroyed if waves exceed 16 meters.

Additionally, survey conducted by Tohoku University found that tsunami waves had reached as far as 5.5 kilometers inland of Sendai Plain. By using remote sensing technologies and GIS, the Geospatial Information Agency of Japan estimated the tsunami swamped areas to about 561 square kilometers covering the hardest hit prefectures of Aomori, Iwate, Miyagi, and Fukui.

**Fig. 2 Overview of tsunami affected areas**



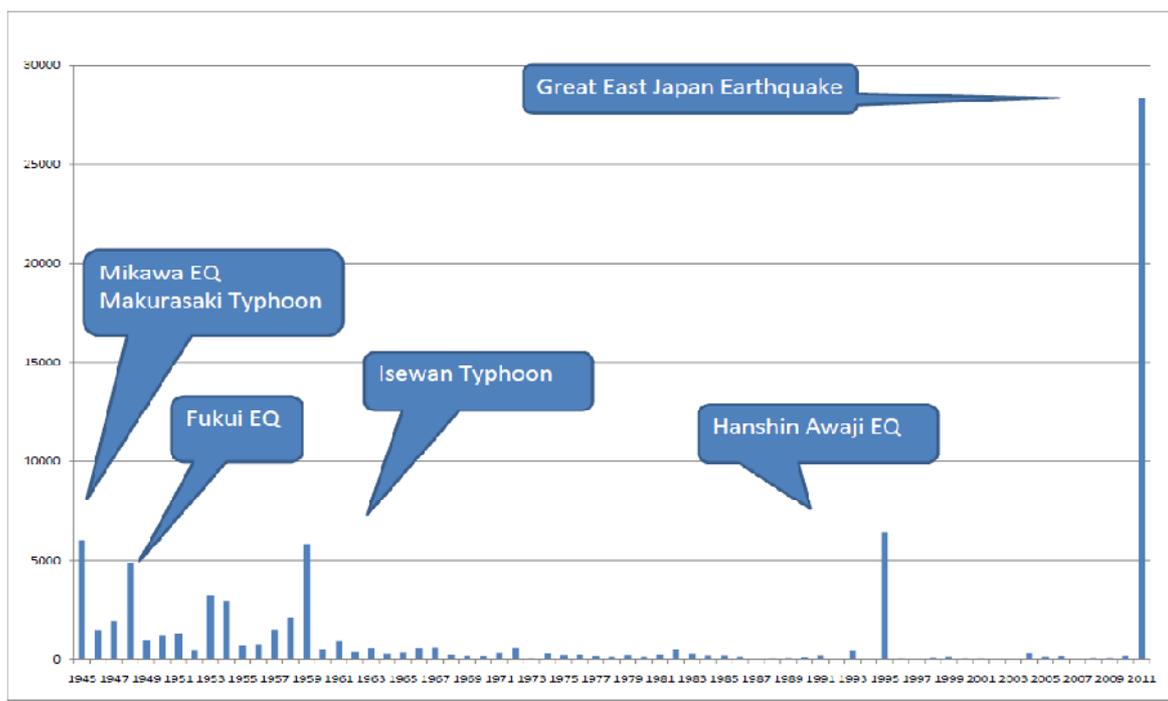
<sup>2</sup> For historical earthquakes and tsunamis, see Fig. 10 on page 12 of this report.

## 2. Effects of March 11 Earthquake and Tsunami

### *Human casualties*

As of April 27, the government has confirmed 14,508 deaths and 11,452 people missing as a result of the disaster. These figures have already exceeded that of the 1995 Great Hanshin Awaji (Kobe) Earthquake, making it the worst disaster in Japan since World War II.

**Fig. 3 Natural disasters in Japan since 1945**

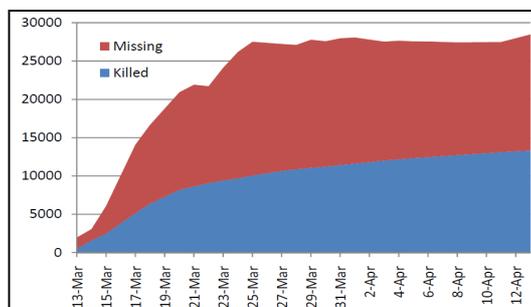


The number of people who are missing covers only those who have been reported to the police by their families or acquaintances. The number of evacuees once topped 400,000 has been declining as the situation stabilizes and services and utilities are gradually being restored.

