The Prioritized Pipeline Maps for Emergency Restoration

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ABSTRACT

In previous earthquake disasters, the water supply facilities suffered serious damage. It required considerable time for them to be restored, which impacted citizens of the area greatly. The 2016 Kumamoto Earthquake also caused a lot of water pipeline damage especially on service pipes and harmed the water supply. Water utilities from all over Japan, including the Yokohama Waterworks Bureau, helped emergency restoration of the water supply in the disaster area. The damage restoration efforts must share their experiences, which will allow effective measures to be taken in order to prepare for earthquakes in the future.

Meanwhile, in Yokohama, we have been replacing aged pipes with earthquake-resistant pipes, establishing emergency water supply stations, encouraging stocking of drinking water, and implementing citizen-participation in emergency water supply drills as earthquake measures.

Moreover, we have learned much through the assistance efforts in Kumamoto. As such, we have created prioritized pipeline maps for emergency restoration in case of earthquake disaster in Yokohama. When receiving external assistance/relief from other water utilities, the maps will serve as effective explanation material. Furthermore, we will consider the idea of emergency restoration of the water supply and sewage facilities in cooperation with offices that manage sewage works in Yokohama City.

In this paper, we report on the contents of the maps, the way of thinking, and future prospects.

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DETAILS

Outline of Water Supply in Yokohama City

Yokohama City has a population of about 3.73 million and about 1.67 million households (July 1, 2017) [1]. The area is about 437.49 km^2. Due to many hills and valleys, there are areas where water is supplied by gravity flow and pump systems. The Yokohama water distribution block system is made up of a total of 41 blocks including 24 pump systems and 17 gravity flow systems in order to provide a stable water supply to the entire city (Figure 1).

In order to grasp the flow rate, water pressure, water quality, etc. from the intake weir to the water distribution facility, measurement facilities were installed at 248 major points along the distribution reservoirs, the main distribution pipes, and the distribution pipes, and constant measurements are carried out. We can acquire the data at the information terminal at each office and an alarm is issued when an abnormal value is indicated.

