– Supplementary Materials–

Assessment of Renewal Priority of Water Pipeline Network against Earthquake Risk

1. Breaking Rate of Pipelines

Table S1 shows the correction factors we used in this study.

Table S1. Correction factors [1].

Diameter [mm]	C_d
200 ~ 450	0.8
500 ~	0.5
Liquefaction	C_l
Overall	2.4
Topographic factors	Cg
Alluvial plain	1.0

2. Case Setting

Figure S1 shows an overview of the cases investigated in this study.

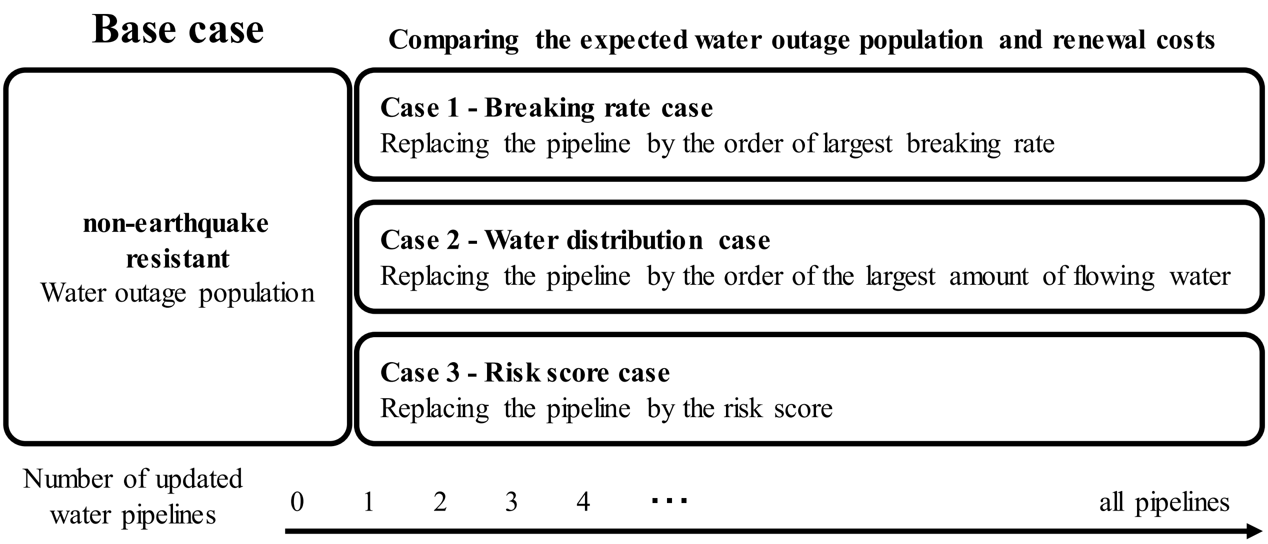

Figure S1. Overview of the three established cases and base case, which carries out no earthquake-resistance countermeasures.

3. Base Case: Water Outage Rate and Expected Water Outage Population

Table S2 shows the population belonging to the mesh of each node and the total amount of water supplied to the area.

Table S2. The population and the sum of the amount of water supplied to the area in each node.

No.	Population	The sum of the amount of water supplied to the area [kL/day]	No.	Population	The sum of the amount of water supplied to the area [kL/day]
1	14,403	7,706	21	82,446	44,109
2	20,216	10,816	22	64,584	34,552
3	11,619	6,216	23	79,485	42,524
4	77,140	41,270	24	10,023	5,362
5	35,839	19,174	25	19,538	10,453
6	52,837	28,268	26	14,053	7,518
7	8,332	4,458	27	38,020	20,341
8	16,350	8,747	28	43,321	23,177
9	24,172	12,932	29	11,341	6,067
10	58,116	31,092	30	36,283	19,411
11	37,815	20,231	31	35,304	18,888
12	18,426	9,858	33	23,793	12,729
13	74,981	40,115	34	28,723	15,367
14	14,220	7,608	35	63,852	34,161
15	16,519	8,838	36	22,924	12,264
16	18,000	9,630	37	24,204	12,949
17	36,559	19,559	38	76,291	40,816
18	23,389	12,513	39	21,124	11,301
19	38,347	20,516	40	99,985	53,492
20	20,618	11,031			

Figure S2 is a 3D representation of Figure (4,a) and Figure (4,b).