**Fig. 4 Casualties by Prefecture as of April 27**

Prefecture	Killed	Missing	Evacuees
Iwate	4,234	3,479	41,521
Miyagi	8,745	6,694	40,701
Fukushima	1,455	1,275	26,429
Others	63	4	21,494
<b>Total</b>	<b>14,508</b>	<b>11,452</b>	<b>130,145</b>

**Fig. 5 Numbers of people killed and missing**

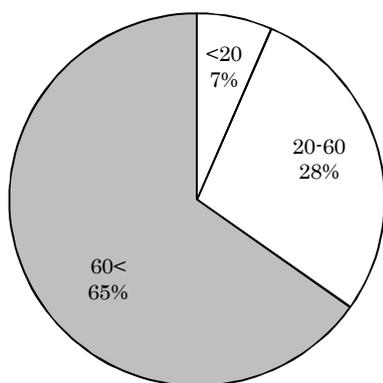


**Note:** The number of evacuees is counted at evacuation centers.

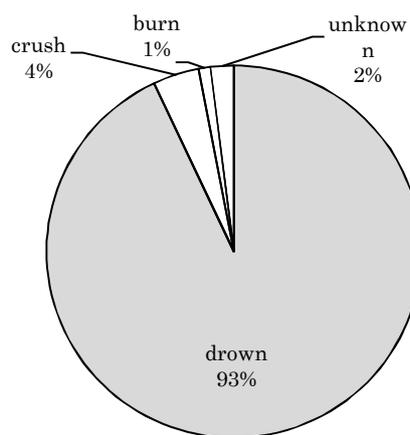
**Source:** National Police Agency

The National Policy Agency reported that out of 13,135 confirmed deaths in the prefectures of Iwate, Miyagi, and Fukushima, 12,143 persons or 92.5 percent resulted from drowning. The figure highlights the difference between the 1995 Great Hanshin Awaji Earthquake, where most of the 6,434 victims were crushed to death by collapsed buildings. The report also showed that out the 11,108 deaths whose ages are confirmed, 7,241 persons or 65.2 percent were aged 60 or above. This indicates many elderly failed to escape the disaster on time and were trapped by the tsunami.

**Fig. 6 Victims by age group**



**Fig. 7 Cause of death**



*Economic damage*

The estimated cost of damage, officially released by the Cabinet Office on March 23, is between 16 trillion and 25 trillion yen. This covers damaged houses, factories, and infrastructure (e.g. roads and bridges) in seven hardest-hit prefectures of Iwate, Miyagi, Fukushima, Hokkaido, Aomori, Ibaraki, and Chiba. On April 27, the Development Bank of Japan Tohoku Branch Office released its detailed estimate of the cost of damage in four prefectures – Iwate, Miyagi, Fukushima, and Ibaraki. The estimated total economic damage in four prefectures is 16,373 billion JPY. This value is about 7.9 percent of their total combined assets. In terms of amount, economic loss of Miyagi Prefecture is about 6,492 billion JPY, the biggest amount among four prefectures. In terms of proportion, economic loss of Iwate Prefecture, where many small cities and towns were heavily destructed, is nearly 47 percent of its total assets in coastal areas.

Moreover, most of the affected prefectures depend largely on the agricultural, fishery, marine farming and marine product industries. These key industries were badly damaged. The total damage to farmlands, agricultural facilities, and agricultural products is estimated at 520 billion JPY. The rebuilding of farmlands can be problematic as the soil became saline. Damage to marine industries, including boats and facilities, is estimated at 350 billion JPY. The Nikkei Newspaper has reported that besides the aforementioned direct cost, economic loss caused by a halt of shipments of intermediate products from the quake-hit areas to the rest of the nation is estimated at 250 billion JPY over the first half of fiscal 2011.

**Fig. 8 Damages of assets**

Prefecture		Damage (Billion JPY)	Damages/total assets (%)
Iwate	Inland areas	754	2.9
	Coastal areas	3,522	47.3
	Total	4,276	12.6
Miyagi	Inland areas	1,595	5.1
	Coastal areas	4,897	21.1
	Total	6,492	11.9
Fukushima	Inland areas	1,270	3.7
	Coastal areas	1,859	11.7
	Total	3,129	6.2
Ibaraki	Inland areas	993	2.1
	Coastal areas	1,483	6.8
	Total	2,476	3.6
Total	Inland areas	4,612	3.3
	Coastal areas	11,761	17.2
	Total	16,373	7.9

**Note:** It covers only the damages to houses, factories and social infrastructures in four prefectures, thus does not cover the whole damages caused by the March 11 earthquake and tsunami.

**Source:** Development Bank of Japan, Tohoku Branch Office

Recognizing that rebuilding of these industrial bases is of supreme importance for local economy and job security, the Japan Business Federation (Nippon Keidanren) made an “Urgent Policy Proposal for the Recovery and Restoration from the Earthquake Disaster” on March 31. Among others, the proposal requested for the development of strong system for an early recovery, building a new region and town, reconstruction of industry, and maintaining and securing employment in the afflicted areas (see the next page for more information).

