The Investigation Team Report on the Damages of Water Supply Utility by the Great East Japan Earthquake 2011

(Provisional translation)

* This is provisional and abridged translation of "the Report" published by Water Supply Division, Health Service Bureau, Ministry of Health, Labour and Welfare (MHLW) and Japan Water Works Association (JWWA) in September 2011. English translation is carried out by WaQuAC-NET and there is no concern of MHLW and JWWA. WaQuAc-NET is fully responsible for the any problems of English description. Please refer to the original report written in Japanese.

http://www.jwwa.or.jp/houkokusyo/houkokusyo_18.html (JWWA Site)

http://www.mhlw.go.jp/topics/bukyoku/kenkou/suido/houkoku/suidou/111101-1.html (MHLW Site)

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1. Introduction

This is a report of the investigation in the disaster area in north east Japan where was directly attacked by the earthquake and tsunami. The investigation team was organized by Ministry of Health, Labor and Welfare (MHLW) in order to comprehend the damage and recovery condition of water utilities and determine the strategy of countermeasures. The team consisted of academic experts and representative of water supply utilities, concerned bodies, JWWA and MHLW, totally 19 members. The team visited 7 water supply utilities for four days from 8th to 11th May ; Rikuzentakada City, Ichinoseki City, Koriyama City, Iwaki City, Ishinomaki District Water Supply Authority, Sendai City, and Miyagi Prefectural Enterprise Bureau.

2. Summary of the Great East Japan Earthquake

The gigantic earthquake hit Japan at 46 minutes past 14 O'clock on 11th March 2011. It was officially named as 'The 2011 off the Pacific coast of Tohoku Earthquake'. It is the largest earthquake on record.

