CHAPTER 3-6 Groundwater Quantity Management in Osaka City

1. Background to the Study Area

The city of Osaka is located in the western part of Japan. It lies along the coast from north to south and is open towards Osaka Bay on the west. The Yodo River runs through the northern part of the city and has long been its main source of water. The city area measures only 221.96 km^2 and was home to about 2.6 million people in 2002 (Osaka City 2006). Annual precipitation ranges from 950–1,300 mm. Most of the city is on lowlands on the Osaka Plain (except for Uemachi Hill located in the city center) located on an alluvial formation with rather soft ground, consisting of cohesive soil and sandy soil. The thickness of the alluvial formation in the coastal area of the city is about 35 m, which consists of layers of clay and silt (GEC 1994).

Osaka has been known for centuries as the city of merchants. In the beginning of the twentieth century, there was a rapid increase in manufacturing industries and heavy industries along the coast of Osaka Bay.
The city enjoyed a booming economy in the 1950s and 1960s, but it began to slow in the 1970s and its production value has decreased since 1990. Even so, Osaka's economic activity in 2003 was over 2 billion USD, more than the gross national product of either Hong Kong or Thailand.

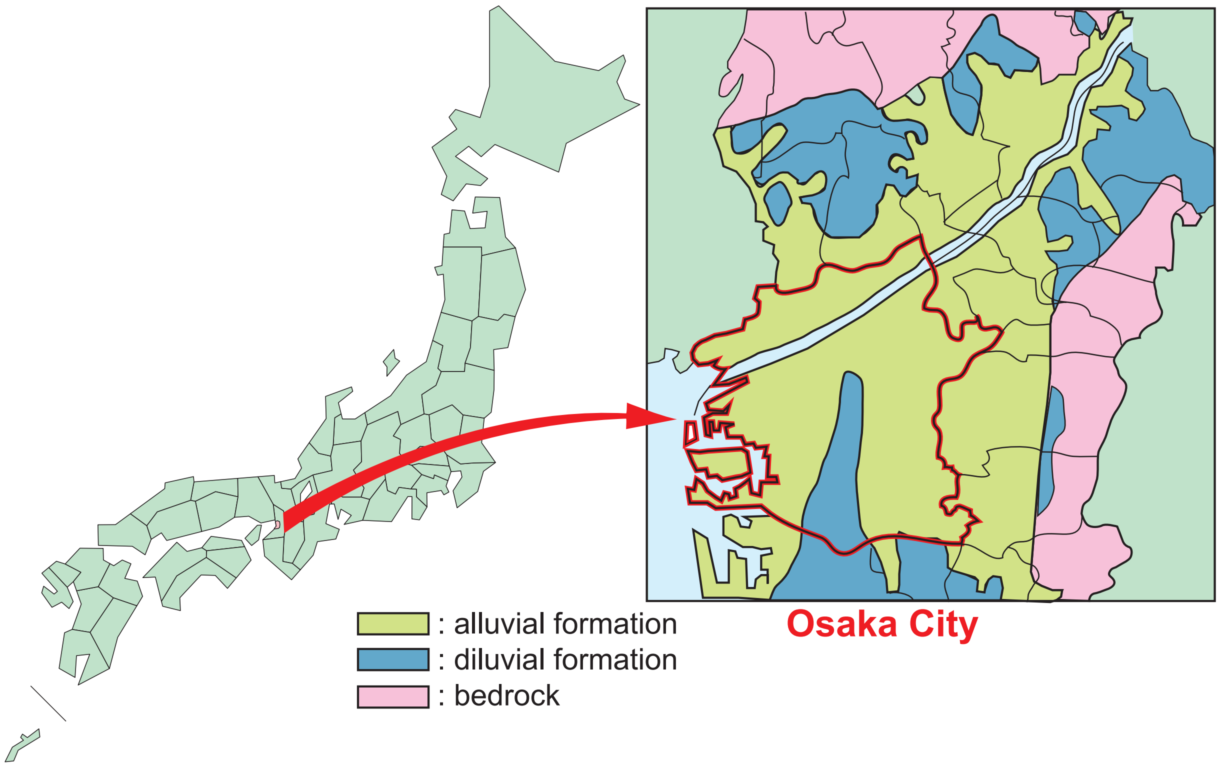

Figure 1. Location of Osaka and its Geological Characteristics
Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1993.

2. Groundwater Use and its Associated Problems

2.1 Groundwater Use

Historically, people in Osaka have depended on an abundant water supply from the Yodo River. A public water works was first constructed in 1885, and the coverage rate of the public water supply reached 100 percent by 1970. The volume of the annual water supply from the river in fiscal year 2002 was 495.5 million m^3 (Osaka City Waterworks Bureau 2003).

