Estimation of earthquake resistant and earthquake proof for distribution system on Hachinohe Regional Water Supply Authority

Noboru Murakami

Hachinohe Regional Water Supply Authority (HRWSA)

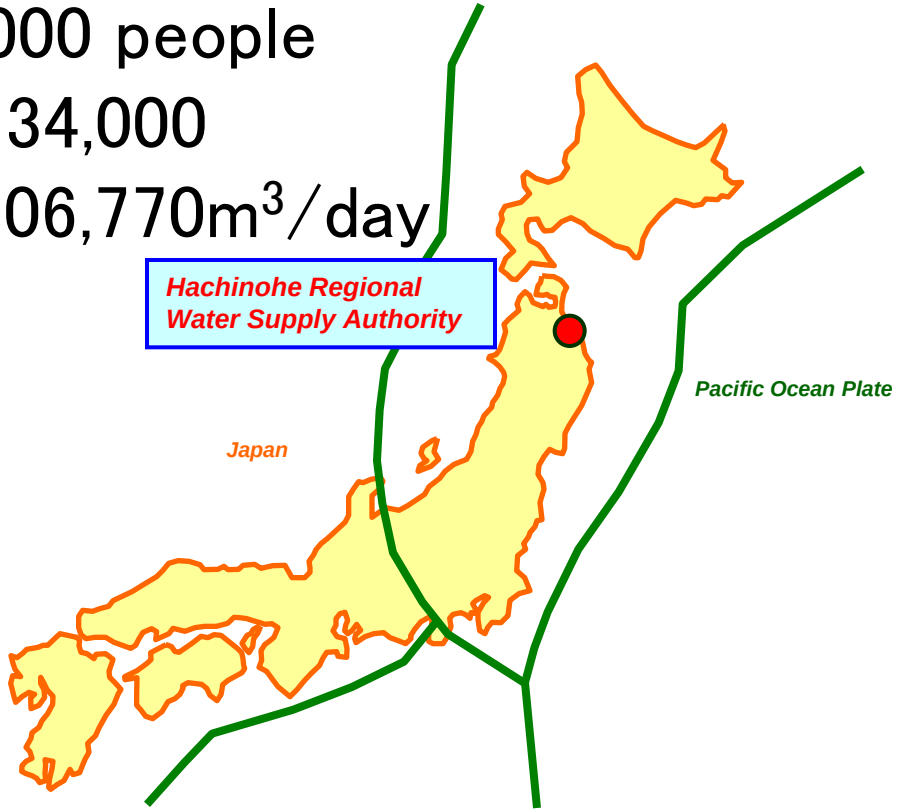
Outline

- The measure for earthquake proof of water supply facilities (Plant and pipes).
- The estimated damage caused by Future Earthquake and estimation of earthquake resistance for distribution pipes.
- The inspection of corrosion of distribution pipes and the estimation of corrosion degree.
- The earthquake proofing of the distribution pipes which connected to the important foothold institutions.

Outline of our waterworks

≪Year 1986：10 waterworks unified HRWSA≫

- Service area：800km^2
- Population served：333,000 people
- Number of customers：134,000
- Maximum daily supply：106,770m^3/day



Quakeproof of the structures (1/2)

（Rapid sand filter of Hakusan water treatment plant)

- Quake-proof diagnosis
  - ⇨ Necessary of seismic reinforcement
    - ⇨ Conduct reinforcement work（May,2008）
- Engan Hokubu earthquake of Iwate prefecture occurred in July 24,2008. （JMA magnitude 6.8）
- 3 columns were damaged.

Pic. 3 columns damaged

Quakeproof of the structures (2/2)

- Lightweighting of the roof member

- Enlargement of the quakeproof wall

- Steel sheet reinforcement of the columns

Quakeproof of the pipes

≪DIPs with seismic flexible joint are introduced.≫

- Raw water transmission main and transmission pipe：After 1989
- Distribution pipes：After 1996

≪Corrosion control of pipes≫

- Polyethylene sleeve：After 1991

DIP with seismic flexible joint

Polyethylene sleeve

Estimated damage caused by Future Earthquake

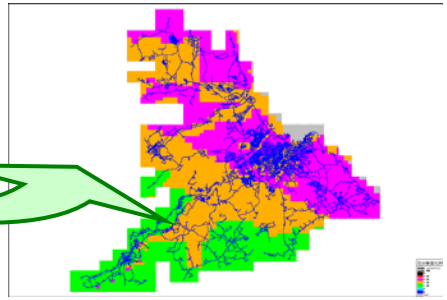
≪ Target : 2,200km, >φ50mm≫

≪Data sets ≫
・Earthquake
(Scenario pacific-side ocean trench earthquake Mj=8.2)
・Liquefaction risk
・Geology

Start

Data sets are Input into grid mesh properties

〔 Input 〕



Grid mesh properties are attributed to the pipes data

Predict the damage rate (The number of breaks per km of pipes)

