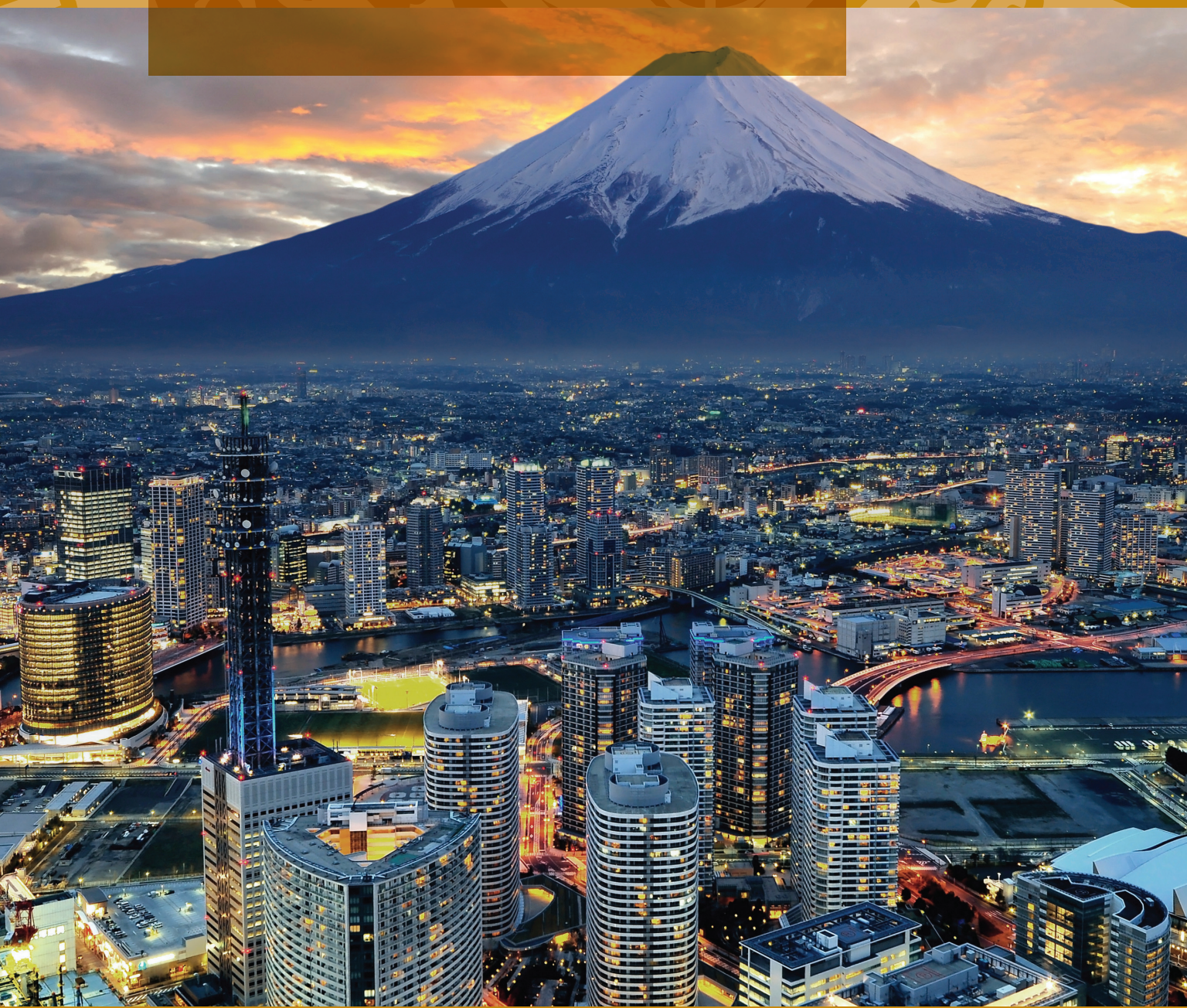
The earthquake and tsunami that struck Japan on March 11, 2011 generated a mega earthquake and tsunami that went far beyond any of the pre-disaster expectations. These events have demonstrated the fundamental role of understanding the risks faced by society from natural hazards as the basis for building countermeasures to extreme events. Through developing damage scenarios decision makers and the public are better aware of the potential effects of natural hazards on human and economic assets. Recognizing that the Great East Japan Earthquake vastly exceeded all levels of damage considered, this chapter shows the importance of accurate risk and damage information to inform prevention and preparedness planning.



