# Securing Materials for Recovery in the Event of Epicentral Earthquake in the Capital City:
# Never-interrupted Supply Chain

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**Theme;**
**⑧Climate Change**
Disaster Risk Management

**Summary**
The Great East Japan Earthquake, which occurred in an unprecedented scale in Japan in 2011, caused unexpected phenomena including tsunami, liquefaction and disruption of the transportation network, and resulted in the situations where goods and personnel for restoring the devastated lifeline could not reach the disaster-affected area. The risk of a major earthquake under the Japanese capital of Tokyo within the next 30 years is predicted as 70%, and it is assumed that water suspension rate exceeds 30%. Delay in recovery of the waterworks infrastructure due to supply chain cut-off jeopardizes the living and urban activities of 13 million people in the capital, and dysfunction of the capital center affects the world greatly. Learned from the Great East Japan Earthquake, the Tokyo Metropolitan Waterworks Bureau reviewed and updated the damage estimate based on objective and scientific data, and will secure sufficient stock materials to respond disasters, place them properly and build a smooth operation system by cooperating closely with public and private sectors in order to realize a supply chain that will never be interrupted.

**Keywords**
Supply chain, reinforcement of material stock, measures for deterioration of materials, distributed placement of materials, streamlining and optimization of material management system

**Background**

Since the beginning of the 21st century, major earthquakes have continuously occurred in various parts of the world, such as Asia and South America, and the Great East Japan Earthquake of magnitude 9 occurred in Japan in 2011 (Figure 1). This unprecedented earthquake caused unexpected phenomena including tsunami, liquefaction and disruption of the transportation network, and resulted in the situations where goods and personnel for restoring the devastated lifeline could not reach the disaster-affected area.

At the time of the Great East Japan Earthquake, waterworks infrastructure also suffered serious damages such as breakage of transmission pipes with a diameter of 2400 mm in wide area water supply, and consequently 2.57 million households in the disaster affected area were affected by water suspension. However, waterworks infrastructure was not promptly recovered at that time compared with other urban infrastructure. Materials necessary for recovery of the waterworks infrastructure need to be delivered by specifying types, quantity and carry-in order of optimal pipes in accordance with damage situations, topography and geography. Furthermore, in order to smoothly supply large-sized materials such as large diameter pipes to the disaster affected area, it is also necessary to carefully consider their carry-in routes and methods. Under these circumstances, at the Great East Japan Earthquake, it took three weeks for most of the households to recover from the water suspension (Figure 2), causing deterioration of hygiene condition, spread of disease and stagnation of industries in the disaster affected area.

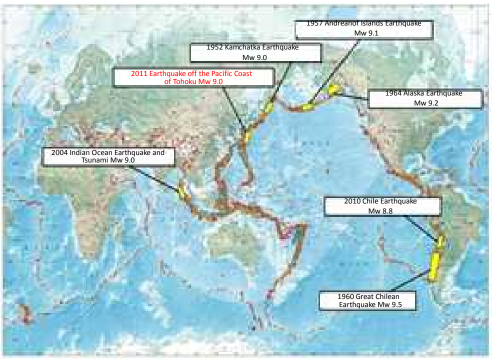



**Figure 1: Earthquakes in the World**

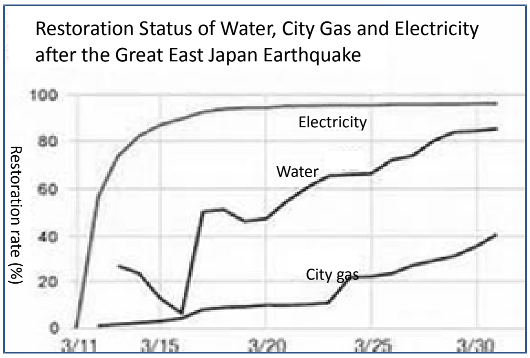



**Figure 2: Recovery of Infrastructure**

The risk of an earthquake directly underneath the Tokyo Metropolitan area within the next 30 years is about 70%. Although the Tokyo Metropolitan Waterworks Bureau (TMWB) has developed the earthquake-resistance of pipes and facilities, water suspension rate ratio is still assumed over 30% in case of earthquake disaster. In case Tokyo is struck by an earthquake and the recovery is delayed due to supply chain cut-off, there will be immeasurable impacts not only on the citizens' living and urban activities of 13 million people in the Metropolis but also on the entire Japan and the world. TMWB is responsible for building a solid supply chain that ensures rapid and reliable recovery from disaster in order to maintain the core function of the capital regardless of any disasters.

