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title: **Effect on the groundwater recharge and the springwater restoration by infiltration facilities**

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INTRODUCTION

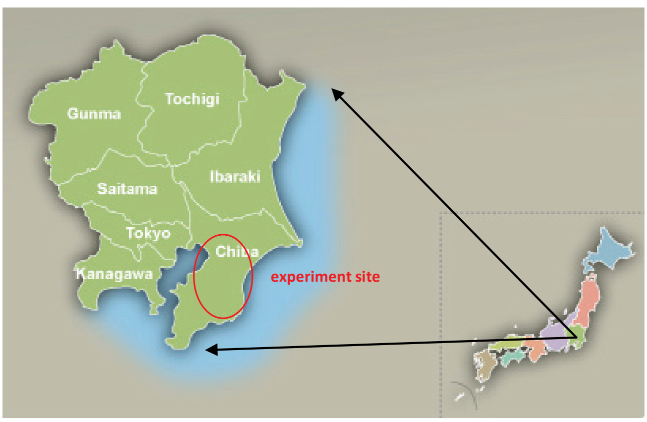
Increase of impermeable surface of roofs, road pavement, etc. with urbanization around catchment basins has been causing the decrease in the quantity of rainwater infiltrating to the ground. As the result, decrease in groundwater level, dryness of spring water and not only decrease of the ordinary flow but also increase of stormwater runoff in urban rivers has been occurring. Therefore, the national and local governments have been cooperating to take the action to install the rainwater infiltration facilities at any space in the basin.

It is well said that infiltration facilities have the effect on groundwater recharge, improvement of the base flow in the river and springwater restoration as well as the reduction of stormwater runoff. However, although there are several numerical simulation researches to learn the effects of infiltration facilities in Japan (for example Jia et al., 2000), proving data of those effects based on the observed data has been very limited. Especially, as for the effect on groundwater recharge, improvement of the base flow in the river, spring water restoration by the infiltration facilities installed in shallow depth, there are some difficulties to prove its effectiveness based on the observed data because the spread of the infiltration facilities doesn't catch up with urbanization in the huge basin area. Therefore, it is unclear how water from infiltration facilities installed in shallow depth infiltrates to aquifer layer and how much its effects in quantitatively.

As the result, it becomes an urgent ongoing problem to install the infiltration facilities in effectively with limited budget in government body. Therefore, here is an attempt to learn those effects by installing real size of infiltration facilities and a system for hydrological measurement system to estimate the effects of facilities, at the comparatively narrow catchment area for the existing spring water where located at urbanized area near the capital of Japan, Tokyo.

SELECTION OF EXPERIMENT SITE

It is very important how to select an experiment site to satisfy the purpose, such as condition of infiltration area (proportion of natural and residential area), installed place, recharge water, flow direction of groundwater etc. Since major purpose of the experiment is to confirm the amount of groundwater recharge and spring water restoration with infiltration facilities, the experimental site was selected under considering of the following viewpoints.



http://www.japan-i.jp/explorejapan/kanto/index.html

Figure 1. Location of experiment site.

- Natural area should be a little and residential area should be a large in the catchment area because it is difficult to know those effects if the natural area is large.
- Public facilities should exit at near spring so that the infiltration facilities are installed easily.
- Recharge water should be available at near experiment site.
- Existing well should be a lot at around experiment site so that the direction of the groundwater flow can be almost estimated widely by using the water level of the wells.
- There are no steep slopes just near the facility installed place because it can cause the instability of slope.

As the result, Minowa spring basin located at Ichikawa city in Chiba prefecture was selected as an experiment site (Fig.1). The Minowa spring was situated at residential district which was constructed as Minowa land readjustment project. The plateau is can be considered as recharging area for the Minowa spring and its width can be estimated as about 30,000m^2. The top of the stratum at the plateau is filled with a volcanic as called Kanto loam up to a depth of 5-6 meters from the surface. Under the Kanto loam area, a Narita sand layer of fine sand is laid. The hydraulic conductivity of Kanto loam layer and Narita sand layer is about 4.0×10^{-4} cm/s and 2.0×10^{-4} cm/s respectively.