CHAPTER 11:
Lessons Learned from the Great East Japan Earthquake: Hazard Information and Damage Scenarios to Inform Effective Countermeasures to Extreme Events

Excerpt from Report of the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the "2011 off the Pacific coast of Tohoku Earthquake, (September 28, 2011)

This chapter is a World Bank abridged version of the submissions of the Government of Japan

Introduction

The Great East Japan Earthquake has brought unprecedented damage in Japan. As the full picture and the dimensions of the damage gradually become revealed, local residents, communities, businesses, local governments, and the national government are unifying their strength in a determined effort toward reconstruction.

However, the bitter experiences and tough lessons encountered in this disaster must be permanently passed on as a testament linking the past, the present, and the future and as wisdom for building a disaster-resilient nation and resilient communities.

The 2011 off the Pacific coast of Tohoku Earthquake generated a mega earthquake and tsunami that went far beyond any of the predisaster expectations. It incurred vast damage, including the greatest loss of human life in a single disaster in Japan since the Second World War, and posed enormous challenges for the nation regarding the way earthquake and tsunami countermeasures have been developed so far. Therefore, the Central Disaster Management Council decided to establish the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the 2011 off the Pacific coast of Tohoku Earthquake[1] to investigate and analyze the recently experienced earthquakes and tsunamis and examine countermeasures for future earthquakes and tsunamis.

The tragic events have demonstrated the fundamental role of risk information and understanding of natural hazards and the way these affect human and economic assets as the basis for developing all countermeasures to extreme events. The following is an excerpt of the committee's report focusing on the importance of understanding hazards and risk to better inform risk mitigation and preparedness measures.

The magnitude of the earthquake, the height and strength of the tsunami, the extent of the inundated area, the occurrence of subsidence across a wide area, and the extensive human and material damage experienced in this disaster all vastly exceeded the levels of damage previously envisaged by the technical committees convened by the Central Disaster Management Council. Although disaster management measures had been promoted according to various disaster management plans based on predisaster assumptions and their implementation, these measures possibly exacerbated the damage in some districts. We have to humbly concede the difficulty of predicting natural phenomena and conduct a fundamental review of how to conceptualize earthquakes and tsunamis for hazard assumption in the future. For tsunami countermeasures in particular, we must urgently conduct across-the-board reviews and thoroughly prepare for mega earthquakes and tsunamis in the Nankai Trough, where, we fear, they may occur in the near future.

Characteristics and Verification of the Damage Caused by the Earthquake and Tsunami

The tsunami and the earthquake exceeded predisaster assumptions and overcame mitigation measures. From this, we must learn the importance of careful hazard assumptions and preparedness measures to respond to all events, including extremely high-impact, low-frequency events. The fact that such events were not envisaged is the result of basing assumptions on the earthquakes and tsunamis experienced over the past several hundred years and means that there are limitations to the hazard assumption methods used before this disaster. The predisaster assumptions of earthquakes and tsunamis were far removed from the earthquake and tsunami that actually occurred, gravely highlighting the importance of principles for selecting earthquakes and tsunamis for future hazard assumptions.

The tsunami that occurred in this disaster was of a scale that vastly exceeded predisaster assumptions. An enormous earthquake with a magnitude of 9.0, a size that could not be envisaged from the history of earthquakes in Japan that stretches back several hundred years, erupted with a wide epicentral area that interlocked several regions. The reasons such enormous tsunamis occurred include the fact that the mechanism causing the tsunami consisted not only of a slipping movement at the deep plate boundaries that lead to a normal ocean trench earthquake, but also a considerable simultaneous slipping movement at the shallow plate boundaries.

Phenomena that particularly exceeded any predisaster assumptions included an enormous tsunami height and extensive inundation area, penetration of the inundation area to a considerable distance inland, inundation caused by tsunami run-up overflowing river banks, and widespread occurrence of subsidence. The level of subsidence remained unchanged six months after the disaster, and secondary damage from this earthquake and tsunami disaster is occurring in the form of flooding in the affected regions because of storm surges and precipitation.

Predisaster Principles in Selecting Earthquakes and Tsunamis for Hazard Assumptions

In addition to estimations for trench-type earthquakes in the vicinity of the Japan and Chishima Trenches that are expected to occur in regions that include the epicentral area of the 2011 off the Pacific coast of Tohoku Earthquake, the committees convened by the Central Disaster Management Council have conducted estimations of expected hazard levels of earthquakes and tsunamis for the Tokai Earthquake, Tonankai and Nankai Earthquakes, Tokyo Inland Earthquakes, and Chubu and Kinki Regions Inland Earthquakes. In the committees' efforts at replicating the earthquakes and tsunamis experienced over the past few hundred years in those

regions, those earthquakes and tsunamis that have repeatedly occurred and are likely to occur in the near future were selected as the impending earthquakes and tsunamis to be used for hazard assumption and were considered for examinations of seismic movement and tsunami hazards.