Water suspension are estimated by MCS based on the damage rate

MCS : Monte-Carlo Simulation

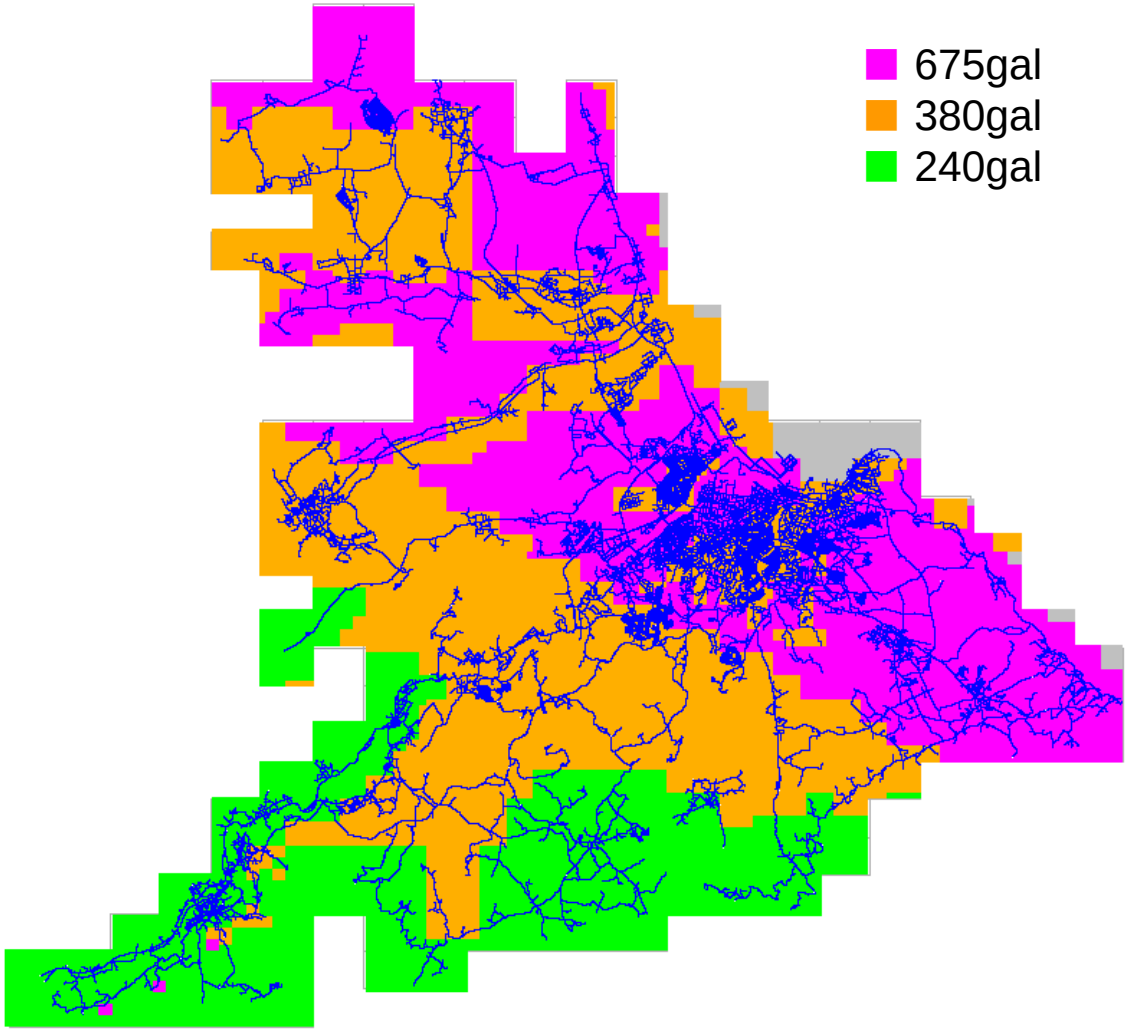
Calculation the number of restoraten days

End

Data sets (1/2)