**Stock of Materials and its Increase**

**Review of Damage Estimation**

The Tokyo Metropolitan Government established the Disaster Management Council on concerned epicentral earthquakes in the capital and created damage estimation of Tokyo in 2006. However, witnessed the serious damage situation in the disaster affected area in the Great East Japan Earthquake in 2011, we completely reviewed the existing damage estimation and created the new one that fits the reality in 2012 after verification based on objective data and scientific evidence. The features of the revised damage estimation include reexamination of each of the cases of the Northern

Tokyo Bay Earthquake and the Epicentral Earthquake under Tama as models of epicentral earthquakes under the capital, as well as addition of subduction zone earthquakes and earthquakes which occur in active faults. As a result, the estimated intensity exceeds 6 upper (the second strongest intensity scale out of 10 scales set by Japan Meteorological Agency) in approximately 70% of the wards area in case of the Northern Tokyo Bay Earthquake and approximately 40% of the Tama area in case of the Tama Epicentral Earthquake. In particular, if the Northern Tokyo Bay Earthquake occurs, a catastrophic situation is estimated that the death toll reaches 9,700 at the maximum.

Out of the pipes with the total length of 26,900 km and the facilities of the capacity of 6,859,500 cubic meters per day, TMWB assumed the scale of damages due to an epicentral earthquake in the capital based on the estimation of the Tokyo Disaster Management Council. Under the estimation made by the Disaster Management Council in 2006, 8,000 places in waterworks facilities are assumed to get damages, while we revised the figure to 13,000 places in the estimation in 2012.

**Stock of Materials and its Increase**

TMWB emphasizes public-private partnerships and public-public cooperation in order to smoothly respond to the recovery of a large number of damaged places. Specifically, it concluded agreements and memoranda with regard to supply and mutual support at the time of disaster with companies, organizations and local governments to get prepared to secure the materials and support system necessary for recovery rapidly and reliably.

However, in the past earthquake disasters including the Great East Japan Earthquake, the stockpile sites owned by the material manufacturers also suffered from damages such as liquefaction and it took considerable days to arrange the supporting system of each manufacturer for recovery. Based on such actual situations, TMWB estimated that it will take around 10 days for the manufacturers to reorganize their supply system of materials once an earthquake disaster occurs and thus, has been trying to create a system for early recovery by keeping stock of materials to be used for 10 days in the Bureau itself as the most reliable means to secure materials.

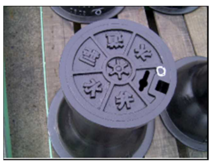
The number of items of stock materials was previously set as 148,000 in accordance with the initial estimation. However, since it became necessary to estimate larger damages were expected based on the experience in the Great East Japan Earthquake as mentioned above, the stock materials were increased to 240,000 items in 2012.

It would be one of the largest stocks in quantity in the world, secured by a single water business entity for the purpose of recovery of waterworks infrastructure. TMWB will properly manage and operate these stock materials and take all possible measures against disasters.

**[Reference] Types of Stock Materials (Partial)**

Straight Pipe

Deformed Pipes



Valve Case

Joining Parts (Bolts)

Steel Lids

### Optimization of Stockpile Sites

The stock materials are stored at 11 material stockpile sites in the Metropolis, located at places suitable for material management, loading and unloading. According to the latest estimation of epicentral earthquakes in the capital there is a risk of disaster every area in Tokyo. Therefore, we divided the whole Tokyo Metropolis into three areas and the stock materials are distributed to each area in a balanced manner (Figure 3).

