KNOWLEDGE NOTE 1-3

CLUSTER 1: Structural Measures

Hydro-meteorological Disasters Associated with Tsunamis and Earthquakes

GFDRR
Global Facility for Disaster Reduction and Recovery
THE WORLD BANK

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Earthquakes and tsunamis increase the risks of hydro-meteorological disasters. After the Great East Japan Earthquake (GEJE), disaster-prevention structures such as coastal and river dikes were quickly rehabilitated. A phased process of rehabilitation work made it possible to address urgent needs for protection against frequently occurring floods and storm surges, while at the same time meeting longer-term targets for protection against mega disasters. The deterioration of levels of protection against hydro-meteorological disasters was quickly assessed after the GEJE in order to identify priority areas for rehabilitation, revise standards for the issuance of warnings, and raise public awareness about the increased risks of hydro-meteorological disasters.

FINDINGS

THE GEJE AND TSUNAMI INCREASED THE RISKS OF HYDRO-METEOROLOGICAL DISASTERS

The Great East Japan Earthquake (GEJE) caused extensive damage to coastal and river infrastructure and diminished the level of protection they provided against floods and storm surges, thereby increasing the risk of hydro-meteorological disasters. Countermeasures against these risks have been successfully put in place (figure 1). According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 426 coastal units (including coastal dikes and revetments extending along 190 kilometers) out of a total of 515 units with a total length of some 300 kilometers sustained damage in the Iwate, Miyagi, and Fukushima prefectures.

The MLIT began on the day of the earthquake to assess the safety of dams and structures in some 30 rivers. Slope failure and subsidence of dikes were observed at 2,115 sites in eight rivers managed by the MLIT, mainly in the Tohoku and Kanto regions (figure 2). Local governments reported damage to a total of 1,627 sites in the rivers they manage. Many river dikes were also damaged by liquefaction caused by earthquakes. The MLIT confirmed

FIGURE 1: **Countermeasures taken against hydro-meteorological disasters following the GEJE**

	Apr	May	Jun	Jul	Aug	Sep	Oct

Flooding period

Snow melt flood — Rainy season — Typhoon season

Period when spring tide is relatively high

Assessment and announcement of secondary disaster risks

Overview assessment

Assessment and announcement of risks

* Subsidence on the Sendai Plain, Miyagi and Iwate coastal areas has already been announced

Discharge of water from inundated areas

Emergency discharge

* River, coastal, agriculture, and sewerage departments collaborate to implement emergency protection of coastal lowlands and continue necessary measures (water removal by discharge pump vehicles, etc.)

Measures against storm surges

Restoration of coastal dikes, etc.

Emergency measures (stacking sandbags to high tide level) → **Temporary measures** (reinforcement of fore side of sandbags, etc.)

	3 prefectures of Iwate, Miyagi, and Fukushima			
	Total	*Fully/partly destroyed*	*Temporary measure**	*Completed*
Coastal dike protection (km²)	ca. 300	ca. 190	ca. 50	ca. 19

* Section where important public facilities exist

Implement as many measures as possible

Full restoration (restoration of damaged embankments and dike protection)

Measures against heavy rains and floods

Warning/ evacuation measures

Lowering of standards for call-out of flood fighters, or announcement standards for river flood forecasting, warnings, communication to residents, etc.

River dikes/ structures (weirs/gates)

Temporary measures → **Implement as many measures as possible**

(emergency rehabilitation of dikes by embankments)

	Damaged sites (state-managed)	*Temporary measure*	*Completed*
Tohoku	1,195	29	29
Kanto	920	24	24
Total	2,115	53	53

		Full restoration	
	Damaged sites (state-managed)	*by end of June 2011*	*by end of June 2012*
Tohoku	1,195	993	202
Kanto	920	733	187
Total	2,115	1,726	389

Measures against sediment disasters

Warning/ evacuation measures

Detailed assessment

Inspection of sediment disaster areas

	Total	*Inspected*	*Deformation identified*
Inspection sites	33,301	32,302	1,143

Strengthen warning level by lowering of announcement standards for sediment disaster warning information or installation of mudslide sensors

Sediment management facilities

Temporary measures

Stacking sandbags, etc.

Construct sediment control dams as emergency measures in areas where failure occurred

	*Before rainy season**	*Before typhoon season***
Construction of sediment control dams	18	24

* Areas where failure was caused by the earthquake
** Areas where there are risks of failure

Source: MLIT.

FIGURE 2: **Damage to the river dikes at Narusegawa**

Source: MLIT.