Groundwater has played a supplementary role to surface water in the city, because it was often too salty for drinking and therefore was used for non-drinking purposes such as washing or watering plants (Osaka City Waterworks Bureau 2000). On the other hand, it played an important role in the development of industry in the city. Intensive industrial use of groundwater began in the early 1900s, when the city experienced a boom in industrial development. In the 1950s, in the course of the economic reconstruction period after World War II, groundwater use began to intensify again. According to a survey of 30 factories in the industrial area of the city in 1955, 65.5% of total freshwater use depended on groundwater (Osaka City 1957). A new trend began in the 1950s of using groundwater for cooling and flushing purposes in large buildings such as office buildings and commercial buildings (Japan Society of Civil Engineers Kansai Chapter 2002).

Total groundwater pumpage in the city was 21 million m^3 in 1953 and reached its maximum in 1962 at about 123 million m^3/year, when 82% of abstraction was used by the industrial sector and the remaining volume by buildings. In the industrial sector, the food industry consumed groundwater the most (33%), followed by the paper and pulp industry (21%) and the chemical industry (18%)[1] . Figure 2 shows the types of groundwater for industrial use and building use in the same year. In both beneficial use, groundwater was used most for the cooling purposes (Osaka City Comprehensive Planning Bureau 1963).

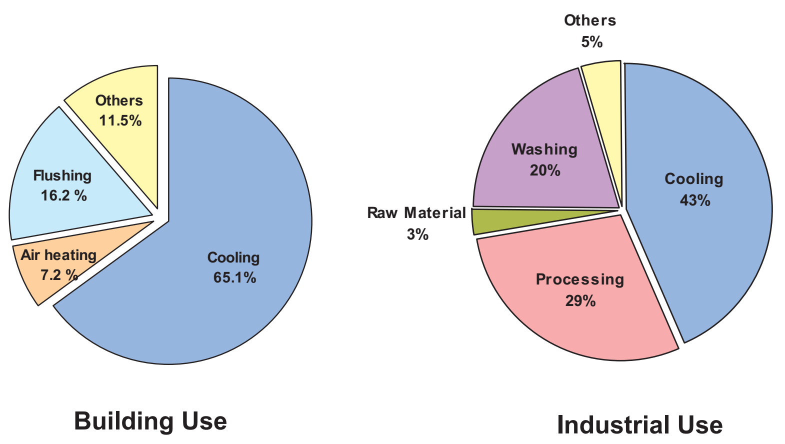

Figure 2. Groundwater Use in Osaka by Type of Use, 1962
Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1972.

1. According to a study in 1960, chemical industries consumed 32 percent of total industrial groundwater abstraction followed by food industries (22 percent) and paper industries. The drop of groundwater use of chemical industries from 1960 and 1962 was the result of introduction of more strict abstraction control measures in 1962.

2.2 Problems Caused by Excessive Abstraction

Land subsidence began to be observed in the 1920s in the industrial areas of coastal Osaka, but there was a scientific debate on the cause—geological processes or over-exploitation of groundwater. Therefore, no active countermeasures were implemented to control groundwater abstraction, but the city government started regular monitoring of land subsidence and the groundwater level to obtain chronological data. The incidence of subsidence ceased during World War II, but in the early 1950s, at the beginning of post-war economic growth, the water table began to drop again and the city resumed sinking (figure 3). The fact was acknowledged that there was a correlation between groundwater abstraction by the industrial sector and land subsidence, and the city government began to take action.

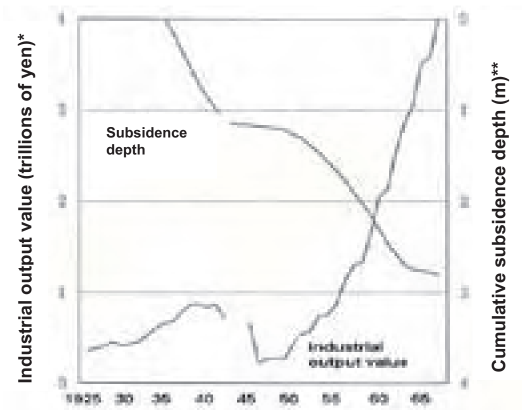

Figure 3. Land Subsidence and Industrial Output Value in Osaka
Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1993.
**In 1965 prices. **At Nishi-4 (Torishima, Konohana-ku)*

The increase in the magnitude of land subsidence resulted in various hindrances to the development of the city. As the land base sank, the height of dykes became lower and they lost their ability to protect the city from flooding. This resulted in a worsening of the negative impacts of flooding, especially during typhoons. The city had to spend about 2.5 billion USD (in 2000 prices) between 1955 and 1969 to reinforce dykes, raise bridges, and develop a drainage system (Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1972). Industries also had to invest in reconstruction and build their own dykes to protect themselves from flooding. Even so, damage to city infrastructure such as bridges and railway stations intensified. Such tangible evidence of the damage caused by land subsidence raised public awareness of the problem.