The 2011 off the Pacific coast of Tohoku Earthquake was a magnitude 9.0 earthquake caused by the interlocking of several epicentral areas in the Japan Trench, an earthquake that could not be found in the earthquake literature of Japan stretching back several hundred years. The fact that such an earthquake could not be envisaged is the result of basing assumptions about Japan Trench earthquakes and tsunamis on this data. This approach means that there are limitations to the hazard assumption methods used before this disaster.

Reflections on the Differences between the Pre-disaster Assumptions and the Actual Disaster

We must gravely accept the fact that the results of the predisaster assumptions of earthquakes and tsunamis were far removed from the earthquake and tsunami that actually occurred. Therefore we must undertake a fundamental review of the principles regarding selection of earthquakes and tsunamis for future hazard assumptions.

Until now, the earthquakes considered to be impending from among the very largest earthquakes experienced in Japan over the past few hundred years have been used for replication of seismic intensities and tsunami heights recorded in the past using seismic source models. The results of these replications have been treated as the hazard assumptions for the next largest-scale earthquake to occur. As a result, if the seismic intensity or tsunami heights of an earthquake were not reproduced by the model, the earthquake was regarded as having a low probability of occurrence, even if such an earthquake may have occurred in the past, and was disregarded from the hazard assumptions. With regard to this disaster, there is a need to deeply reflect on the fact that earthquakes such as the Jogan Sanriku Earthquake of 869, the Keicho Sanriku Earthquake of 1611, and the Enpo Boso Earthquake of 1677 were all disregarded when developing the hazard assumptions.

These earthquakes were disregarded despite knowledge of them because of the difficulties in reproducing the complete picture of the earthquakes, including their intensities and tsunami height, which are necessary as the basis for examining concrete disaster management measures. In the future, the use of these earthquakes in hazard assumption must be examined, regardless of the inadequate understanding of their complete picture. Despite the probability of their occurrence being low, earthquakes in which earthquake and tsunami damage occurred on an overwhelming scale must be adequately examined.

Because the actual earthquake and tsunami differed from the predisaster hazard assumptions, the scope of the seismic movement, the tsunami height and extent, and the inundation area all exceeded expected levels by far. In particular, although the estimated inundation area was used to prepare disaster management material including hazard maps, the fact that the tsunami inundation area and tsunami height were far greater than the estimated levels led to the proliferation of damage. It is possible that the hazard maps that were prepared on the basis of the predisaster hazard assumptions led to a false sense of security among people and that the tsunami that exceeded these assumptions led to an expansion of the damage.

Looking at the construction of coastal protection facilities suggests that, although these are effective against tsunamis with heights within the scope of their design, the massive tsunami and colossal damage witnessed during this disaster exposed the limitations of disaster management measures that rely excessively on coastal protection facilities.

Gravely acknowledging that this disaster event caused damage greatly exceeding the predisaster damage estimate, the former principles for hazard assumption need to be fundamentally reviewed and thorough reviews need to be conducted for all procedures from the selection of earthquakes and tsunamis for hazard assumption to the development of individual measures. Disaster management measures can then be rebuilt entirely.

Selection of Earthquakes and Tsunamis for Development of Disaster Management Measures

Assumptions about natural hazards underlie all risk assessments and risk mitigation measures. The magnitude of the event expected directly dictates and guides the various disaster management measures. Adequate understanding of prevalent hazards must be obtained, and the selection of events for future hazard assumptions must be as comprehensive as possible. Countermeasures need to take into account low-frequency, high-impact events as well as medium- and high-frequency events that can be better mitigated. Comprehensive preparation and planning should always include the possibility of actual damage exceeding the damage expected by the hazard assumption.

Significance of Earthquake and Tsunami Hazard Assumptions

Since before this disaster, earthquake and tsunami countermeasures have been developed by national and local governments by first selecting earthquake hazards to be assumed. Next, government formulates and promotes various disaster management measures based on the results of hazard assumptions of seismic movement and tsunami. Though the earthquake and tsunami experienced in this disaster greatly exceeded the predisaster assumptions, this does not necessarily mean that the exercise of hazard assumptions for earthquakes and tsunamis is pointless. Governments need to: (a) adequately investigate and analyze the reason phenomena far beyond the predisaster hazard assumption occurred, (b) continue to revise assumptions for earthquakes and tsunamis, (c) reexamine future damage scenarios, and (d) proceed with disaster management measures.

