6th Canadian Conf. Earthquake Engineering / Toronto / 1991 / 6ème Conf. Canadienne Sismique

An example of aseismic measures for water supply systems: the case of Yokosuka City

Hiroshi Sato[I], Akinobu Watanabe[II], and Seiyu Kamata[II]

ABSTRACT: In this paper, as an example of systematic anti-earthquake measures for water supply system, we will discuss about the case of Yokosuka City. Most important feature of water supply system in Yokosuka City is that 99 % of water resources depends on the long distant places. Then, we must consider not only how to prevent the damage to the facilities during earthquakes, but also how to secure the drinking water as much as possible in the city area. This report is to demonstrate the fundamental ideas in earthquake preparedness of water supply facilities and executed counter-measure acts as an example of synthetic earthquake counter-measure acts for lifeline facilities by a local government.

1.INTRODUCTION

In general, water supply facilities are consisted of such three basic elements as a point, line and plane element. For example, a filtration plant and a water distribution basin may be defined as a point element, and all kinds of pipeline and a network of pipelines may be defined as line and plane elements, respectively. These facilities are affected by the conditions of the change of ground conditions and the passage of time. In the earthquake counter-measure acts for water supply facilities, therefore, the empirical and local regulations may have been employed.

This report is to demonstrate the fundamental ideas in earthquake preparedness of water supply facilities and the executed counter-measure acts in Yokosuka city, which is an example of synthetic earthquake counter-measure acts for the lifeline facilities executed by a local government.

2. SPECIFIC FEATURES OF WATER SUPPLY NETWORK IN YOKOSUKA CITY

Yokosuka city is located in the center part of Miura Peninsula and faces to Tokyo Bay in a east direction and to Sagami Bay in a west direction as shown in Fig. 1. This city has the population of 430,000 and the capability of 320,000m^3 per day for water supply. The water supply network in Yokosuka city is a kind of closed system due to the geographical situation. That is, since there is a few water sources within the city, more than 99% of water should be secure from the neighboring cities. The extended distance of traveling pipelines becomes about 30 to 70 km. And there are many ground faults and narrow valleys within the city, because it is closed to the trough of Sagami Bay called the source of earthquakes. Thus this city is under the geological condition that the ground has a weakness for earthquakes. From the

I National Defense Academy, Yokosuka, Japan
II Yokosuka City Waterworks Bureau, Yokosuka, Japan

slow pace of water operation, due to the geographical restrictions, there is only one border of water within the city and the water is distributed by natural flow after pumping water up from 23 pump stations to 27 main distribution basins. Accordingly the water supply network depends entirely on the other facilities as mentioned.

