PART I



RECOMMENDATIONS FOR SUSTAINABLE GROUNDWATER MANAGEMENT IN ASIAN CITIES

Groundwater management in Asian cities should be dynamic and proactive, considering not only the diversity of hydro-geological conditions but also the policy environment that keeps changing in the course of continuous urbanization and industrial development in Asian cities.

Groundwater is a reliable resource for drinking and production both in terms of quantity and quality. However, the resource is now under severe stress in some Asian cities because of the excessive groundwater abstraction in the course of socioeconomic development. Problems such as water table drawdown, decreasing well yield, land subsidence, and salinity intrusion that have emerged as the results of overexploitation of groundwater may incur socioeconomic losses and disturb the development of the cities that face the problems. These problems are either irreversible in nature or require extended periods to abate. Therefore, we need to consider how we can conserve this precious resource while taking full advantage of it for the development of Asia.

The overexploitation of groundwater has already created problems in cities such as Tianjin (China), Bandung (Indonesia) and Bangkok (Thailand). Although groundwater problems are not well recognized, a city experiencing rapid population and economic growth such as Ho Chi Minh City (Viet Nam) may depend more on groundwater to meet the growing demand for water, and experience subsequent problems with the groundwater. In the case of Colombo and Kandy (Sri Lanka), the groundwater has not been fully utilized. However, it has the potential of playing a supplemental role as the demand for water increases.

The following recommendations were created with the intention of highlighting promising or important elements for better groundwater management in the growing Asian cities. The recommendations are based on our empirical studies on groundwater in some Asian countries that have differing socioeconomic status: Tianjin (China), Bandung (Indonesia), Colombo and Kandy (Sri Lanka), Bangkok (Thailand), Ho Chi Minh City (Viet Nam), and Osaka (Japan). The recommendations consist of three parts, namely General Recommendations (from 1-1 to 1-4), Recommendations for Respective Beneficial Uses (from 2-1 to 2-7), and Recommendations for Overcoming Barriers to Implemtation (from 3-1 to 3-3). Some boxes are attached to provide the further infomation relevant to the recommendations.

Groundwater management should be implemented in accordance with the local hydro-geological, social, economic and cultural conditions. Therefore, our recommendations may not be universally applicable. Instead, they should be interpreted and optimized according to local contexts.

1. General Recommendations

1-1. The optimal combination of different policy measures can maximize the effectiveness of groundwater management. The review and adjustment of existing policy measures is crucial in meeting the changes in the socio-economic and environmental background of the respective cities.

The review of groundwater management of seven Asian cities shows that there are four major elements in groundwater management. They are: (a) regulation governing groundwater abstraction, (b) provision of economic incentives/disincentives to reduce groundwater abstraction (e.g. charges for groundwater usage and wastewater discharge), (c) provision of alternative water resources to groundwater, and (d) support for the major groundwater users in their water-saving activities (table I-1). **Successful groundwater management is a function of how optimally the different policy measures are integrated according to the local situations**.

It is also important that **groundwater management should be regularly reviewed and updated to meet the policy needs that can change over time**. In the case of Bangkok, the Groundwater Act was revised twice and strengthened to further regulate groundwater to meet the expansion of the city. In some Japanese cities, such as Osaka, regulations on groundwater abstraction enacted nearly a half century ago now need to be reviewed and updated to cope with emerging problems such as the excessive increase in the groundwater level.

1-2. Groundwater conservation should be an integral part of urban planning.

Urbanization is a typical phenomenon observed throughout the Asian region, and the accompanying land usage changes can alter the natural setting of the area in many ways. Water resources are heavily exploited and the land surface is completely disturbed and changed into either denuded, cultivated or paved areas. These changes reduce the area available to replenish the groundwater, thereby increasing and accelerating surface runoff. In addition, the increased demand for water as the city expands often draws attention to groundwater as a useful resource and often results in excessive abstraction as we observed in the case of Bandung.