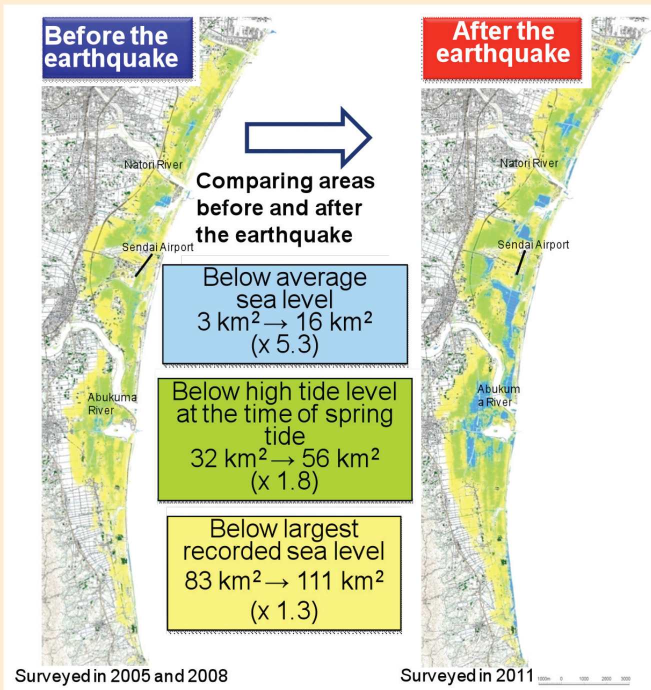
that none of the country's dams suffered structural problems, except for minor leaks and cracks. One irrigation dam failed, killing seven leaving one person missing in Fukushima Prefecture.

INCREASED INUNDATION RISKS FROM SUBSIDENCE

The earthquake caused extensive subsidence in some areas. Rikuzentakata City in Iwate Prefecture, for example, saw subsidence of 84 centimeters, which led to flooding of coastal areas and roads at high tide, often hampering recovery and rehabilitation efforts.

The level of protection against storm surges and flooding was significantly diminished in the Sendai Plain. The area below mean sea level more than tripled (from 3 km^2 to 16 km^2) after the earthquake (figure 3), as revealed in the MLIT's laser profiling survey. The MLIT produced subsidence maps and revised downward the water levels at which it issues flood warnings. For management of spatial data and their use in mapping, see KN 5-2.

FIGURE 3: **Subsidence caused by the earthquake increased inundation risks**



Source: MLIT.

LANDSLIDES CAUSED BY THE EARTHQUAKE

The earthquake caused 141 landslides, as a result of which 19 people lost their lives (as of February 2012). Immediately after the earthquake, the MLIT began inspecting 1,952 sediment control facilities managed by the ministry, while the prefectural governments inspected 4,324 facilities. The MLIT conducted emergency inspections of about 32,000 sites with potential risks of sediment disasters such as debris flows and landslides in 220 municipalities where the Japan Meteorological Agency (JMA) had observed seismic intensity of 5+ or larger. Significant deformation was found at 66 locations; minor deformation at 1,077. The MLIT shared this information with municipalities so that they could take the necessary measures.

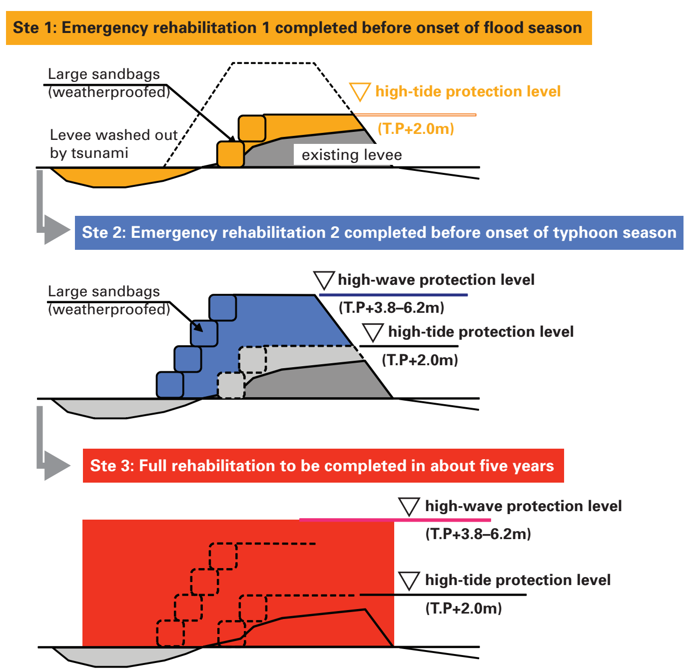
With the higher risk of sediment disaster since the earthquake, triggers for the issuance of sediment disaster warnings were temporarily lowered. Local meteorological observatories and prefectural governments jointly issue warning about such disasters. Prefectural governments and the JMA are reviewing the standards for the issuance of warnings by investigating the relationship between the amount of precipitation after an earthquake and the probability of a sediment disaster.

REHABILITATING COASTAL AND RIVER DIKES TO PREVENT SECONDARY DISASTERS

After the GEJE, emergency measures were implemented to restore coastal dikes to prevent coastal flooding from storm surges. Emergency rehabilitation was first implemented along about 50 of the 190 kilometers of damaged coastline. Those 50 kilometers were selected because of the important facilities and properties in the area, or because of the urgency of restoring livelihoods, industrial activities, transportation, and agricultural activities.

The emergency rehabilitation work was implemented in three phases determined by climatic conditions and the seasonal occurrence of natural disasters (figure 4). The first step was to reinforce and raise the height of the damaged dikes up to the high-tide protection level. This work was done before the June-July flood season. The second step was to raise the dike height to the high-wave protection level, which was completed by September, before the typhoon season.