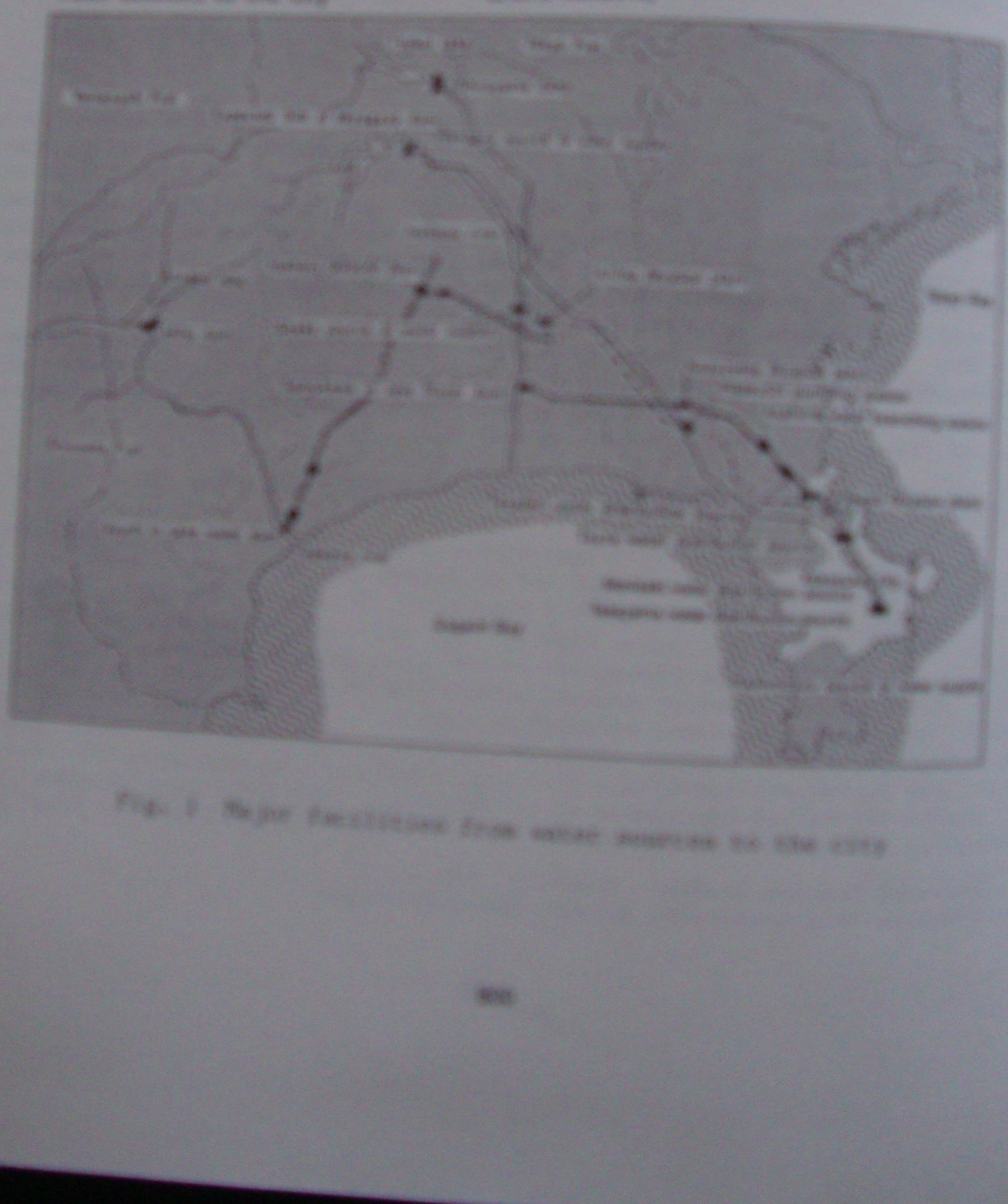

Fig. 1 Major facilities from water sources to the city

3. FUNDAMENTAL POLICIES FOR SEISMIC PROTECTION OF WATER SUPPLY FACILITIES[1)]

With these circumstances as back ground, the diagnosis of existing facilities has been done regularly by Yokosuka City Waterworks Bureau to secure the drinking water for citizen. Deciding the following five fundamental policies:(1) to reinforce the trunk of transmission and distribution pipelines, (2) to develop the alternative water sources in emergency, (3) to secure the drinking water, (4) to establish the water supply system and (5) to define the role to each personnel, the acts of seismic protection have been proceeded seriously for seven years between 1979 and 1985. Some examples of the acts of seismic protection are discussed in the following chapter.

4. EXECUTED EXAMPLES OF SEISMIC PROTECTION

4.1 Aseismic diagnosis of existing facilities[2)]

In order to understand the present situation of water supply facilities, the key facilities are selected from the existing one and then the aseismicity of them are diagnosed in accordance with the Guideline for Seismic Protection Works of Water Facilities(1979). 6 pump stations, 10 distribution basins and 47 distribution pipelines with the extended length of 82km are chosen as the object facilities of aseismic diagnosis.