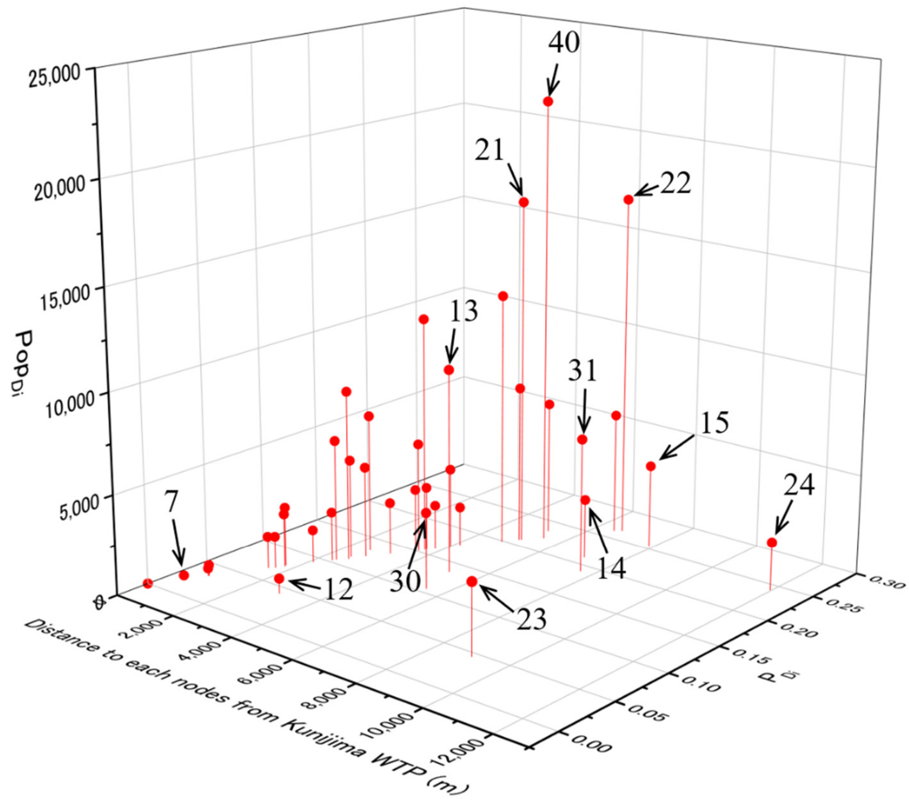

Figure S2. The relationship between the distance to nodes from Kunijima WTP, water outage rate (P_{D_i}), and expected water outage population (Pop_{D_i}) in the base case. The numbers in the graph correspond to those of nodes in Figure 3.

4. Case 1: Pipeline Replacement by Order of Breaking Rate

Table S3 shows the ideal order of pipeline renewal in Case 1.

Table S3. Ideal order of renewal in Case 1 and the breaking rate of each pipeline.

Renewal order	No.	Breaking rate [%]	Renewal order	No.	Breaking rate [%]
1	23-24	19.728	22	20-21	6.341
2	15-23	14.053	23	5-6	6.128
3	17-18	12.784	24	9-11	5.921
4	18-23	11.421	25	37-38	5.803
5	12-13	9.798	26	26-27	5.583
6	30-31	9.601	27	14-15	5.574
7	22-23	9.560	28	37-39	5.173
8	13-14	8.713	29	27-30	5.003
9	19-20	8.700	30	3-5	4.553
10	39-40	8.619	31	9-10	4.130
11	33-34	8.483	32	32-33	3.911
12	3-4	8.287	33	11-12	3.889
13	1-19	7.687	34	19-28	3.849
14	29-30	7.661	35	33-35	3.526
15	7-16	7.416	36	2-3	3.503
16	2-36	7.364	37	8-9	3.382
17	21-22	7.178	38	36-37	3.337
18	28-29	7.057	39	25-26	2.909
19	16-17	6.671	40	28-32	2.737
20	19-25	6.558	41	1-7	2.037
21	8-12	6.454	42	7-8	1.548

Figure S3 is a 3D representation of Figure (5,a) and Figure (5,b).