**Urgent Policy Proposal for the Recovery and Restoration from the Earthquake Disaster**  
**- Towards an Earliest Possible Restoration of the Afflicted Areas and the Creation of a New Japan -**  
**March 31, 2011**  
**Nippon Keidanren**

Japan is indeed facing a national crisis. All citizens must unite and work in a collective effort for the quickest possible recovery from the earthquake damage and the creation of a new Japan. Of utmost importance is that the nation of Japan strives with a sense of urgency to aid those affected, recovery of the afflicted areas, an early conclusion of the nuclear crisis and the rebuilding of Japan's economy. In order to achieve these objectives, a strong political leadership is indispensable. Keidanren posted the proposition "Urgent Appeal for an Early Recovery and Restoration from an Unprecedented Earthquake Disaster" on March 16, which focused on the earliest possible recovery of the livelihood of those affected and the industry and economy of the afflicted areas. Moving forward, efforts towards the reconstruction of the afflicted areas will be important. In carrying out these efforts, the Japanese government must establish a command center with strong authority, and haste towards formulating a "basic law" and "master plan," reflecting sufficiently the voices of those in the afflicted areas, for the early reconstruction of and creation of a new Japan. Likewise, the business community is in the position of fully committing to revitalizing the Japanese economy, starting with an early reconstruction of supply chains and the maintenance of industrial infrastructure.

**1. Developing a Strong System for an Early Recovery**

- (1) Establishing within the government a command center with strong authority
- (2) An early formulation of "basic law" (basic law concerning recovery from the Great East Japan Earthquake)
- (3) Unified implementation of national measures and a strengthened cooperation between the government and local public entities

**2. Building a New Region and Town**

- (1) Formulating and implementing various "master plans" (master plans for expansive reconstruction, expansive infrastructure development, etc.)
- (2) Facilitating urban reconstruction
- (3) Reassuring urban safety and security

**3. Reconstruction of Industry**

- (1) Drafting and implementing plans for expansive reconstruction of industries (including agriculture, forestry, fishery and livestock)
- (2) Prompt response to prevent damage of from rumors of radiation (including appropriate and swift information disclosure and communicating with foreign governments and international organizations)
- (3) Maintenance and recovery of business activities
- (4) Taxation measures for assistance of those affected peoples and companies
- (5) Financial response
- (6) Response with the Corporation Law, etc. (including companies with account settlements from March 2011 onward)

**4. Maintaining and securing employment in the afflicted areas**

- (1) Early implementation of new reconstruction operations to create local jobs
- (2) Assistance towards company efforts to maintain jobs
- (3) Bringing stability to the lives of those who lost their jobs and supporting their early reemployment
- (4) Providing work opportunities
- (5) Response such as smooth labor insurance benefits

**5. Securing sources of funding for restoration and realizing fiscal soundness**

- (1) Early formulation of budgetary measures, etc., needed for reconstruction (including supplementary budget)
- (2) Adherence to a mid- to long-term fiscal soundness policies and reaching a national consensus on the cost burdens of reconstruction
- (3) Deliberate over ideal reconstruction funding

### 3. Disaster Affected Area

The disaster-affected areas can be roughly categorized into three types based on their functioning capacity.

**Type 1:** *Functions are not severely affected.* These are cities or towns that suffered extensive damage but mostly in their coastal areas. Thus, the entire city or town can function relatively well. Sendai City and Natori City in Miyagi Prefecture fall under this type;

**Type 2:** Functions are partly paralyzed. These are cities or town centers that were heavily damaged and their functions were partly paralyzed. Ishinomaki City and Higashi-Matsushima City of Miyagi Prefecture and Ofunato City, Kamaishi City, and Miyako City of Iwate Prefecture fall under this type.

**Type 3:** Functions are totally paralyzed. These are cities or towns that were almost entirely devastated. Thus, their functions were totally paralyzed. Cities or towns of this type include those located in rather narrow land areas along sawtooth (ria) coastline.<sup>3</sup> Minimi-Sanriku Town and Onagawa Town in Miyagi prefecture as well as Rikuzen-Takata City and Ootuchi Town in Iwate Prefecture fall under this type.

#### *Wakabayashi Ward, Sendai City*

Wakabayashi ward is located in the eastern part of Sendai city facing the Pacific sea. Much of the area is flat plain used as rice paddies or fields with some scattered settlements. The local hazard maps were prepared for a tsunami of 3m high, but, in reality, a much higher tsunami, more than 10 meters, hit this area. It was along this area that tsunami waves reached as far as 5.5 kilometers inland. One of the intriguing findings from the field survey was that the embankment at West Sendai Road, about 5-6 meters high, parallel to and a few kilometers away from the coastal line, had been effective to stop tsunami waves from flowing further inland. Massive pile of debris was accumulated near the West Sendai Road.