Since the distribution pipelines are constructed in the underground, they are constituted as the complicated network. Even when a part of network system is damaged, the total system of pipelines may loose its function. Thus the aseismicity of key pipelines which cover the whole city should be diagnosed. The procedure of diagnosis has been done with two stages. In the first stage of diagnosis, the geological map of traverse along pipelines, the geological condition learned from the field survey, the informations on faults, the results obtained by the response analysis based on the above mentioned guideline and the considerations on liquefaction are used for evaluating the aseismicity of total pipelines and for predicting the behaviors of their pipelines in earthquake. In the second stage, based on the results by the first stage of diagnosis, the pipeline running along the basin of Hirasaku River, where the weak ground mostly distributes within the city, was picked up. Then the dynamic analysis was carried out for estimating the behaviors of this pipeline with the modeled ground.

It is found from the diagnosis that the expected damage in pipeline comes up to the extension distance of 19km and then the prescribed damage rate to the length of 82km for the whole pipelines becomes 23%. Based on the analytical results obtained from the diagnosis, the renewing plan for distribution pipelines are scheduled, and the replacing of existing pipelines to the aseismic one and the saving for emergency restoration resources have been proceeded.

4.2 Examples of countermeasures

(1) Reinforcement of the trunk pipelines for the transmission and distribution facilities. 18 tunnels which amount to the total length of 10,500m are existed in the pipeline of Arima and Kosuzume water systems. Since these tunnels were made by handwork and were severely weathered, all parts of tunnel without lining were completely fixed up and the bridges of aqueduct were renewed as shown in Photo-1.