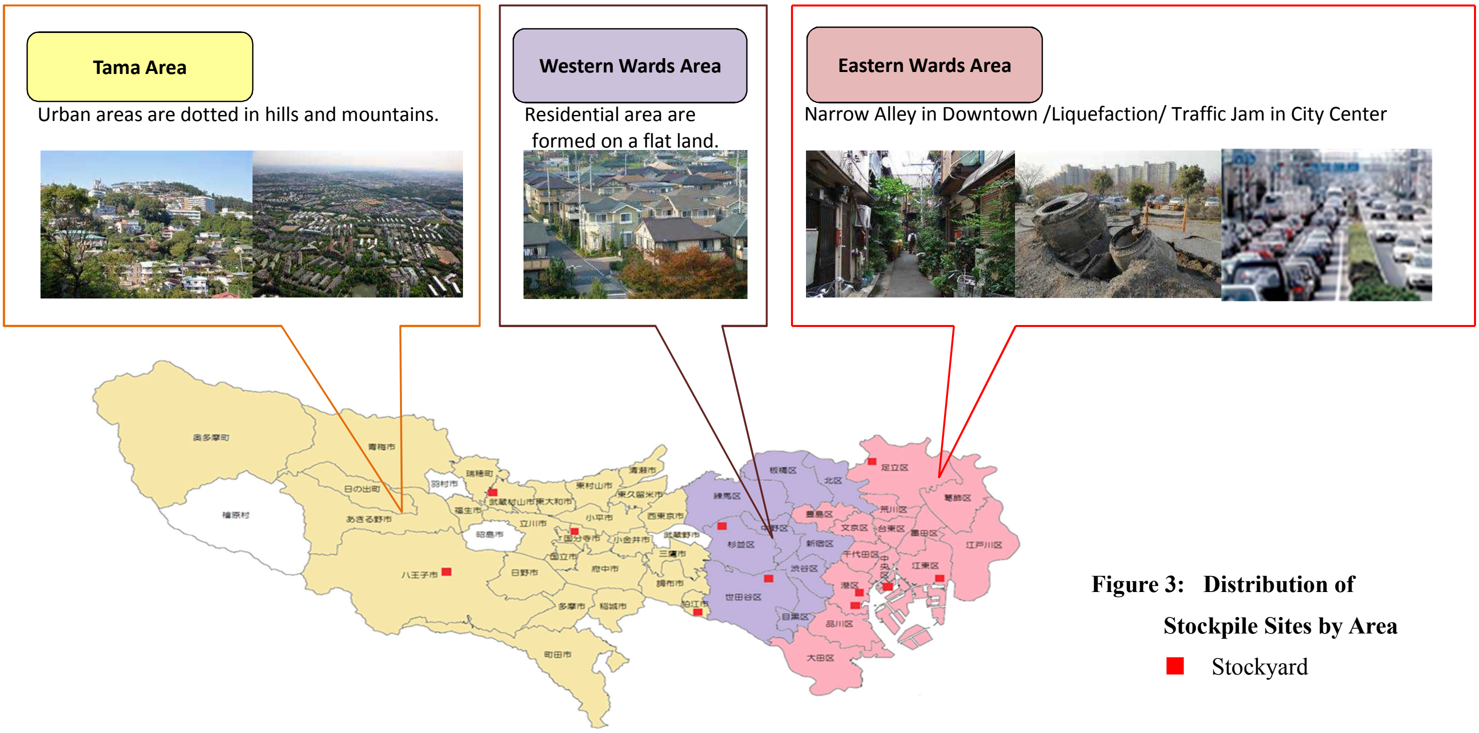



**Figure 3: Distribution of Stockpile Sites by Area**

■ Stockyard

### Features of Each Area

The three areas are the eastern area of the Wards, the western area of the Wards and the Tama area, and each has the following features:

*Eastern Area of the Wards*

This area has an urban center, while the downtown spreads in the eastern part, forming a dense area with wooden houses. Traffic jams are always intense in the urban center, and in the event of a disaster more serious congestion is expected due to evacuation and recovery activities. According to the latest damage estimation, due to an epicentral earthquake in the capital, in narrow roads with a width of less than 13m in the area where buildings will be completely destroyed by an earthquake with a seismic intensity of 6 upper, it is assumed that blocking of narrow streets where traffic cannot pass (a state where the width of passable road is 3m or less) will occur at many places due to a collapse of houses and other buildings around the road caused by tremors or liquefaction (Figure 4). In addition, in this area, sandy ground with high groundwater level is spreading mainly in reclaimed land in the coastal section, and there is a high possibility of liquefaction due to tremors caused by earthquake (Figure 5).