Wakamiya elementary school which apart about 120m in horizontal distance form the Minowa spring is selected as experiment site to infiltration facilities (Fig.2). According to the estimation results of flow direction by groundwater levels of the surrounding existence wells, it can be confirmed that infiltrated water flow to the direction of Minowa spring.

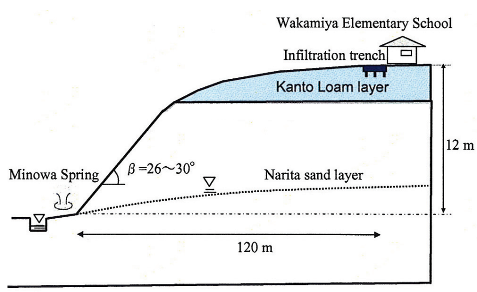


Figure 2. Positional relation of experiment site (Wakamiya elementary school) and Minowa spring.

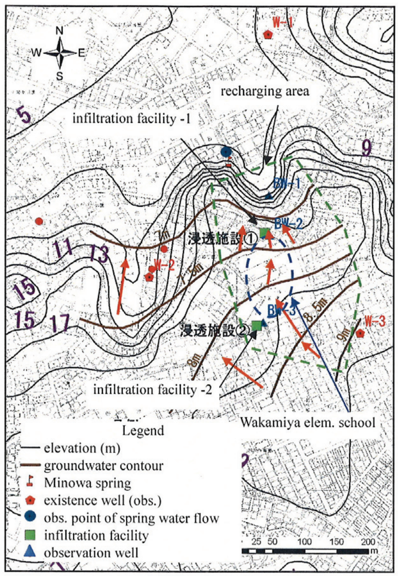


Figure 3. Topography and groundwater contour around Minowa spring

INFILTRATION FACILITIES AND MONITORING FACILITIES

The infiltration facilities which were installed at Wakamiya elementary school were the following two types.

Infiltration facility-1

The facility is composed by one trench (width 0.5 m, height 0.6 m, length 4.4 m) and three holes (15 cm in diameter and 1.0 m in depth) as shown in Figure 4. According to the calculation results by using proposed method of [Association for Rainwater Storage and Infiltration Technology] (Guideline for rainwater storage and infiltration technology — investigation and planning edition 2000), estimated infiltration capacity is about 2.0 m^3/hr.

Infiltration facility-2

The facility is composed by three holes (18 cm in diameter and 2.8 m in depth) and each hole is connected by porous pipe, as shown in Figure 5. Infiltration capacity is estimated to be about 0.77 m^3/hr.

Each facility was installed by using handed digger and small backhoe as shown in Photo 1 and Photo 2. Each facility was connected with roof drainage pipe as shown in Photo 3 and Photo 4.

At the experiment site, groundwater level, spring water flow rate and soil moisture are being measured and the monitoring facilities can be described as Table 1 and Photo 5.

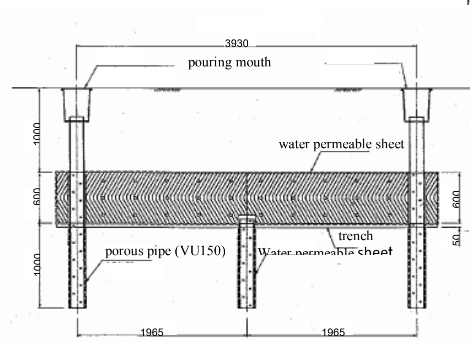


Figure 4. Structure of infiltration facility-1.

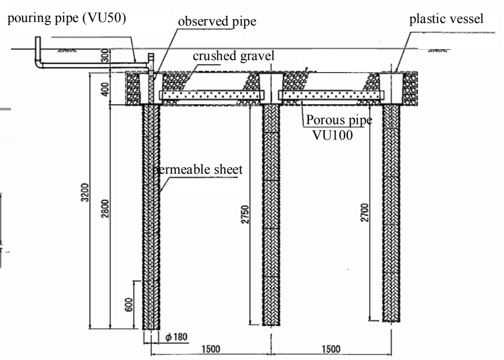


Figure 5. Structure of infiltration facility-2.