The pipeline structure may be mostly damaged in every water supply

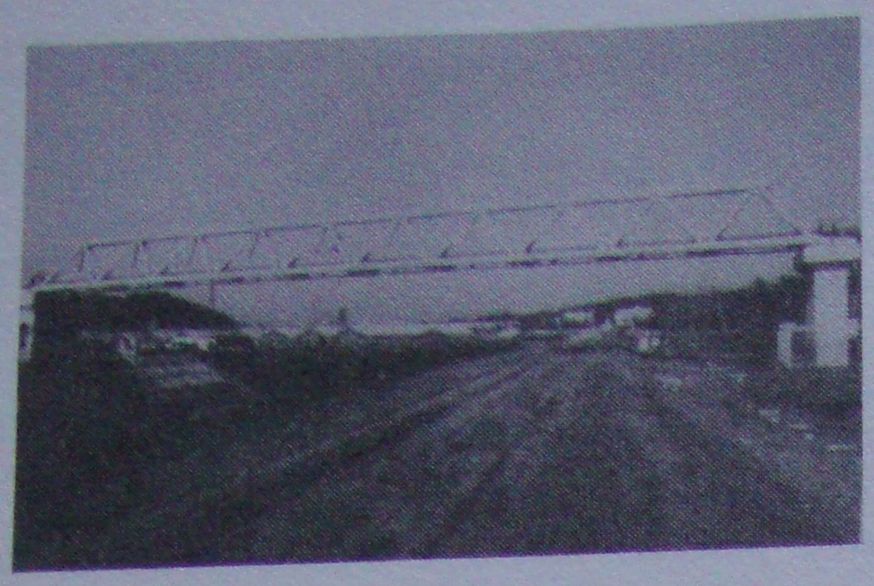

Photo 1 Renewed water piping brige

Photo 2 Well for emergency use

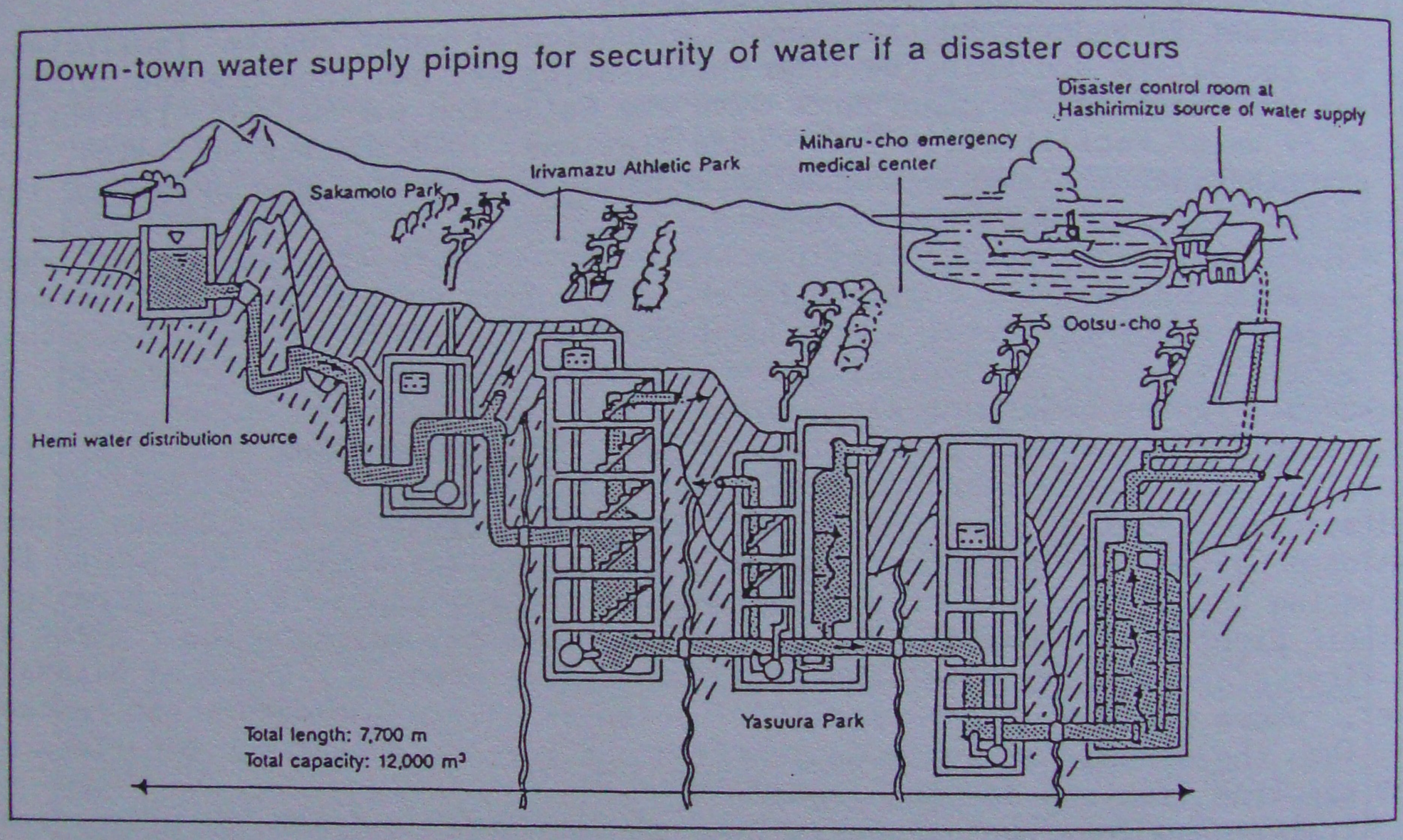

Fig. 2 Down-town water supply piping for security of water if a disaster occurs

(2) Exploitation of new water resources in emergency

Since it is not enough to secure the drinking water only from Hashirimizu source of water supply which has a capacity of 2,000m^3 per day, the emergency wells for gathering water having a capacity of 3,000m^3 per day were founded on the basis of the measured data of natural radioactivity in this area as shown in Photo-2. Also in the west district of the city, the gathering water wells having a capacity of 2,000m^3 per day were founded. Then the emergency water sources in earthquake run up to 7,000m^3 per day in amount.

