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REINJECTION PROBLEMS ENCOUNTERED IN SUMIKAWA GEOTHEMAL POWER PNANT, JAPAN

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ABSTRACT

The Sumikawa geothermal power plant is located at the Hachimantai volcanic region in Akita Prefecture, Northeastern Japan. The 50 MWe unit has been operating since March 1995. From the environmental viewpoint, thermal water and steam condensate are reinjected into each reinjection well.

In these five years, many reinjection wells have encountered some problems. For example, the wellhead pressure of SD-1 was kept constant condition, while the amount of the thermal water decreased. To improve such state, we reinjected to the mixture of thermal water and steam condensate in order to recover reinjection capacity. Then the reinjection capacity of thermal water was recovered.

Decrease of steam production is also observed in some production wells, which is strongly observed in the production wells S-4 and SC-1.The temperature decrease of production zone is presumed that the reinjected water may return into the production zone. Because of decrease of silica geothermometer and/or increasing Cl^- concentration are observed in their brine.

Tracer tests were conducted in order to reveal the influence of reinjected water on production zone in 1991 and 1999. In the case of 1999, the tracers, KI and KBr were introduced into the well SE-2 used for reinjection of steam condensate and the well SD-4 is for the thermal water. Iodine was detected most of the production wells which occur thermal water, except SC-2, and KBr was detected all of such kind of wells.

Bromine was concentrated in the wells S-4 and SC-1 strongly. For example, the well S-4 is most affected by reinjection waters, 23% of discharged fluids (steam and thermal water) are reinjected water.

To avoid reservoir temperature decrease, the most effective way to keep reinjection capacity higher is to drill new additional reinjection well far from production zone. Moreover, suitable utilization of reinjection wells is also needed.

Keywords: reinjection capacity, return, tracer test

1. INTRODUCTION

The Sumikawa geothermal area is located at the Hachimanatai volcanic region in Akita prefecture, northeastern Japan (Figure 1). In this area, Tohoku Electric Power Corporation has started a 50MWe generation since 1995, steam is provided by Mitsubishi Materials Corporation (MMC).

After a start of commercial operation of the Sumikawa geothermal power plant, we met some troubles on producing steam. We met serious reinjection problems such as ones indicated by Sanyal and Menzies (1995); they are (a) cooling of the produced fluid, (b) excessive injection pressure, and (c) loss of productivity of steam wells.

Returning of reinjected water to production zone causes above-mentioned problems. In addition, decline of steam production is observed in some production wells. We are investigating suitable reinjection method to avoid such problems by conducting a field test.

2. GENERAL OUTLOOK OF THE SUMIKAWA AREA

The Sumikawa geothermal area is located in northern part of Mt. Yakeyama, in Hachimantai volcanic region, and its geology is composed of Quaternary volcanic rocks and Neogene formations. The Sumikawa area lies within a north-south trending geological graben structure, which extends many kilometers (Garg et. al., 1997).

Subsurface temperature is over 250 deg. C at sea level. This high-temperature zone is located in the south of the Sumikawa area. Subsurface temperature decreases toward north. Isothermal contours at sea level are shown in Figure 2 (Bamba et al., 1995). Permeability of rocks tends to show low permeability toward north. On the contrary, distribution of high-permeability rock zone is south of the Sumikawa area.

Arrangement of wells and drilling directions are planned based on subsurface thermal gradient and permeability. Production wells are drilled to the south of Sumikawa region (with high temperature and permeability), and reinjection wells are toward north (with low temperature and permeability).

3. REINJECTION PROBLEMS

3.1 Present state of the reinjection

The fluid from production wells is separated into thermal water and steam in separator at 5 kgf/cm^2 (absolute) in order to prevent the transmitting pipes from silica scaling. The transmission system of thermal water is shown in Figure 3. It tells that, for example, reinjected water in the D base comes from C base, and that reinjected water is the mixed thermal water from SC-1 and SC-2 production wells.

In figure 4, the present reinjection capacity is represented by each size of circle at each base. Total amount of the thermal water increases year by year against the steam flow rate. In these years, the problem that reinjection capacity became equal to the amount of reinjected thermal water, nevertheless a new reinjection well was added. This indicates the capacity of each reinjection well is decreasing.