FIGURE 4: **Rehabilitation of coastal dikes**



Source: MLIT.

Full-scale restoration, the third step, is scheduled to start in fiscal 2012 in accordance with reconstruction plans and other rehabilitation projects. The works will be carried out over about a five-year period so as not to disrupt community development and industrial activities. On the Iwanuma Coast and in other coastal areas with facilities that are critical to recovery and reconstruction, such as wastewater treatment plants, full restoration will be completed by the end of fiscal 2012, March 2013.

Rehabilitation of river dikes began directly after the earthquake as the first step in preparing for heavy rain and floods. One of the most urgent tasks was to reconstruct the dikes to their predisaster height before the rainy season began in June. Emergency rehabilitation work was conducted at the 53 heavily damaged sites: 29 in the Tohoku Region and 24 in the Kanto Region. These works were completed by July 11, 2011. The standard for flood warnings was lowered during the flood seasons. The MLIT and the prefectural governments measure rainfall and the water level in rivers, using automatic monitoring equipment and telemeter systems. The ministry and the governments then issue flood forecasts and warnings through the mass media, the Internet, and mobile phones.

Complete restoration of the river dikes to their predisaster condition began after the typhoon season and was completed by the time the 2012 rainy season began in June. Countermeasures against liquefaction also have also been implemented. The final step will be to improve dikes on the major rivers in the Tohoku region—the Abukumagawa, Narusegawa and Kitakamigawa—to protect against floods and tsunamis.

MEASURES TO MITIGATE INUNDATION RISKS IN THE DISASTER-AFFECTED AREAS

Inundation risks from heavy rain have increased in the disaster-affected lowlands of the Sendai Plain, where river dikes and drainage pump stations were damaged or destroyed and where extensive subsidence occurred. Temporary emergency measures were taken to reduce the risk of flood damage. Thirty-three drainage pump vehicles, provided by other regional bureaus of the MLIT around the country, were deployed in the disaster-affected area. A risk map showing inundation levels from daily precipitation of 100 millimeters and 200 millimeters provided information for local residents and municipalities. Inundation sensors were installed in areas with a high risk of flooding, and the information they collect is published to a Web page. Measures have been taken to send timely notifications automatically to relevant municipalities and local residents when there is a high risk of flooding.

LESSONS

Disaster prevention structures such as coastal and river dikes need to be rehabilitated quickly to prevent secondary disasters. Rehabilitation work should ideally be completed before the next rainy season and typhoon season.

In the aftermath of a disaster, it is important to identify the priority areas for rehabilitation and for protection against hydro-meteorological disaster. Priorities can be determined based on the existence of important facilities or commercial production centers and their significance for recovery and reconstructi on activities.

Rehabilitation work should take place in phases. This is an effective way of meeting the communities' most urgent needs for protection against frequently occurring floods and storm surges, while at the same time meeting longer-term targets for protection from mega disasters.

Deterioration in levels of protection against hydro-meteorological disasters needs to be quickly assessed, and the relevant agencies, organizations, and the public should be informed. Damage information should be collected and disseminated as soon as possible (KN 5-2). Warning standards should be revised according to the assessment.

RECOMMENDATIONS FOR DEVELOPING COUNTRIES

Following any disaster, protective measures against collateral damage and secondary disasters is essential. The following actions are recommended:

Conduct an assessment immediately following the disaster. Damage to disaster prevention facilities and the risk of ensuing disasters should be assessed immediately after a disaster by quickly collecting relevant information. To make the most efficient use of resources, the areas to be rehabilitated should be dealt with in order of priority. Expert emergency teams should be formed during normal times by drawing on national networks (KN 3-1). Advance agreements can be made to allow the organizations concerned to mobilize private sector resources without going through the usual procurement processes (KN 4-1).

Rehabilitate crucial structures before the next disaster. A staged approach is appropriate, taking into account time constraints before the onset of the next season susceptible to hydrometeorological disaster. Rehabilitation works should be prioritized. Practical works, such as temporary structures made of sand bags or gabion boxes, need to be set up quickly.

Consider financial mechanisms. Financial arrangements, in particular the responsibilities of the central and local governments, should be made in advance during normal times (KN 4-1).

Share risk information with the community. "Post-disaster disaster risks" should be shared with local communities that may be affected. Nonstructural measures such as warnings should be strengthened in at-risk areas, since the effectiveness of countermeasures will have been diminished by the disaster.

KEY REFERENCES

MLIT (Ministry of Land, Infrastructure, Transport, and Tourism). 2012. Follow-up Report on Countermeasures for Sediment Disasters (*Doshasaigaiheno taioujyokyo, zokuho*) (in Japanese). River 788: 59–61.

MLIT. 2012. Rehabilitation of River Dikes (*Kasenteibotouno fukyujyokyo*) (in Japanese). River 788: 50-54.

Sato, Y. 2012. Rehabilitation of Sea Dykes Damaged in the Great East Japan Earthquake (*Kaiganteibotouno fukyufukojyokyonitsuite*) (in Japanese). *River* 788: 55–58.