(3) Security of drinking water

In order to secure immediately after disaster, the drinking water of 3 days (that is, 3 liters per day for a person) for the citizen, the following counter-measures were being put into practice.

i) To prevent from flowing due to the breaking of pipe, the water distribution basin was equipped with the emergency shut-off valve apparatus.

ii) To secure the drinking water in emergency for a wide spread refuge, the trunk line of water distribution was provided with the function of storage as shown in Fig. 2.

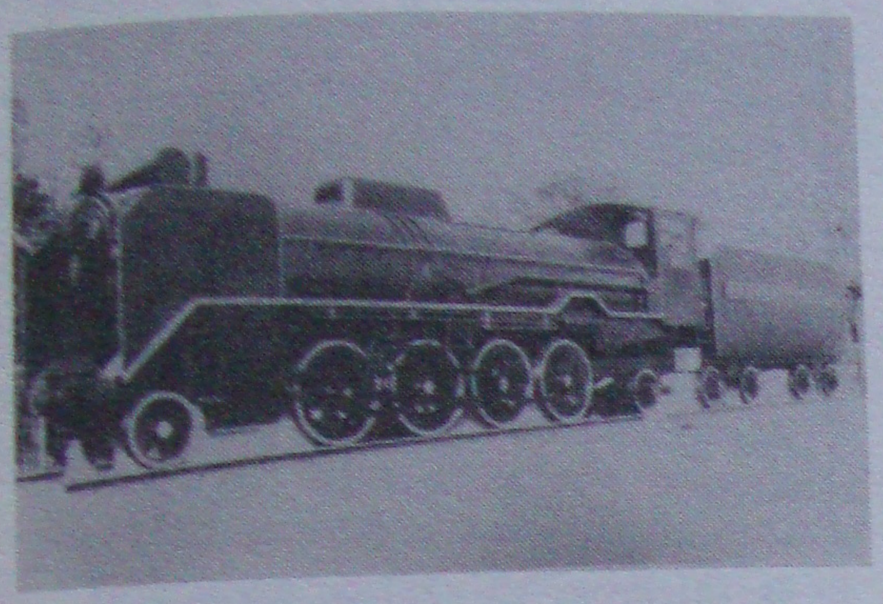

Photo 3 Steam-locomotive shaped emergency reservoir directly connected to water supply piping

Photo 4 A joint with simple mechanism for temporary piping

iii) The water storage tanks, which connected directly to the water pipe, was founded in a refuge within the city as shown in Photo-3.

(4) Establishment of water supply system

Since 7,000m^3 per day of underground water and 85,600m^3 of storage water are secured as the water source for emergency use, the system which enables to supply 20 liters per day to one person for 45 days is arranged. As for the measures of water transportation from Hashirimizu source, the use of aseismic pipeline, the transportation by ship and that by land can be employed. To cope with any of these measures, a joint with simple mechanism shown in Photo-4 was developed for connecting the pipe and they have been stored for emergency use.