3.2 Problems caused by reinjection

Decrease of reinjection capacity

There are several causes may bring out decrease of reinjection capacity. They are scaling in the casing pipe, scaling in the fractures around the well, corruption of the wall rock, casing pipe breakdown, excessive injection pressure, and so on. In the Sumikawa area, many reinjection wells have met with these problems. Most of them are thought to be the excessive injection pressure and scaling in fractures.

Problem caused by excessive injection pressure was observed right after reinjection just has been started. At the beginning, wellhead pressure is low and the amount of reinjection water is large. Then the wellhead pressure suddenly increases and the reinjection amount is getting lesser. However, when reinjection is stopped, the capacity becomes as before. Figure 5 shows the pressure change of the well SD-1 since reinjection has started. While the wellhead pressure of the reinjection well was kept constant, the amount of the thermal water decreased. From the above-mentioned situation, we reinjected to the mixture of thermal water and steam condensate in order to recover reinjection capacity. This method was taken intermittently within one or two weeks. Then the reinjection capacity of thermal water was recovered.

It is supposed that the injection pressure was released by stopping high temperature reinjection and reinjection of low temperature water. Ariki and Hatakeyama (1997) indicates that water temperature affects, one of which is the injection flow rate, due to the changes in fracture aperture and reservoir pressure around the injection well. It was demonstrated by injecting high-temperature thermal water and mixture of that and low-temperature thermal water.

Scaling of rock fracture lets the reinjection capacity lesser from year to year. This may be indicated by that the reinjection capacity did not recover to its former state. Figure 6 shows the reinjection capacity of the well SD-3. The capacity decreases year by year, though the wellhead pressure keeps almost maximum state. In 1999, when we swept out well SD-3, large amount of silica scale was sampled. The silica scale was from inside the reinjection-casing pipe; then, it considered to be deposited to the fracture outside the well SD-3 as well.

Influences on steam production

Since the beginning of the plant commercial operation, the amount of steam is getting fewer (Figure 7). One reason of the steam declining may be that the reservoir pressure becomes lower than heat of the initial state. However, it may not be a serious problem except if it keeps declining. The temperature of the production reservoir may also be decreased, which is serous.

In the Sumikawa area, we found that reservoir temperature of each production zone, represented by silica geothermometry, have been becoming lesser (Figure 8). Cl^- concentration is increasing year by year as shown in Figure 9. That is clearly observed in the production wells S-4 and SC-1. The decrease of temperature and increase of Cl^- concentration are presumed that the reinjected water may return into the production zone as indicated by Malate and O'Sullivan (1991).

Phenomenon of the reinjection water return is found not only in hydrothermal water, but also in steam condensate. Seasonal change of Cl^- concentration in thermal water discharged from the well SB-1 is the one. The amount of steam condensate increases in winter because of temperature fall down, and it decreases in summer. The Cl^- concentration shows different behavior against flow rate of steam condensate. That is, thermal water which contain less Cl^- are found in winter because of diluted by much amount of steam condensate, on the contrary, more Cl^- are found in summer because of small amount of steam condensate (Figure 10).

3.3 Analysis of flow path of reinjected water

Tracer tests were conducted in order to reveal the influence of reinjected water on production zone. That is an appropriate way to analyze flow path of reinjected water, and carried out in 1991 and 1999. In the case of 1991, KI was selected, as a tracer because of concentration of iodine was low and stable in the reservoir.

In 1999, KI and KBr were introduced. Condition of the test is listed in Table 1. KI and KBr were introduced into the wells SE-2 and SD-4, respectively. The well SE-2 is used for steam condensate and the well SD-4 is for the thermal water. Iodine was detected from most of the production wells that produce thermal water, except well SC-2. KBr was detected from all such of wells.

Iodine was detected only in three days highly concentration in the thermal water from the wells S-4 and SB-1 and, its concentration decreased fast day by day. Another well, for example, the well SC-1 moderately increases and decreases.

The wells S-4 and SC-1 responded immediately and strongly, after bromine was introduced. In addition, they show similar patterns as those of iodine in wells S-4 and SB-1.

Accordingly, major paths from well SE-2 to wells SB-1 and S-4, and from wellSD-4 to wells S-4 and SC-1 are assumed. It is also revealed that the steam condensate has come into production zone within three days. Both of the tracers come to almost all of the production wells. On the other hand, in some production wells, iodine was detected 10 days after the introduction and its concentration changed little by little. Same situations were recognized on Bromine. Such patterns may indicate transfer of iodine and bromine by diffusion. The result of the test is shown in Table 2.