Meanwhile, governments need an adequate understanding that natural phenomena are inherently uncertain and there are certain limitations to hazard assumptions.

Principles for Conducting Earthquake and Tsunami Hazard Assumptions for the Future in Consideration of the Great East Japan Earthquake

For selection of earthquakes and tsunamis for hazard assumptions, the historic occurrences of the earthquakes and tsunamis need to be investigated going back as far as possible. Then investigations can proceed on the basis of scientific analysis of ancient documents and other historical material as well as surveys of tsunami deposits and coastal topography. These investigations must be implemented with the continued collaboration of the Headquarters for Earthquake Research Promotion's Earthquake Research Committee, which has been undertaking a long-term evaluation of seismic movements.

If one bears in mind that forecasting earthquakes is difficult and that there are uncertainties with long-period assessments, earthquakes and tsunamis must be examined considering all possibilities, including the actual damage exceeding the damage expected by the hazard assumption.

In other words, when one conducts earthquake and tsunami hazard assumptions in the future, the largest-possible mega earthquakes and tsunamis should be considered from every possible angle. Furthermore, even when it would be difficult to develop the facilities needed as disaster management measures against the earthquakes

and tsunamis based on a hazard assumption, such an assumption must be adopted without hesitation.

Research and analysis explaining the mechanisms that trigger earthquakes and tsunamis will become even more essential. For verification of the occurrence of mega tsunamis over several thousand years, enhanced research must include the areas of seismology, geology, archaeology, and history, as well as tsunami deposits on land and the ocean floor, the geology of coastal terraces, and biological fossils, among others.

In addition, to ascertain accurately the state of the ocean trench that is thought to have been the source of the mega tsunami, researchers need to include direct observations of not only inland movement but also ocean bottom crustal movement. They also need to study interplate coupling and make further efforts to promote seismology-based research to improve the precision of earthquake and tsunami hazard assumptions.

The mega tsunami generated by the magnitude 9.0 earthquake occurred because the so-called "interlocking of a normal ocean trench earthquake" and a "tsunami earthquake" simultaneously occurred. This kind of earthquake could occur not only in the Japan Trench where the 2011 off the Pacific coast of Tohoku Earthquake erupted, but also in other regions such as the Nankai Trough. Therefore, research and analysis of the tsunami earthquake mechanism and the multisegment rupture of normal ocean trench earthquakes and tsunami earthquakes are vital so that their generating mechanism can be adequately explained and tsunami scenarios can be created for future mega ocean trench earthquakes.

In the event of the 2011 off the Pacific coast of Tohoku Earthquake, a massive tsunami was generated together with tremendous shaking. However, if a tsunami earthquake, not accompanied by a large quake, erupts by itself, there is a possibility that the tsunami will reach the coast before the residents become aware of the need to evacuate. Because tsunami earthquakes, including such disasters as the 1611 Keicho Sanriku Earthquake and the 1896 Meiji Sanriku Earthquake, have repeatedly caused extensive damage, special measures are needed to warn and evacuate the population in the event of tsunami earthquakes.

Because the impact is enormous when damage is caused in regions where facilities such as nuclear power stations are located, earthquake and tsunami hazard assumptions must be based on more elaborate research about and analysis of epicentral areas and tsunami source areas. This research and analysis must consider the viewpoint of ensuring safety.

Principles for Future Tsunami Hazard Assumptions and Development of Tsunami Countermeasures

Developing future tsunami countermeasures requires the assumption of two levels of tsunamis. On the first level are the largest possible tsunamis envisaged on the basis of developing comprehensive disaster management measures, which focus on the evacuation of local residents as the main pillar. Such tsunamis would be determined by ultra-long-term tsunami deposit research, crustal movement observations, and so forth. Although the frequency of their occurrence is extremely low, when such tsunamis do occur, the damage would be enormous. The tsunami triggered by the 2011 off the Pacific coast of Tohoku Earthquake belongs to this group.

On the second level are tsunamis envisaged on the basis of constructing coastal protection facilities such as breakwaters to prevent tsunamis from penetrating inland. These tsunamis occur more frequently than the largest possible tsunamis and cause major damage despite their relatively lower tsunami heights.

