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An Overview of Experiences of Basin Artificial Recharge of Ground Water in Japan

Noboru HIDA*[1]

Abstract

In this paper, the author reviews the present situation of basin artificial recharge of ground water (MAR: managed aquifer recharge) as of 2007 in Japan. Most of the artificial recharge of basin method is carried out using alluvial fans. The enhancing groundwater resources in the *Rokugo* alluvial aquifer has resulted in sustainability for the groundwater environment, especially in the distal fan. As a general judgment, the basin artificial recharge contributes to sustainable aquifer management in alluvium. As a result of this review, the basin artificial recharge will be utilized more in the future, not only in Japan, but in monsoon Asian countries as well.

Key words: Artificial recharge of ground water, Aquifer, Alluvial fan, Paddy field, Snowfall

I. Introduction

Regarding artificial recharge (MAR: managed aquifer recharge), there are various methods (Thoa *et al.,* 2005; Luck *et al.,* 2006). Methods using a basin or pond and wells are generally spread. In the case of the well method, pure water must be injected into an aquifer, but the basin method does not always need pure water. The water may be polluted to some extent, such as due to turbidity. The basin method is used not only for enhancing groundwater resources, but also for purifying water through the process of percolation (BMI, 1985; O'Hare *et al.,* 1986).

In Japan, after World War II, the artificial recharge well method was performed for the prevention of subsidence in the industrial areas where subsidence occurred. However, the well method has not used for a long time and the application of the method is, at present, almost finished. This is because subsidence was stopped as a result of pumping regulations and clogging problems were unavoidable. Furthermore, the history of basin artificial recharge is superficial. Japan has a lot of precipitation, river beds are steep, and river water is not polluted. As such, river water has been used for paddy field irrigation, residential water supplies and industrial purposes (Hida, 2002).

In recent years, however, basin artificial recharge has attracted attention. Why is this? In this paper, the author reviews the present situation of basin artificial recharging as of 2007 in Japan.

II. Models of artificial recharge of basin method

As for basin artificial recharge, it is operated mainly in two topographical locations. One is on

＊1 Akita University Honorary Professor

the river or lakeside and the other is on the alluvial formation.

1. River or lakeside type

In this type, the basin for artificial recharge is installed in the bank of a river or lake. It pumps up subsurface water again which is mixed with original groundwater and underflow water created from the bank filtration basin (BMI, 1975; Holzbecher, 2005).

2. Alluvial fan type

An alluvial fan is a place suitable for basin artificial recharge. Utilizing the characteristic of a groundwater cycle in an alluvial aquifer, a recharge basin is installed in the proximal and center fans, and groundwater is pumped again into the distal fan (Hida, 2002). The main subject of this paper focuses on this method.

III. Basin artificial recharge operating in an alluvial fan

The artificial recharge of basin method operating in Japan in 2007 is present in the *Rokugo* alluvial fan in Akita Prefecture, in the *Umamigasaki* alluvial fan in Yamagata Prefecture and in the *Shou River* alluvial fan in Toyama Prefecture. In addition, for basin artificial recharge, there are some experimental examples in *Showa-machi* Town in Akita Prefecture and *Oono-shi* City in Fukui Prefecture. In this paper, only operating examples are selected.

1. The Umamigasaki alluvial fan in Yamagata Prefecture

The basin artificial recharge of the *Umamigasaki* alluvial fan was set up at the proximal fan (38° 14' 38" N, 140° 21' 37" E) (Yamagata-shi, 1988). The operation began in September, 1991. The basin area is 62m^2. The basin draws source water from an irrigation canal (*Sasa-zeki* canal) for paddy fields. In the beginning, water was supplied only in the non-irrigation period from September to April. Starting in 2005, water was supplied year-round.

The infiltration rate of the basin was maintained at 18.4cm/h at a level of about 100,000m^3 annually until 2001. After 2002, the infiltration rate of the basin declined to 9.2cm/h at a level of about 50,000m^3 annually (Kakubari, 2006). It may be said that the rate is still considered substantial.

2. The Shou River alluvial fan in Toyama Prefecture

(1) Station of the promoting division in Toyama Prefecture (Enomoto, 2007)

The promoting division in Toyama Prefecture operated a basin system for artificial recharge in 2004. The system existed on the right bank of the *Shou River* situated in the center of the fan (36° 37' 23" N, 137°0' 38" E). Two artificial recharge basins of about 1,000m^2 (19.5m × 56.0m) were installed on a contour line, and are used in turn while repeating removal of sedimentary solids waste from the basin bed. These basins are covered by a building with a roof.