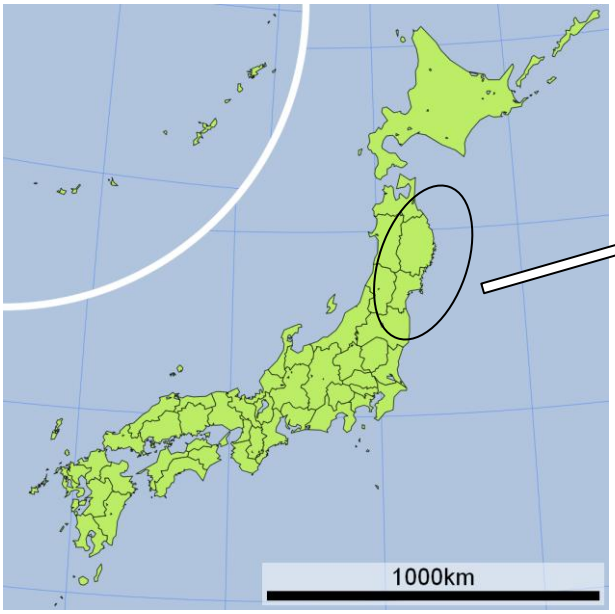


Fig. 1 Reference Map

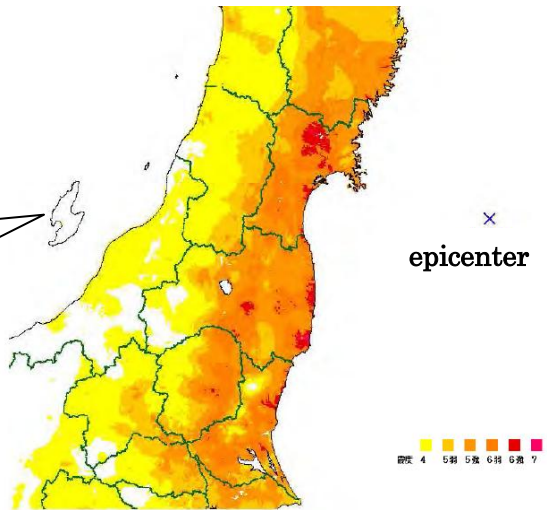
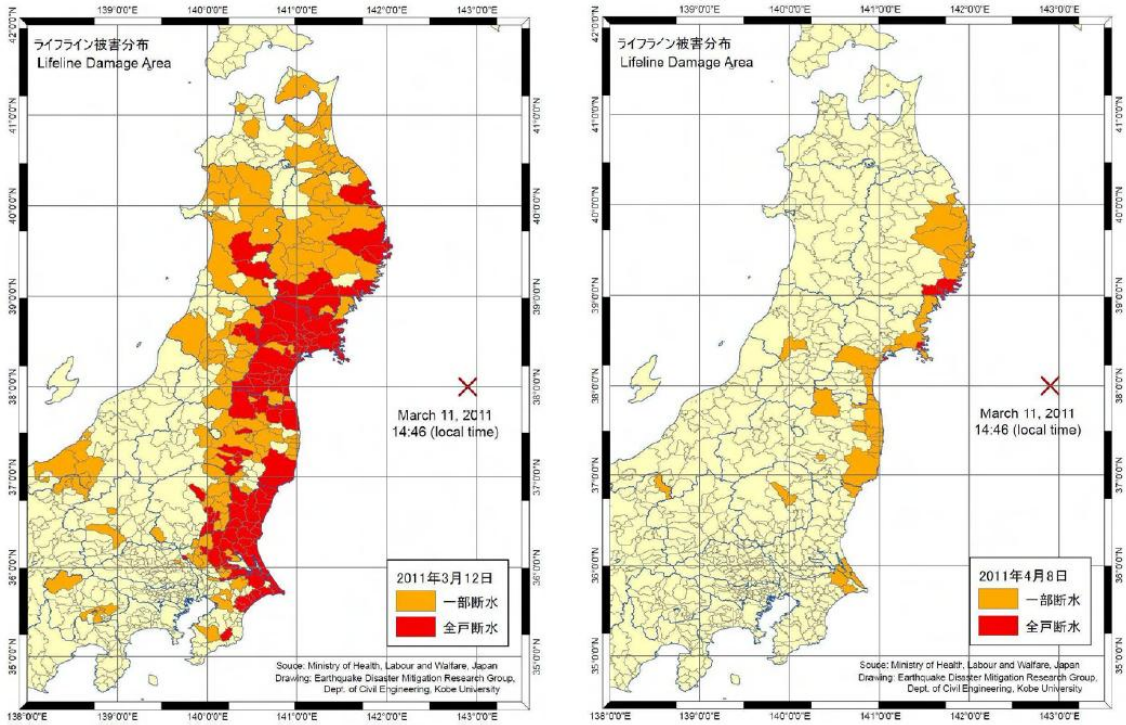


Fig. 2 Earthquake intensity

Fig.3 Flooded area in **Ishinomaki City**
(highlighted in pinkish color)