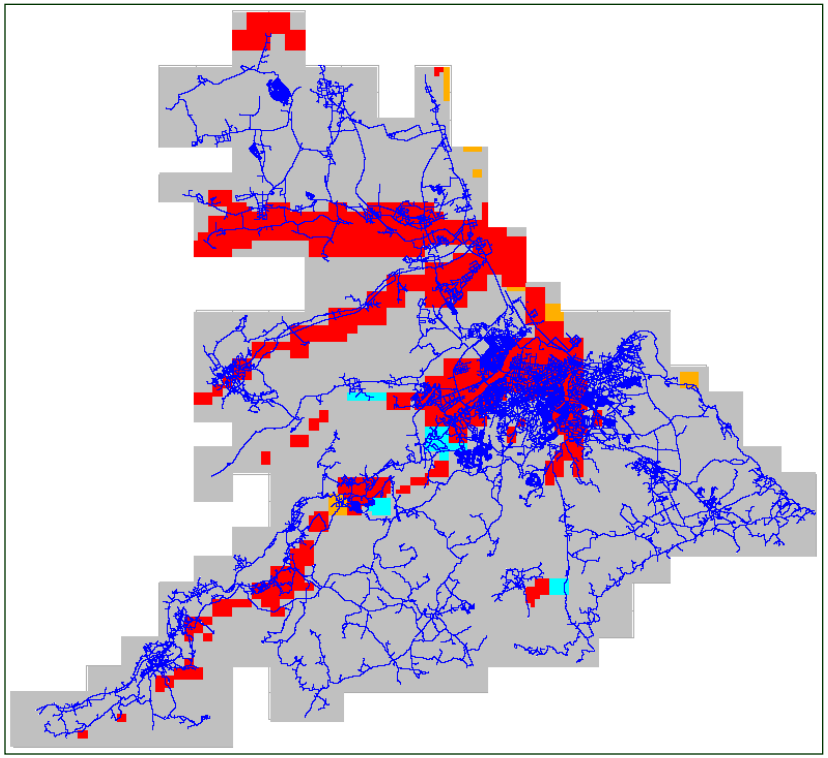
- A distribution map of acceleration

(Scenario pacific-side ocean trench earthquake)



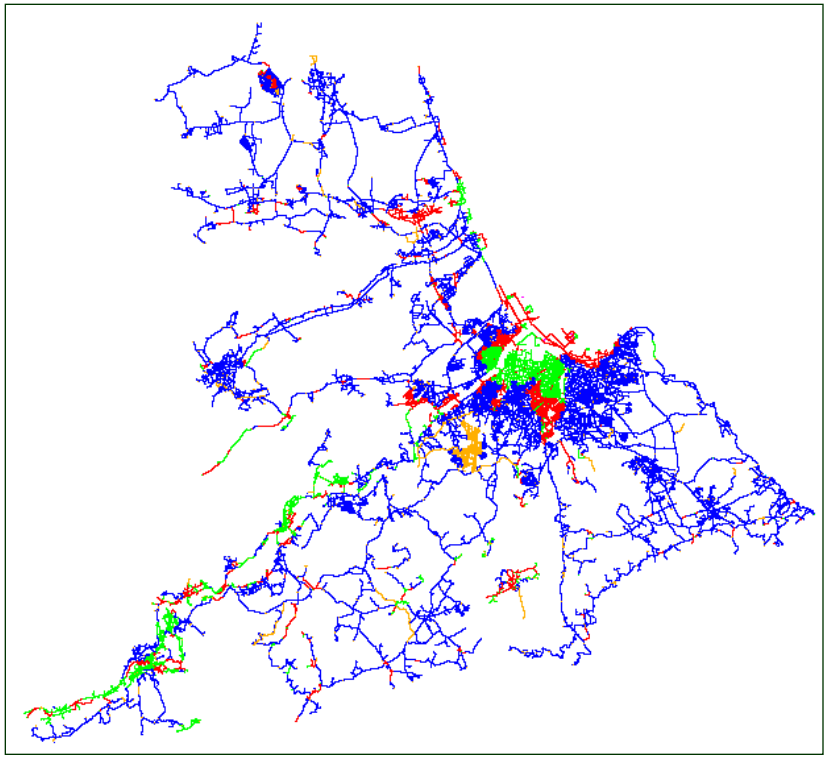
Data sets (2/2)

- Liquefaction risk



- Extremely high
- High
- Extremely low
- None

- Geology



- Valley
- Artificially modified foothill
- Alluvial flatland
- Artificially modified hill
- Stiff ground