This indicates that the Sumikawa geothermal area may be divided into some hydrogeologic blocks. In the border of each block, there assumed to be the fault. Direct response of the fluid may be occurred almost in this block.

Tracer recovery ratio was calculated. 61% of the amount of iodine and 55% of the amount of bromine have recovered five months after they had been introduced. Their mixing ratio in thermal water is also calculated. For example, the well S-4 is most mixed with reinjection waters, 23% of discharged fluids (steam and thermal water) are reinjected water.

4. MEASURES TO THE PROBLEMS

To improve the above-mentioned situation, the followings are generally considered

<u>Sidetracking of reinjection well</u>

In general, sidetracking of the reinjection well is effective against the scaling on the rock fracture near reinjection well. It is expected that reinjection capacity to come back as it be.

<u>Additional well drilling</u>

The most effective way to keep reinjection capacity higher is to drill new additional reinjection well. However, present state is that the cool fluids return directly into the production zone and is restored there. To avoid this, reinjected feed zone should be opened deeper than the production zone is set. As a matter of course, an ideal convection is that the cool fluids must be reheated and returned to the production zone. That is, we must drill to the deeper area for the reinjection wells. Then, reinjected water will be reheated in deeper area thoroughly and will be return above there after that.

Another way to avoid direct return, we need to drill farther area because the reinjection area may not damage to the production zone.

<u>Suitable utilization of reinjection wells</u>

It is the most economical way to exchange the reinjection water flow rate among reinjection wells. It costs for only constructing new transmitting system or merely addition several valves. In such a case, enough numbers of reinjection wells must be possessed.

5. CONCLUSIONS

(a) Next problems were encountered during the Sumikawa geothermal power plant operation

(i) Decline of the reinjection capacity

(ii) Return of the reinjection water may causes the temperature decrease of the reservoir.

(b) Tracer test revealed the connection between reinjection wells and the production wells.

(i) The Sumikawa Geothermal area may be divided into some geological blocks from a view of fluid transmissivity, but they have a little relation each other.

(c) Measures to the reinjection problems

Return of reinjection water to the production wells makes reservoir temperature lower, accordingly the reinjection capacity also come down. Then the ways for avoiding return of reinjection water are considered as follows, from a view of fluid transmissibility and subsurface temperature gradient.

(i) Additional reinjection wells are needed especially far from production zone.

(ii) Deeper reinjection wells may avoid return of cool fluid.

(iii) Suitable utiliziation of reinjection wells.

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Table 1. Tracer testing results

	Iodine (SE-2)			Bromine (SD-4)		
	Initial Return time	**Peak Time**	**Maximum concentration** (mg/liter)	**Initial Return Time**	**Peak Time**	**Maximum concentration** (mg/liter)
SA-1	221 hrs (9 days)	989 hrs (41 days)	0.69	604 hrs (25 days)	2860 hrs (119 days)	2.3
SA-3	127 hrs (5 days)	869 hrs (43 days)	1.24	412 hrs (17 days)	3196 hrs (133 days)	2.6
SA-4	ND	ND	ND	ND	ND	ND
S-4	47 hrs (2 days)	188 hrs (8 days)	1.82	121 hrs (5 days)	268 hrs (11 days)	4.4
SB-1	47 hrs (2 days)	176 hrs (7 days)	5.7	677 hrs (28 days)	3196 hrs (133 days)	2.8
SC-1	140 hrs (6 days)	677 hrs (28 days)	0.33	220 hrs (9 days)	293 hrs (12 days)	3.6
SC-2	Not changed	-	-	1373 hrs (57 days)	2525 hrs (105 days)	1.8