Fig. 4 Flooded area in **Sendai**



12th March 2011 (following day of earthquake) 8th April 2011

Partially supply shutdown

Water supply shutdown in whole area

Fig. 6 Damage of water supply

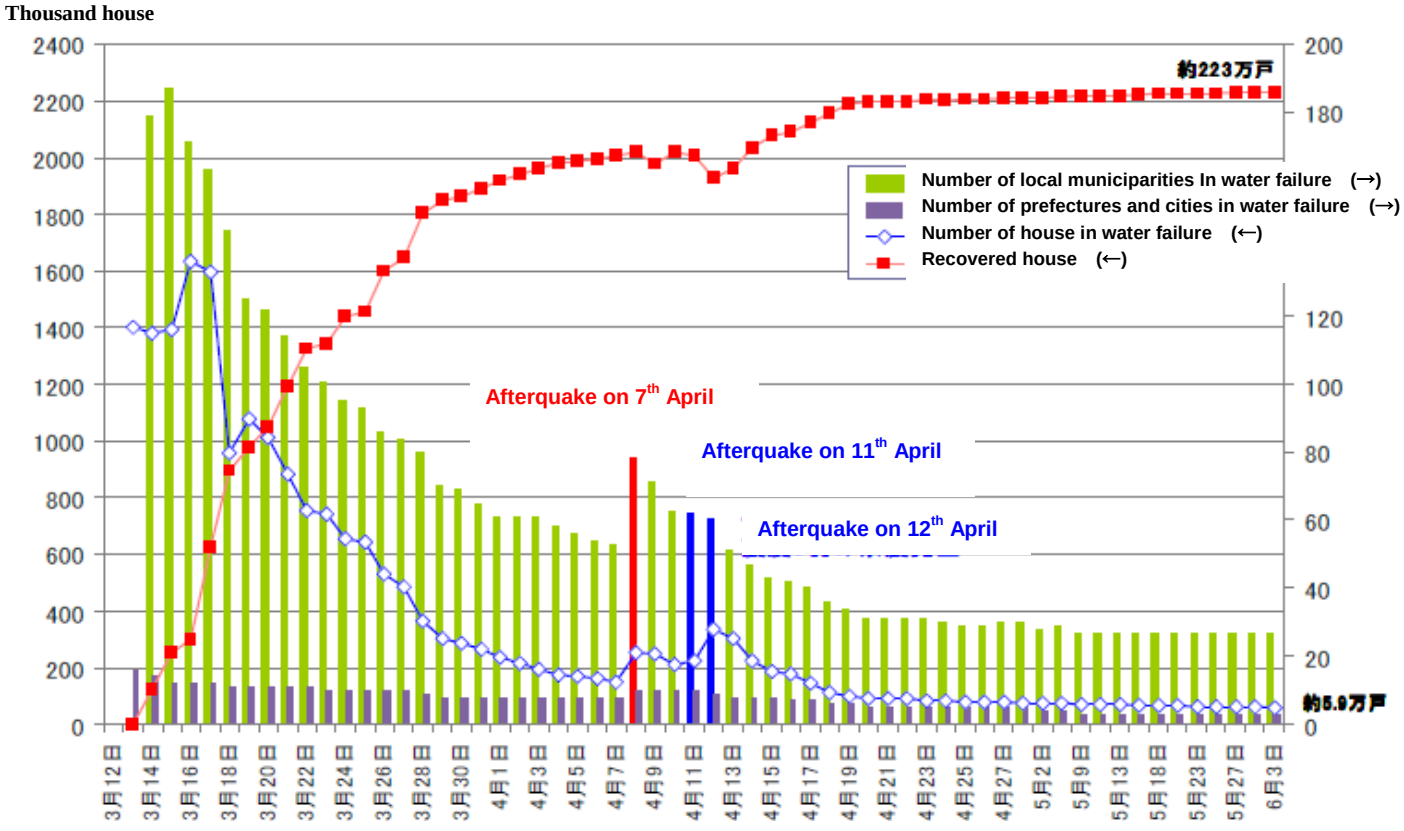


Fig.7 Recovery of water supply

3. Initial reaction, emergency water supply and emergency rehabilitation

3.1 Action taken by water authority

Case of Sendai city

(1) Initial motion

The earthquake occurred at 14:46 and it was usual working time. Firstly, the confirmation of safety of the staff at outside was done by radio. The safety of staff who was on a vacation was checked by manager. Finally, the safety of all staff members was confirmed on 14th.

The disaster countermeasure headquarters was immediately established at the Senday city and the meeting was held at 16:00, 19:00 and 22:20. On the other hand, the disaster countermeasure headquarters of department of water works was organized, and totally 19 staff members of the position higher than department chief gathered for meeting at 16:00.

There were 230 thousand of household (population 500 thousand persons) facing water failure immediately after the earthquake. The rate of water failure was about 50% at that time. Actions taken are summarized in following table after the earthquake till starting emergency restoration.

date	time	Action	Tactics
11th Mar.	14:46	• Earthquake occurrence • Establishing countermeasures headquarters • Power shutdown	
	14:49	(Warning massive tidal wave)	
	15:00	• Power generation at all WTPs	
	15:40	• Request of stopping water by prefecture wide water supply	
	16:00	• 1st meeting of headquarters'' members	• To secure continuous operation of WTP • To assess the situation • To confirm safety of staff • To secure food
	16:30	• Request to pipe constructors to be stand-by at the office	
	17:20	• Inability of monitoring due to power failure	• To identify point of leakage • To tighten sluice valve in

		• Water suspension due to leakage at main transmission (ϕ 2400mm)	case of large amount of leakage
	22:30	• Installation of emergency water storage tank at 5 places • Request of assistance of emergency water supply	• To start emergency water supply at 6 o'clock at following day's morning
12th Mar.	5:10	• Installation of emergency water storage tank at 8 places • Starting water supply to emergency medical care hospital	• Investigation of damaged point
	8:30	• Starting emergency restoration work	• To restore from main distribution

(2) Emergency water supply

Based on the 'Memorandum of mutual support system among 18 metropolitan waterworks', 3 water truck were from Sapporo City, 4 trucks from Tokyo metropolitan government, 48 trucks from many cities through JWWA. Maximum number of water trucks was 75 a day. And the emergency water supply continued until the end of March. Water supply bases were installed at 5 points on the first day, and it was increased as 19 points. 30 of canvas made water tanks were settled at the evacuation centers.