Damage Scenarios

Damage scenarios serve as the foundation for formulating disaster management measures. There is a need to continuously review and improve damage scenarios according to new scientific insight and lessons learned from damages sustained. Because natural phenomena are inherently uncertain, there are certain limitations to assumptions and scenarios. Therefore, multiple damage scenarios need to be examined, including a worst-case scenario. Improvements to the damage estimation system must be sought along with review of damage scenarios to prepare for future catastrophic events.

Significance of Damage Scenarios

In promoting earthquake and tsunami countermeasures, the Central Disaster Management Council has envisioned the seismic movement and tsunamis from the target earthquake. Using damage scenarios based on these, various disaster management measures to be implemented by the government such as Policy Frameworks for Earthquakes, Earthquake Disaster Reduction Strategy, and Guidelines for Emergency Response Activities have been developed. Necessary countermeasures have also been promoted.

With damage estimates calculated and a clear picture of the potential damage provided, damage scenarios help widely inform the society about the necessity for disaster management measures. At the same time, damage scenarios serve as the foundation stones for formulating wide-area disaster management measures.

Therefore, in response to the colossal damage caused by the Great East Japan Earthquake, there is a need to meticulously research and analyze the nature and state of the damage. Once the methods and content of scenarios are reviewed, the council will continue working on creating future damage scenarios.

Predisaster Damage Scenarios and the Actual Damage Caused by the Great East Japan Earthquake

The damage scenario published in 2005 by a committee of the Central Disaster Management Council anticipated trench-type earthquakes near the Japan and Chishima Trenches. The report contained quantitative estimates of physical damage (building damage, earthquake fires, and disaster waste), human damage (deaths, people forced to live in evacuation centers, and so forth), lifeline damage (electricity, communications, gas and water supplies, and so forth), transportation damage (roads, railways, and ports), and economic damage (direct and indirect). However, the height of the tsunami, the inundation area, and the human and material damage caused by the 2011 disaster far exceeded anything envisaged in predisaster damage scenarios.

In addition, enormous damage was caused by factors for which qualitative but not quantitative scenarios had been created. These factors included tsunami fires; missing people; and destruction caused by the shaking of the earthquake and the tsunami to substations and power lines, water intakes, water purification and sewage treatment plants, and oil storage tanks.

Although many buildings were damaged by the shaking of the earthquake, the damage was not as extensive as expected, and an examination of the suitability of the estimation methods used in predisaster damage scenarios is required. Research and analysis also is needed about the relationship between the length of the earthquake cycle and the damage caused, with examples that include indoor damage such as ceiling collapses from short-period seismic movement and damage to high-rise buildings and other large structures caused by long-period ground motion, a cause for concern in the event of a mega ocean trench earthquake. Particular attention must be paid to shaking resulting from long-period ground motion during a future

Tokai Earthquake. Such an earthquake is estimated to be at least twice the size of what was experienced in the Great East Japan Earthquake.

Future Damage Scenarios

The majority of the damage witnessed in the Great East Japan Earthquake far exceeded any predisaster damage estimates. In response to this, the causes must be adequately investigated and analyzed and, after a clear identification of the issues in the scenario methods, the requisite improvements should be made. Furthermore, sufficient investigation and analysis is essential with regard to the phenomena for which the actual damage fell below the predisaster estimate, the reason this was the case, and the relationships between regional characteristics and the shaking generated by the earthquake.
Disaster management measures must be examined and drafted on the basis of a more concrete damage scenario. This needs to be done after minutely researching the matters that were only qualitatively considered in the damage estimation scenarios used before the disaster, the matters that have become apparent following the Great East Japan Earthquake but were not considered in predisaster scenarios, and the matters that should be considered in future damage scenarios.

Because natural phenomena are inherently uncertain, one must bear in mind that there are certain limitations to assumptions and scenarios.

In a review of the methods used in developing damage scenarios, quantitative assessment should be conducted for damage mitigation by future countermeasures, such as reducing human damage by promoting early evacuation of residents or construction of earthquake resistant buildings.

During the Great East Japan Earthquake, regional differences in the evacuation distances and evacuation procedures became apparent for the lowland plains and rias costal area. A means to consider regional characteristics needs to be devised when future scenarios are developed.

The 2011 off the Pacific coast of Tohoku Earthquake occurred during daytime and not in the middle of winter. Had it occurred under other seasonal conditions, or at a different time of day or under different meteorological circumstances, the damage could have been even greater. Therefore, multiple damage scenarios need to be examined, including a worst-case scenario. In doing so, the scenarios need to consider that the damage differs greatly in the urban and rural districts and that the areas outside the disaster zone are subject to secondary effects of the disaster.