The source water for the basins is drawn from the *Wada-gawa Kyoudou* waterway (irrigation canal for paddy fields). Pre-treatment is not carried out. The maximal amount water, 8,200m^3/day, is supplied in theory. Groundwater is pumped up by a well installed about 250 m downstream from the basin and is used for industrial purposes.

(2) Station of agriculture and forestry division in Toyama Prefecture (Tonami-Nouchirinmu-Jimusho, 2006)

Agriculture and forestry division, Toyama Prefecture's infiltration basin was built in autumn of 2006. This basin was designed for flood control and not for enhancing groundwater resources. However, the form is the same as in artificial recharge basins. While it operates, it should lead to the enhancement of subsurface water as well. The infiltration basin was installed in three places in the west of Tonami City.

The three basins are lined up along 3km stretch of the *Suwagawa* irrigation and drainage canal. The canal flows in a northwest direction in the center of the *Tonami* alluvial fan. Basin No. 2, midway among the three, is installed at 36° 39' 06" N and 136° 55' 08" E. The capacity of each basin is about 8,000-9,000m^3.

Operation is limited to flood times, because the basin is aimed for flood control along the *Suwagawa* irrigation and drainage canal. Flood water, which is highly turbid, so clogging is a major problem.

IV. The Rokugo alluvial fan, Akita Prefecture

The *Rokugo* alluvial fan is the place where the author studies basin artificial recharge of groundwater. In this paper, he focuses on the *Rokugo's* case, among other examples.

1. Hydrological environment of the Rokugo alluvial fan (Hida *et al.*, 2005; 2006)

The *Rokugo* alluvial fan lies around 39° 25' N and 140° 34' E in northern Japan. The distance between the proximal fan, at 90 meters above sea level, and the distal fan, at 45 meters, is about four kilometers (Fig. 1).

The unconfined aquifer of the *Rorugo* alluvial fan consists mainly of gravel, of which hydraulic conductivity is 10^0~10^{-2}cm/sec and specific yield is over 20%. The depth of the aquifer is over 100 meters around the center of the fan. Annual mean precipitation is 1,653mm and annual mean potential evapotranspiration is estimated at 660mm. Maximum snow depth occurs during a period from mid-January to mid-February. It averages 130cm in the distal fan and 150cm in the proximal fan.

The annual groundwater level changes regularly. The level is high during the period of paddy field irrigation from May to August and low during the non-irrigation period. As for land use, the paddy field accounts for 70 per cent of the total surface of the fan.

2. Artificial recharge basins

Four basins (Nos.1 - 4) are installed in the fan (Fig. 1). The source water supplying each basin uses the irrigation canal water, which is drawn from the *Maruko* River.

Table 1 shows the site of each basin, the constructing year, the basin area, the basin depth and the photo number of each basin.

3. Observation equipment

Two piezometer nests were installed as the main observation equipment. One is at *Nonaka* (N) station in the center of the fan (39° 25' 02" N, 140° 33' 55" E) and the other is at *Umamachi* (U) (named, *Yukawa* as well) station (39° 25' 18" N, 140° 33' 03" E) in the distal fan. Each nest consists of three pipes, drilled to depths of ca. 20, 50 and 100m. Table 2 shows the specifications of the N and U piezometers. The geologic column section of each is shown in Fig. 2.

In addition, some observation wells were installed in the alluvial fan.

4. Results

The following points are summarized by the result of the precedent study of basin artificial recharge in the *Rokugo* alluvial fan (Hida, 2005; 2007; Hida, *et al.,* 1999; 2005; 2006).

(1) Groundwater mounds were formed under the bottom of the artificial recharge basins. In the

