The Estimated losses and Preparedness Strategy for Emergency Water Supply of Fire Fighting and Life Supporting in a Rupture Scenario of the Shanchiao Fault.

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ABSTRACT

Taiwan is located on the Circum-Pacific Seismic Zone. Devastating earthquakes occurred frequently. Taiwan’s Central Geological Survey announced that there exists 33 active faults in this island. Among them, the Shanchiao Fault stretching along the edge of Taipei basin is the most imperil to Taiwan since Taipei is the political, economic and cultural center. Therefore, a comprehensive preparedness strategy for catastrophic earthquakes caused by the Shanchiao Fault is very important.

This paper first presents the estimated loss of water pipes for the rupture scenario of the Shanchiao Fault by Taiwan Earthquake Loss estimation System developed by The Taiwan’s National Center for Research on Earthquake Engineering. Needed water supply for firefighting and life supporting including drinking water and for daily use is focused and taken into concern by days after the scenario event. Short amount of life supporting water supply can be calculated by the population, restoring rate and emergency storage capacity. This deficiency can be made up by neighboring county’s supporting. However, a pre-disaster planning and contract should be made before a major earthquake. The results of this study can provide a sufficient advice to the government.

Keywords: Earthquake Scenario, Damage of Water Pipes, Water Supply, Firefighting

Introduction

Water supply system is an indispensable infrastructure to the public. Any long term interruption of water supply will jeopardize a city’s life function. Fires after shock are hardly extinguished not only because the rescue capability might be impaired but also due to lack of water. Taiwan is located on the Circum-Pacific Seismic Zone. Devastating earthquakes occurred frequently. Since Taipei is the capital of political, economic, and socio-cultural matters in Taiwan, whether or not it can sustain a major earthquake striking becomes an important issue to the whole country. Currently, water supply in Taipei area is managed by Taipei Water Department of Taipei city government with a consumer population of 3.85 million [1].

According to Taiwan's Central Geological Survey, there exists 33 active faults in Taiwan (Figure 1). Among them, the Shanchiao Fault stretching along the edge of Taipei basin is the most imperil to Taipei. A comprehensive preparedness strategy for catastrophic earthquakes caused by the Shanchiao Fault is very important. We investigated the estimated damage of water pipes for the scenario of the rupture of the Shanchiao Fault by Taiwan Earthquake Loss Estimation System (TELES)[2,3] developed by Taiwan's National Center for Research on Earthquake Engineering (NCREE)[4]. Then, we focus on needed water supply for life supporting including drinking water and daily use and also take into concern the recovery by days after the scenario event. Short amount for life supporting can be calculated by the population, restoring rate and the regulated requirement for emergency supply. We also estimate number of urban fires and need firefighting water and dispatch teams. The deficiency can be made up by neighboring county's supporting. However, a pre-disaster planning and contract should be made before a major earthquake. The results of this study can provide a sufficient advice to the government.