3. Policy Response

Management measures in Osaka started to work in controlling land subsidence by reducing groundwater abstraction. As figure 4 shows, there are two lines of management according to use: (1) industries and (2) buildings. The main element of groundwater control was regulations on abstraction, which were supported by provision of alternative water resources and financial and technical assistance to take the actions necessary to reduce groundwater use.

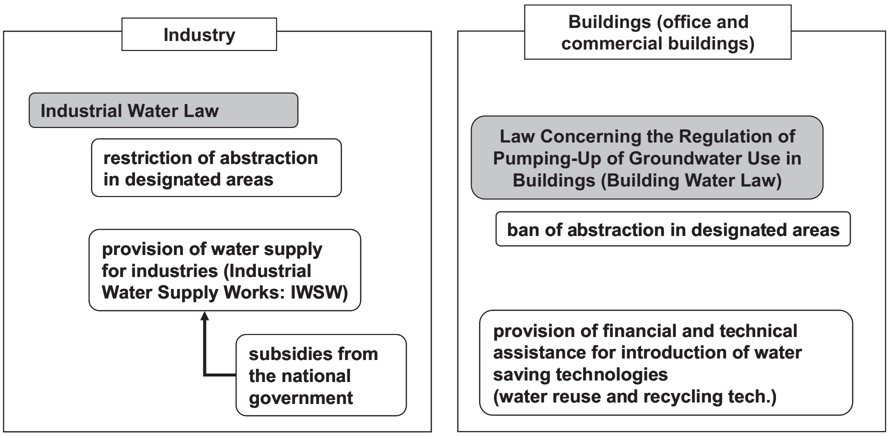

Figure 4. Outline of the Types of Groundwater Management in Osaka

3.1 Regulation of Groundwater Abstraction

The main element of effective groundwater management is regulation of groundwater abstraction. For the industrial sector, a national law, named the Industrial Water Law, was enacted in 1956. Even so, because groundwater is regarded as an exclusive right of landowners there was hesitation to regulate groundwater abstraction at that time. In one sense the law was a breakthrough for groundwater control, but as a tool for controlling groundwater abstraction it was very weak, because it only applied to new wells, not existing ones.

Another significant feature of the law was that it had the dual purposes of industrial development and controlling land subsidence in the designated area, and it set construction of plants for industrial water supply works (IWSW), a new scheme of water supply exclusively for the industrial sector, as one of the terms of groundwater control.

Regarding groundwater abstraction for use in buildings, the Osaka city government enacted the Osaka City Land Subsidence Control Ordinance in 1959 and tried to regulate well abstraction in five wards *(ku)* under the same conditions as the Industrial Water Law. Therefore, the ordinance did not apply to existing wells either.

Consequently, both the Industrial Water Law and the ordinance failed to effectively control groundwater abstraction, and land subsidence intensified. At Kujyo Station, located in the coastal area of the western part of the city, the groundwater level was recorded at minus 24.44 m in 1957, minus 26.84 m in 1959, and minus 31.09 m in 1962 (Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1972). The area affected by land subsidence expanded to the central and eastern parts of the city and intensified as well.

The Industrial Water Law was amended in 1962 to strengthen control of groundwater abstraction. In addition to restricting new well construction, pumping from existing wells also became regulated. Under the amendment, abstraction from wells with an outlet size more than 6 square centimeters and a depth up to 500 –600 m was prohibited in the city, which meant that smaller and deeper wells came under control of the law, making groundwater abstraction by industries in the city illegal. In the same year that the Industrial Water Law was amended, another national law on groundwater control, the Law Concerning the Regulation of the Pumpingup of Groundwater for Use in Buildings (the Building Water Law), was enacted to regulate groundwater pumping for use in buildings. The Building Water Law was different from the Industrial Water Law in that it did not mandate provision of an alternate water source as a condition of groundwater control. This was because groundwater demand for building use could be reduced by introducing water-saving technologies such as cooling towers.

3.2 Construction of Industrial Water Supply Works to Provide an Alternate Water Supply to Replace Groundwater

As mentioned above, provision of alternative water sources by the IWSW was a pre-condition of controlling groundwater pumping under the Industrial Water Law. Local governments (prefectures or 12 ordinancedesignated cities) were made responsible for the construction and operation of IWSWs. In Osaka city, construction of an IWSW plant had already started in 1951 as a measure to reduce industrial groundwater abstraction, and it began to supply surface water to industries even before the Industrial Water Law was enacted. After the Industrial Water Law was amended in 1962, IWSW water supply was expanded through new plant construction and expansion of supply capacity, in accordance with the groundwater abstraction restriction schedule (figure 5).