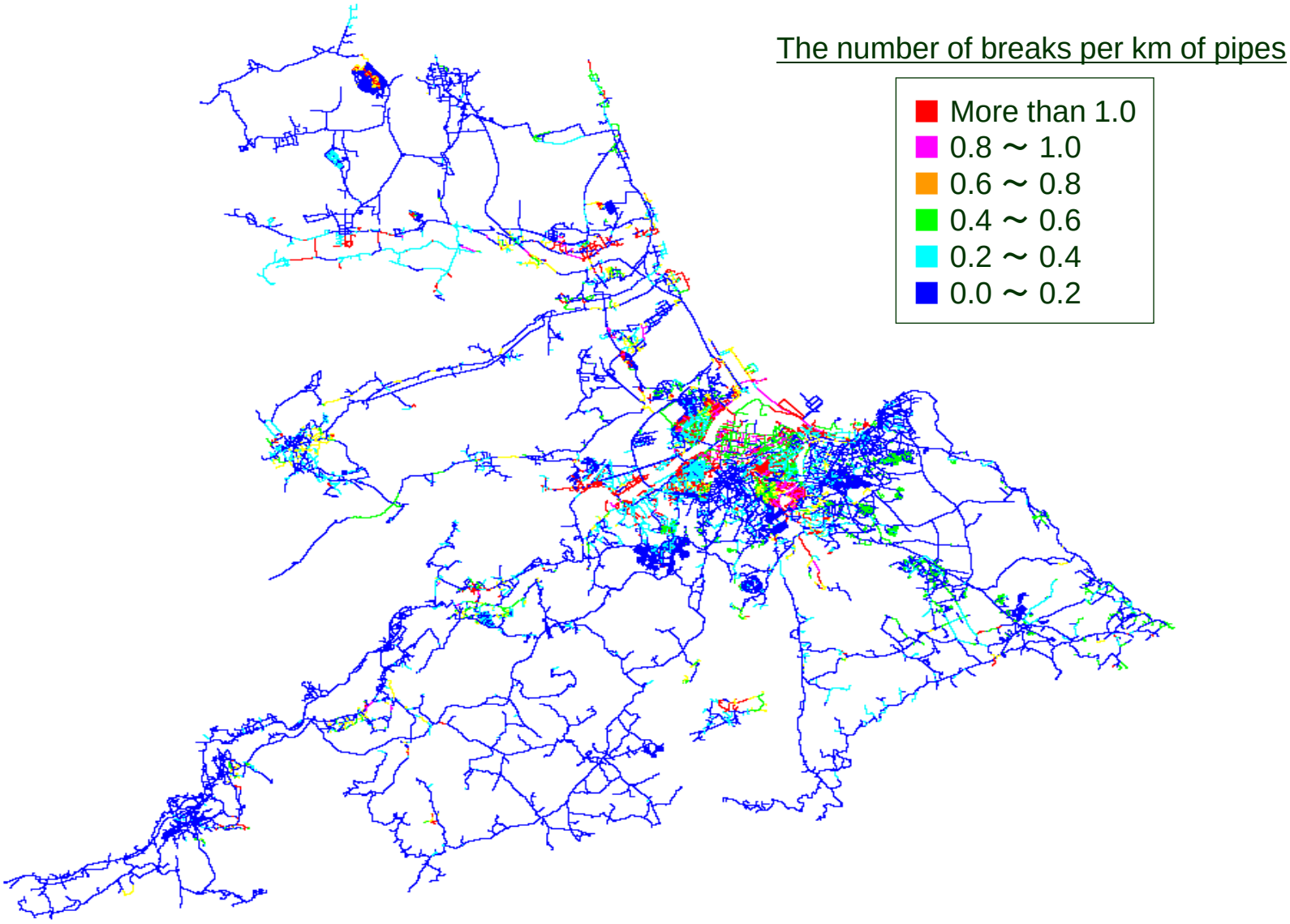
Equation of pipe damage prediction

$$Rm(\alpha) = Cp \times Cd \times Cg \times Cl \times R(\alpha)$$

Rm(α) : Damage rate for peak ground acceleration [breaks/km]
Cp : Coefficient of pipe material
Cd : Coefficient of pipe diameter
Cg : Coefficient of ground/foundation
Cl : Coefficient of liquefaction risk
R(α) : Standard damage rate [breaks / km] $(=2.88 \times 10^{-6} \times (\alpha-100)^{1.97})$
α : Peak ground acceleration [gal]

C p		C d		C g		C l	
ACP	1.2	−φ75	1.6	Artificially modified hill	1.1	None	1.0
DIP	0.3	φ100−φ150	1.0			Extremely low	1.0
DIP(Seismic)	0.0	φ200−φ450	0.8	Artificially modified foothill	1.5		
CIP	1.0	φ500−φ800	0.5			High	2.0
SSP	0.0	φ900−	0.2	Valley	3.2	Extremely high	2.4
SGP	1.0			Alluvial flatland	1.0		
VP	1.0						
PP	0.3			Stiff ground	0.4		

Distribution map of pipe breaks



Damage rate and number of breaks

- Comparison of Scenario pacific-side ocean trench earthquake & Sanriku Harukaoki Earthquake

Earthquake	PGA (gal)	Ave. Damage rate (breaks / km)	Number of breaks
Scenario pacific-side ocean trench earthquake	675	0.31	708
Sanriku Harukaoki Earthquake (1994)	602	0.06	113