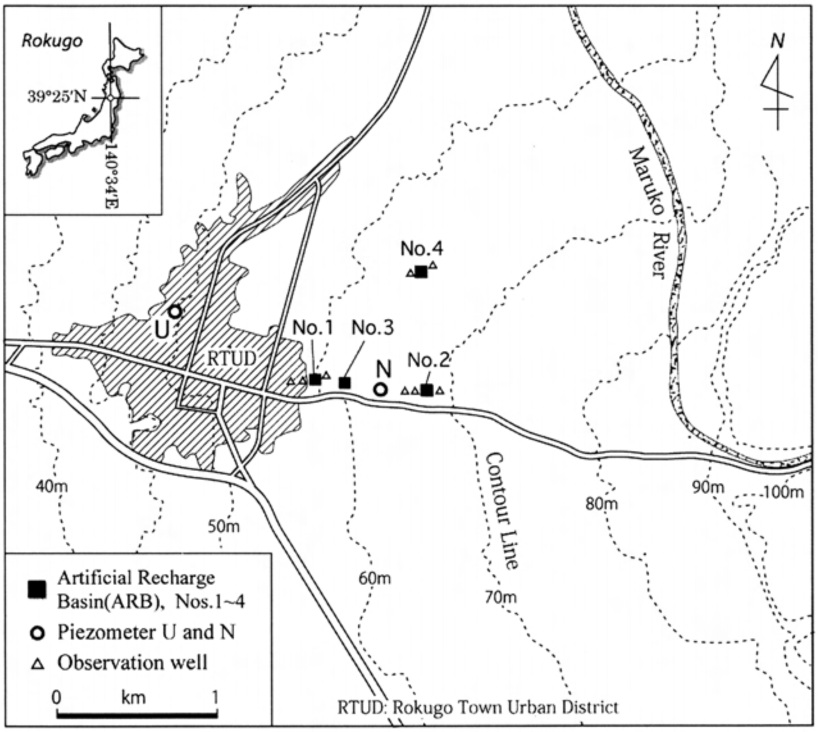

Fig. 1 Study area, the *Rokugo* alluvial fan. See Tables 1 and 2

example of artificial recharge basin No.2, the water supply of 60-70ℓ/sec raised the water table by 3-5m in the aquifer around the basin area.

(2) The effect of basin No.2 resulted in the water table rising at piezometer U in the distal fan as well. The water supply of approximately 60-70ℓ/sec raised the water table by 10-30cm approximately 14 days later at piezometer U at the depth of 20m.

(3) The infiltration rate of the basins Nos. 1, 2 and 4 generally recorded about 20cm/h at the beginning of the water supply and become about 8cm/h several months later.

(4) When low temperature water, due to snow melt, entered basin No.2, the characteristic phenomenon of ground water temperature was recorded by piezometers at a depth of 20m at both sites of the central (N) and distal fans (U). Consideration of this point is a theme for future studies.

(5) The enhancing groundwater resources in the *Rokugo* alluvial aquifer has resulted in sustainability for the groundwater environment, especially in the distal fan.

V. Paddy field and unpaved irrigation canals with the artificial recharge function

1. Paddy fields

Paddy fields are a place for growing rice. At the same time, paddy fields possess a function that is the same as the artificial recharge basin in that the fields also effectively recharge groundwater (Hida, 1989).

Table 1 Artificial recharge basins in the *Rokugo* alluvial fan.

Basin	Site	Elevation, m	Bain Area, m^2	Basin Depth, m	Const. Year	Photo No.
No.1	39° 25' 05"N, 140° 33' 35"E	58.0	1,192	1.0	1991	1-1 ～ 2
No.2	39° 25' 00"N, 140° 34' 05"E	68.0	2,120	3.4	1992, 1994	2-1 ～ 2
No.3	39° 25' 01"N, 140° 33' 44"E	61.0	212	2.9	1998	3
No.4	39° 25' 27"N, 140° 34' 05"E	62.0	1,045	3.0	1998	4

Basin Nos.1~4: See Fig. 1. 1994(No.2): Expansion. Photos were taken by the author.

Photo 1-1 Basin No.1, just before water supply, Sept. 4, 2000

Photo 1-2 Basin No.1, in snowfall season, Dec. 12, 2002

Photo 2-1 Basin No.2, the side of water supply, Apr. 5, 2001

Photo 2-2 Basin No.2, the side of taking out sediment, Apr. 5, 2001

Photo 3 Basin No.3, during water supply, Apr. 4, 2001

Photo 4 Basin No.4, just after stopping water supply, Mar. 27, 2002

Table 2 Specifications of the N and U piezometers.