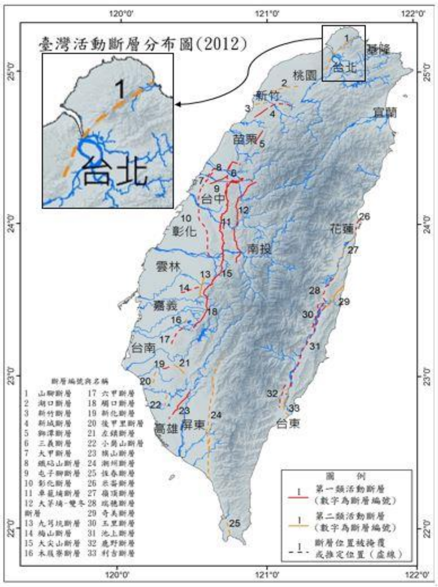


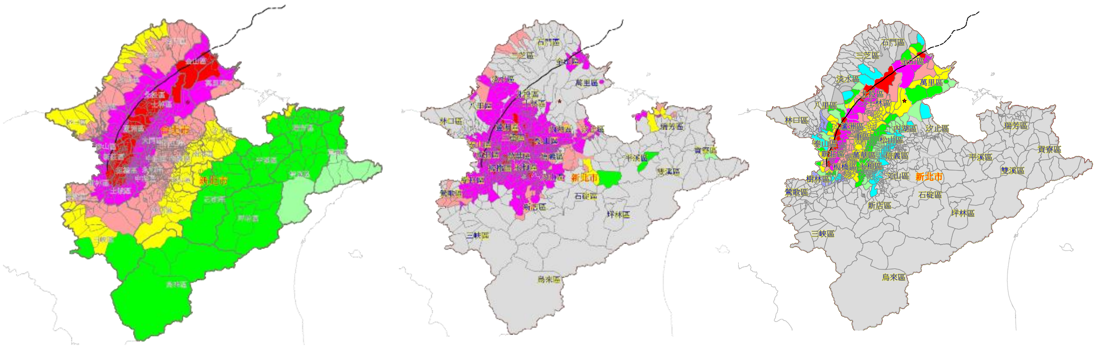
Figure 1 Active Faults in Taiwan

Table1 Seismic Parameters of the Scenario Event

Richter Magnitude (M_L)		6.9
Focal Depth		8 km
Epicenter Longitude		121.589
Epicenter Latitude		25.139
Rupture of the Fault	Dip Angle	50 degree
	Length	56 km
	Width	20 km

Research Methods

The seismic parameters of the scenario event are listed in Table 1. Although, it is considered too conservative by Taiwan's Central Weather Bureau, there are still many researchers regard it as proper. Especially, after the Great 2011 East-Japan Earthquake disaster prevention planners are prone to consider the event beyond expected. We can obtain *PGA*, *PGD*, liquefaction, and land off-set (Figure 2) form TELES outputs.



PGA Soil Settlement due to Liquefaction PGD

Figure 2 PGA, PGD, Soil Settlement due to Liquefaction of the Scenario Event by TELES

The damage ratio (*DR*) of water pipes are then calculated by the following equations [5].

$$DR = C \times DR_0$$

in with

$$DR_0 = Max\left(DR_{PGA}, DR_{PGD(Fault)}\right) + DR_{PGD(Liquefaction)} \times p_{Liquefaction}$$

$$C = Correction\ factor$$

$$DR_{PGA} = 4.501 \times (PGA - 0.1)^{1.97} \quad (PGA\ in\ g)$$

$$DR_{PGD} = 0.04511 \times PGD^{0.728} \quad (PGD\ in\ cm)$$

$$DR_{PGD} = 0, if\ PGA < 0.1g$$

$$p_{Liquefaction} = Probability\ of\ Soil\ Liquefaction$$

The outbreak of fire after a major earthquake can be estimated by following equations [6].

1. Outbreak Ratio of Fires: $F = 0.3131 \times PGA(g) + 0.03 \times PGD(cm)$
2. Number of Fires: Area (Million m^2) $\times$ Outbreak Ratio of Fires
3. Required Firefighting Dispatch Team：
   (1)Population Above 150 thousand: Number of Fires $\times$ 1.7
   (2) Population 100~150 thousand: Number of Fires $\times$ 1.4
   (3) Population under 100 thousand: Number of Fires $\times$ 1.0
4. Water Needed for Fire Fighting (ton): Firefighting Dispatch Team$\times$ 40

Research Outcomes

I. *Water for Life-Supporting*

The inventory of transmission, distribution and feed water pipes of Taipei Water Department is listed in Table 2 and shown in Figure 3. By bringing these data and TELES outputs into the above equations, we can obtain the damage number of water pipes as shown in Table 3 and Figure 4.

Table 2 Pipe Length of Various Diameters of Taipei Water Department

Pipe Diameter (mm)					Total Length (m)
S1	S2	S3	S4	S5	
10-80	100-250	300-450	500-900	Above 900	
2,844,978 m	2,730,607 m	664,108 m	286,380 m	201,373 m	6,727,446 m

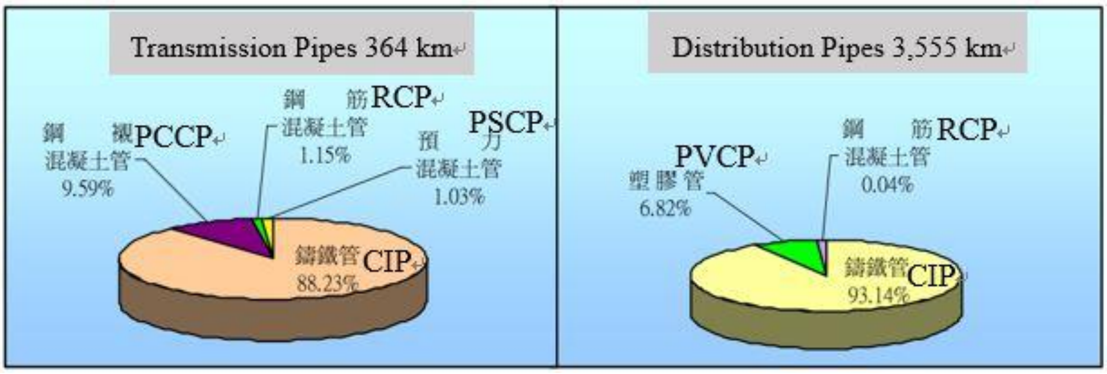


Figure 3 Length Ratio of Various Materials of Transmission and Distribution Pipes [7]