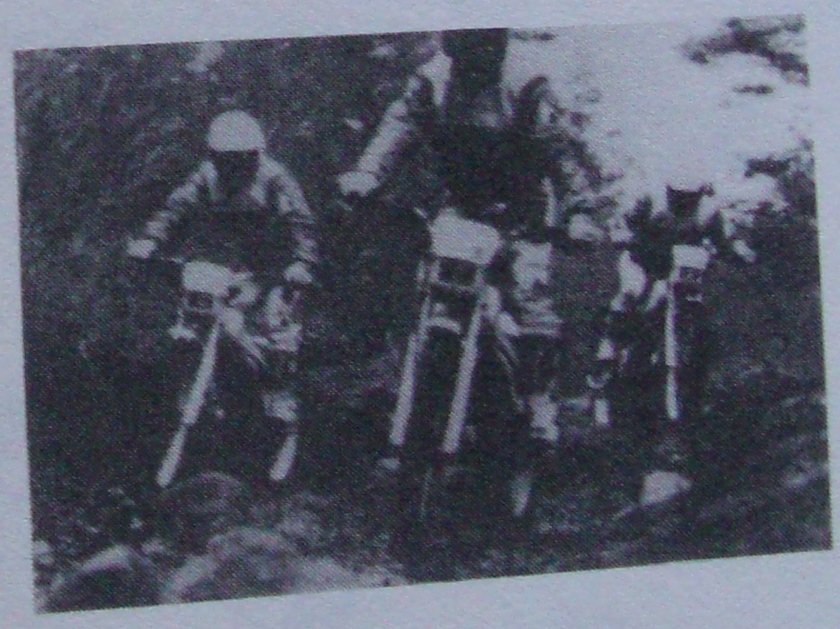

Photo 5 Motorcycle reconnaissance

(5) Definition of official duties

To save the life of citizen in earthquake disaster, securing the drinking water, supplying it immediately and recovering the water supply facilities as soon as possible are the official duties of waterworks. Thus the system for mobilizing officials, which enables to make them understood completely their duties and to do the efficient acts, and the system for supporting of related institutions were constituted. And the motorcycle reconnaissance were organized to grasp immediately the disaster situation as shown in Photo-5.

4.3 Standardization of select works of pipes [3)]

After completed both the replacement of normal pipes with aseismic one in the trunk pipeline and the reinforcement of water supply points, the guideline on selecting pipes for water supply was standardized in 1985 on the basis of the results by surveying the local works of pipe selection. The objective of standardization is to arrange effectively the network of water supply pipelines which has the total extension of 1,200km within the city. In this process, first of all, the geological informations on Yokosuka city, which are possessed individually by some institutions, were combined and rearranged. Then

Table 1 Rank of seismic risk

Kind of Ground	Risk of liqucfaction		
	15<PL	5<PL≦15	PL≦5
30<Hs	A	A	B
10<Hs≦30	A	B	C
Hs≦10	A	C	C
Land slidc Fault	A		