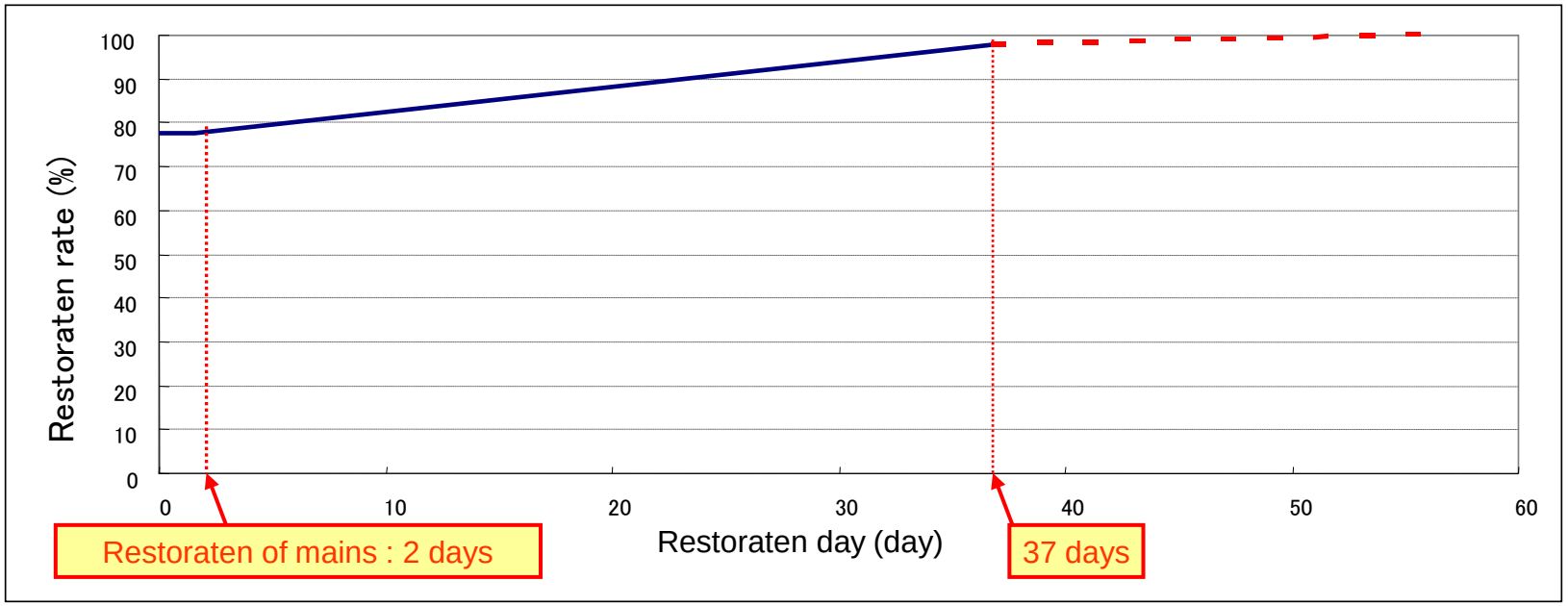
- Pipe material

- Distribution mains (More than φ300mm) : 22
- Distribution submains (Less than φ250mm) : 686

Pipe material	Ave. Damage rate (breaks/km)	Number of breaks
ACP	0.49	30
CIP	0.51	9
DIP (Not seismic joint)	0.17	277
PP	0.33	58
SGP	1.08	14
SSP	0.00	0
PVC	0.76	315
Others	0.63	5