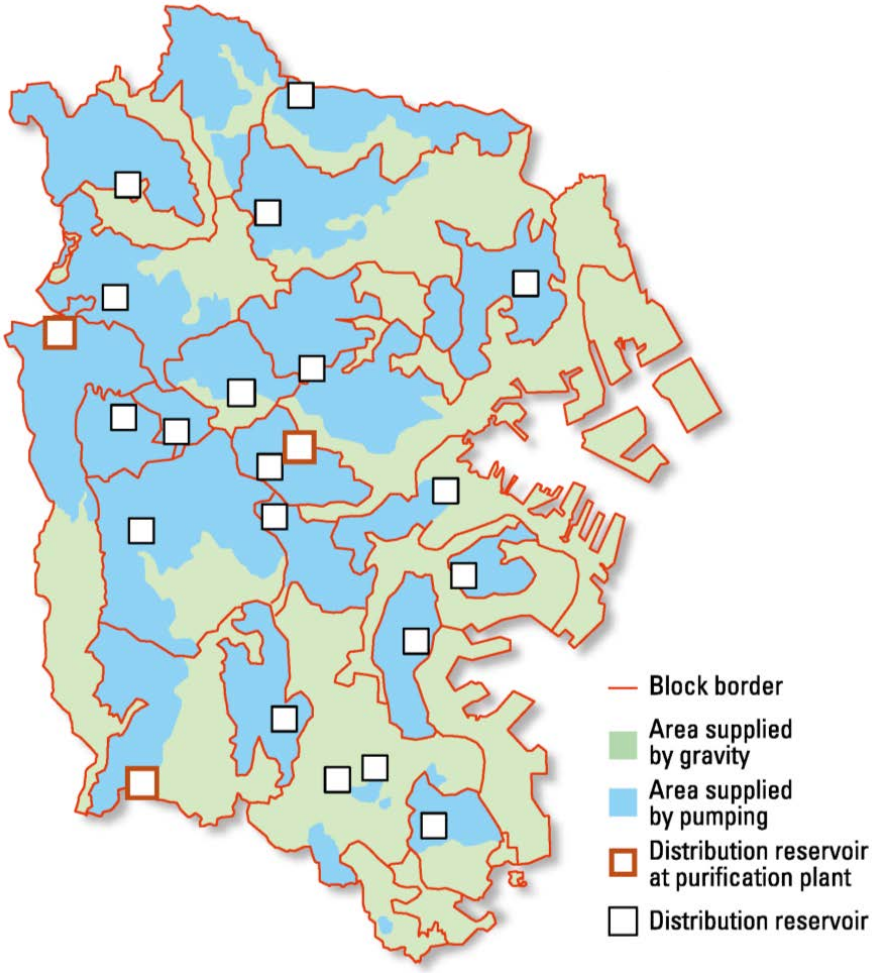


Figure 1. Yokohama water distribution block system

Earthquake Countermeasure of the Water Supply in Yokohama City

Japan is one of the countries where earthquakes occur most frequently. During the Great Kanto Earthquake that occurred in 1923, a maximum seismic intensity of 6 on the Mercalli intensity scale was recorded in Yokohama City, and severe damage occurred across the city. According to the Headquarters for Earthquake Research Promotion in 2017 report, the probability of ground motion equal to or larger than seismic intensity 6 Lower on the Japan Meteorological Agency seismic intensity scale, occurring within 30 years from the present, is estimated at 81% in Yokohama [2]. In order to maintain an essential lifeline for daily living, it is urgently necessary to take effective measures against any future earthquakes.

In Yokohama, we have taken earthquake measures as follows. From FY1996, we have been replacing aged pipes with earthquake-resistant pipes. In a Middle-term management plan from FY2016 to FY2019, we plan to replace 110 km of aged pipes annually and our target rate for earthquake-resistant water transmission and distribution pipes is 28%, and the rate for the main water pipes is 68% by FY2019 [3]. Moreover, we have begun establishing 358 emergency water tap stations and 134 underground water supply tanks for emergencies at important facilities in disasters, such as local disaster prevention centers. The taps and tanks are directly connected by earthquake-resistant pipes from the water distribution pipes of 400 mm or more. The underground water supply tanks contain 118 tanks with a capacity of 60 m^3, 11 tanks with a capacity of 100 m^3, and five tanks with a capacity of 700 to 1,500 m^3. Furthermore, we have been promoting the stocking of drinking water and implementing citizen-participation in emergency water supply drills. In this way, we aim to have a disaster-resistant water supply, which involves people protecting themselves on an individual basis (self-help), communities and companies assisting each other (mutual help), and official help via the Waterworks Bureau (public help).

Issues Revealed by the Emergency Restoration after the 2016 Kumamoto Earthquake

In April 2016, the 7.3-magnitude earthquake with maximum seismic intensity 7 occurred in Kumamoto. Up to 446 thousand houses were without water because a lot of service pipes were damaged.

As a part of the relief effort, 35 employees of the Yokohama Waterworks Bureau provided transportation, leakage investigation, emergency restoration, and contact adjustment for the disaster area. From these experiences, when receiving external assistance/relief from other water utilities, the following issues were revealed [4].

(1) In order to prevent confusion of other water utilities, it is necessary to give appropriate directions according to a pre-planned restoration procedure.

(2) In order to carry out the emergency restoration work smoothly, we have to prepare suitable maps in advance and promptly provide them to other water utilities.

(3) The sewage system also suffered great damage, and it was not possible to supply water even when the water supply system was restored. Therefore, we have to make plans for restoration in cooperation with offices that manage sewage works.

Solving these issues, we prepared explanatory materials as emergency restoration workflows assuming a disaster has occurred when requesting emergency restoration to other water utilities.

Concepts of Emergency Restoration for Important Facilities

The main concepts of emergency restoration are the followings. A lot of service pipes will be damaged in case of great earthquake disaster. Therefore, we close valves of the distribution pipes branching off from the main distribution pipes in order to prevent leakage of service pipes. Then, we restore pipelines in order from important facilities close to the distribution reservoir and secure water supply to important facilities.

We decided the restoration order in consideration of the following steps and priorities. Important facilities prioritized for water supply restoration are the following. There are 358 emergency water taps, 13 disaster base hospitals, 48 designated emergency medical centers and 254 local disaster prevention centers. We decided the priority of restoration for these total of 673 facilities.