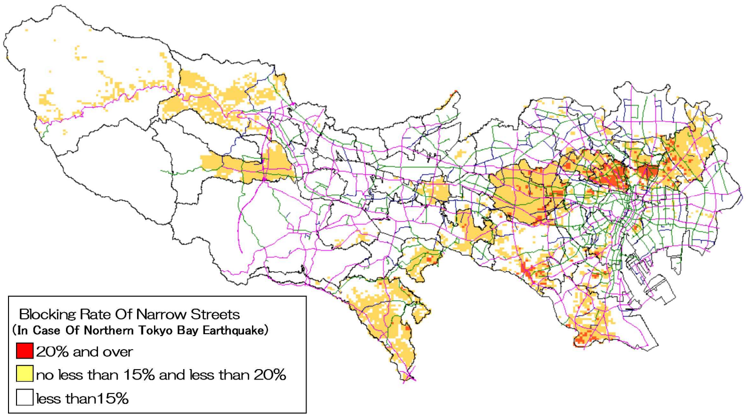



**Figure 4: Blocking of Narrow Streets**

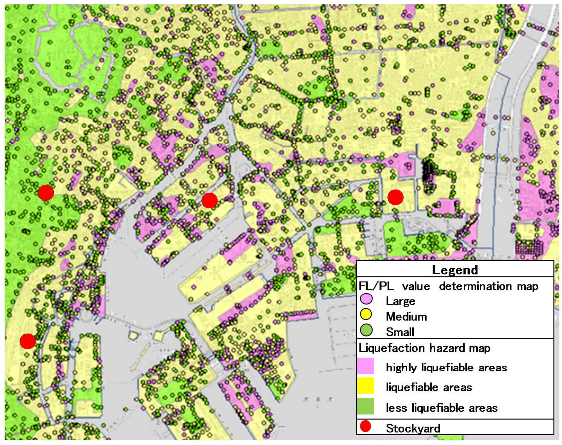



**Figure 5: Liquefaction Risk in the Eastern Wards Area**

Source: *Liquefaction Estimation in Tokyo (revised in FY2012)* From the Website of Civil Engineering Support and Training Center, Tokyo Metropolitan Government

From the viewpoint of their locations, the stockpile sites for materials in this area are indispensable for quick recovery of the core function of the capital. However, as mentioned above, it is an area with high risks in storing materials and carrying them in and out.

*Western Area of the Wards*

Similarly to the eastern area of the wards, there are many residential zones and commercial zones formed in this area, and careful adjustment is required for piping construction. As a result, the implementation status of the earthquake-resistant construction works of the water distribution pipes is almost the same as that of the eastern area. As the expected water suspension rate is 20 to 30% on average, the disaster risk is not especially low. However, this area has a characteristic that the ground is stable as compared with the eastern area of the wards and the topography is relatively flat compared to the Tama area, and that it is located in the middle of those two areas. Due to these facts, it plays quite important role in the management and operation of materials as supply and relay stations of materials for quick recovery of the core functions of the capital and for the eastern area of the wards and the Tama area.

*Tama Area*

In this area, the earthquake resistance of the water distribution pipes is slightly higher than that of the wards area. However, as a result of the review of the damage estimation after the Great East Japan Earthquake by assuming earthquakes directly hitting the Tama area such as an epicentral earthquake in the capital in Tama and an earthquake occurring in the Tachikawa active fault, it has become clear that the water suspension rate would exceeds 20% all over Tachikawa city and Hachioji city, the most urbanized areas in the Tama area. In addition, as there are some places where urban zones are developed in hilly or mountainous parts in this area, there is a possibility that it may be difficult to transport or carry out materials and to conduct construction work. Based on this assumption, we strengthened the stockpiling system of the Tama area by adding the most new stockpile site to Kokubunji city and at the same time, increased the amount of stock materials in the entire Waterworks Bureau.

**Balancing the Quantity of Stock Materials**

We reviewed not only the distribution of stockpile sites but also the arrangement balance related to the stock quantity at each site. Until the Great East Japan Earthquake, the Tokyo Metropolitan Bureau of Waterworks had a relatively high percentage of storage in the eastern area of the wards in order to secure storage locations of the material near the center of the Metropolis. However, as mentioned in details in the preceding paragraph, there is a concern about blocking of narrow streets and liquefaction in the eastern area of the wards and thus, it is risky to store materials in a concentrated manner.

In addition, since it is estimated that 30% of the total road sections both inbound and outbound will be congested at the time of a disaster, it would be quite difficult to achieve rapid transportation. In order to realize carry-out of materials in a short time for 400 teams of restoration workers in total scheduled to be organized in all areas of the Metropolis, we corrected the excess stock of the materials in the eastern wards to distribute and store materials in a balanced manner in terms of quantities and contents (Figure 6). As damage estimation and risk are constantly changing, we will continue to keep optimal placement balance while trying to gather information and grasp the situation.