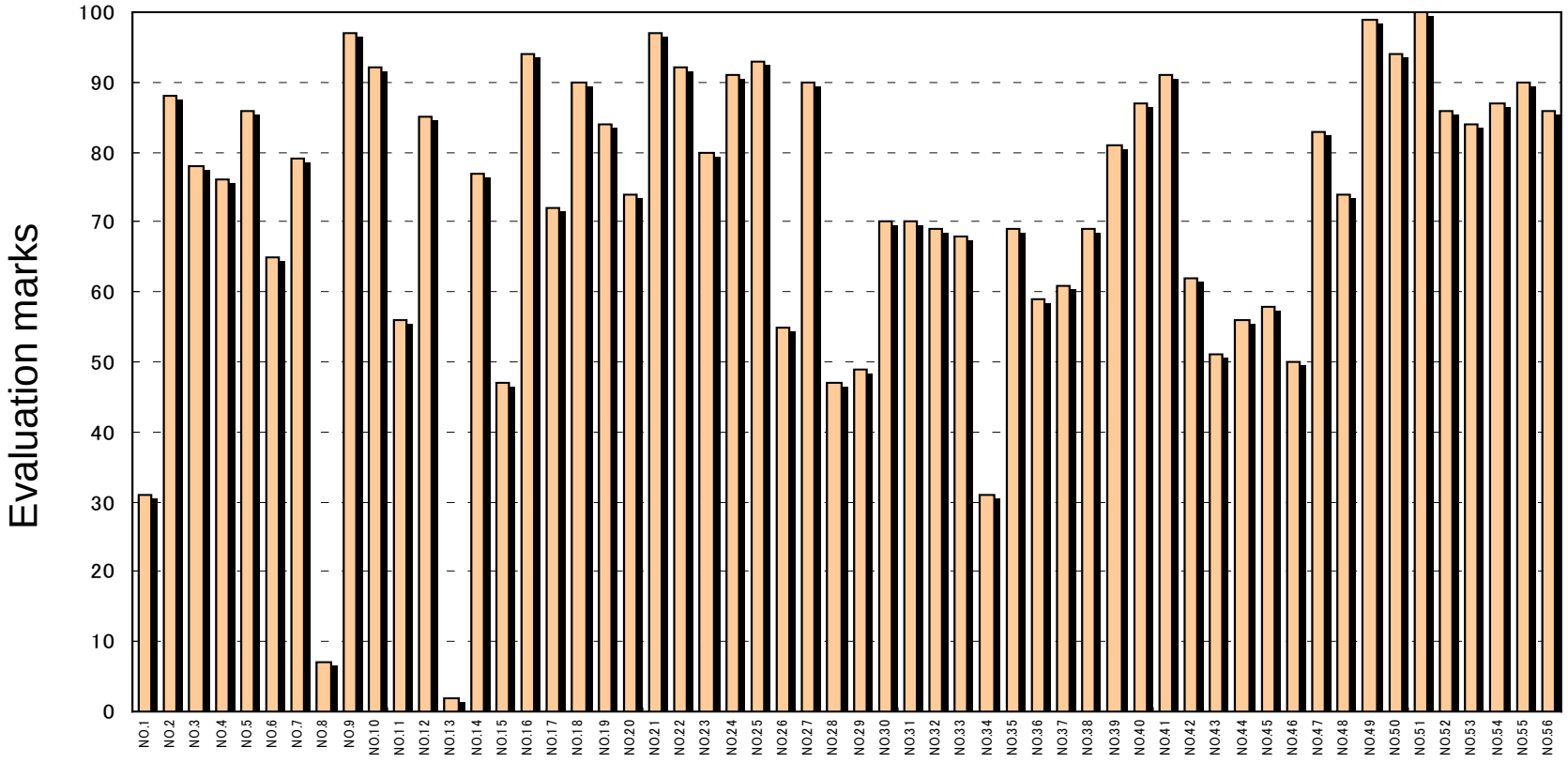
Water suspension ratio, population affected by water suspension and restoration day

- Water suspension ratio : 22.3% (in water supply area)
- Population affected by water suspension : 74,200 people (in water supply area)
- Restoration day : 37 days (Mains : 2 days, Submains : 35 days)



Evaluation of earthquake resistant

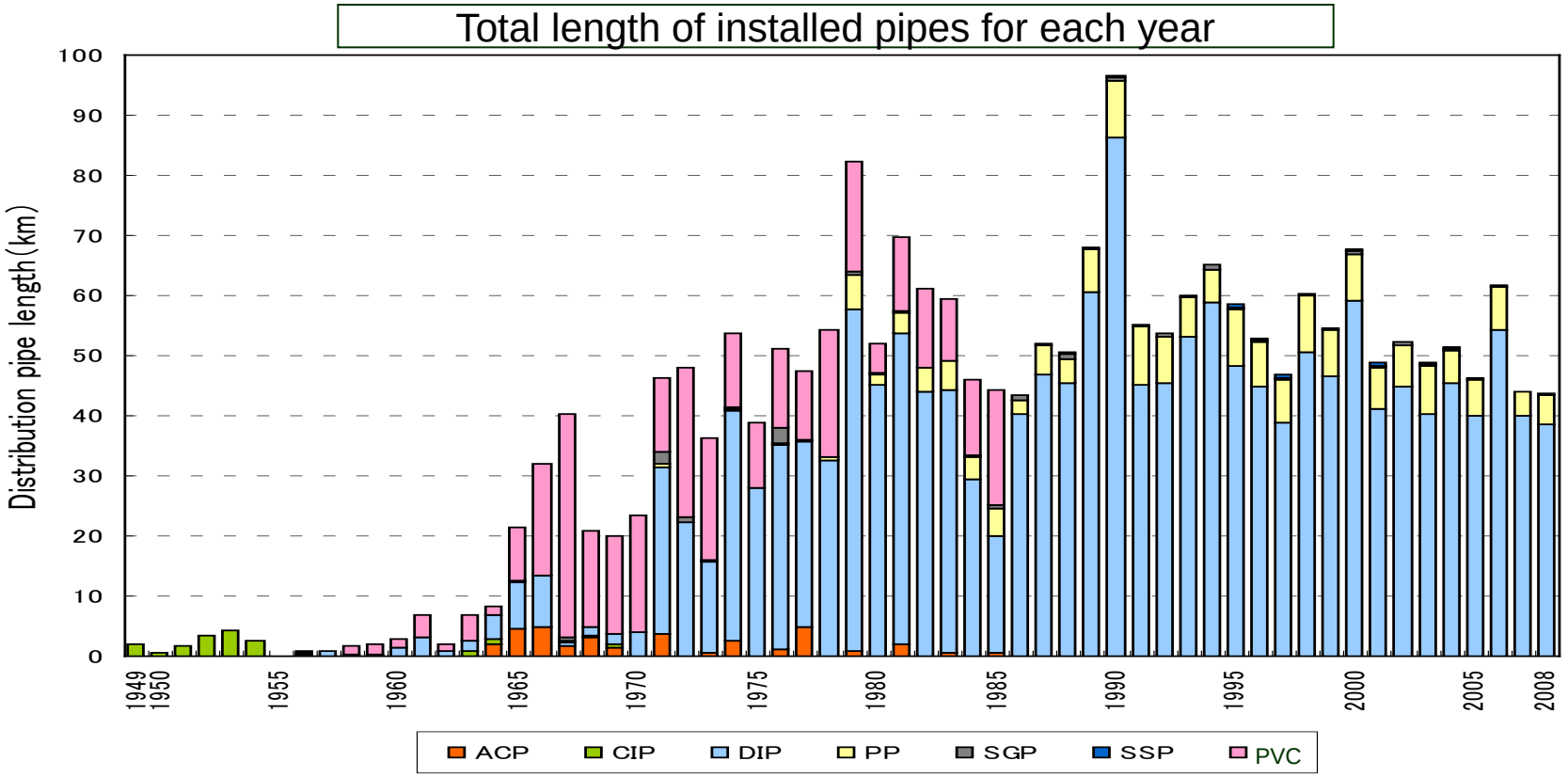
- Object items : water suspension ratio for Future Earthquake (%)
- Mark standard : water suspension ratio 100% = 1 point, 0%=100 points