(3) Emergency restoration

Because the water utility was mainly damaged at the pipelines, the restoration activities were performed at pipelines by priority.

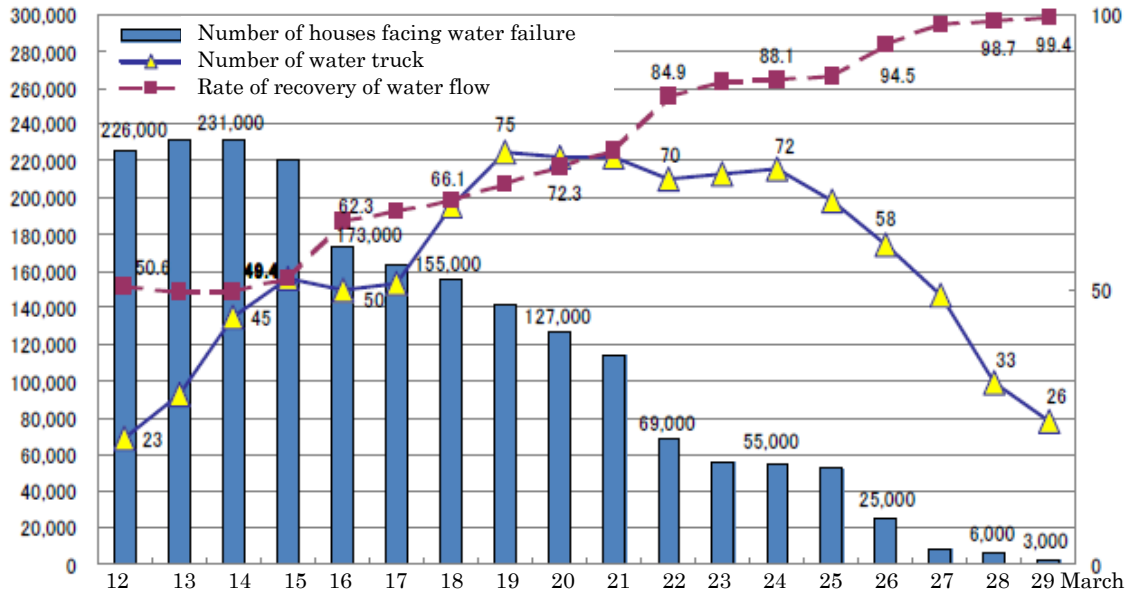


Fig. 8 Process of recovery in Sendai City

4 Damage of conveyance pipes, transmission pipes and network

4.9 Diagnostic characteristic of the damages

The diagnostic characteristics of the damages from the earthquake are summarized as follows.

4.9.1 Comparison with the past earthquake

(1) Average ratio of damages

The average ratio of damages in Sendai City was small compared to the past big earthquakes. The reasons are thought that the area of artificially modified ground was small and ground improvement work had been conducted since Miyagi earthquake in 1978.

Average ratio of damages

Earthquake	Entity	Number of cases (Case)	Total conduit length (km)	Ratio of damage (cases/km)
Great East Japan Earthquake	Sendai City	264	3,761	0
Great Hanshin earthquake	Kobe City	1,264	4,002	0
	Ashiya City	297	185	2
	Nishinomiya City	697	966	1
Chūetsu earthquake	Nagaoka City	328	1,080	0
Noto earthquake	Monzen City	56	175	0
Chūetsu offshore earthquake	Kashiwazaki City	518	949	1