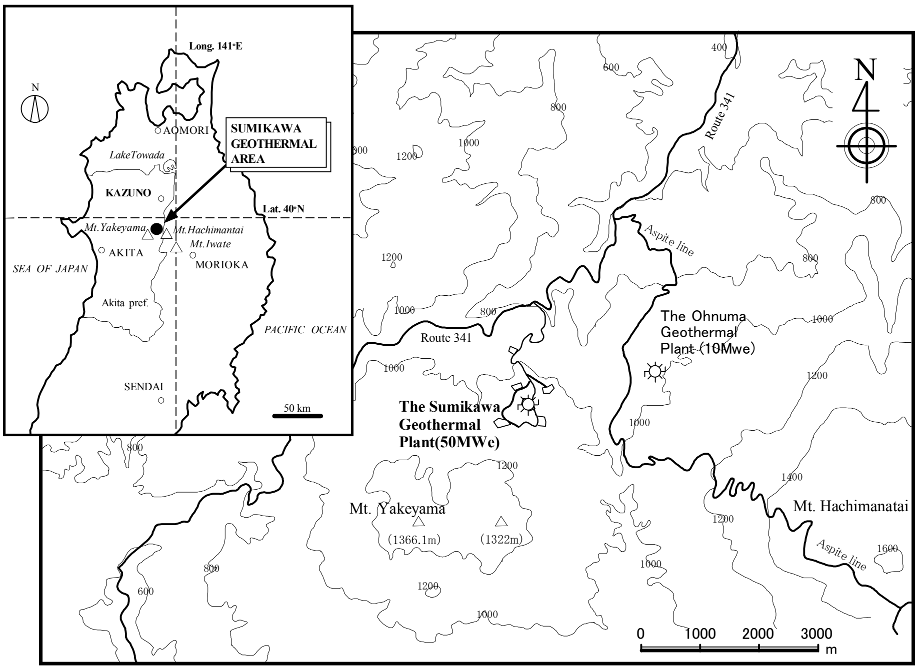

Figure 1. Location map of the Sumikawa Geothermal Field.

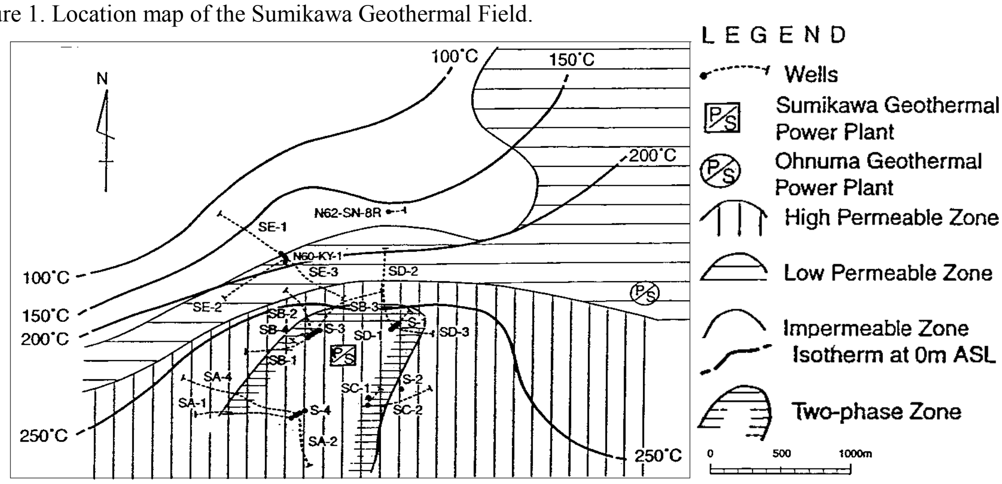

Figure 2. Map Showing Isothermal Contours at Sea Level and Permeability (after Bamba et al., 1995).