Results for Hachinohe-district distribution block

Present condition of distribution pipes (2,200km)

- DIP : 75% (1,650km)
- PVC : 16% (350km)
- PPφ50 : 7% (150km)
- Others : 2%（50km）
- Length of distribution pipes installed before 1969
  (about 180km : 40 years passed in legal durability)



Inspection of corrosion (DIP・CIP)

- 214 spots of corrosion on DIPs & CIPs
  without polyethylene sleeve were chosen and inspected.

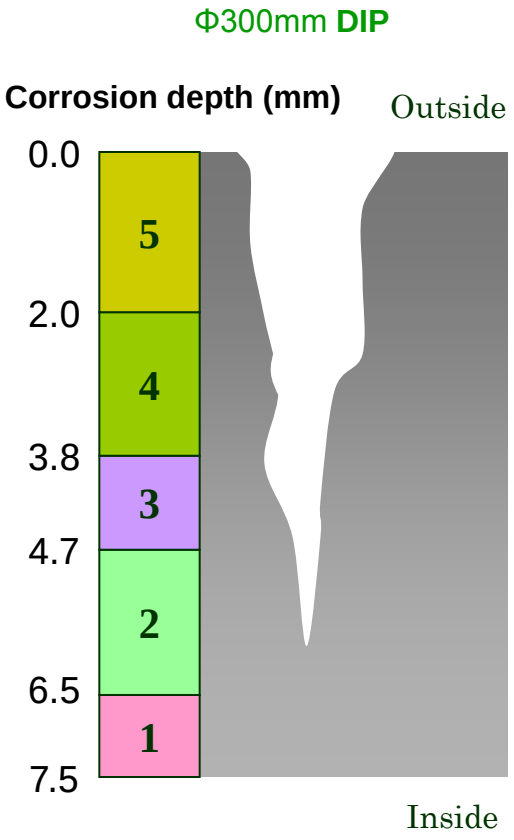
DIP φ200 (installation in 1973)

DIP φ100 (installation in 1979)

Judgment standard of corrosion depth

Corrosion depth

Rank	Definition	Measures
5	Corrosion depth =< 2.0 mm	Diagnose it again within 20 years
4	2.0 mm < Corrosion depth =< 3.8 mm (Design safety factor = more than 2.0~2.5)	Diagnose it again within 10 years
3	The state that a safety factor for the inner and external pressure is short (Design safety factor = more than 1.0 and less than 2.0~2.5)	Drafting of a renewal plan
2	The state to be not worthy of inner and external pressure (Design safety factor = less than 1.0)	Renewal
1	A penetraten by the corrosion	Renewal



JWWA [Guidelines for renewal of water supply facilities]