Difference of damage ratio in different diameter

Type of pipe		Sendai City			Kobe etc.	Ratio
		Number of cases (Case)	Total conduit length (km)	Ratio of damage (cases/km)	Ratio of damage (cases/km)	Ratio (%) Sendai/Kobe
diameter (mm)	φ75 or less	92	438.2	0.21	1.90	11
	φ100 - 150	144	2,234.8	0.06	0.93	7
	φ200 - 250	15	452.9	0.03	0.94	4
	φ300 - 450	9	408.0	0.02	0.78	3
	φ500 or more	4	227.1	0.02	0.51	3

Difference of damage ratio in different type of pipe

Type of pipe	Sendai City			Kobe etc.	Ratio
	Number of cases (Case)	Total conduit length (km)	Ratio of damage (cases/km)	Ratio of damage (cases/km)	Ratio (%) Sendai/Kobe
DIP	108	2,722.3	0.04	0.49	8
SP	9	134.9	0.07	0.47	14
VP	147	881.1	0.17	1.43	12

5 Damage of structural object and facility

5.8 Diagnostic characteristic of the damages

(1) Damaged facilities located coastal area by the tsunami

There were many cases of breakup or outflow of facilities, and equipment failure by the tsunami. In case of shallow wells, many of water sources became impossible to utilize water due to high concentration of saline after tsunami attack. Outflow of water pipe bridges crossing the river near the coast was occurred by the tsunami.

(2) Damages of tower like structural object of low quake resistance

An elevated tank type distribution reservoir was destroyed by the earthquake motion in Icihnoseki City. The main shock on 11th March created cracks at underneath of RC, and the aftershock destroyed it on 7th April. This reservoir was constructed in 1978, so the size of frame members was relative small. Moreover, a tower like structural object has longer natural period than pond like structure, and it can magnify the earthquake motion. The reservoir is supposed not to satisfy the current earthquake resistant design code.

(3) Damages from quick sand

Hebita WTP in Ishinomaki City sustained enormous damage by quick sand at the structural object, connection pipe on a premise of WTP, facilities of electric and machine. Previous several earthquakes caused damages such as ground sinking through the rapid sand.

(4) Relative minor damages of pond like structural object

Pond like objects such as distribution reservoir, sedimentation basin, etc had damages but it could continue the operation. The damages were deterioration of expansion joint, leak from wall cracks, damages at the connection with pipeline.

6 Tasks and lessons for future

6.1 earthquake retrofit

Seismic pipes showed the good performance of aseismic capacity. However, the old pipes settled to follow the earthquake resistant design code before 1997, were damaged like as the disconnection of expansion and flexible pipe, leakage at the joint, etc. And it brought about the longtime water supply shutdown. It made realized again the importance of backup such as loop or duplex of pipelines. Main pipeline is the most important so that the use of earthquake resistant pipe and joint are recommended like expansion and flexible pipe.

6.2 Effect of electric power failure

Generator is a very important facility to operate the WTP when the energy supply failure happens. It was recommended in 'Design Criteria for Waterworks Facilities 2000' that the capacity of fuel tank is for 24 hours operation with the consideration of the time of disaster.

In case of this earthquake, the power supply problem continued long time and wide area. Many WTPs faced difficulty to secure the necessary amount of fuel for running generator. Some entities couldn't obtain the fuel and stopped running of WTP. And also the power failure and damage of transmission facility caused the problems of monitoring and control system.

The water supply control and management system should be examined with the consideration of possibility of long time power failure.

6.3 Initial motion

(1) Confirmation of communication method

The bottleneck of the initial motion was the problem of communication. Many of telephones and mobile phones couldn't connect but satellite phones were effective, which were distributed to the local chapters and prefecture chapters. And radio transmission was effective for intra-entity communication. Additionally, the packet communication of mobile phone was effective.

Some entities had damage of government building and couldn't use community wireless system for public relation activities. The staff of such entity went to the TV or radio station by foot or bicycle to provide a manuscript of public relation.

(2) Initial motion

The opinions of disaster affected entities are as follows.

1) Manpower

- Monitoring by telemeter stopped due to power failure. The appropriate number of staff members is required to obtain the damage at the site.

- Many complaints came to the office due to water supply failure and staff had to answer the phone call and disturbed working for their own job. It should be established the backup system from departments and agencies of mayor, and volunteer system of retired employee

2) Procurement of materials and equipment

- It took long time for procurement and installation of of temporary construction materials such as sheet-pile, lighting, submergible pump, vehicle, etc. It is necessary to establish the information system or agreement with construction industry.
- Manufacture of chemicals had damage and there was difficulty of obtaining some sort of chemicals. It is considerable the confirmation of supply chain and establishment of mutual accommodation among water suppliers.