Table 3 Damage of Water Pipes in the Scenario Event [8]

Pipes	**Damage Number**
Transmission Pipes	57
Distribution Pipes	1,309
Feed Pipes	3,685

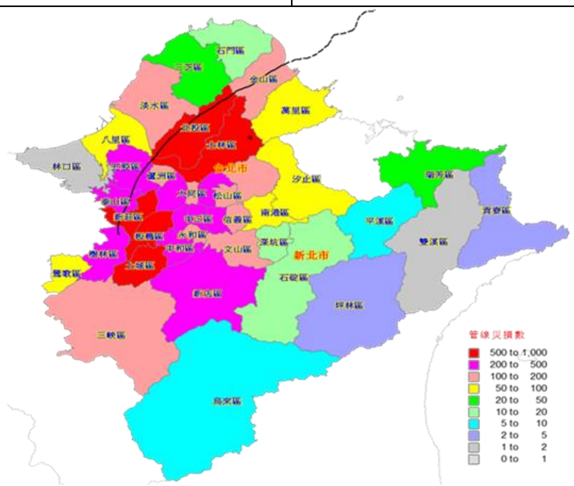


Figure 4 Damage Distribution of Water Pipes in Administrative Regions [8]

Based on the past experience, estimated repair team-hour are listed in Table 4. Taipei Water Department can summon 40 repair teams in ordinary days, but in case of emergency, up to 80 teams can be called, however this cannot last too long. We suggest the repair strategy could be arranged in three stages, first stage (0-4th day): only for critical facilities and transmission mains; second stage (5th -11th day): only for facilities transmission and distribution mains; third stage (12th -last day): for distribution and feed pipes. Then, we can make a progress list for repairing on the basis of each day.

Table 4 Estimated Repair Team-Hours for Pipe Damages [9]

		Pipe Diameter (mm)				
		S1	S2	S3	S4	S5
		10-80	100-250	300-450	500-900	Above 900
Team-Hours	Replacing of Breaking Pipes	7	11	19	27	42
	Leakage Fixing	3.5	5.5	9.5	13.5	21

As days go by, the number of damages and its corresponding DR will descend. By applying Kawakami's empirical equation for failure ratio of water supply to pipe damage ratio $failure\ ratio\ of\ water\ supply = 1/(1 + 0.0473 \times DR^{-1.61})$ [10], we can calculate the recovery ratio of water supply by days after the scenario event. The result is shown in Figure 5.