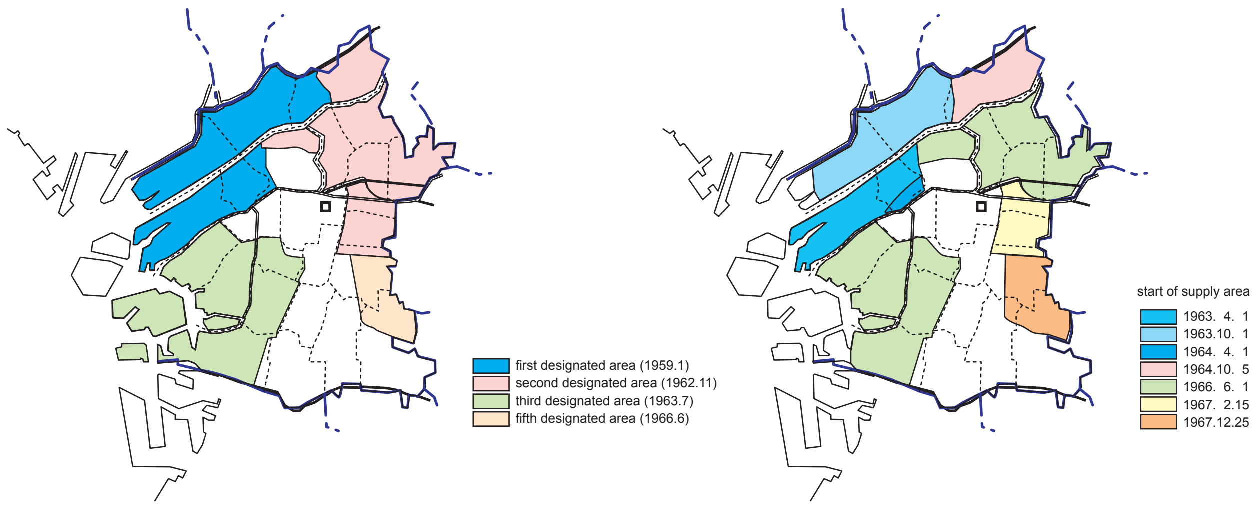

Figure 5. Areas Designated under the Industrial Water Law and Provision of Industrial Water Supply Works
Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1971.

The IWSW expansion project was completed in December 1968 and covered all the designated area with 575,500 m^3/day of total capacity (Osaka City Waterworks Bureau 2005). The tariff of IWSW in Osaka in 1954, 6.8 JPY/m^3, was calculated based on the cost of construction and operating the IWSW at that time. It was estimated that the cost of groundwater abstraction was about 3–4 JPY/m^3; therefore, the cost of industrial water supply was a little higher than the cost of groundwater abstraction. After the Industrial Water Law was enacted, the national government began providing subsidies for the tariff in order to set the IWSW water price as low as the cost of groundwater abstraction. To ensure regular revenues, the volume of water to be purchased by individual industries was set (the contracted volume), and industries had to pay for the contracted volume even if they used less water. This charging policy was criticized as a distortion of tariff structure and a barrier to promoting rational use of water in industrial sector (Simazu 1981).

3.3 Subsidies and Favorable Tax Treatment for Installation of Water-saving Technologies

Municipal governments provided subsidies and/or favorable tax treatment for installation of water-saving technology such as cooling towers, in particular for groundwater users regulated under the Building Water Law. Financial support in the form of a favorable tax and low rate loans was also provided to install the necessary equipment to receive water from industrial water works.

4. Effectiveness of the Intensive Measures to Manage Groundwater

4.1 Gaining Control of the Dropping Water Table and Land Subsidence

As figure 6 shows, groundwater abstraction by the industrial sector dramatically decreased and shifted to the IWSW water supply between 1963 and 1969, following the restriction schedule set out in the Industrial Water Law. Groundwater abstraction for building uses also sharply decreased for a few years after the Building Water Law was enacted in 1962. This reduction was achieved solely by the introduction of water conservation technologies, without provision of other water sources. As a result, the groundwater level began to rise and the land stopped sinking.