There was a considerable discrepancy between the rapid damage estimates conducted by the Cabinet Office immediately after the earthquake and the damage caused to people and buildings by the Great East Japan Earthquake. Improvements to the damage estimation system must be sought along with review of damage scenarios to prepare for future mega ocean trench earthquakes.

Countermeasures to Mitigate Tsunami Damage

Better hazards assumptions and damage scenarios should inform counter-measures against largest possible events based on a disaster risk management policy that focuses on minimizing damages. All measures rely on as comprehensive an understanding of risk as possible. This is crucial to inform structural and nonstructural measures. In the planning of countermeasures, it is necessary to consider all possible scenarios including worst-case scenarios. Risk information also needs to be communicated effectively to adequately inform the population about effective prevention and measures to take if a disaster strikes.

Countermeasures must be enacted against the largest possible tsunamis according to a disaster

reduction philosophy that focuses on minimizing damage. To do so, tsunami damage should be mitigated as much as possible not only through structural measures such as coastal protection facilities, but also through nonstructural measures centering on evacuation with thorough disaster education and hazard maps preparation. These measures will help prepare for tsunamis that exceed the protection levels of the structural facilities.

Easing tsunami evacuation requires, in addition to the construction of coastal protection facilities, a combination of measures such as (a) construction of secondary barriers using transportation infrastructure to prevent tsunami waves from penetrating further inland, (b) land raising, (c) construction of evacuation sites, (d) tsunami evacuation buildings and evacuation routes and stairs, and (e) land use and building regulations that account for the risks of inundation. These steps must be implemented in a manner appropriate to local circumstances. To achieve swift and assured evacuation from tsunamis, town planning should allow evacuation within the shortest possible time—about five minutes in the case of communities where tsunamis arrive quickly—while placing evacuation on foot as the basic principle for response in local circumstances. In communities where topographical conditions or land use make such responses difficult, measures for tsunami evacuation must be thoroughly examined considering factors such as the tsunami arrival time.

From the perspective of securing the safety of residents and mitigating damages to livelihood and industry, the basic and vital countermeasures to tsunamis are the swift and assured evacuation of residents, promotion of land use that mitigates inundation risks, and construction of coastal protection facilities to prevent tsunami penetration inland. There is a need to combine all of these nonstructural and structural measures and to build systems and mechanisms for integrated efforts taking local circumstances into account.

Development of Resilient Communities

With regard to the newly envisaged largest-possible tsunamis, potential inundation risks for different communities need to be shown. These risks need to take into account assumptions of a worst-case scenario of impact from tide levels and damage to facilities. In addition to securing the safety of residents and obtaining local consensus with this scenario, community development efforts to mitigate the scale of the damage caused to livelihood and industry need to proceed.

In the regions devastated by the recent disaster event that have often been exposed to tsunamis, old inscriptions on stone monuments warned of the dangers of tsunami damage. History shows that when houses have been rebuilt on low-lying land, they have repeatedly suffered damage. These stone monuments need to be left standing and their meaning needs to be correctly passed to future generations to avoid the repetition of such calamities.

When considering land use in the future, planners need to reflect on changing social conditions, such as the advent of an aging society and a declining population. They also need to consider measures to coexist with the oceans that at the same time protect human life, lifestyles, and industry and tie in with community revitalization.

By incorporating a perspective of gender equality, realistic and practical measures that reflect the diverse viewpoints of those living in the communities will be achieved. It is also conceivable that a community's ability to manage disasters will be improved. Therefore, when concrete evacuation procedures and development of communities are explored, female perspectives that have not been adequately considered in the past will be incorporated, through means such as enthusiastically promoting the inclusion of female members in disaster management councils.

Measures need to combine land use planning, including designation of residential districts in the areas less prone to tsunami inundation risks, with educating residents about the inundation risks from largest-possible tsunamis. In addition, a local consensus needs to be sought for these measures.

By adequately verifying the causes of the earthquake and tsunami devastation in the recent disaster and disaster management measures introduced before the disaster and by using the lessons learned, facilities such as evacuation sites, tsunami evacuation buildings, evacuation routes, and stairs should be developed or designated in a planned manner. These facilities should account for local circumstances such as the risk of tsunami inundation and the time it takes for tsunamis to arrive. It is particularly important that the designation of tsunami evacuation buildings and development of evacuation sites, routes, and stairs, are incorporated in the whole of community development to ensure complete evacuation. Besides the attempt to make tsunami evacuation buildings resistant to earthquakes and waves, responses need to be examined in cases where the inundation height exceeded the controlled height in local zoning regulations.