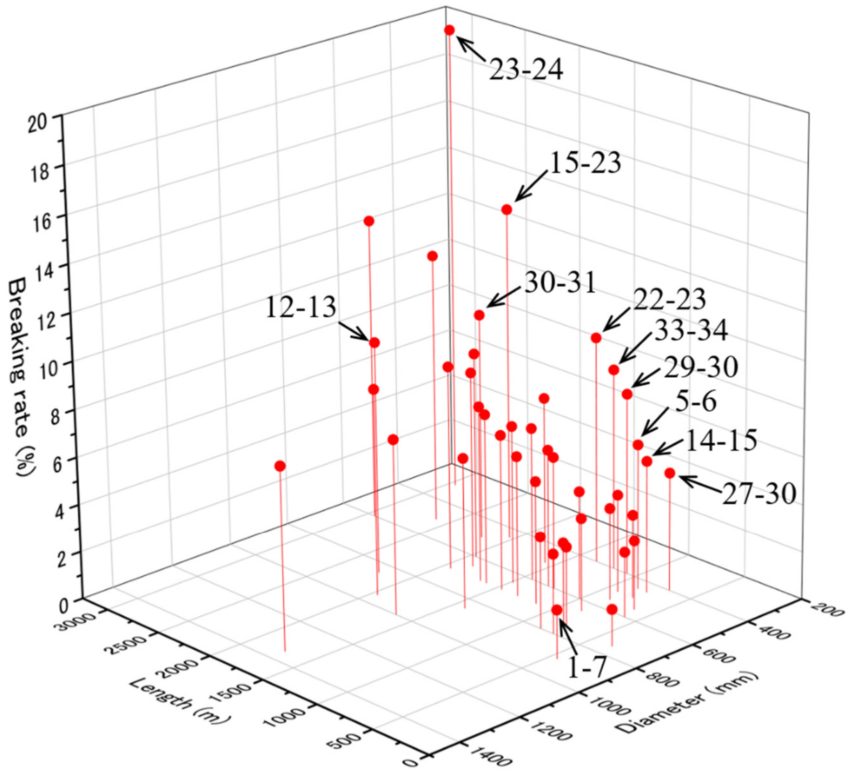

Figure S3. The relationship between breaking rates of water pipelines, their lengths, and diameters. The numbers in the graph correspond to those of pipelines in Figure 3.

5. Case 2: Pipeline Replacement by Order of Water Distribution

Table S4 shows the water distribution volume of each pipeline.

Table S4. Ideal order of renewal in Case 2 and the water distribution volume of each pipeline.

Renewal order	No.	Water distribution [kL/day]	Renewal order	No.	Water distribution [kL/day]
1	1-19	294,282	22	25-26	47,009
2	1-7	217,505	23	3-4	41,270
3	7-8	155,383	24	8-12	41,190
4	2-36	130,822	25	11-12	41,190
5	36-37	118,558	26	37-38	40,816
6	19-28	110,651	27	26-27	39,490
7	19-20	105,654	28	33-35	34,161
8	8-9	105,445	29	13-14	32,408
9	2-3	94,928	30	9-10	31,092
10	20-21	94,623	31	17-18	28,475
11	12-13	72,522	32	5-6	28,268
12	37-39	64,793	33	28-29	25,217
13	28-32	62,257	34	14-15	24,800
14	32-33	62,257	35	27-30	19,150
15	9-11	61,421	36	29-30	19,150
16	7-16	57,664	37	30-31	18,888
17	19-25	57,461	38	15-23	15,962
18	39-40	53,492	39	18-23	15,962
19	21-22	50,515	40	22-23	15,962
20	16-17	48,034	41	33-34	15,367
21	3-5	47,442	42	23-24	5,362

6. Case 3: Pipeline Replacement by Order of Risk Score

Table S5 shows the risk score of each pipeline.

Table S5. Ideal order of renewal in Case 3 and the risk score of each pipeline.