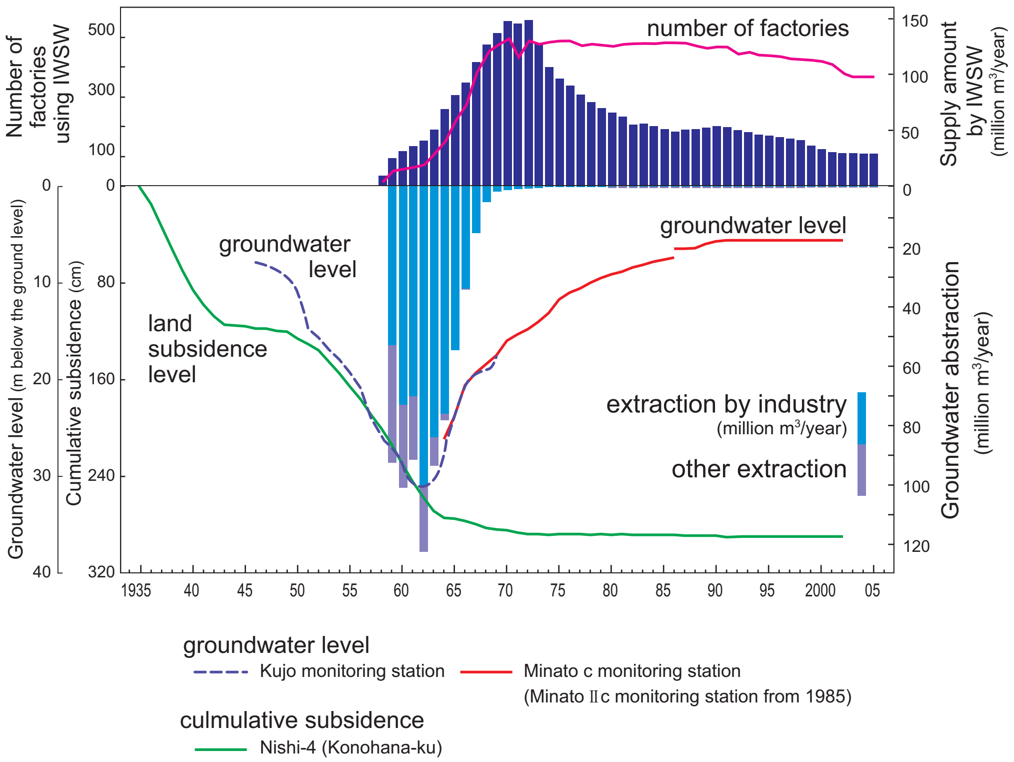

Figure 6. The Shift from Groundwater to Industrial Water Works for Water Supply in Osaka City

Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1993. for land subsidence and groundwater level. Osaka City Water Works Bureau 2005. for the data of industrial water supply works.

In addition to the three elements of control measures (regulations, provision of alternative water sources, and financial and technical support), the following should be mentioned as enabling factors in the success of the city of Osaka in reducing groundwater use:

i. Land subsidence was monitored by the city government for more than three decades, which helped in policymaking.
ii. The Committee on Comprehensive Countermeasures against Land Subsidence in Osaka was established as a platform of discussion on land subsidence issues between local governments (municipal and prefectural) and the industrial sector to tackle the problem.
iii. The main users of groundwater were industries and large buildings, and therefore control measures focused on these two sectors.
iv. Surface water was available as a source for the industrial water supply works.

4.2 Deficiency - Lack of a Comprehensive Groundwater Basin Management Strategy

Although intensive measures in Osaka effectively mitigated groundwater problems, when considering groundwater problems at the groundwater basin level, the delay in introduction of groundwater control in neighboring administrative areas caused the worsening of negative impacts of land subsidence. For example, in Higashi-Osaka area, which is also located in the Osaka Plain, the drop in water table and land subsidence intensified in the late 1960s to early 1970s (figure 7), while land subsidence had already stopped in the city of Osaka. It was five years later than Osaka that the Industrial Water Law was designated to apply to Higashi- Osaka. In 1971, the Osaka Prefectural Ordinance was enacted to mitigate land subsidence in the rest of the city area. The delay in the introduction of countermeasures intensified the incidence of land subsidence that could not be reversed. The countermeasures should have been introduced beyond the administrative boundaries.