Raising Disaster Awareness about Tsunamis

Although tsunami disasters occur only about once every 10 to 15 years, when they do occur the damage can be devastating. Local residents need to be adequately informed that a tsunami can hit at any point along the coastline of Japan, disaster management measures need to be continuously promoted, scientific understanding of earthquakes and tsunamis needs to be deepened, and disaster awareness needs to be improved among residents and others. In addition, raising awareness with the cooperation of mass media such as television, radio, and newspapers will be effective.

Earthquakes and tsunamis are natural phenomena, and there should be an adequate understanding that they might exceed our assumptions. Examples were witnessed during the recent disaster where, although the hazard level went far beyond the scope of scenarios envisaged, appropriate evacuation actions helped prevent or mitigate damage. Gaining a shared awareness of risk through disaster education—so-called risk communication—is vital to encourage an understanding of the precise meaning of the numerical values used in tsunami scenarios and to enable people to evacuate flexibly according to rapidly changing circumstances in the midst of an impending tsunami whose scale and nature is unknown.

Passing down disaster-related culture over generations based on the earthquake and tsunami damage that has occurred across history is very important. In response to the investigations conducted into the recent disaster, people's understanding of earthquake and tsunami disasters and their management needs to improve. In addition to school education, comprehensive education programs need to be developed that examine various scenes with participation of experts and practitioners on the ground.

Improvements to Hazard Maps

The results of a post-earthquake survey in the damaged areas show that the residents' awareness of hazard maps was low. Because the maps were prepared on the basis of former scenarios, they led to providing a false sense of security among people. Therefore, the hazard maps may well have exacerbated the damage caused by the tsunami. Continued investigations and analysis into the deficiencies of hazard maps are necessary, including the manner in which the maps are used.

For assurance that hazard maps are effectively used by residents in evacuation, the way that hazard maps are created must be examined, including clarifying the relationships between tsunami warnings and evacuation advisories

and instructions, envisaging multiple hazard levels of tsunamis, and indicating ground elevations on hazard maps. Furthermore, because tsunamis are natural phenomena with a great deal of uncertainty, an emphasis must be placed on risk communication, including the continuous and regular communication that the inundation areas for a largest-possible tsunami shown on the hazard maps may actually be exceeded. Because there are limits to raising residents' awareness merely by handing out hazard maps, systems and mechanisms need to be built to communicate the message of hazard maps thoroughly. For example, include them in city planning books and use them to explain important matters contained in the Building Lots and Buildings Transaction Business Act.

Preparations for the Future

Earthquakes can occur anywhere in Japan, not only in the Nankai and Tokyo metropolitan areas where intense concerns exist for a mega ocean trench earthquake in the Nankai trough or Tokyo Inland earthquakes. For areas that have not yet experienced a major earthquake or tsunami, full preparations need to be made for the possibility of an earthquake or tsunami.

First, the seismic movements, tsunami, and subsidence that are to be expected should be estimated. Then estimations should be made for human and material damage based on damage caused by the 2011 off the Pacific coast of Tohoku Earthquake and newly available scientific and technological knowledge. Based on these estimates, all possible measures should be taken to improve future disaster management measures, such as formulating earthquake and tsunami countermeasures that fully reflect the lessons learned from the Great East Japan Earthquake.

Because a worst-case scenario may not necessarily ensue if Tokai, Tonankai, and Nankai earthquakes all occurred at the same time, consideration must also be given to scenarios in which earthquakes occurred in these areas at different times. For example, if earthquakes occurred in these areas within a few minutes to a few hours of each other, the height of the ensuing tsunami would increase owing to the overlapping of the tsunamis; accordingly, if the time until the next earthquake occurs is longer than this, there is the danger that facilities that have been or are being recovered and reconstructed will be damaged again, causing an aggravation of social anxiety. Moreover, one must also consider complex disasters that may occur if these coastal earthquakes occurred at the same time as an inland earthquake, typhoon, or other natural disaster.

In the case that key Japanese industries are affected by a large-scale earthquake, recovery will require a substantial amount of time and domestic economic activity may stagnate. For these reasons, business continuity plans for times of disaster are necessary.

In addition, investigation and research on earthquakes and tsunamis that could occur in Japan should be promoted on the basis of the latest scientific knowledge. The investigation and research findings should be used to strengthen disaster management measures.