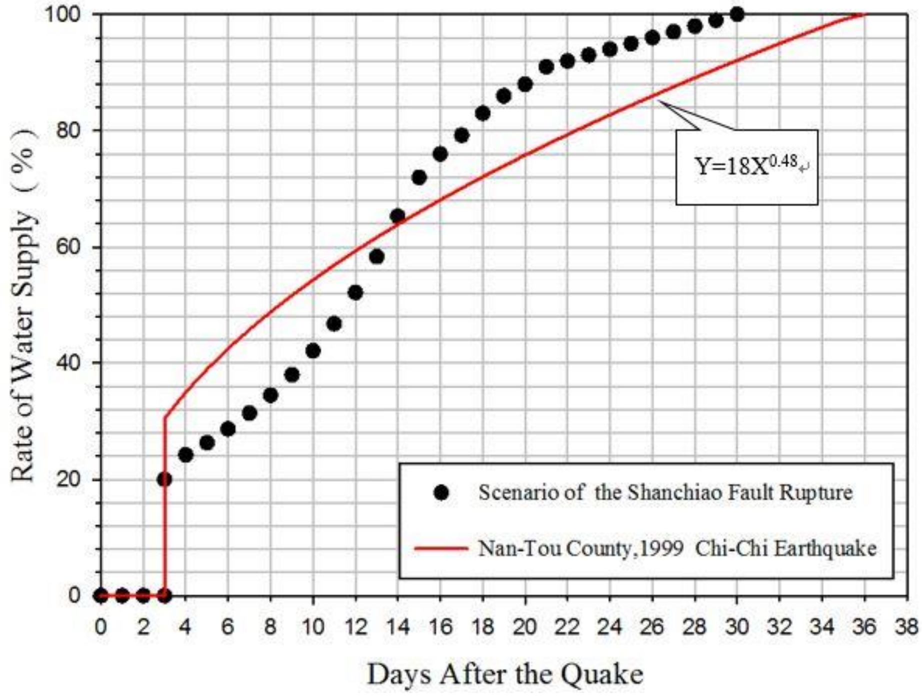


Figure 5 Recovery Ratio of Water Supply by Days

Figure 5 shows that in the first 3 days. Taipei Water Department hardly provides any supply of tap water in Taipei metropolitan. However, after one, two and three weeks of the event, there will have 32, 65 and 92 % of customers resume their water supply, respectively. The restoration is quite fast compared to the 1999 Chi-Chi earthquake.

Short amount for life supporting water can be calculated by the population, recovery ratio and the regulated requirement for emergency supply. We suggest that at least 3 liters for drinking water per person for the first 3 days and 20 liters per person for daily use in the following days should be provided. Therefore, a pre-disaster planning and contracts can be made before a major earthquake.

II. Outbreaks of Fire and Firefighting

On the general spec, one tank truck can carry at least 3 tons of water for firefighting, while 12 tons for a reservoir truck. After a major earthquake, water is not possible to come out from any fire hydrant because severe damage to pipes and facilities. Intakes of firefighting water were already arranged from rivers, ponds, pools and reservoirs.by city governments [11, 12]. On average, one ton of water can be pumped form water source to fire trucks in one minute, and water trucks can shuttle back and forth form fire site to water intakes within one hour. Moreover, It is regulated by governments that fires after quake should be extinguished at the first 12 hours [11, 12]. Therefore, it is adequate to assume that one water truck can shuttle 12 times. In this study, we can estimate the needed amount of firefighting water as well as the supply capacity of fire departments by their existing tank/reservoir trucks. Therefore, lack of water or water trucks can also be estimated. The result of estimated outbreak of fire, needed amount and lack of firefighting dispatch team and water is shown in Table 5. Since this deficit of water trucks should be compensated from other counties outside of the disaster area, to reach a mutual supporting agreement between county governments becomes important.

Table 5 Result of Estimated Fire, Firefighting Water and Dispatch Team

Area	Number of Fires	Needed Firefighting Dispatch Teams	Currently Firefighting Dispatch Teams[13,14]	Lack of team	Needed Amount of Firefighting Water (ton)	Water Tank Trucks in First 12 Hours[13,14]	Lack of Water (ton)
Taipei City	204	343	246	-97	13,649	8,676	-4973
New Taipei City	369	578	904	+326	23,140	10,800	-12,340

Discussion and Conclusion

As shown in Table 6, the damage ratio of transmission and distribution pipes in the 1999 Chi-Chi Earthquake was 0.15, while, 0.35 in this scenario study. It seems reasonable because Taipei is a high-density populated city, and very close to the Shanchiao Fault. However, the damage ratio of feed pipes in the 1999 Chi-Chi Earthquake was 6.58, while, 1.31 in this scenario study. Although, the seismic capability of feed pipes should be much weaker than that of transmission and distribution mains because of material and diameter, the times of damage ratio seems unrelated. This needs more investigation to reach an adequate result.

Table 6 Comparison of Damage Ratio (DR) of Water Pipes

Event	**DR** of Transmission and Distribution Pipes (number/km)	**DR** of Feed Pipes (number/km)
Nan-Tou County,1999 Chi-Chi Earthquake[15]	0.15	6.58
Scenario of Shanchiao Fault Rupture	0.35	1.31

Regarding to the recovery rate of tap water, as shown in Table 7, this scenario event is worse than the Chi-Chi Earthquake at the first week because damage is also more serious. However, the disaster area of the Chi-Chi Earthquake was in countryside, and some villages were even far remote, as well as the restoration capability of Taipei is stronger, the restoration rate of this study catches up very quickly and even exceeds. At last, tt was estimated to need 30 days for a full recovery of water supply in this study.

Table 7 Recovery Rate of Water Supply

Days after Quake	Nan-Tou County,1999 Chi-Chi Earthquake[15]	Scenario of Shanchiao Fault Rupture
7th Day	54.5 %	31.4 %
13th Day	61.8 %	58.3 %
24st Day	85.5 %	94.0 %
30th Day	92.0 %	100.00 %
37th Day	99.0 %	

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