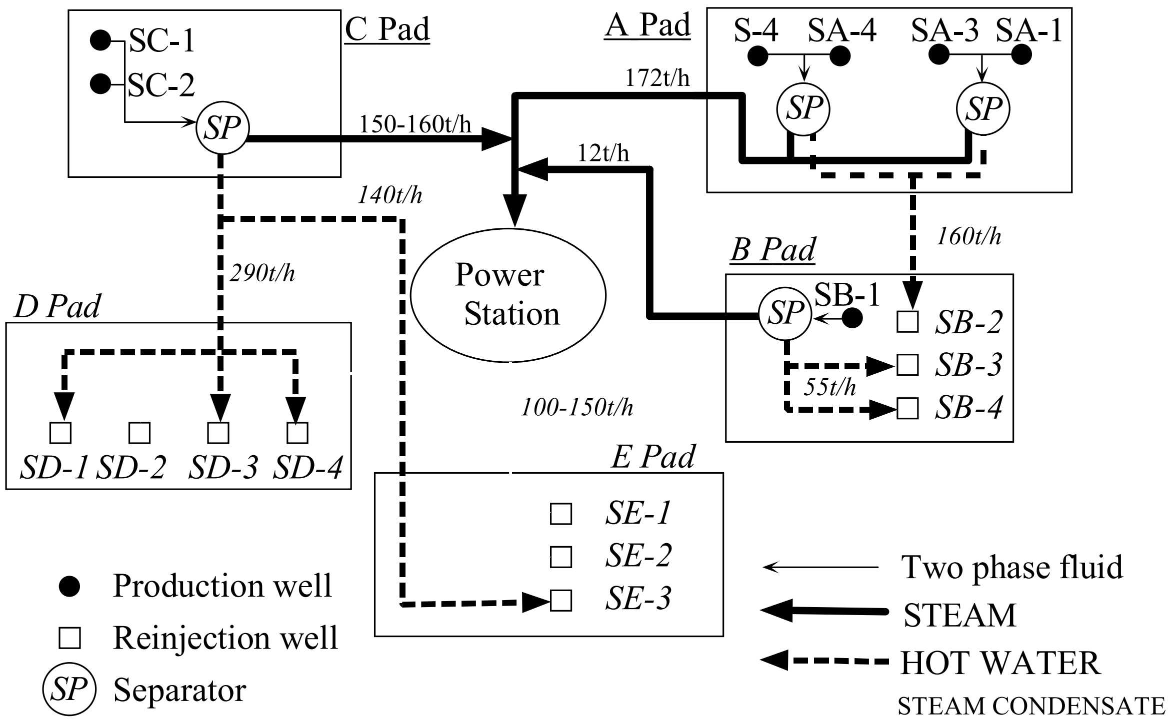

Figure 3. Schematic Gathering System at the Sumikawa Geothermal Field.

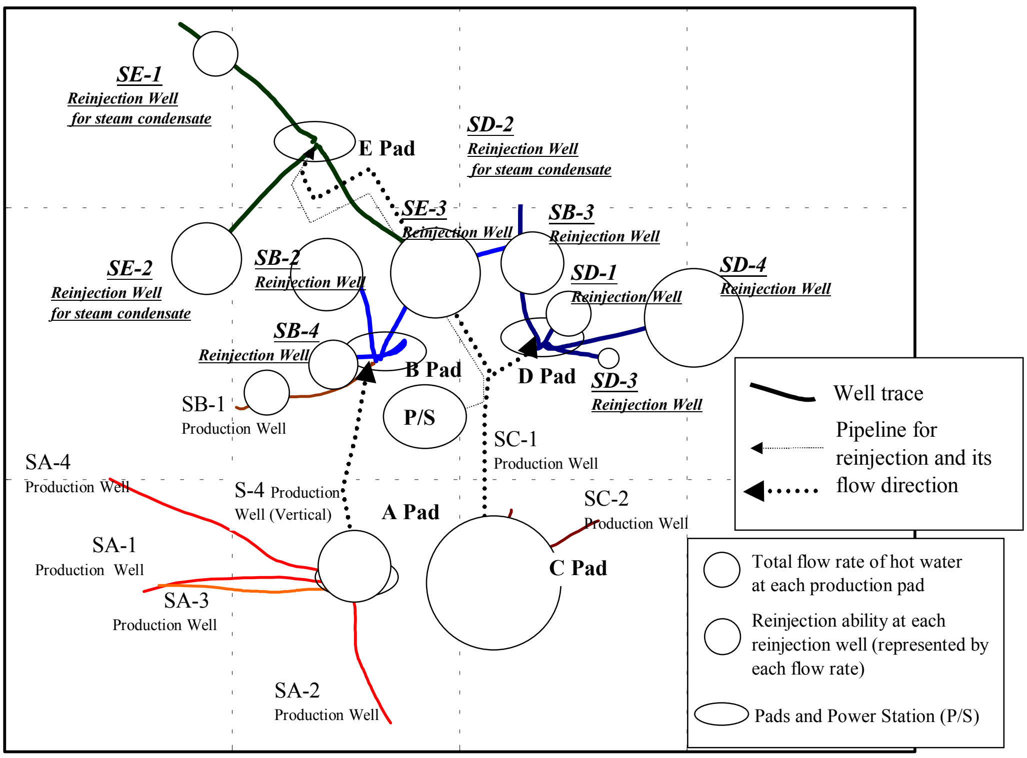

Figure 4. Map of Current Production and Injection Rates at Sumikawa.
Circle size represents reinjection capacity and amount of discharged water.