Photo 1. Installation work for facility-1.

Photo 2. Installation work for facility-2.

Photo 3. Connection of infiltration facility and cullis water pipe (facility-1).

Photo 4. Connection of infiltration facility and cullis water pipe (facility-2).

Table 1. Monitoring facilities.

Measurement item	Observation point	Location	Well type	Target of monitoring	Measuring method
water level	W-1	lowland part	existing well	groundwater behavior at lowland part	piezometer
	W-2	near at slope	existing well	to monitor instability of slope	piezometer
	W-3	plateau part	existing well	groundwater behavior at plateau part	piezometer
	BW-1	near at Minowa spring	newly setup	groundwater behavior at near of spring	piezometer
	BW-2	near at infiltration facility-1	newly setup	groundwater behavior at near of facility-1	piezometer
	BW-3	near at infiltration facility-2	newly setup	groundwater behavior at near of facility-2	piezometer
	infiltration facility-2	inside of infiltration facility-2	newly setup	amount of water storage inside facility	piezometer
spring water	Minowa spring	discharged channel	to know change of spring water flow rate		v-notch
soil moisture	SW-1（200cm）	near at infiltration facility-2	to know change of soil moisture		ADR
	SW-2（400cm）	near at infiltration facility-2			

Photo 5. Close view of some of monitoring facilities.

Since main target of this investigation was to know the quantity of groundwater recharge and spring water restoration, there were no investigation for the change in the chemical composition of ground- and spring water.

RECHARGING EXPERIMENT

Recharging experiment were carried out by artificial recharging and natural recharging (rainfall). Artificial recharging experiments were carried out four times as shown in Table 2. Here, the recharge water used in experiments was tunnel drainage water and tap water from Wakamiya Elementary School. Because of the experiments works were conducted at school premise, it was difficult to conduct longtime artificial recharge. Therefore, pouring water was stopped when it was confirmed that infiltrated water reach to groundwater surface and then groundwater level rose up.

Table 2. Detail conditions of artificial recharging experiment.

No.	Recharging facility	Recharge water (m^3)	Recharge method	Recharge period	Water source	Cullis (roof) water	Rise up of groundwater at nearest obs. well
1	facility-1	108	intermittent (day time)	5 days	tunnel drainage water	no	7 cm
2	facility-1	142	continuance (day&night)	5 days	tap water	no	8 cm
3	facility-2	170	continuance (day&night)	8 days	tap water	no	9 cm
4	facility-1 facility-2	252 103	continuance (day&night)	7 days	tap water	no	10 cm

Next, natural recharging is now being carried out during rainy season by investigation [how much groundwater level at near of facility rise up and how much amount of spring water increase during rainfall].

Results of experiment No. 2 and No. 3 are shown in Fig. 6 and Fig. 7 respectively. In the former case of experiment No. 2, groundwater level at the nearest point of BW-2 rose up 8cm during recharge period and those of rose up of groundwater level during experiment No. 3 at point BW-3 was 9 cm. Even though rainfall was occurred during experiment, the rise up of groundwater level has stayed in about 1cm at plateau part during rainfall, and so it can be considered that the influence of rainfall during recharge period is small and most of rise up of groundwater level is the effect of recharge water.