Hs:Thickncss of surfacc stratum(m)
PL:Liqucfaction indcx

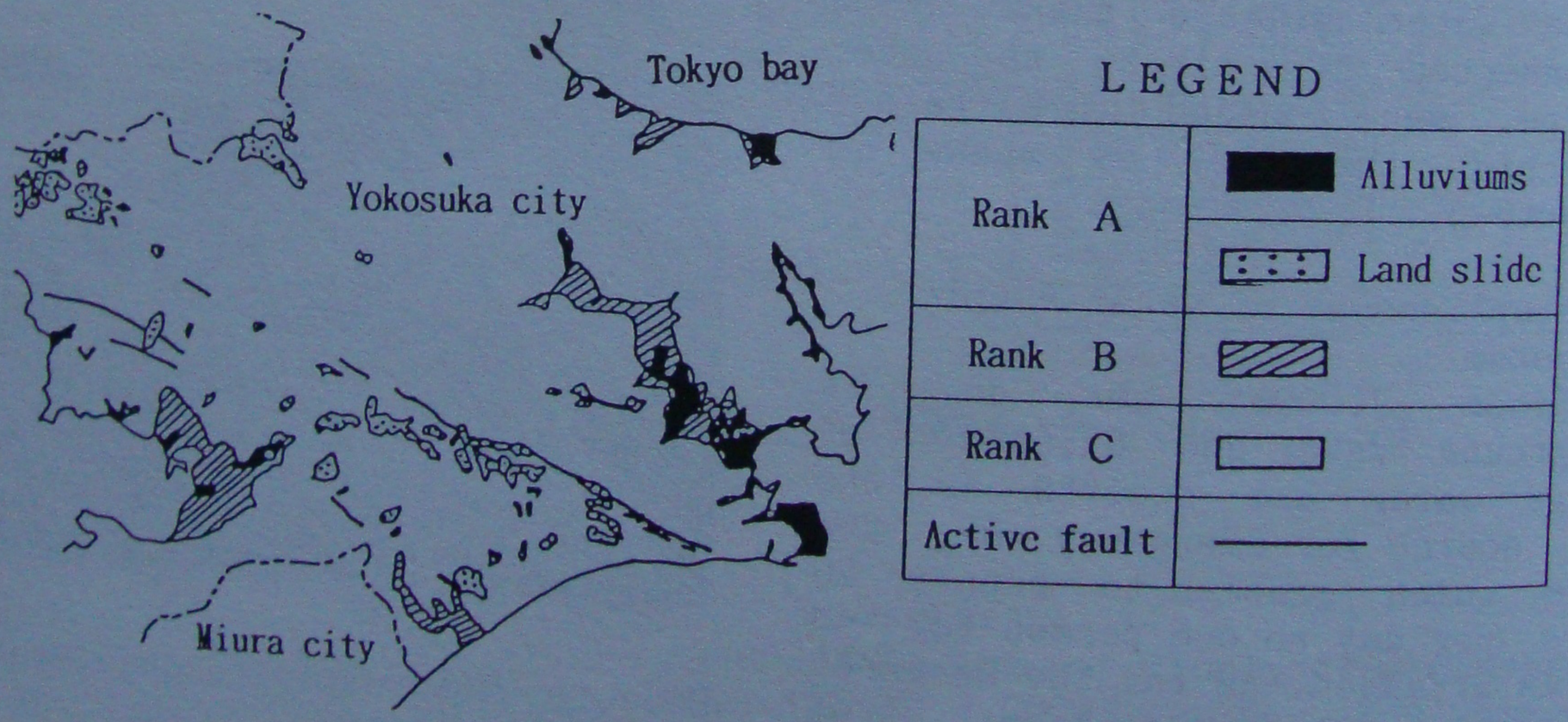

Fig. 3 Zoning in accordance with the classification of seismic risks

the rearranged informations were computerized. Considering both the strain distribution of ground and the occurrence probability of liquefaction, the ground within the city was classified into three ranks of seismic risks as shown in Table-1. Also the whole area of city was zoned in accordance with the classification of seismic risks as shown in Fig. 3. As the indication of renewing the pipeline in each rank of ground, the standard of the usable type of pipes was framed as given in Table-2.

5. CONCLUDING REMARKS

As for the seismic protection works of water facilities in Yokosuka city, some features of Yokosuka city and a few examples of aseismic counter-measures for water supply pipelines are presented in this report.

Table 2 Standard of the usable type of pipes

Rank	Steel pipe	Ductile iron pipe
A	Special thickness	S Ⅱ, S
B	Ordinary thickness	A, K, T
C	Ordinary thickness	A, K, T

The counter-measures of water supply facilities against earthquake in Yokosuka city has been improved gradually from a monistic treatment to a dualistic one. That is, at the present, the two approaches of improving aseismicity in the whole facilities by a renewal of old pipes etc. and establishing the decision-making system which can respond immediately to the unexpected situation in the future have been pursued simultaneously. It is considered that constructing the mapping system for making maximum use of the all kinds of data and dividing the water supply network into small blocks, which is the fundamental counter-measure for making efficient operate of water supply, will contribute toward improving the total system of water supply works.

REFERENCES

1)Yokosuka City Waterworks Bureau:Vital Water for Disaster,1982.2(in Japanese)
2)Y.Saito et.al: Survey of Aseismicity of the Water Supply Facilities in Yokosuka City I,II,III, Journal of Water Supply Association, 1981.9.10.12 (in Japanese).
3)Yokosuka City Waterworks Bureau: Report for Surveying the Local Works of Pipe Selection, 1986.2 (in Japanese).