To avoid this situation, **urban planning should incorporate measures to conserve groundwater**. The following factors may be considered:

- The establishment or protection of replenishing zones to retain the capacity for replenishing the groundwater;
- The introduction of decentralized recharge schemes in household or community areas such as backyard

Table I-1. Measures Taken in Selected Cities

measures / city	(a) Regulations governing groundwater abstraction	(b) Economic incentives/ disincentives to reduce groundwater abstraction	(c) Provision of alternative water resources	(d) Support for water saving activities
Bangkok	National law (to regulate all sectors in principle)	User charge and groundwater preservation charge	Surface water (by public water supply scheme)	No specific measures
Bandung	Local law (to regulate all sectors in principle)	User tax	Expansion to include surface water usage being considered	No specific measures
Tianjin	Local level (to regulate all sectors except agricultural use)	User charge	Surface water transfer from other basins	Water conservation policy for industries
Osaka	National laws (industrial and commercial-scale uses in control area)	No user charge, but wastewater treatment charge applies.	Surface water to industrial sector (by new water supply scheme for industries)	Financial support for the introduction of water-saving technologies

rainwater tanks;
- The installation of water-saving technology stipulated in the building code (e.g. recycled water for flushing toilets).

Such attempts have already been introduced in Japan, Western Australia and Chennai in India. Sri Lanka recently introduced a rainwater harvesting policy which mandates that all new large establishments should have rainwater harvesting facilities. As another step, they are planning to restrict the use of tap water in activities such as washing cars and gardening.

1-3. Groundwater management should be designed within the framework of a holistic urban water management policy.

It is a well-established fact that both groundwater and surface water are interlinked and have an interdependent relationship through the water cycle. Therefore, **it is essential to look at these two water sources more holistically rather than individually**. This approach not only optimizes management costs but is also very useful in minimizing risks during extreme situations such as droughts or incidents of contamination.

In many Asian cities including Tianjin, Bandung, Colombo and Ho Chi Minh City, surface water is highly contaminated as a result of the improper discharge of untreated wastewater and solid wastes from households and industry. Therefore, **surface water quality control should be further promoted in the context of preventing potential pollution to groundwater in Asian cities**.

1-4. Groundwater abstraction rights should be assigned to the government sector in statutory form to enable effective groundwater control.

Groundwater abstraction rights should be stipulated in a statutory form and a public entity (in principle, the national government) should be entitled to have overall responsibility of groundwater management for the effective control of groundwater abstraction.

In countries such as Japan and Sri Lanka where the groundwater use rights are not clearly defined by law, it is difficult for governments to take proactive responses to groundwater management, including the allocation of groundwater usage rights by the government and groundwater charges. Therefore, the **right to control groundwater resources should be assigned to governments** by law to ensure the effective allocation of groundwater resources to the respective beneficial applications.

On the other hand, the case of Bandung showed that a municipal government made available more groundwater abstraction permissions to generate more revenue, and this resulted in accelerated groundwater pumping. This indicates that government control over groundwater abstraction does not always contribute to conservation of the resources. To prevent this abuse of governmental responsibility, **a panel of different stakeholders including experts and groundwater users should be established to regularly monitor the groundwater management policy**.

2. Recommendations for Respective Beneficial Uses

For the Industrial Sector

Industry is a major user of groundwater in Asian cities and it consumes a huge amount of water. The trend in industrial activities is a big factor in changes in water demand. This was evident in Bandung, where groundwater abstraction had dramatically dropped in 1997 because many industries stopped or scale down production as a result of the Asian economic crisis. Therefore, the control of groundwater use by the industrial sector is the key to groundwater management in Asian cities.

2-1. Available government resources should be allocated more to water reuse and recycling in industry.

The encouragement of water conservation practices in industry is very effective both in controlling groundwater abstraction and in the conservation of available water resources, as the experience in Osaka shows.

Therefore, **governments should put the priority of their policies on encouraging the efforts of industry to conserve water and allocate more resources, both finance and human resources, for that purpose**. For example, groundwater control regulations should be implemented with the provision of technical guidance and modest financial support for the introduction of water-saving technologies. Improving water pollution control measures, such as enforcing effluent standards, can also encourage industry to minimize its water inputs to reduce the volume of wastewater.

The purpose and amount of groundwater usage differs according to the type of industry. Therefore, **it is also necessary to consider all types of industry to determine what types should be given priority**. For example, rather strict regulations governing groundwater usage can be introduced in combination with measures to promote the introduction of water-saving technologies to an industry, such as the steel industry, which uses a lot of water but can recycle wastewater within its production process. But for an industry that needs rather good-quality water and cannot recycle or reuse it in its production process, such as the food industry, the same combination of policy measures as those that apply to the steel industry cannot work well.