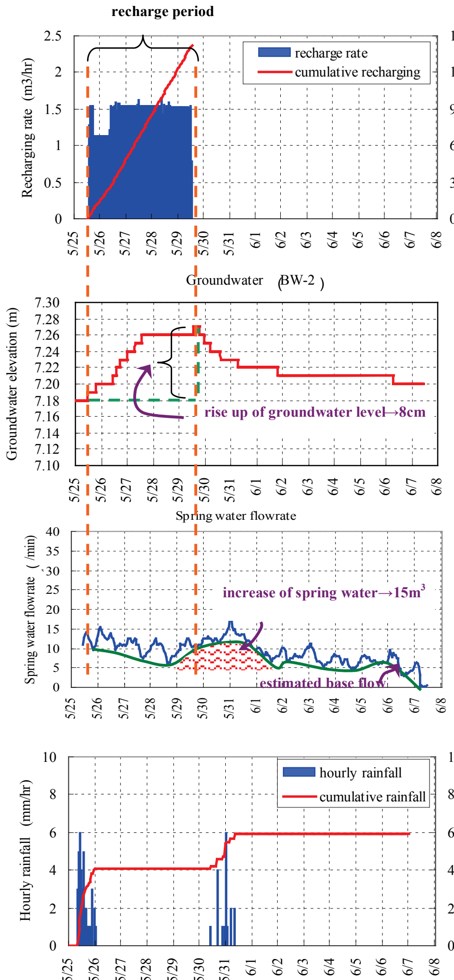


Figure 6. Results of artificial recharging experiment (experiment No.2).

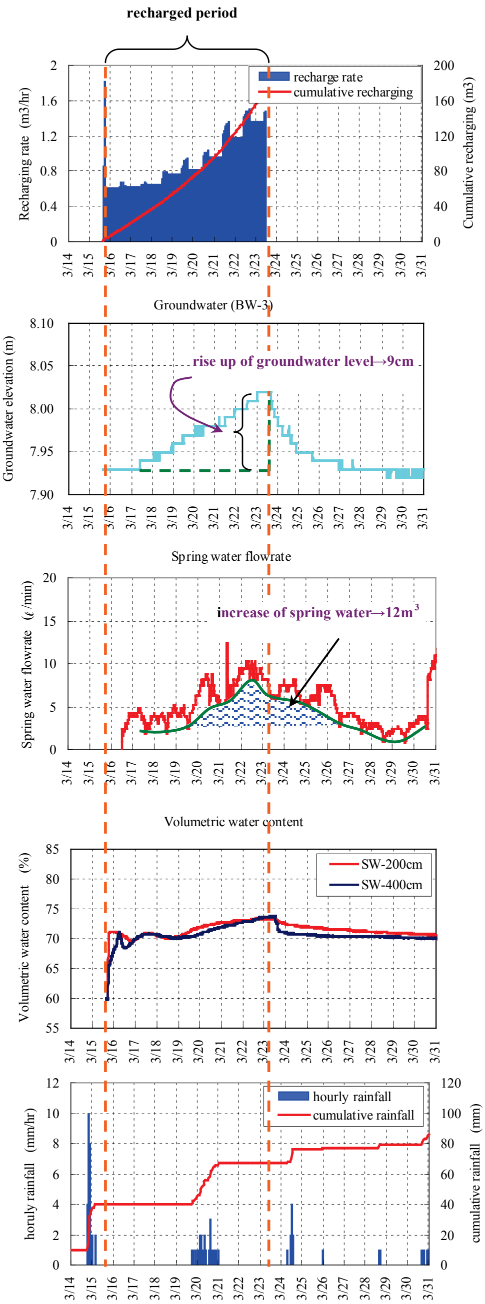


Figure 7. Results of artificial recharging experiment (experiment No.3).

Next, increase amount of spring water during recharge period were 12-15m^3 but it was difficult to estimate how much influence of rainfall was included.

To understand the mechanism of effect of recharge water, 2D and 3D of saturated and unsaturated infiltration analyses were carried out. Details of analyses will be omitted in this paper because of space. It will be introduced at another opportunity. Figure 8 to 10 show the simulation results of groundwater level and spring water during recharge period. It is difficult to get completely agreement between calculated and observed results but it can be evaluated as approximately agreement. That means, the effect of infiltration facility for groundwater recharge and spring water restoration can also be recognized by simulation results.