**Wakabayashi Ward, Sendai city (March 22)**



<sup>3</sup> A coast with several parallel rias extending far inland and alternating with ridgelike promontories.

*Ishinomaki City and Higashi Matsushima City*

Ishinomaki city is the second largest city in Miyagi prefecture with population about 170,000. Most of the city's downtown areas were inundated about 2 to 3 meters, damaging mostly the ground floors of buildings. Boats, vehicles, mud, and other types of waste were accumulated.

**Downtown area of Ishinomaki city (March 22)**



**Kadowaki District of Ishinomaki city (March 22)**



**The coastal residential area of Higashi-Matsushima city (March 22)**



*Onagawa Town*

Onagawa town is located in eastern Miyagi prefecture. The downtown area was totally destroyed by the tsunami. Along the coast, wooden houses were washed away, leaving only their foundations. Even reinforced concrete buildings collapsed. A hill just behind the fishing port was designated as an evacuation area. In the hospital, located on top of this hill which is nearly 16-17 meters high, traces of water were found. This indicates that tsunami waves were very high in this area perhaps because of topographical characteristics.

**The port area of downtown of Onagawa Town (March 22)**



**The evacuation pass to the Onagawa Municipal Hospital (March 22) in the port area**



*Minami-Sanriku Town*

Minami-Sanriku town is located in northeastern Miyagi prefecture. The tsunami washed away most of the buildings, and the town was completely devastated. At Shizugawa Hospital located near the coast (some 200 meters inland), there were indications that the tsunami had reached the roof of a four storey building. In an apartment building near the seashore, which had been designated as a tsunami evacuation building, there were traces of water indicating that the tsunami had reached the 4th floor as well.

The disaster management center of Minami-Sanriku, a three-story building, was designed to function as a tsunami evacuation building. When the tsunami struck, about 30 municipal officials evacuated to the rooftop, but only 10 survived. A young official who kept delivering evacuation notices to the villagers until the very last moment was among the casualties.

It was generally believed that a three-storey reinforced concrete building could be designated as evacuation building. However, during this disaster, such kind structure was insufficient for protection.

**Panoramic view of Minami-Sanriku town(2011.3.23)**



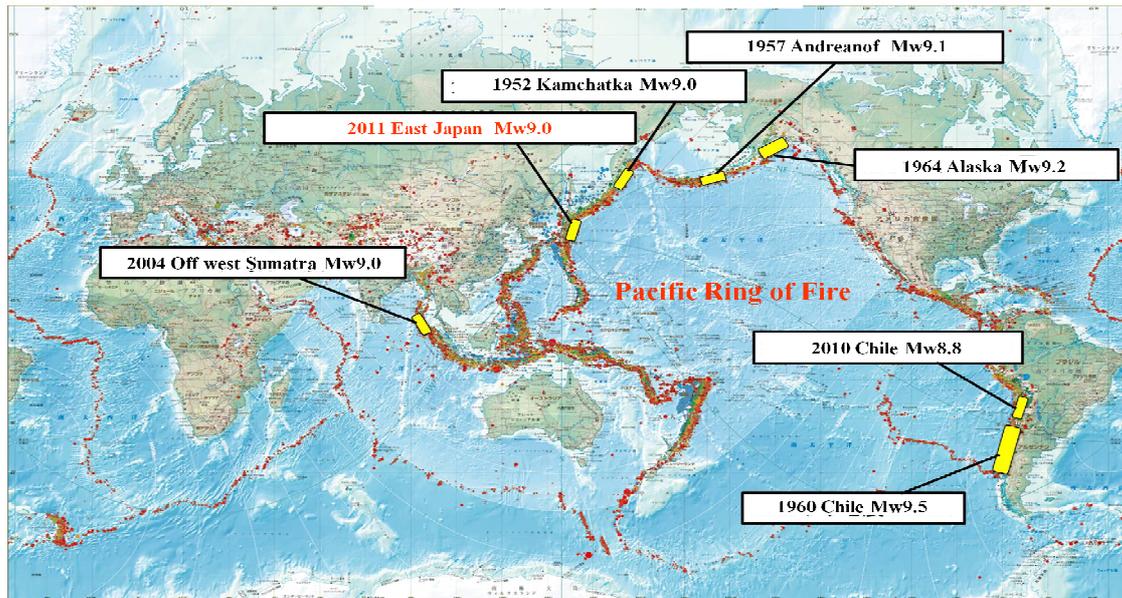
**The disaster management center of Minami-Sanriku town(2011.3.23)**



#### 4. Disaster Preparedness Measures

It is known that about 80 percent of all the world's earthquakes occur along the rim of the Pacific Ocean called "the Ring of Fire". Most earthquakes occur at fault zones, where tectonic plates—giant rock slabs that make up the Earth's upper layer—collide or slide against each other. The impacts are usually gradual. However, immense stress can build up between plates. When this stress is released quickly, it sends massive vibrations, called seismic waves, often hundreds of miles through the rock and up to the surface<sup>4</sup>.