- Liquefaction risk
- Traffic conditions at the time of earthquake disaster
- Effective retrieval of material to 400 operation teams

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Correcting the excess stock in the eastern-ward area, distributing materials in different parts of Tokyo in a balanced manner

Unit: Item

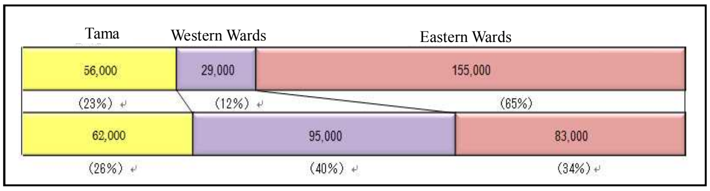


**Figure 6: Review of Balance after Increasing Stockpiles**

## Streamlining and Optimization of Material Management System

### Utilization of Outsourcing to the Private Sector

The management of the stockpile sites is collectively entrusted to the private sector to improve efficiency through integrated management. The contractor is required to have not only know-how to carry out appropriate management but also knowledge on material to be managed. The operation systems of the contractor are classified into three types in accordance with the scales and locations of the stockpile sites: namely a type that supervisors stay 24 hours a day, a type that supervisors work only during the daytime on weekdays and a type that supervisors visit on patrol. Each type of stockpile site is monitored 24 hours a day, 365 days a year, and its safety is always maintained.

### Method Suitable for Material Management

Warehouses are installed in each stockpile site and materials are properly managed outdoors and indoors (within the warehouses) according to their sizes and nature. Outdoors pipes are being stored with polyethylene caps and waterproof sheets attached to them and are placed on wood called base rods. Although materials are easily rusted outdoors due to exposure to rain, using caps, seats and base rods brings a certain effect to prevent rusting. On the other hand, indoors (in the warehouses) we store parts that are particularly susceptible to deterioration such as like rubber rings using rubber materials.

The contractor checks the conditions and qualities of the materials on a daily basis by on-site patrol as well as performs security checks including the storage conditions of the materials and the presence or absence of suspicious individuals and objects intruding into the stockpile sites. In addition, inventory clearance is being carried out four times a year to thoroughly check deterioration conditions of the stock materials. As for materials stored outdoors in particular, as there is a risk of rusting, we conduct repairing and cleaning such as painting and rust removal as necessary. Those materials judged as unusable at inventory clearance are discarded.

**Situation of Storage and Management of Materials at Stockpile Sites**

**Measures against Aging of Materials**

*Material Provision System*

As a supply method of materials used for construction, TMWB currently employs the “System of Material Supply by Contractor,” under which, in principle, the contractor of construction should be responsible for supply of materials. However, in order to prevent aging of materials due to storage for a long time, we introduced the “Material Provision System, " under which TMWB, as an ordering party of construction works, provides contractors with construction materials, to a part of its emergency construction works so as to ensure turnover of the stock materials.

Constructions subject to the "Material Provision System" include construction related to water supply emergency construction unit price contracts (maintenance repair work and water leakage repair work) (such as recovery and repair of sudden damage accidents at water facilities, small scale maintenance repair), construction related to small-scale maintenance construction contract for water distribution pipes (such as a part of pipe work requiring immediate response, small scale pipe work, and others).

*Renewal Frequency of Stock Materials*

The amount of stock materials used in emergency construction items from April 2015 to March 2016 is 50,461, which corresponds 17.7% of 284,952 items of stock materials as of March 2016. Although there might be changes in quantity of use depending on the year, it is considered that the number of occurrences of the targeted emergency constructions is expected to continue to be on the same level. Therefore, assuming that all the stock materials are used for emergency construction, it is calculated that it will take 5 to 6 years to renew stock materials. However, materials that are not frequently used in emergency construction, such as large-diameter straight pipes, are being replaced each time they deteriorate.

**Public-Private Partnership in Case of Disaster**

As mentioned above, in preparation for a disaster, the stock materials are being managed efficiently and appropriately at normal times by utilizing contractors. In addition, we have prepared a system under which we can response promptly and properly through public-private partnership when utilizing the materials at the stockpile sites at the time of a disaster.