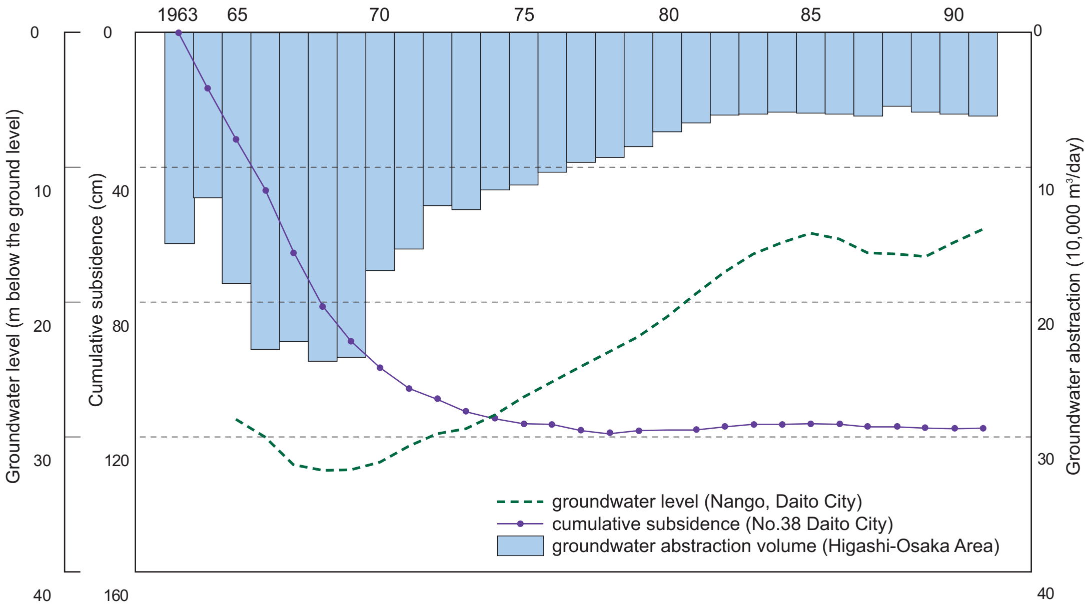

Figure 7. Cumulative Subsidence Depth and Drop in the Water Table in Higashi-Osaka
Source: Committee on Comprehensive Countermeasures against Land Subsidence in Osaka 1993.

4.3 Experiences of Other Japanese Cities and the Uniqueness of Osaka's Situation

In other Japanese cities, with different socioeconomic and environmental backgrounds, the effectiveness of the same policy measures was different from that in Osaka.

(1) Experience of Tokyo in Groundwater Quantity Management
Although the two national laws (Industrial Water Law and the Building Law) applied both in Osaka and Tokyo, it took more time in Tokyo to reduce groundwater abstraction. One of the reasons why it took time in Tokyo to reduce groundwater use is the limited availability of alternative water resources. As it was difficult to acquire the rights to river water use for IWSWs in Tokyo, this alternate supply could not be provided right away. As well, wastewater was also utilized as a source of IWSW in Tokyo instead of surface water, but industries hesitated to use it because of concerns about consistent water quality. In fact, IWSW using treated wastewater stopped their operation because of the quality of water they produced.

Another reason of the delay of groundwater use control is that the natural gas abstraction was a cause of groundwater abstraction in the Tokyo Bay Area. To cope with this, the Tokyo Metropolitan Government purchased the right of mining from the industries which abstract natural gas and stopped groundwater abstraction.

In addition, the Tokyo Metropolitan Government tried to promote reduction of groundwater use to request industries to rationalize groundwater use through the Pollution Control Ordinance issued in 1970. Under the groundwater use rationalization plan, groundwater users (mostly industries) with abstraction volume more than 1000 m^3/day were requested to reduce their use to the negotiated volume with the local government in 1975. In 1978, the request was extended to groundwater user with abstraction of 500 - 999 m^3/day and also to the groundwater users with abstraction of 250 - 499 m^3/day in 1981. The Pollution Control Ordinance also regulated smaller groundwater users who were not regulated by the national laws. Due to the efforts to rationalization of water use and more strict regulations to groundwater users by the local regulation, groundwater abstraction had been decreasing since 1970 in Tokyo.

(2) Hiratsuka's Experience

The rationalization of water use seemed to contribute substantially to the reduction of groundwater abstraction by the industrial sector. For example, in the city of Hiratsuka in Kanagawa Prefecture, industrial groundwater abstraction was successfully decreased through rationalization of water use. The city government set individual caps on groundwater abstraction for factories through negotiation and also encouraged water rationalization practices. As a result of promoting water conservation, total groundwater pumpage decreased from 100,000 m^3/day in 1972 to about 50,000 m^3/day in 1975 (Mizu Syushi Kenkyu Group 1993).

In accordance with the reduction of groundwater pumpage, the incidence of land subsidence in the city was also halted, and in 1976 the city declared that it had succeeded in stopping land subsidence. An analysis by Shibazaki (1981) showed that the introduction of wastewater treatment charges for industries was an incentive for them to reduce water use. It is estimated that industries had to spend 28–56 JPY/m^3 for wastewater treatment, while the investment cost for water-saving technology was about 19.5 JPY/m^3, and this economic advantage of water conservation motivated them to reduce their water consumption. Water pollution control measures strengthened in 1970s also contributed to promotion of water rationalization in the industrial sector. In order to meet effluent standards, industries had to introduce wastewater treatment technologies. They had to pay wastewater treatment charges. To minimize costs of wastewater treatment, industries tried to reduce the water inputs and also promote water recycling in the factories. In addition, the energy crisis (or oil shock) in 1973 further served to promote energy conservation practices in the industrial sector. The change in social consciousness became a driving force to promote water rationalization in industrial activities, which contributed to a reduction of groundwater pumpage in Japan, as seen in Tokyo and Hiratsuka.