**Fig. 9 Seismicity of the world**



**Note:** Yellow squares are the fault planes indicating the size of the magnitude.  
**Source:** ERI, the University of Tokyo

Sitting on the Pacific Ring of Fire, Japan's archipelago covers only 0.25% of the land area on the planet, the number of earthquakes and distribution of active volcanoes are at a quite high level. According to USGS's and JMA's information, some 20 per cent of 912 earthquakes with the magnitude of 6.0 or larger between 1995 and 2005 in the world occurred in or nearby Japan.

##### *Sanriku Coast*

A coastal region on the Pacific Ocean, extending from southern Aomori prefecture through Iwate prefecture and northern Miyagi prefecture, is known as "Sanriku Coast". This region is famous for a sawtooth (ria) coastline of 600 km in total. Offshore at the Sanriku coast is where a cold current and a warm current meet, creating a rich fishing spot that is considered to be one of the Four Great Fishing Grounds in the world.

The Sanriku Coast is known to be vulnerable to tsunamis. It has been devastated by previous tsunamis, particularly the 1896 Meiji-Sanriku earthquake and tsunami, the 1933 Showa-Sanriku earthquake and tsunami, and the 1960 Chile earthquake and tsunami. Some experts are currently examining the similarities between the 2011 Great East Japan Earthquake and the 869 Jogan Sanriku Earthquake and Tsunami.

<sup>4</sup> Based on an article on National Geographic (<http://environment.nationalgeographic.com>)

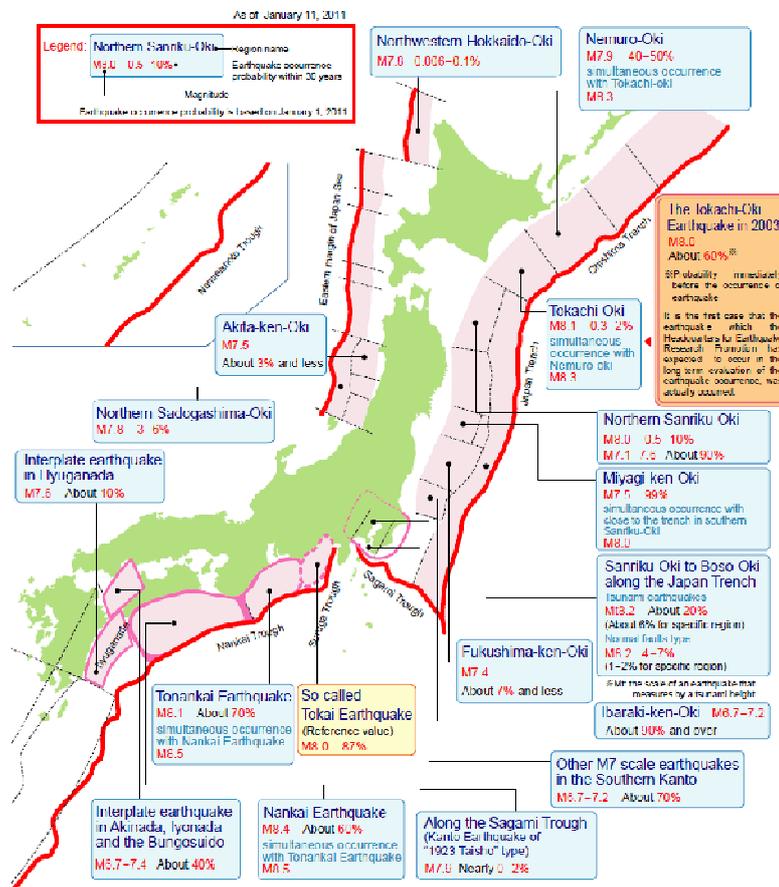
Fig. 10 Major historical earthquake and tsunami on Sanriku Coast

Earthquake/ Tsunami	Year/Date	Magnitude	epicenter	People died or missing	Maximum height of tsunami
Jogan Sanriku	July 869	Mw 8.6?	Unknown	Unknown	unknown
Meiji Sanriku	June 15 1986	Mw 8.2	Off Iwate	21,959 (Only people died)	38.2 (Ofunato city)
Showa Sanriku	March 3 1933	Mw 8.1	Off Iwate	3,064	29.3 (Ofunato city)
Chile	May 22 1960	Mw 9.5	Off Chili in South America	142	5.6 (Miyako city)

*Evaluation of seismic activities*

Large inter-plate earthquakes had been predicted for this region, including “Miyagi-ken-Oki” earthquake which was predicted to occur at magnitudes ranging from M7.5 to M8.0 within 30 years with a 99% probability. However, it is clear by now that the Great East Japan Earthquake was much larger than those predicted. Its multiple hypocenters were linked, resulting in 400 km long and 200 km wide range. It is the 4th largest earthquake in the world since 1900. Some experts said that this scale of earthquake and entailing tsunami occurs with a one thousand year return period.