2-2. Groundwater usage charges, wastewater treatment charges and other economic disincentives for groundwater usage can effectively control the demand for groundwater.

Charging for groundwater usage can be an effective tool when properly applied as the experience of Bangkok and Bandung shows. In particular for the industrial sector, the system of charges work well because industries are more sensitive to increases in the cost of water in their production process. Bangkok's rapid increase in charges for the use of groundwater illustrates the effectiveness of a charging scheme to discourage groundwater abstraction (Box I-1). In addition to direct user charges, **indirect charges especially wastewater discharge/treatment charges can contribute to the reduction in groundwater abstraction**, as well. Hiratsuka City in Japan managed to halve the volume of industrial groundwater pumping from 1972 to 1976 by rationalizing water usage (Shibazaki 1981). An analysis concluded that the introduction of a wastewater treatment charge motivated industry further to rationalize its water usage. It was estimated that the wastewater treatment charge was 28 - 56 yen (0.24-0.48 USD)/m^3, which was below the investment for water-saving technology, estimated about 19.5 yen (0.17 USD)/m^3.

Box I-1. Effectiveness of Groundwater User Charges

The Success of Bangkok and the Inefficiency of Bandung in Introducing the Charging System

In the Bangkok study area, groundwater charge rates rapidly increased from 3.5 Bt (0.09 USD)/m^3 to 8.5 (0.22 USD)Bt/m^3 from 2000 to 2003, and the number of private wells began to decrease after 2001 (figure I-1). In addition to groundwater charges, the Groundwater Preservation Charges were

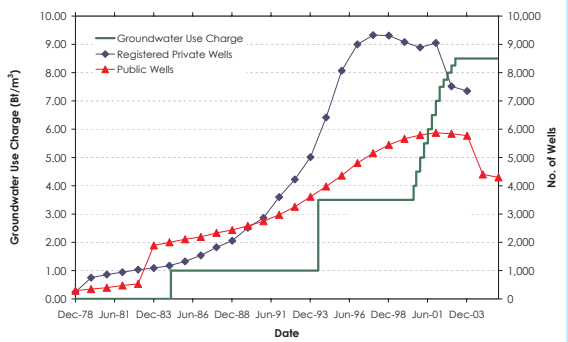

Figure I-1. Variations in Groundwater Usage Charges and Number of Private and Public Wells in Bangkok

introduced in 2004. The total amount of the two charges far exceeded the price of public water supply. Therefore, groundwater lost its attraction over surface water, particularly to industry, which consumes a large amount of water. On the other hand, in Bandung, groundwater tax were determined based on a calculation of the value of water which was stipulated by law. However, the groundwater charge ranged from about Rp 1,750 (0.19 USD) to Rp 3,138 (0.34 USD)/m^3, while the water tariff of public water supply was about Rp 2,725 (0.29 USD) to 9,600 (1.05 USD)/m^3 for industry. Because of the comparative strength of groundwater in terms of cost, industry continued to use groundwater although the level of the water table was decreasing. This indicates that the pricing of groundwater should be set at a price that is the same or higher than other sources of water if the groundwater charge intend to discourage groundwater usage. However, the affordability of the marginalized people, must be considered in price-set.

2-3. Governments should pay prior attention to groundwater pollution by Volatile Organic Compounds (VOCs) and take the necessary preventative measures.

In addition to heavy metals and toxic chemicals, contamination by substances known as Volatile Organic Compounds (VOCs), such as trichloroethylene and tetrachloroethylene, may emerge as the major pollutants in Asian cities in the course of industrial development. Trichloroethylene, for example, can be found in cleansing solvents used in such applications as metal and semi-conductor factories. With the possible development of related industries in Asia, the prevalence of aquifer contamination by the VOCs cannot be denied. Once aquifers and soils become contaminated with pollutants, it becomes difficult to remove the pollutants considering the available technologies and required cost, making it all the more important to take preventive measures. Environmental standards and the monitoring of suspected pollution sources should be introduced by the governments. The environmental or effluent standard targeted for these substances has not been set up in the cities in the case studies, except for Bangkok and Osaka.