Results of evaluation of corrosion ranks（DIP・CIP）

Length of distribution pipes
according to the corrosion ranks

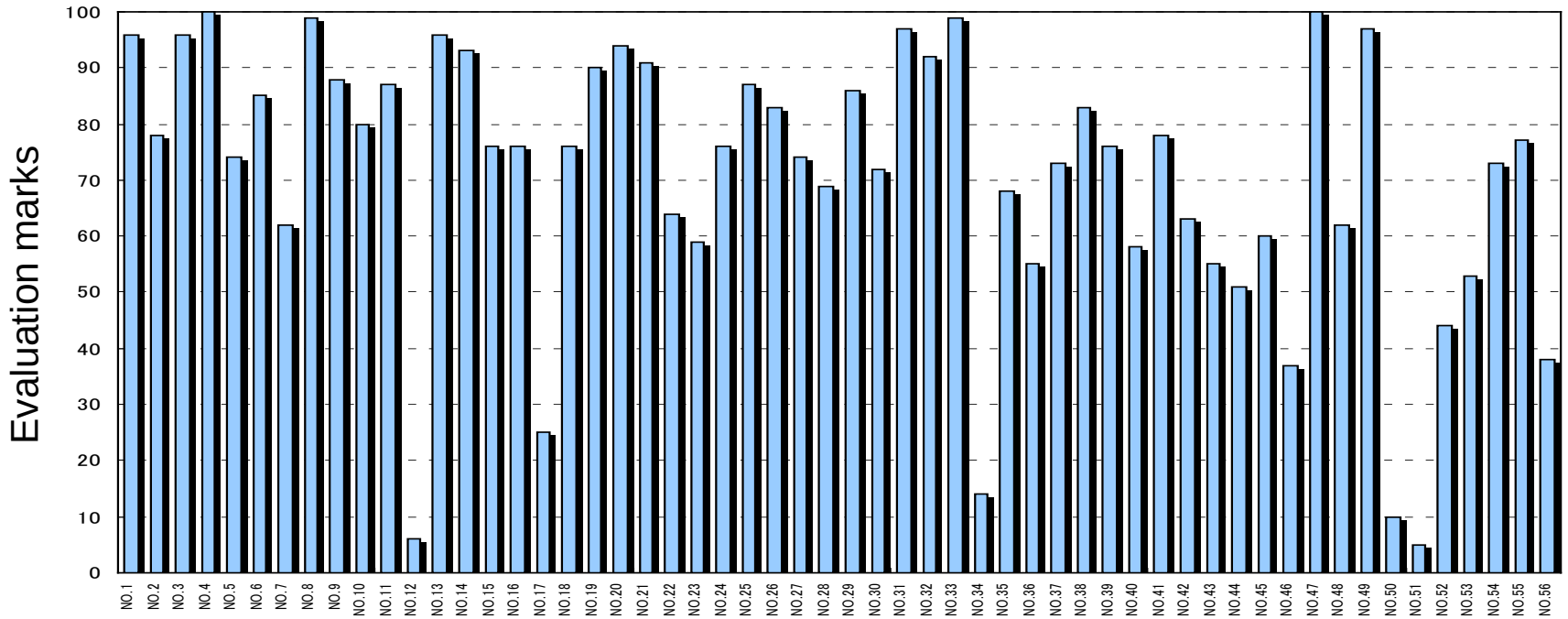
Rank	1	2	3	4	5
Pipe length (km)	0.0	2.7	25.9	600.0	73.5

Renewal (CIP)

Diagnose it again within 10 years

Evaluation of corrosion degrees

- Object items: 1) Corrosion ranks, 2) Break rate in normal conditions,
  3) The number of years of installation
- Evaluation method : A geometric mean of the three object items
- Mark standard
  1) More than rank 4 (100 points), Less than rank 2 (1 point)
  2) More than 0.003 breaks / km (100 points), Less than 0.4 breaks / km (1 point)
  3) Less than 40 years (100 points), More than 55 years (1 point)



Results for Hachinohe-district distribution block

Earthquake resistant rate of the distribution pipes which connected to the important foothold institutions

- Hospital : 472 places
- School : 399 places
- Distribution route from service reservoirs were searched using the hydrological model
- Earthquake resistant rate = length of earthquake resistant pipes / Total length of distribution pipes

≪Result≫

Facilities	Total length of distribution pipes (km)	Length of distribution pipes as PVCs (km)	Length of distribution pipes as earthquake resistant pipes (km)	Earthquake resistant rate (%)
Hospital	413.0	15.1	131.9	31.9
School	493.8	24.6	151.7	30.7
Hospital and School	652.5	38.5	197.4	30.3

The problems that should be improved

- Updating PVCs to quake-proof pipes as soon as possible
- Building substantial support systems ;

  realizing restoration for less than 28 days of targeted restoration period
- Making a steady update quake-proof plan of pipes
- Earthquake resistant proofing of the distribution pipes connected to important institutions

  (i.e. polyclinic hospitals)

Conclusions

- Promotion of earthquake resistant proofing of pipes.
  - Examination of the priority of earthquake proofing based on an evaluation result.
  - Exploitation of fixed-quantity assessment with numerical value.
  - Setting the future numerical target.
  - Progress management of the achievement.

Thank you for your attention !

DIP with seismic flexible joint (φ1,000mm) : completed in 1978