Fig. 11 Long-term evaluation of subduction earthquakes

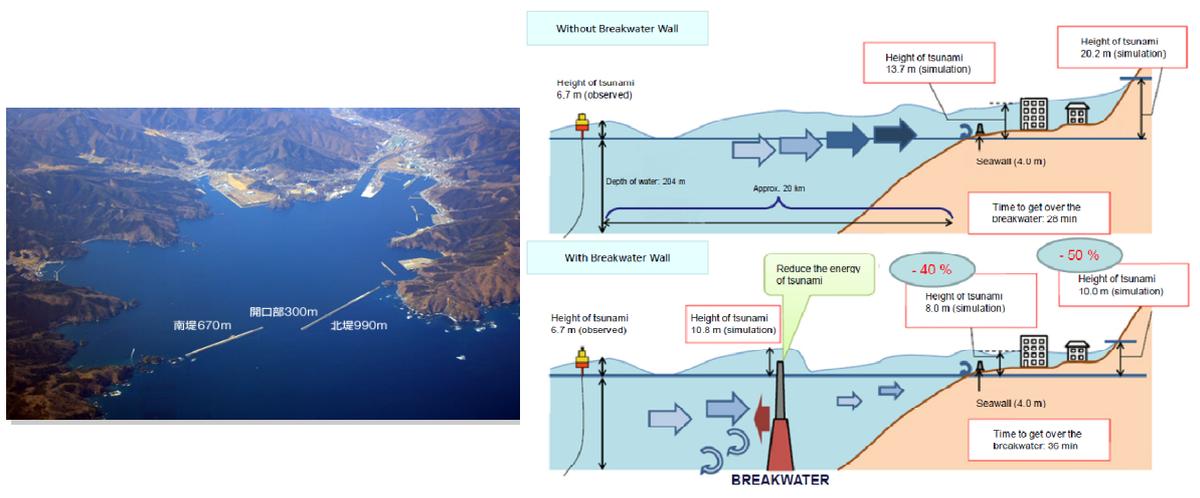


## 5. Pre-Disaster Measures

### Structural measures

Various measures, both structural and non-structural, had been taken in those areas to protect people and communities from tsunami before the March 11 earthquake and tsunami. The most notable were the construction of 10m high and 2.5 km long dykes in Taro area of Miyako City in Iwate Prefecture which is often called as “the Great Wall” and the world’s biggest breakwater (8 meter high above sea which is 63 meter deep) in Kamaishi City. The Kamaishi City’s breakwater wall at the mouth of Kamaishi Bay collapsed and the tsunami reached 6.9m - 9m high at several points. However, based on the simulation by Port and Airport Research Institute, the tsunami would have reached up to 13.7m high and would have caused damage to much wider areas without the wall. The breakwater wall was estimated to have impeded tsunami energy by 40%.

Fig. 12 Simulation of the effectiveness of breakwater



Source: Port and Airport Research Institute

It is generally believed that a three storey steel reinforced building is desirable for tsunami evacuation. This is still true in many cases, but as observed in the field survey where tsunami waves reached the fourth floor or higher, a three storey building may not be always enough. It was also observed that some areas steel reinforced buildings collapsed, hence, further examination is necessary on this point.