3) Review of manual for disaster countermeasure

- It was observed some difficulties for following the manual e.g. information collection, communication and chain of command at the initial motion. The review of manual is required with the consideration of tsunami disaster.
- There was a case of difficulty of use of office automation due to damage of government office.

6.4 Emergency water supply

The disaster was so large and the branch chief authority was damaged that the existing hierarchic order system could not work efficiently. The disaster was extremely large and wide, so the many kinds of squads of emergency water supply came to the site It created a confusion at the receiving side. The affected entity had a limit of manpower and difficult to allocate a person who guide a water truck to the site. Car navigation system becomes essential for the water truck. It should be considered the utilization of volunteer and block association.

For help receiving side, it is important to prepare a map to direct places of water delivery and receipt and points of emergency water supply.

For helping side, it is preferable to upgrade the equipment like pressure water truck for practical and effective work, and the collection of prior information to know the needs of affected entities.

6.5 Emergency restoration work

(1) Emergency restoration at the seismic affected area

1) Assistance structure of restoration work

Advance investigation teams were dispatched by the rule established in ‘Emergency response guidance such as earthquakes’.

The headquarters formulated the structure or effective assistance and determine the responsible area for each local chapter. It could work smoothly, and the continuous dispatch of communication and coordination officers was also helpful.

2) Public announcement of the target of emergency restoration

The problem of bulk water supply due to leakage of transmission pipe was one of distinctions of this disaster. Miyagi Bureau of Enterprise made a recovery plan on 16th March and released the information of the target date of water supply restarting at the website. Consequently, Sendai City and Ishinomaki District Water Supply Authority announced the recovery plans. It is no wonder that these PR activities could clarify the magnitude of help request. And it could reduce users' psychological burden.

3) Storing against emergency

Stockpile of particular kind of materials enabled immediate action for emergency restoration

Cut-down of stocks for efficient asset management is important, however, the low operation frequency material like the large diameter pipes should be stocked and the information of stock should be shared among industries and entities.

4) Input from inhabitant

Input from inhabitant is important for early detection of leakage. Adversely, the public information by loudspeaker van is useful to inform the situation of recovery.

5) Enhancement of logistic support

Huge scale disaster needs the system of long period support of logistics for the activities of recovery. Procurement of commodity, arrangement of accommodation, food, vehicle, fuel, etc and assignment of standby person could support the long-lasting recovery activities. The immediate establishment of the logistic support system is also important.

(2) Emergency restoration at the tsunami affected area

The tsunami attacked area was seriously damaged not only pipelines but water sources. Water quality of damaged area exceeded the standards for the parameters such as chloride, sodium, TDS, etc. In this area the water supply was done by water truck for long period.

In order to recover the water quality, cleaning of well and withdrawing water had been done for more than one month. As a result, the water quality became better and finally satisfied the standards two months after the incident. Consequently, the supply has started in some area.

The priority of water supply in the tsunami affected area was put on the route for evacuation center and temporary housing, and supply route passing the tsunami affected area. The most difficult area was the area where houses were swept away

due to the tsunami and buried by wreckage.

In such area, the restoration work was done as following steps repeatedly, (1) investigation of buried pipe, (2) searching of sluice valve, (3) Filling water in distribution pipe, (4) Check of water supply facilities, e.g. closing water shutoff valve, (5) leak detection, (6) leak repair, (7) detergent drain, (8) test of water pressure.

In the area of flood due to ground sinking was difficult to do leak detection, and there was no good prospect of early recovery. The settlement of provisional pipeline was done as an above-ground piping in such area, with the purpose of supplying for lower stream area.

6.6 Information management of facilities and pipeline

It is recommended that the drawings must be dept in paper-based even if the electrical mapping system is existing, and the back-up data are better to be kept separately.

One tsunami attacked water supply utility had kept the all data at the government building, so that the evaluation of damage and emergency restoration were disturbed.

6.7 Others

Many of entities send water trucks for emergency water supply, however, it was highly disturbed by the shortage of fuel etc, due to fragmented supply chain.