(3) Water Recycling in Industries

Osaka also experienced a sharp increase in water recycling and reuse in 1970. The recycling rate was approximately 10% in 1958 increased to about 50% in 1970 and 90% in 2000. If the city had failed to control groundwater abstraction in 1960, water rationalization would have been a promising option for groundwater management. However, for the city, the incremental cost incurred by the introduction of IWSW water might have been the motivation for industries to employ water conservation, contrary to the experiences of Tokyo and Hiratsuka.

5. Long-term Impacts of Regulating Groundwater Pumping

More than fifty years have passed since groundwater control measures were introduced. The intensive measures have helped to maintain and conserve groundwater resources, but some contradictions were observed.

5.1 Increase of the Groundwater Level and the Effective Use of Available Resources

Strict groundwater control policy succeeded in mitigating falling groundwater levels and land subsidence in Osaka. The groundwater level has been rising as a result of the pumping regulations for about half a century, but this has caused damage to subway stations and water seepage and uplifting problems in underground structures. The rise of the water table may also increase the possibility of a liquefaction incident during an earthquake and therefore could intensify the damage to building infrastructure. To prevent such negative impacts of a higher groundwater table, groundwater should be abstracted and used more effectively. There is still a need for scientific study on safe yield levels, but the groundwater management policy should nevertheless be regularly reviewed and updated according to the current situation.

5.2 Decrease in Demand for Water from Industrial Water Supply Works

Figure 6 shows that IWSWs played an important role in controlling groundwater abstraction in Osaka. One of the advantages of the IWSW scheme is that construction of IWSW plants was rather simple and therefore they could be built relatively cheaper and quickly. The water treatment process can also be simpler, because quality control is less restricted than treating water for drinking (Aya and Matsumoto 2003). In other Japanese cities, IWSW plants were constructed for more effective water supply to industries rather than to control groundwater abstraction.

Figure 6 also shows, however, that the volume of IWSW water supply has been decreasing since 1974. As a result, IWSW revenues have also decreased. As a part of management restructuring, downsizing of supply capacity and even a plant shutdown were conducted. Since 1973, with permission of the Ministry of Economy, Trade and Industry, the Osaka IWSW began to supply water to the city government's facility in order to sell more of their water. Currently, 23 percent of the total IWSW water supply in Osaka is sold for non-industrial use (Osaka City Waterworks Bureau 2005). The IWSW capacity utilization rate is now only 50%, and the rate would be less than 40% if it were based on the average supply amount. As the IWSW was originally built for the industrial sector, it is not easy to sell the water for other uses. This challenge is a common management problem for IWSWs in Japan. The main reason for the decrease in demand for IWSW water was the increase in the rate of water recycling and reuse, as seen in figure 8.

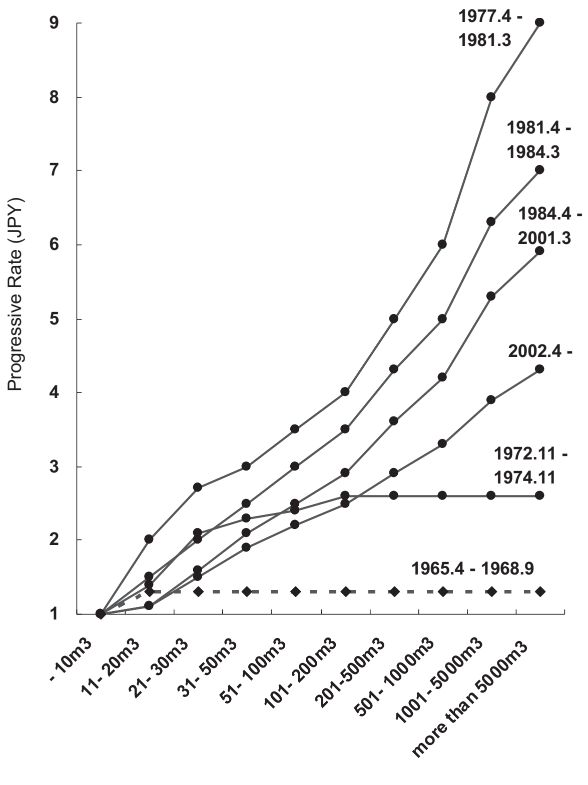

Figure 8. Progressive Rate of Sewage Charges in Osaka
Source: Takahashi 1992.