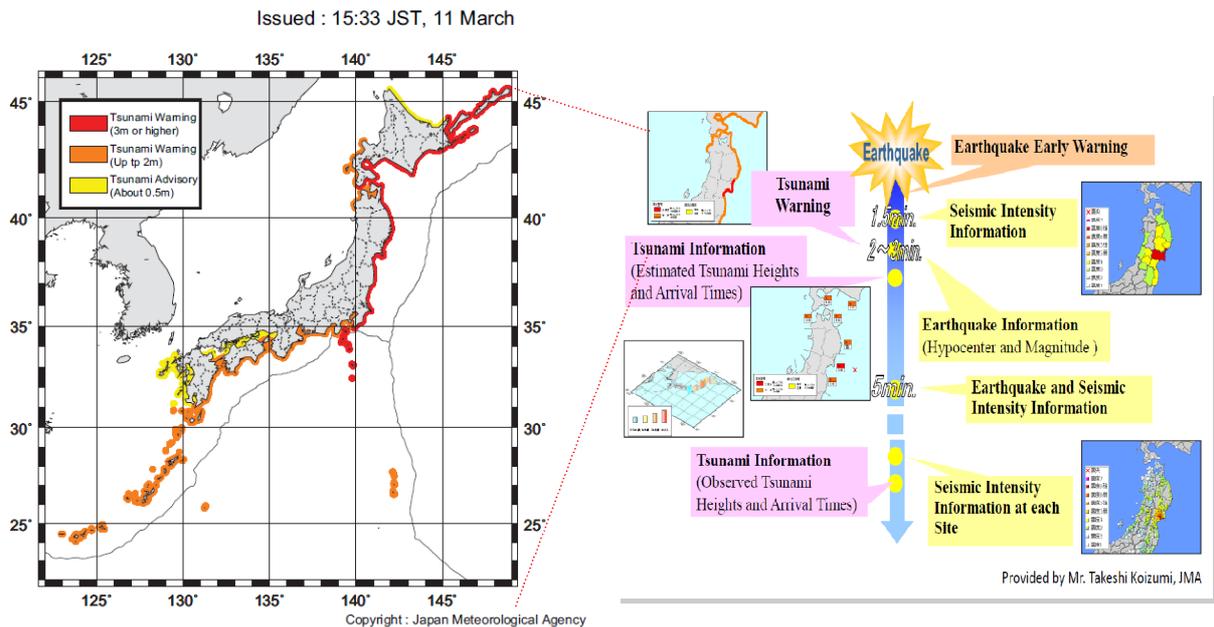


*Non-structural measures*

Structural measures must be complemented with non-structural measures. Too much reliance on structural measures might have resulted in the delay for people to take appropriate actions.

Tsunami Warning: Japan Meteorological Agency started issuing tsunami warning three minutes after the first main shock. Through media and other channels, tsunami warning messages including information on expected tsunami height and arrival time were disseminated. The local governments were also sending tsunami warning messages by sirens and by community wireless system. It helped people to escape from tsunami by evacuating to higher grounds or elevated buildings.

**Fig. 13 JMA tsunami warning**



Indigenous wisdom *Tsunami Tendenko*: The word *Tsunami Tendenko* means “at time of tsunami: go uphill independently, care only for your own safety, and don’t think of anyone else, even your family.” This is a local wisdom known in the Tohoku Sanriku region.

Awareness, Education and Training: Kamaishi city is one of the hardest hit areas. Pre-disaster education and various activities to raise people’s awareness had been conducted in this city, which helped many people take appropriate actions and saved their lives.



On the other hand, it has been reported in many cases that many people did not expect tsunami waves would be so high and reach far inland. As a result, many areas which had been previously thought safe from tsunami, either multi-story buildings or higher grounds, were hit by

the tsunami. Therefore, it is necessary to further examine what pre-disaster measures worked, what measures did not work and why.

## 6. Recovery Efforts

This earthquake disaster is unprecedented in its scale and scope, so the recovery is expected to take a long time. The following recovery efforts have already been launched in these disaster-affected areas.

### *Infrastructure*

The Ministry of Land, Infrastructure and Transport (MLIT) reported that as of end of March, almost 90% of major land, sea, and air transportation networks disrupted by the March 11 earthquake and resulting tsunami were restored.

- Highways and major national roads running north and south through the Tohoku region have all been reopened, except those within the evacuation zone around the crippled Fukushima Daiichi nuclear power plant.;
- Of the 15 ports in the disaster hit areas, only the Aomori terminal was open to public use immediately after the quake, but all have been reopened to-date;
- All 12 airports in the region are back in operation, including for public use. The Hanamaki, Yamagata, Fukushima and other airports are open around the clock to handle Self-Defense Forces and U.S. military transport planes;
- Tohoku Shinkansen (bullet train) services between Tokyo and Shin-Aomori was reopened late April.

Already good progress has been made to restore damaged infrastructure especially major transport facilities as described above, but it is true that it will take many years to recover the whole.

### *Evacuation Centers*

As of April 27, 130,145 displaced people are staying at evacuation centers, such as community centers, schools, and sports stadiums. This figure does not cover those who are staying at their homes, in cars, or at other locations under harsh living conditions. Since the provision of temporary shelters expected to take many months to complete and the sanitation conditions at the evacuation centers continue to deteriorate, some local authorities, such as Minami-Sanriku town, have started to temporarily relocate some evacuees to other places with better living conditions, such as hotels and public

**Fig. 14 Number of evacuees since March 11**



apartments in less affected areas.

The Special Headquarters for Measures to Assist the Lives of Disaster Victims conducted a survey to grasp the situation of 1,047 evacuation centers in three hardest-hit prefectures, namely Iwate, Miyagi and Fukushima. The survey results became available to the public on April 15.