In Step I, we established the restoration order for important facilities based on the following four criteria. Priority (1) is medical institutions: disaster base hospitals and designated emergency medical centers, priority (2) is disaster bases: local disaster prevention centers and emergency water tap stations, priority (3) is emergency restoration bases: City hall and Ward Administration Offices, etc. and priority (4) is transport hubs: Yokohama Station and Shin-Yokohama Station. Then, in Step II, we restore the main distribution pipes of 400 mm diameter or larger and major pipes of 300 mm diameter or less which were not restored in step I. Details of the procedure for restoration of the pipeline are as shown in the workflow of Table I.

Based on the above approach, we created prioritized pipeline maps for emergency restoration of 41 water distribution blocks. In this paper, we introduce the map of a Miho gravity flow block.

How to Create a Prioritized Pipeline Map

We introduce how to create a prioritized pipeline map of a Miho gravity flow block in Figure 2. The Miho gravity flow block supplies water to approximately 28,000 houses from the Miho water distribution reservoir via a gravity flow system. There are one designated emergency medical center, seven local disaster prevention centers, and four emergency water taps in this block. Three of the emergency water taps overlap the local disaster prevention centers, so there are nine important facilities in total.

In Step I, we prioritize nine important facilities. Kamoi Hospital is priority (1) and is the designated emergency medical center. Upstream of the pipe to Kamoi Hospital, there are Miho

Elementary School, Midori Ward Administration Office, Nakayama Elementary School, Kamoi Junior High School, and Midori Elementary School as priority (2), which act as local disaster prevention centers and emergency water tap stations. First, we restore pipelines (A) and (B) close to the distribution reservoir and supply water to Miho Elementary School and Midori Ward Administration Office. Second, we restore pipeline (C) and supply water to Kamoi Hospital and Nakayama Elementary School.

Up to this point, restoration of priority (1), the designated emergency medical center is completed and all remaining facilities are priority (2) local disaster prevention center and emergency water tap stations. Considering the efficiency of emergency restoration, we restore from facilities with a short pipe extension. Third, we restore pipeline (D) branching from pipeline (C) where restoration is completed and supply water to Kamoi Junior High School and Midori elementary School. Fourth, we restore pipeline (E) close to the distribution reservoir and supply water to Niharu Elementary School. At last, we restore pipeline (F) and (G) and supply water to Tsudanishi Elementary School and Kawawa Elementary School. Thus, restoration of the pipeline to all nine important facilities is completed.