*Stockpile Site Management Personnel*

TMWB has designated its staff members who are in charge of carrying materials out at each stockpile site in collaboration with contractors as "Stockpile Site Management Personnel" in advance based on the Tokyo Waterworks Bureau Earthquake Disaster Emergency Response Plan. The criteria for designation of these personnel consisting of requirements such as job classes and distance from home are stipulated according to work contents and the number of workers required on the day of the disaster, and they are prepared to promptly gather at each stockpile site in case of disaster to take appropriate actions.

*Roles of Public and Private Sector and Their Collaboration in Case of Disaster*

When a disaster occurs, the Stockpile Site Management Personnel, who are staff members of TMWB, as well as supervisors of the contractors gather in the predetermined stockpile site, and the Stockpile Site Management Personnel give necessary instructions such as loading and unloading of materials to the contractors. In the stockpile site at the time of disaster, it is necessary to handle many tasks in a limited time, such as confirmation of safety, ensuring the flow line at the stockpile site, coordination and adjustment with the other stockpile sites, information gathering, responses to neighboring residents, reception and inspection of new materials. The Stockpile Site Management Personnel grasp the whole situation of the stockpile site as well as the situation of other sites and their mutual relations obtained by utilizing the system described in the next section, work closely with officials of the head office and issue appropriate instructions to contractors. The contractors, who act according to the instructions of the Stockpile Site Management Personnel, can respond to each instruction more efficiently, promptly and accurately as they can utilize their experience and knowledge of the site through daily management particularly with regard to site management such as securing the flow line at the stockpile site, loading and unloading of materials. In this way, in the event of a disaster, public and private sectors share roles and collaborate each other, and thereby make it possible to realize the smooth operation of stockpiling materials.

*Operation Management by Utilizing the System*

In order to efficiently and appropriately manage the huge amount of stock materials, TMWB is effectively utilizing the "Inventory Management System." Even when utilizing stock materials for emergency construction as part of measures against aging of materials at normal times, we use the system to grasp the situation of usage and renewal of the materials at each stockpile site. At the time of disaster when the stockpile sites are to be used for recovery construction, we will use the same system to check the carry-out status and remaining status of each stockpile site. Such information obtained through this system is indispensable to judge efficient material supply to disaster affected places. Since this system may be damaged in the event of disaster, we have prepared another system within the disaster-resilient "earthquake disaster server" to fulfill the function of the "Inventory Management System" for such case. Furthermore, a dual backup system of the main and the sub is established in the earthquake disaster server. Meanwhile, as systems are not always perfect, we are also promoting a mechanism that does not depend too much on these systems by preparing a structure of operation even on paper basis for a case where all systems are affected by the disaster.

*Implementation of Training*

We regularly conduct "emergency gathering drills" and "emergency disaster drills" to improve the level of responses so that staff members of the Bureau and employees of the contractors smoothly cooperate in the event of disaster, implement carry-out of materials, and other activities promptly. "Emergency gathering drill" is a training in which the concerned personnel gather in the stockpile site and form the initial structure immediately after the disaster when confusion is most likely to occur. In this training, we also train them how to handle portable generators and other equipment installed at major stockpile sites, assuming the occurrence of power failure in case of disaster at night. “Emergency disaster training" is a training to enhance immediate response skills. This training contains issuance of instructions on quantities of the materials necessary for recovery of damages, supply methods, transportation routes, and others by simulating specific factors of disaster such as facilities affected, date and time, damage scales.

## Conclusion

TMWB has put in place a complete system for rapid and appropriate recovery of water supply in case of a disaster by taking maximum advantage of the scale merit that it covers the 23 wards and the majority of the Tama area in Tokyo as its water supply target area. TMWB manages water supply from water source to faucet in a centralized manner and by securing and distributing sufficient stock materials to respond to the assumed damage based on scientific and objective data. However, it is difficult to maintain efficient and unified management of huge amount of materials both at normal times and in times of disasters with the know-how and human resources of TMWB alone. In order to build disaster-resilient waterworks infrastructure, it is important to prepare a system based on cooperation with all stakeholders including citizens such as a wide range of daily public-public and public-private partnerships with attention also to development of infrastructure such as three ring roads that are being steadily developed. Although the circumstances in and around Tokyo, including the risk assumption of concerned epicentral earthquakes under the capital, will change from moment to moment, TMWB will never be satisfied with various collaborations and trust relationships it has built so far and is determined to maintain and develop the disaster-resilient supply chain that will never be interrupted by always grasping the risk accurately.