Preservation of Records of the Great East Japan Earthquake and Information Dissemination on Future Disaster Management Measures

To make good use of the lessons learned from the Great East Japan Earthquake, a disaster that took the greatest number of lives in a single event in Japan during the postwar period with extensive human and material damage, and to strengthen countermeasures against earthquakes and tsunamis that may occur in Japan in the future, we must firmly pass these lessons to the next generation so that the experience and memories of the Great East Japan Earthquake do not fade and are not forgotten.

Preservation of Records of the Great East Japan Earthquake

Firm efforts are needed to pass these experiences to the next generation, such as making a broad range of materials available to the public, including the results of investigations and analyses conducted by relevant government ministries and agencies, universities, and private research institutions as well as the visual images taken by relevant government ministries and agencies and the mass media. Availability should be made through the Internet and other channels in addition to being stored in the National Diet Library and National Archives of Japan.

Furthermore, Japan also needs to make a collective effort to carry out an investigation and research of the mechanisms that generated the massive tsunami in the 2011 off the Pacific coast of Tohoku Earthquake and summarize the results of this research so that they can be used in formulating earthquake and tsunami countermeasures for the future.

Information Dissemination Regarding Future Disaster Management Measures

Following the Great East Japan Earthquake, Japan received wide-ranging support from the international community, with many countries, regions, and international organizations sending rescue and specialist teams to Japan and providing food, water, blankets, and other relief supplies.

Through the investigation and discussion by this committee, new knowledge and valuable lessons about earthquake and tsunami countermeasures have been gained. This knowledge and experience will contribute to the strengthening of disaster management measures not only in Japan but also in other countries. For this reason, this information needs to be widely disseminated to other countries through international conferences and other forums.

Conclusion

Because of the extensive damage brought by the mega tsunami in the Great East Japan Earthquake, the report of this committee focuses on tsunami countermeasures. However, it is highly possible that a mega ocean trench earthquake in the Nankai trough—which is feared will occur in the near future—would cause not only damage from a mega tsunami but also extensive damage from strong shaking by earthquakes. Accordingly, countermeasures against both earthquakes and tsunamis need to be strengthened more than ever before.

For this reason, the lessons of the Great East Japan Earthquake need to be thoroughly reviewed. Accordingly, detailed investigation and analysis of the 2011 off the Pacific coast of Tohoku Earthquake, the mechanisms that generate mega tsunamis, and the status of damage caused by these events need to continue. A system needs to be established for compiling materials such as summaries of investigation and analysis results and visual images and for presenting them to the general public as well as using them to formulate disaster management measures for the future.

Furthermore, for support for the recovery of the disaster-affected areas, surveys of the process of recovery and reconstruction in the devastated areas need to be carried out in real time so that the power to recuperate from disasters can be scientifically surveyed and analyzed.

We cannot simply mourn the losses and damage inflicted by the Great East Japan Earthquake. While mourning the damage, we must stand and face whatever catastrophic disaster may occur and do all that we can to protect human life. On the basis of this conviction, we must further strengthen earthquake and tsunami countermeasures while carrying through with the recovery and reconstruction of the devastated areas. We must systematically build a nation

and cities that are even stronger against earthquakes and tsunamis as we educate and raise awareness of the public about earthquake and tsunami disasters. Moreover, there is a need for disaster management–related fields of science and engineering, humanities and social science, and life sciences to join forces in a collective effort to carry out scientific surveys examining the reasons for the occurrence of disasters and comparing local characteristics, such as whether or not damage was inflicted, as well as to strengthen the research system.

Based on the report of this committee, the national government can be expected to perform necessary revisions of Japan's overall earthquake and tsunami countermeasures and pour every effort into enhancing disaster management measures for the future, thus liberally fulfilling the fundamental government role of protecting the lives and property of the nation's citizens.

Notes

1 The 2011 off the Pacific coast of Tohoku Earthquake refers to the earthquake of magnitude 9.0 that occurred March 11, 2011, and was named by the Japan Meteorological Agency based on a standard naming convention. The Great East Japan Earthquake, named subsequently by the Cabinet Office of the Government of Japan, refers to the earthquake and tsunami disaster and the accompanying nuclear accidents.

The Central Disaster Management Council, one of the councils that deal with crucial policies of the cabinet, is established in the Cabinet Office based on the Disaster Countermeasures Basic Act. The council consists of the prime minister, who is the chairperson, the minister of state for disaster management, all other ministers, heads of major public institutions, and experts. The council promotes comprehensive disaster countermeasures including deciding important issues on disaster reduction according to requests from the prime minister or minister of state for disaster management.