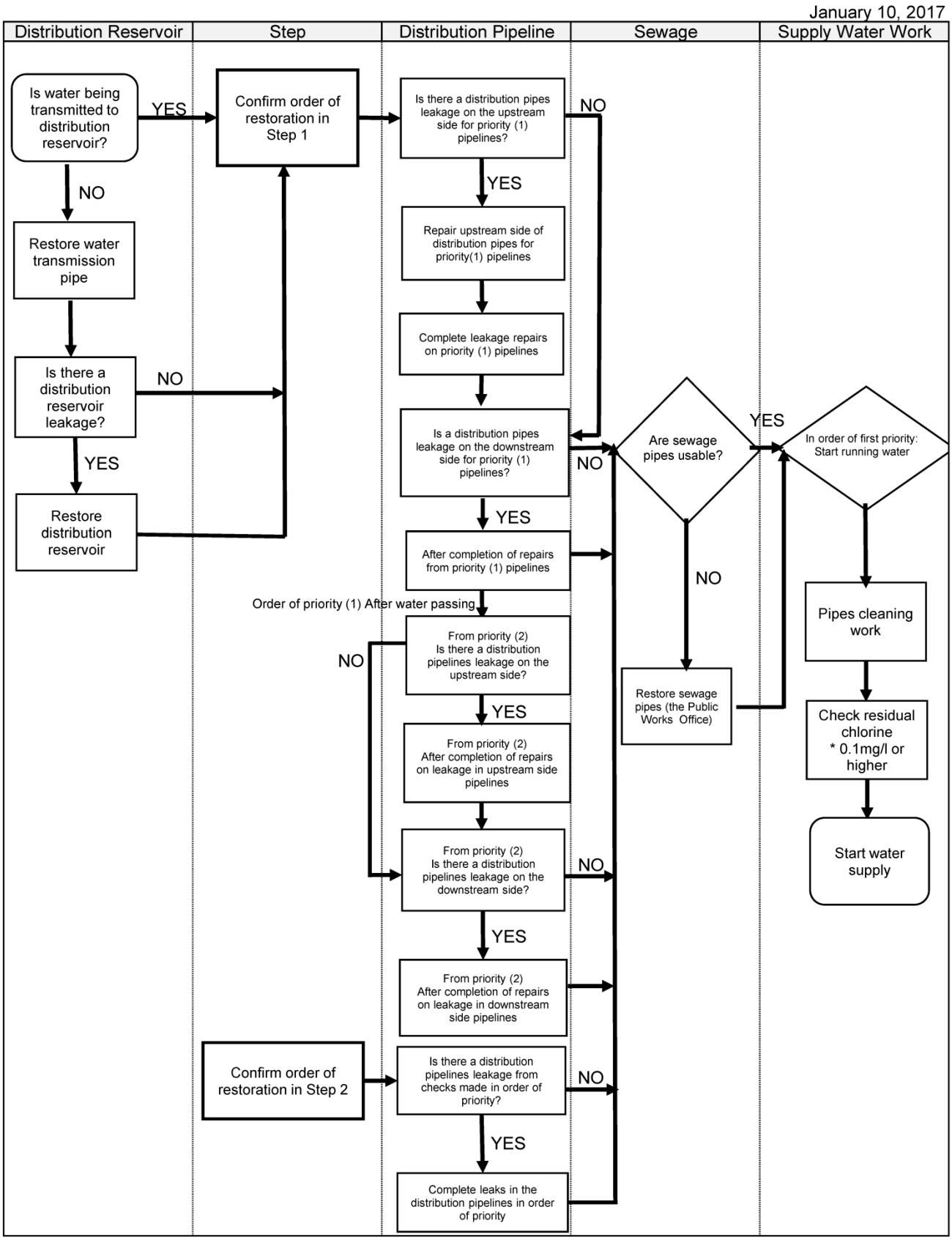
In Step II, we restore three pipes of 400 mm diameter or larger and four major pipes of 300 mm diameter that were not restored in step I. In order to preferentially loop the main pipeline, we restore Miho pipeline with a 600 mm diameter, Aoto pipeline with a 500 mm diameter, and Nakayama pipeline with a 500 mm diameter in order. Finally, we restore four pipelines with a 300 mm diameter important for water supply.

Actions for the Future

Although we created the prioritized pipeline maps this time, in order to restore in case of disaster, we must calculate the number of people needed and the time for restoration work. Also, in order to help other water utilities to provide support when receiving external assistance/relief, we have to prepare detailed drawings and information on routes. We plan to keep the maps in each Waterworks Office as a disaster prevention base for emergency restoration so that information can be promptly provided to other water utilities. Although we have carried out disaster drills in anticipation of an earthquake, by utilizing these maps, it is possible to conduct drills in the assumption of situations when receiving external assistance/relief.

In previous earthquake disasters, there were cases where the water supply was interrupted because the sewage system was not restored. Based on the priority for emergency restoration of the water supply, we plan to prepare plans for restoration of sewage in cooperation with offices that manage sewage works. As a result, efficient restoration aiming for a swift restoration of the water supply and sewage system will be possible.