	N-20m	N-50m	N-100m	U-20m	U-50m	U-100m
Site			See: Fig. 1			
Head/Piz. (m) (1)	64.56	64.59	64.57	48.88	48.85	48.86
Ground level, (m)	64.19	64.19	64.19	48.37	48.37	48.37
Depth, (m) (2)	24.0	55.0	107.0	25.0	55.0	106.0
Screen, (m) (3)	19-21	46-49	100-103	19-21	47-50	99-102
Diameter, (m/m)	150	150	150	150	150	150
Water level gauge			all NDR			
Recorded from			all 1991			
Year of const. (4)			all 1991			
GCS (5)			See: Fig. 2			

Notes (1) Elevation of the head of piezometer column, (m)
(2) Drilling depth from ground level, (m)
(3) Screen: in depth above sea level, (m)
(4) Year of well construction
(5) Geologic columnar section

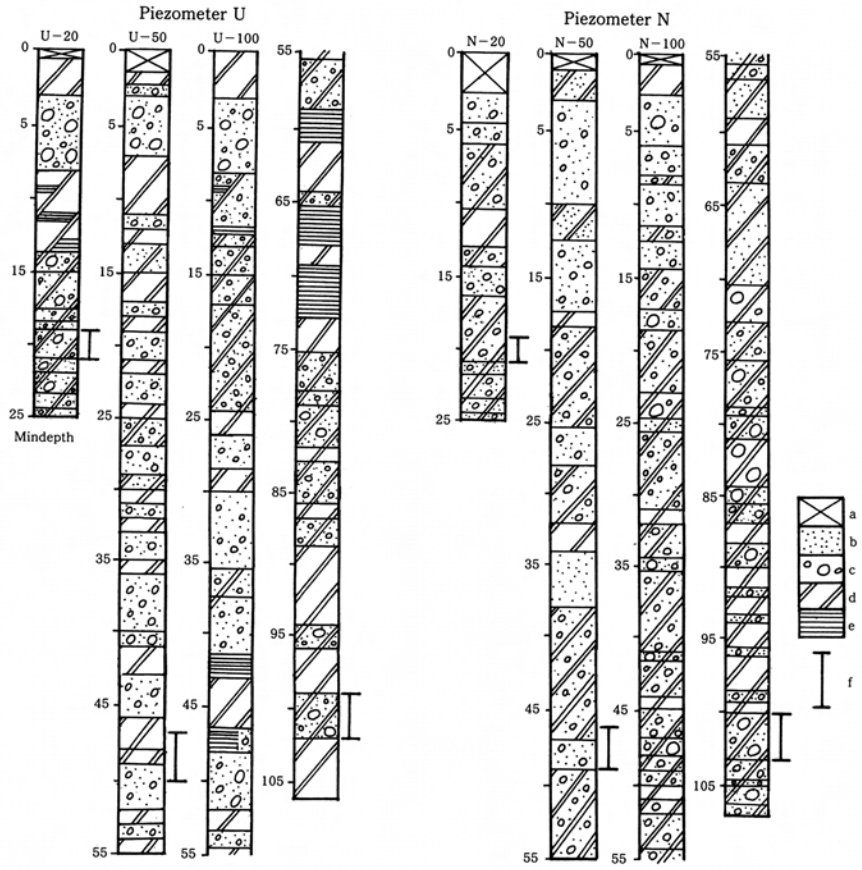

Fig. 2 Geologic columnar section at the site of piezometers U and N.
Legend; a: Soil, b: Sand, c: Gravel, d: Clay, e: Humicsoil, f: Screen
GL (Avb. Sea level), Piz. U: 48.37m, Piz. N: 64.19m
See Fig. 1 and Table 2. by Hida, *et al.* (2005)

2. Unpaved irrigation canals

Wakasa *et al.* (2006) studied infiltration from May to August, 2005, using unpaved irrigation canals for paddy fields. The total length of the canals was 21km. The canals were distributed in the central part of the *Narusegawa* River alluvial fan in Northern Japan. As a result, average infiltration rate during the observation period was estimated at about 18.8cm/h. As a numerical value, unpaved irrigation canals in this district have a superior groundwater recharge function.

VI. Concluding Remarks

This paper reviewed the situation regarding the basin artificial recharge of groundwater, which operated as of 2007 in some alluvial fans in Japan. As a general judgment, the basin artificial recharge contributes to sustainable aquifer management in the alluvial fan. From the viewpoint of the researchers, the basin artificial recharge for the management of alluvium will be utilized more in the future.

The author wants to introduce this method not only in Japan but in the monsoon Asian countries. The trials will continue under the support of JSPS Grant- in-Aid for Scientific Research (B), No.19401002 in 2007-2010, Representative: N. Hida, Research theme: Field investigation and research on development and practical use of the optimum aquifer artificial recharge system in southeast Asian countries.

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