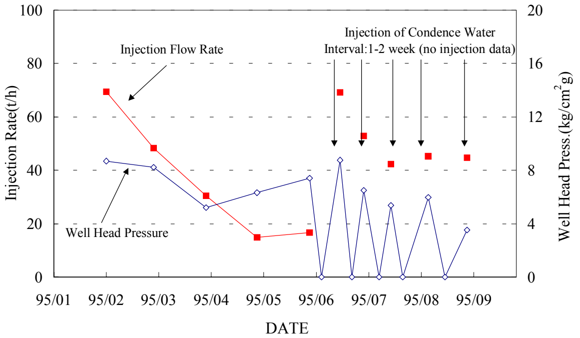

Figure 5. Wellhead Pressure History of Injection Well SD-1.

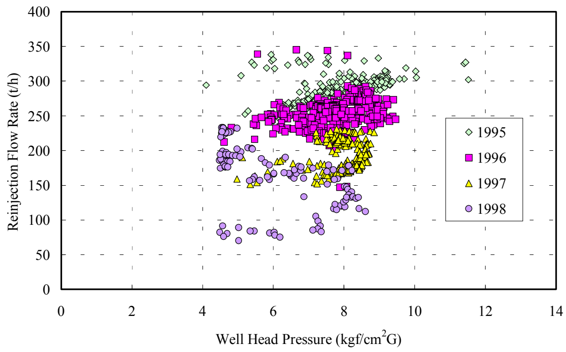

Figure 6. Graph of Reinjection Flow Rate vs Wellhead Pressure for Well SD-3.

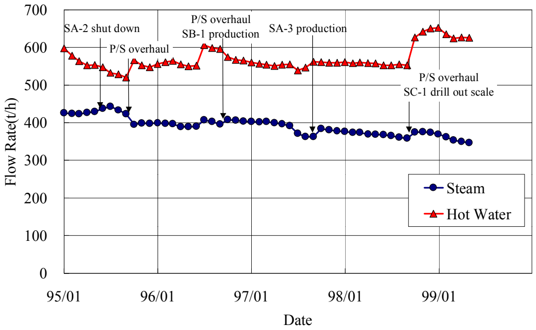

Figure 7. Graph of Total Mass Flow Rate and Steam Flow Rate vs Time at Sumikawa.

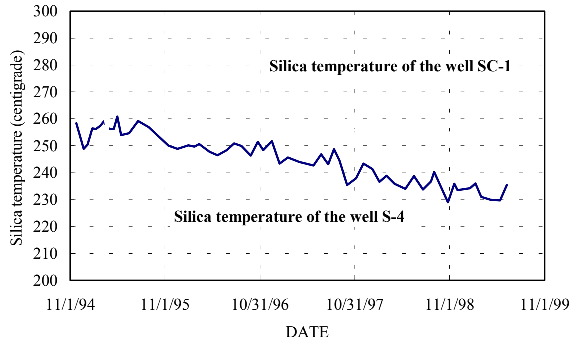

Figure 8. Silica Geothermometer Temperatures From Wells SC-1 and S-4.

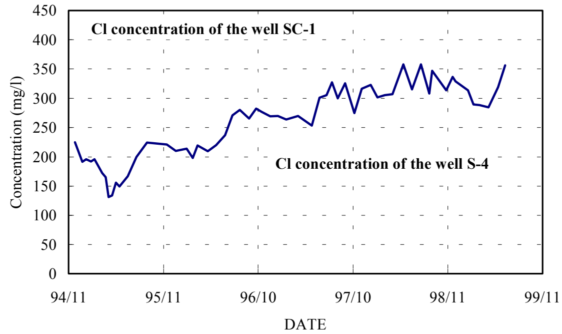

Figure 9. Chloride Concentration in Wells SC-1 and S-4 versus Time.

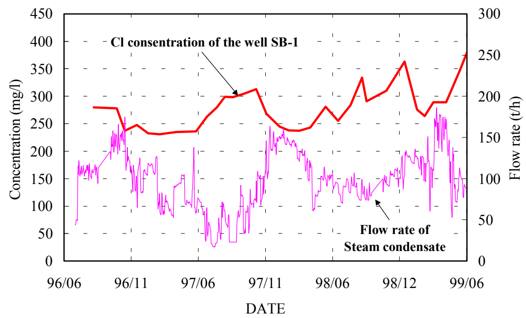

Figure 10. Graph of Chloride Concentration from Well SB-1 and Steam Condensate Injection Rates.