TABLE I. EMERGENCY RESTORATION WORKFLOW



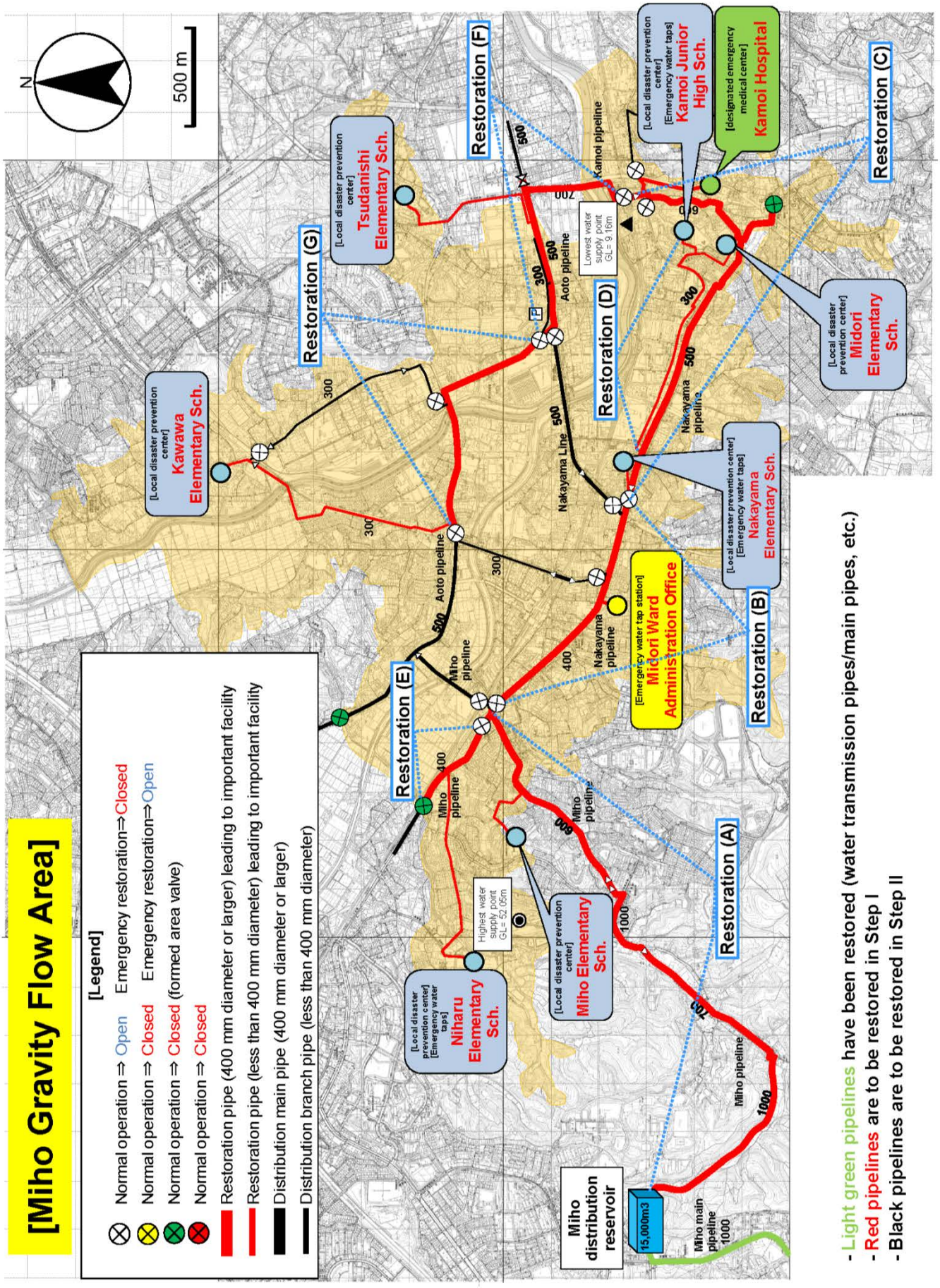


Figure 2. The prioritized pipeline map

CONCLUSION

During the disaster relief operation for the 2016 Kumamoto Earthquake, we reaffirmed the importance of earthquake measures. In order to smooth restoration works when receiving assistance/relief, we created prioritized pipeline maps for emergency restoration. By utilizing the maps, we can early establish place where citizens receive water in case of disaster, and we don't have to send water trucks to some important facilities. The information of facilities equipped for disaster countermeasures has not been in a state where other utilities can utilize it quickly or easily. Maps and workflows that collect this information will be important material for emergency restoration. However, since these materials alone are inadequate for restoration when receiving external assistance/relief, we must organize detailed maps and procedures for restoration efforts. In addition, by creating an emergency restoration plan of the water supply and sewage systems in cooperation with offices that manage sewage works, it is possible to perform more efficient emergency restoration.

What water utilities have to do for future earthquakes is to provide safe water to citizens as soon as possible. To this end, we have to anticipate the possible damage to the facilities, plan restoration in advance, and restore suffered facilities in the most efficient way.

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