In the case of Osaka, as mentioned earlier, industries had to pay more for IWSW water. In addition, industries had to pay a tariff on sewage, and the city also introduced a progressive charging system for sewage, with large water users having to pay more than those that consumed less. At the same time, there was an additional charge on sewage based on wastewater quality (BOD and COD) introduced in 1974 (Takahashi 1992). This pricing system was designed as a water pollution control measure, but it also contributed to water rationalization by industries. In addition, national water policy encouraged water recycling and reuse in the industrial sector through financial and technical support to try to find a balance between limited water resources and growing water demands. Rationalization of water use in industry itself is a very good trend, but the current situation of IWSWs shows that groundwater management should be designed more closely linked with plans of other areas of water management such as surface water development, improvement of water efficiency, and pollution control. The IWSW experience also tells us that countermeasures to control groundwater should be flexible enough to cope with changes in water demand as a result of changes in social and economic conditions.

5.3 Potential Demand for Groundwater

After a half century of implementing control measures, it appears that groundwater is a resource that can be safely utilized again, and it is worth considering how to utilize surplus groundwater in Osaka without causing problems. On the other hand, the current trend of groundwater use in neighboring cities with less strict groundwater controls shows that the city needs to consider groundwater management in a bigger context of overall water management in the region. Recently, groundwater use by private water supply schemes for specific users, called senyo-suido, has been increasing in Osaka Prefecture. Senyo-suido is defined in the Waterworks Law as waterworks "for individual specific users of which the number is more than 101 persons and/or the maximum supply amount per day exceeds 20 m^3." Individual waterworks were often introduced for domestic use in areas without public water supply, but the recent trend shows an increase in individual waterworks using groundwater as their primary source. Large users of public water supply, such as hotels, fitness clubs, hospitals, and retail stores, are the main owners (users) of senyo-suido, and one of the major reasons why they use it is the lower cost of water. Under the current tariff structure for municipal water supply, heavy users have to pay more than individual customers. Consequently, a decrease of water demand from heavy users can directly affect the business of a municipal water supply plant, and it is presently a big problem for public water supply schemes, because it threatens the economic viability of public waterworks. In 2003, for example, 23 commercial-scale utility customers in Osaka Prefecture introduced their own water supply systems (based primarily on groundwater), the largest number compared to other prefectures. This resulted in a loss of revenue from April 2003 to March 2004 for the Prefectural Public Waterworks estimated at 350 million JPY (Osaka Prefecture 2004).

The city of Kusatsu in Shiga Prefecture, faced with an increase of groundwater use by commercial-scale users, reduced the tariff for large users (Okuno 2004). In addition, the city decided to publish the names of heavy water users who intended to stop or greatly reduce their purchases from the public water supply scheme. Groundwater should be effectively utilized where it is available. As the case of groundwater use in individual water works illustrates, the expansion of groundwater use can affect the economic viability of the existing water supply scheme. If public water supply provides cheaper water to heavy users in order to keep them using the public supply scheme, then there may be a risk of wasteful water use. One of the possible solutions to the problem is to introduce a charge system for groundwater abstraction, although more discussion is needed on how to calculate the appropriate price. In Japan, however, groundwater abstraction rights belong to those who own the land, in principle, making it difficult to charge a groundwater use fee. Without any control measures, groundwater is easily depleted by over-exploitation.

On the other hand, if properly managed, groundwater is a very reliable resource that provides various benefits. This case study of groundwater management in Osaka provides several lessons for future policymaking in Asian cities. For example, the study shows that the provision of alternative resources with strict regulation of groundwater pumping can effectively reduce pumpage volume. Under a critical state of groundwater resources in the course of industrial development, the intensive measures implemented in Osaka might be useful. As a long-term result, however, as the experience of the city revealed, intensive control of groundwater can increase the availability of the resource and allow its use again under proper control. In Bangkok, groundwater abstraction has been reduced to control the dropping groundwater level and land subsidence, but the city should not take the same path as Osaka in the future. While concentrating on controlling groundwater abstraction, it may be necessary to examine how to sustainably utilize groundwater, and this should include studies of past experiences elsewhere. Such a mediumand long-term perspective of management should be incorporated into policymaking and implementation.

The importance of demand management should also be more emphasized in groundwater management. The sharp decrease of water demand in the industrial sector in Osaka, which caused management problems for the local IWSW showed a great potential for rationalization of water use as a groundwater management measure. However, encouragement of water conservation practices in the industrial sector is not well incorporated in groundwater management in Asian cities, or such an effort has been promoted in the other area of water management. In order to reduce water inputs, efficient utilization is a very primary but important element of management of limited water resources, including groundwater. User fees or taxes are one of the tools that can control water demand. Altering water demand is very crucial for the management of other water sources, and therefore more comprehensive or integrated water management policy design should be promoted to avoid unnecessary wastefulness and damage to water resources.

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CHAPTER 1

CHAPTER 2

CHAPTER 3