Renewal order	No.	Risk score	Renewal order	No.	Risk score
1	1-19	22,621	22	32-33	2,435
2	2-36	9,634	23	7-8	2,405
3	19-20	9,192	24	37-38	2,368
4	12-13	7,106	25	15-23	2,243
5	20-21	6,000	26	26-27	2,205
6	39-40	4,610	27	3-5	2,160
7	1-7	4,430	28	18-23	1,823
8	7-16	4,276	29	30-31	1,813
9	19-28	4,259	30	28-29	1,780
10	36-37	3,956	31	5-6	1,732
11	19-25	3,768	32	28-32	1,704
12	17-18	3,640	33	11-12	1,602
13	9-11	3,637	34	22-23	1,526
14	21-22	3,626	35	29-30	1,467
15	8-9	3,566	36	14-15	1,382
16	3-4	3,420	37	25-26	1,367
17	37-39	3,352	38	33-34	1,304
18	2-3	3,326	39	9-10	1,284
19	16-17	3,205	40	33-35	1,204
20	13-14	2,824	41	23-24	1,058
21	8-12	2,658	42	27-30	958

7. Renewal Cost

Figure S4 shows the renewal cost of each pipeline.

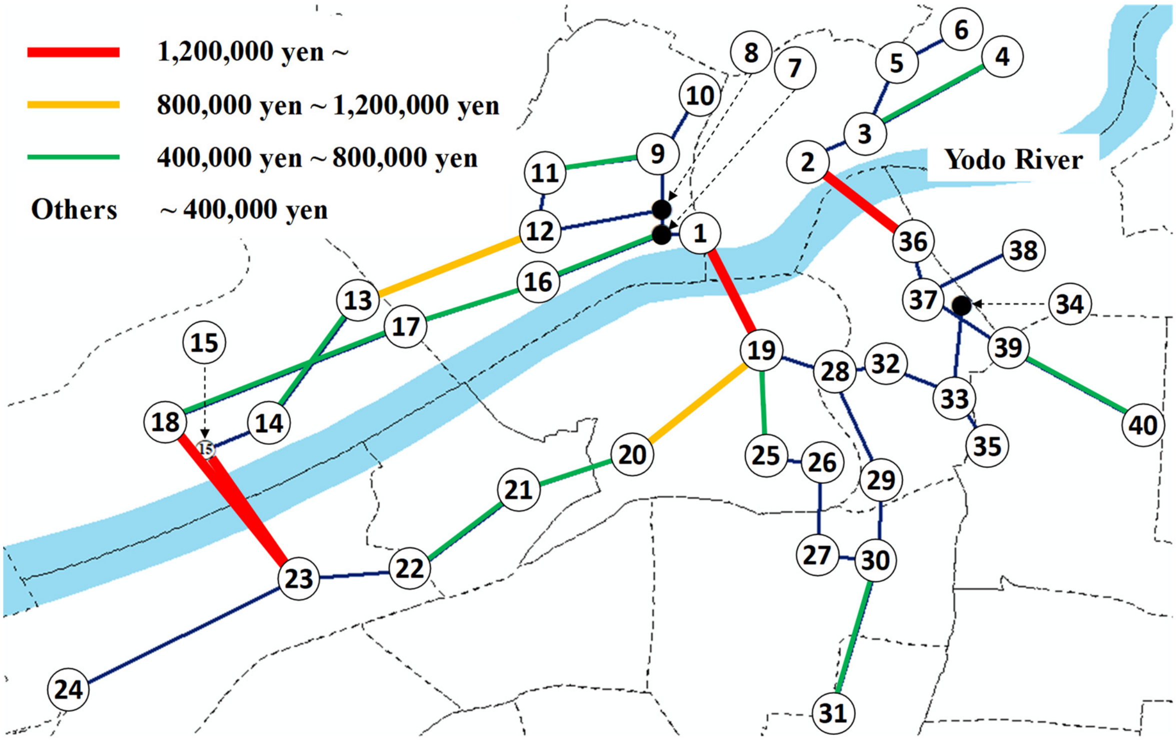

Figure S4. Renewal cost of the studied pipelines. Each color of a pipeline between nodes reflects the renewal costs for the earthquake-resistance countermeasures.

References

1. Isoyama, R.; Ishida, E.; Yune, S.; Shiramizu, N. Suidou Kanro No Jishin Higai Yosoku Ni Kansuru Kenkyuu (Study on damage prediction of water pipes by earthquake). *J. Jpn. Water Work. Assoc.* **1998**, *67*, 25–40.