(Main findings from the survey)

The period of the survey was from April 6<sup>th</sup> to 10<sup>th</sup> and its response rate was 30.9 per cent. The following highlights the major findings. Of the 323 evacuation centers that responded to the survey,

- 72.8 per cent have gained access to water, electricity and gas (only 7 evacuation centers have not yet gained access to water, electricity and gas);
- Foods have been distributed to most of evacuation centers to a reasonably great extent, but hot foods have not yet been served at 7 evacuation centers;
- 151 evacuation centers reported that evacuees do not have underclothes to change or cannot wash them;
- 91 evacuation centers reported that there is no partition between family spaces;
- Medical and hygiene situation (frequent visit by medical doctors, enough medicines, bathing, toilet and waste disposal) is reasonably fine, but there are still some evacuation centers without medical care, no bath facility or waste dumping site;
- In a nutshell, 36 evacuation centers are still under extremely harsh or harsh conditions.

### *Temporary Housing*

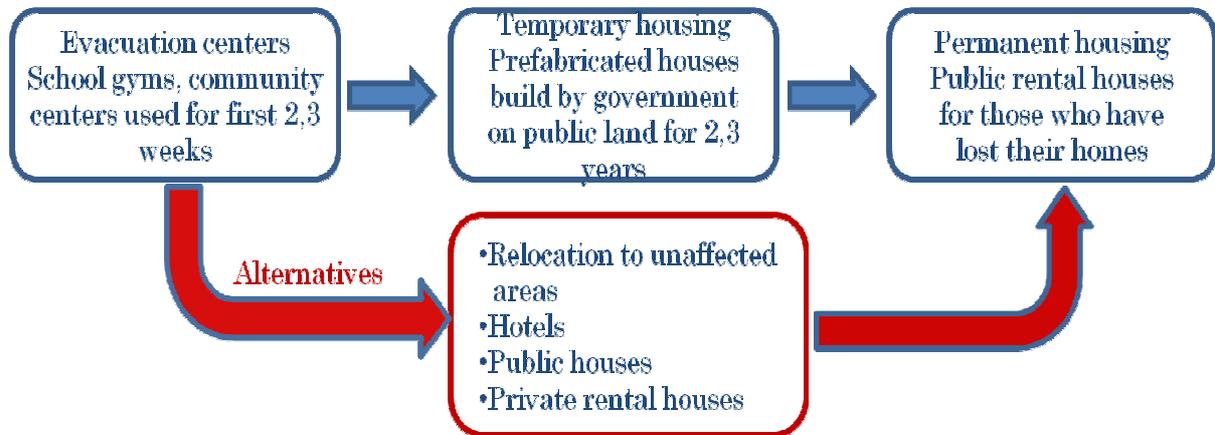
The construction started in Rikuzen-Takata city in Iwate prefecture on March 19, and the transition of residents into those housings started on April 9. Currently, of 72,290 housing units requested, approximately 30,400 units are estimated to be completed by the end of May according to Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The 18,000 units requested by Iwate Prefecture are likely to be completed by end of July, and the 24,000 units requested by Fukushima Prefecture are likely to be completed by end of September.



Other alternatives to accommodate displaced people were also considered. For instance, the government has already secured 52,913 housings units that are originally intended as government officials' apartments or public housing. As of April 27, 7,805 of these housing units

have already been provided to the displaced families..

Fig. 15 Transition of types of shelters



#### Recent developments

On April 11, a month after the earthquake and tsunami, a Reconstruction Design Council with the participation of experts from various fields was created “to deliver a blueprint for the reconstruction plan around the time of June”. The Council has already convened several meetings to share experiences and ideas. The Council will submit its first set of recommendations in June.

The Prime Minister, on April 15, posted his message on several newspapers overseas (Washington Post and Herald Tribune) stating: *“The government will dedicate itself to demonstrating to the world its ability to establish the most sophisticated reconstruction plans for East Japan, based on three principles: first, create a regional society that is highly resistant to natural disasters; second, establish a social system that allows people to live in harmony with the global environment; and third, build a compassionate society that cares about people, in particular, the vulnerable.”*

The Parliament passed the first supplementary budget totaling some 4 trillion JPY on May 2. It is the first of a planned series of spending packages to deal with the aftermath of the disaster. The budget will be used for measures such as removing debris, constructing temporary housing and repairing infrastructure as well as providing financial support to businesses affected by the disaster.

The Central Disaster Management Committee, chaired by the Prime Minister and with members comprising all cabinet ministers, heads of public bodies such as Bank of Japan (BOJ) and Japan Broadcasting Corporation (NHK) and experts, has started the examination of measures necessary for future mega disasters. The results of the examination will be used to improve government’s disaster management plans and policies.

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