Establishment of records and reporting system to promote voluntary improvements in business in the management of such chemicals, the so-called Pollutant Release and Transfer Register (PRTR) systems, is also an option to effectively manage the substances.

For the Domestic and Commercial Sectors

A substantial number of people living in Asian cities depend on groundwater as a source of drinking water. Municipal water supply in Bandung still depends on groundwater to some extent because of the available surface water resources. In Ho Chi Minh City, groundwater is also used as an important source of municipal water supply. Because groundwater is a decentralized resource, it is difficult to monitor and regulate groundwater abstraction by individuals. It is believed that a large number of unregistered wells, especially those for domestic usage, constitute one of the challenges of groundwater management. In terms of quality, shallow groundwater, on which many people depend, has deteriorated because of improper sanitary conditions.

2-4. Groundwater abstraction by heavy users should be minimized first in places facing excessive groundwater abstraction associated with negative impacts on society.

In places where the negative impacts of overexploitation of groundwater is substantial, minimization of or a ban on abstraction by heavy groundwater users such as public water suppliers and commercial and business users should be implemented first. Such an abstraction regulation should be accompanied by other initiatives, such as the provision of other water sources including rainwater and recycled water for non-drinking purposes; the repairs of water leakage; and the provision of temporary financial support for water saving technologies.

On the other hand, the monitoring and control of individual groundwater abstraction at household level should be also improved, e.g. through a community groundwater management scheme.

2-5. Proper guidance on on-site wastewater treatment should be provided for conservation of groundwater quality and the reduction of health risks.

It is well recognized that urbanization affects both the quantity and quality of the underlying groundwater systems in many ways. This is particularly true when a city straddles a productive shallow aquifer that is subject to heavy use. Major groundwater withdrawals results in the lowering of the water table and this can often result in increased water leaking from the surrounding layers. If waste disposal in the area is poor, as often seen in developing countries, the groundwater resource can easily become contaminated.

Shallow aquifer contamination is becoming a serious problem, especially because of the poorly managed or constructed on-site sanitary systems. In the case of Ho Chi Minh City, the incidence of the installation of improper septic tanks, which are not appropriately covered by concrete, is considerably high in some districts. More than 70% of the domestic septic tanks in two districts are reported to be improperly constructed, which increases the risk of effluent leaking from the septic tanks to contaminate shallow aquifers. The present situation in many of the other cities such as Colombo, Kandy and Bandung is not significantly different. The shallow groundwater in these cities is

often contaminated with coliforms.

One of the major causes of the shallow groundwater contamination is the lack of technical guidance in on-site sanitary systems. To control the quality of shallow aquifers in particular, the government should provide technical guidelines on construction and maintenance. In addition, awareness programs and technical training in maintenance should be given to the local people to enable them to follow the guidelines.

Box I-2.The Need for Proper Infrastructure Development

Safeguarding all water resources in the cities in the case study and as a whole within the Asia region as a whole is more critical mainly due to the limited coverage of proper piped water supply, and therefore a high percentage of people have to depend on alternative sources of water for their everyday needs. Among the area of the case study, most cities have very low water supply coverage (Bandung 20-50%, Colombo 44% and Kandy 39.5% with some areas less than 10%) forcing people to use shallow groundwater.

Many recent studies have shown that shallow groundwater contamination is very common, mainly due to poor wastewater management. Therefore, it is imperative to have proper sanitary disposal systems or domestic wastewater treatment plants accompanying the urbanization process. Moreover, the situation has been exacerbated by a number of factors. These include a lack of proper wastewater discharge standards. (In Sri Lanka, wastewater discharge standards do not include limits for nutrients.) Other factors are poor enforcement, such as Colombo, Kandy, Ho Chi Minh City, Bandung and Tianjin, and poor or nonexistent building regulations for onsite sanitary systems. Introducing strict standards will ensure the protection of the surface water resource as seepage from surface water bodies can contaminate the entire groundwater resource in the area. This is especially true in areas with heavily contaminated canal systems and rivers, such as Ho Chi Minh City, Bandung and Colombo.