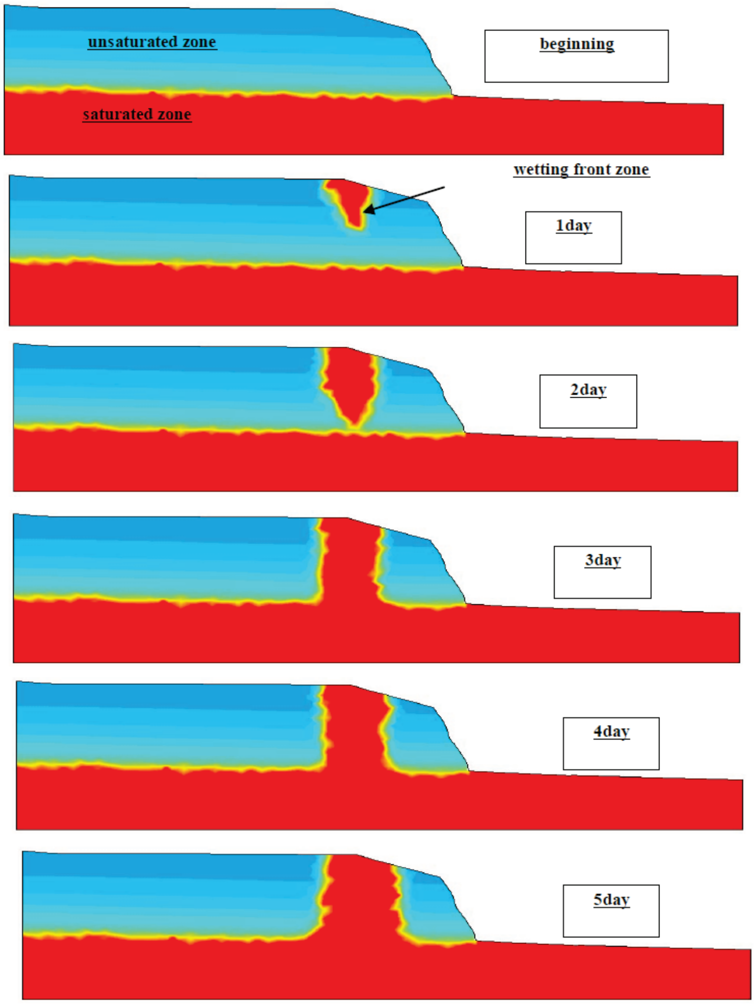


Figure 8. Seepage flow analyses.

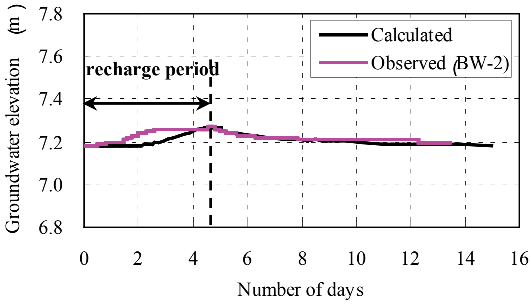


Figure 9. Simulation results (groundwater level).

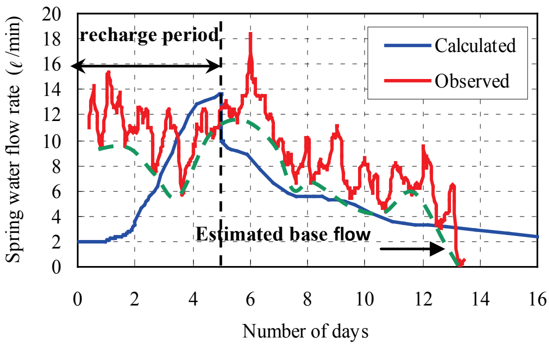


Figure 10. Simulation results (spring water).

CONCLUSIONS

According to analyzing the results of a series of artificial recharging experiment, it is clear that the effectiveness on the groundwater recharges and the spring water restoration by the infiltration facilities has been verified.

An effective infiltration pattern and the effective arrangement of infiltration facilities in the catchment basin should be considered in detail in order to decide the priority of the implementation in practice. For this study, the authors carried out 3D saturated and unsaturated infiltration analyses. The results will be introduced in the next opportunity.

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