For the Agricultural Sector

Urban sprawl is widespread in Asia. The conjunction of agricultural and urban areas is often observed in particular in peri-urban areas. Conflict over water, including groundwater, between the agricultural and urban sectors is recognized as an issue in Asian cities. Agriculture uses a substantial amount of water, and therefore the rationalization of the agricultural use of groundwater is a key in sustainability. Agricultural activities may have negative impacts on groundwater quality, and this has recently been observed in many Asian countries.

2-6. Groundwater use by the agricultural sector should be controlled to prevent possible environmental impact due to intensive exploitation.

In principle, groundwater use by all beneficiaries should be controlled to prevent the excessive abstraction of groundwater resource and its associated problems. However, groundwater abstraction control in the agricultural sector often remains insufficient. In particular, peri-urban areas, in the course of development, may be faced with conflicts in water demand between the agricultural sector and the growing domestic and industrial sectors. Therefore, the domestic and industrial sectors as well as the agricultural sector should be a target of groundwater management.

A registration and/or capping system of groundwater abstraction should be encouraged for the sector. In addition to such regulatory measures, support for the introduction of water conservation technology and expertise should also be promoted at the same time. This support includes financial assistance for the introduction of available technology to promote less-water intensive agricultural production.

Box I-3. Sri Lanka's Agrowell Program

The introduction of the latest irrigation techniques through subsidy schemes can improve the irrigation efficiency but require better planning for control of usage

The recently introduced subsidy program in Sri Lanka, the "Agrowell Program," encourages shallow groundwater irrigation to enable individual peasant farmers to irrigate their crops at their discretion and to diversify their activities.

Although the program has substantially improved the economic conditions of the local farmers, the rapid and uncontrolled diffusion of groundwater extraction and practices that include excessive irrigation and the overuse of fertilizers is presenting the risk of the shallow groundwater receding and of the groundwater becoming contaminated by excess nutrients. Therefore it is vital to raise the farmer's awareness and introduce new technology to improve irrigation efficiency along with such programs to prevent these outcomes.

2-7. Fertilizer inputs should be capped to reduce the nitrate contamination of groundwater.

Nitrate and pesticide contamination in aquifers has been identified as a major problem in many Asian cities. For example, nitrate was the most frequently detected substance among the 18 chemicals in a national survey of groundwater quality conducted in Japan in 1982. Approximately ten percent of the 1360 samples exceeded 10 mg/l, the drinkable limit for nitrates in Japan. Rather high values of nitrates in aquifers have been detected in Bandung, Ho Chi Minh City, Colombo and Kandy.

Fertilizer use in agriculture in believed to be the main cause of nitrate contamination. The reason is that excessive nitrates in soil can leak into the groundwater, leading to nitrate contamination. More fertilizer tends to be used for more agricultural production to sustain an increasing population and generating more income. Measures should be taken in advance without much impact on the farmers. Capping the inputs of fertilizers is one alternative, as in the test case of Kakamigahara in Japan (Box I-4). In conjunction with the necessary technical improvements, a capping policy should be encouraged.

Box I-4. Reduction in the Use of Fertilizers Will Not Harm Agricultural Production

- A Field Survey in Kakamigahara, Japan -

Kakamigahara, Gifu Prefecture, Japan is known for its carrot production. In this city, most of the potable water comes from groundwater. However, the nitrate concentration of groundwater had been increasing since the 1970s, resulting in the damage for groundwater usage in this area. The overuse of fertilizers in agricultural activities was suspected as a cause for the high nitrate concentration, and thus better management of fertilizer use was a timely requirement. Field surveys conducted in the city revealed that reduction in the use of fertilizers by around 25 % from 400 kg-N/ha/y to 300 kg-N/ha/y was possible without harming the production and the quality of the carrots.

This is a good example of better fertilizer management, where an attempt is made to protect aquifers from nitrate contamination. It is critical for farmers to become aware that an appropriate amount of fertilizer should be consumed in the farming, avoiding the overuse of fertilizers. In this regard, public awareness is essential in promoting an appropriate volume of fertilizer use in farming.

(source) Hirata. T, 2000

3. Recommendations for Overcoming Barriers to Implementation

3-1. Scientific research and monitoring should be promoted by governments and research institutes to obtain reliable information for groundwater policy-making.

Reliable information is essential for effective policy-making and implementation. However, the groundwater resources in the cities in the case study are often poorly understood by both the decision-makers and the users of the groundwater. Even if there is available information, it is not well organized and not properly shared among relevant stakeholders. The poor situation concerning groundwater information makes groundwater management in the case study cities difficult.

Therefore, the monitoring of groundwater quality and quantity should be regularly conducted and properly organized so that the data can be readily used for policy-making. International cooperation in understanding the resources should be encouraged to improve the capacity of human resources to manage the knowledge.

Box I-5. Common Database, Funding for Research and International Cooperation for the Sustainability of the Groundwater Resources within National Boundaries

The existing monitoring programs are very limited, as is reliable information and research on the groundwater in cities in the case study. In all cases, the extent of available resources is poorly understood and in most cases, only approximate safe yields are available. With very few new research studies being initiated recently, the situation has become critical. For example, no programs for proper monitoring of groundwater quantity and related problems were seen except in Bangkok. Significantly, there was no monitoring of groundwater quality whatsoever in Bandung, Colombo or Kandy. Most of the available data within the cities is either incomplete or of doubtful reliability. Even the limited data is scattered making access and use difficult.

In terms of quality data, the situation is even worse. Neither city has given any priority to the monitoring of quality. Also, the

influence of global issues, such as the far-reaching and increasingly severe effects of climate change, has not even been considered. This is particularly true in Colombo, one of the cities in the case study, which is facing surface water shortages from changes in rainfall patterns. The effects are being felt in the groundwater resources. The problems are felt in other cities, although the extent of the problem is unknown due to the lack of research.

These facts indicate that it is apparent that the available data is very limited within Asia and that negligible focus is given to research. These deficiencies often delay policy-making decisions as no facts or persuasive data is available to guide the policymakers. These details also show that the lack of information and research is the main reason for the cities in the case study facing groundwater problems. Therefore, the urgent attention of decision-makers is required. This may be achieved through a common database, through the establishment of a fund for research (such as that implemented in Bangkok through a groundwater preservation levy) and through international forums to share research findings.

3-2. An agency should be established and reinforced to direct the coordination and facilitation of groundwater policy-making and implementation.

In most of the cities in the case study, there is more than one institute that has different and sometimes overlapping responsibilities in groundwater management. This discrepancy in institutional arrangement becomes an obstacle to the implementation of holistic management planning and implementation.

One such example is in Sri Lanka, where three agencies are involved in groundwater development and research, and there is very poor coordination between them. They very seldom share information, instead blaming each other for failures. Also, in Bandung, the policy of political decentralization assigned the responsibility for policy-making and implementation to the municipality level. This devolution of authority is basically beneficial for water management because it becomes possible to implement water management close to the users. However, in the case of Bandung, the new responsible resulted in an increase in groundwater abstraction. In Ho Chi Minh City, the necessary data is scattered among relevant organizations and is not well utilized in policy-making. On the contrary, in the case of Bangkok, the Department of Groundwater Resources of the Ministry of Natural Resource and Environment is responsible for overseeing activities related to groundwater resources and contributed to the groundwater management.

3-3. Dialogues among relevant stakeholders should be incorporated in the policy-making and review process as a tool for promoting efforts in groundwater conservation.

The stakeholder meetings that were organized in the case studies showed that such gatherings were helpful in enhancing awareness of groundwater issues and mutual understanding among the stakeholders. Lack of proper understanding and awareness of groundwater issues is one of the major barriers to the implementation of groundwater control measures. Therefore, an opportunity such as stakeholder meetings should be incorporated in a management cycle of groundwater to remove the barriers.

References

Hirata, T. 2000. Groundwater Quality Management. *In Water Pollution Control Policy and Management : The Japanese experience*, edited by Okada, M and Peterson,S.A,102-112.Tokyo: Gyosei

Shibazaki, T. 1981. Chikasui riyo hozen no shinkyokumen, sono chiho bunsanka to tayo-ka ni taioshite [New dimension of groundwater conservation — corresponding to localization and diversification]. In *Gendai no Mizu Mondai (Julist Zokan Sogo Tokusyu 23)*, 57-64. Tokyo: Yuhikaku.