Research Institute for Humanity and Nature Project 2-4

Human Impacts on Urban Subsurface Environments

Progress Report 2007

NO.4

Makoto Taniguchi, Research Institute for Humanity and Nature, Feb. 2008

Preface

This is the Progress Report on the RIHN (Research Institute for Humanity and Nature) Project FR2-4 "**Human impacts on urban subsurface environment**", which started in 2003 as Incubation Study, followed by Feasibility Study (2004), Preliminary Research (2005), and Full Research (2006).

This project aims to evaluate the relationship between the development stage of the city and various subsurface environmental problems which were ignored for a long time because of the invisibility of the problems and the difficulty of evaluations. The project has four sub-themes; **urban**, **water**, **heat,** and **material**, and the target study areas are the basins including Tokyo, Osaka, Bangkok, Jakarta, Manila, Seoul, and Taipei. The research groups, with about 60 project members, have done many field works, analyses, and discussion at domestic and international meetings.

In this progress report, the summary of the interim results of the project and results from each sub-group are presented. In order to integrate the results of this project, the **2nd International Symposium and Workshop** was held in Bali, Indonesia on Dec 4-8, 2007, which was also authorized as one of the side events of COP13. The number of symposium participants was 157 and they came from 9 countries (Indonesia, Japan, Thailand, Philippines, USA, Germany, Australia, Korea and Taiwan).

The interim results of the project are also planned to be published in a special issue of **STOTEN (Science of Total Environment,** Elsevier) Journal in 2008. New methods for evaluating the changes in groundwater storage by Satellite GRACE, and residence time by ^{85}Kr and CFCs, have been developed in this project. The results of submarine groundwater discharge and dissolved material transports through groundwater into the ocean by using stable isotopes (C, N, O, Sr) revealed the origin of groundwater in each city. The study on subsurface temperature in Asian cities showed the magnitude and timing of urbanization, and the results published in the peer reviewed paper were also introduced in the open scientific news "Scitizen".

Cross cutting themes, such as groundwater and religion, laws and change in reliable water resources between groundwater and surface water, development of integrated indicators based on GIS for understanding the relationship between human activities and subsurface environment, and combining subsurface environmental problems into socio-economic model, have been considered as additional insights for the project.

The RIHN Project 2-4 also works with UNESCO-**GRAPHIC** (**G**roundwater **R**esources **A**ssessment under the **P**ressures of **H**uman**i**ty and **C**limate Changes), GWSP (Global Water System Program) - Asia network, and other international organizations. The results of the project were featured in some newspapers (Yomiuri and Mainichi), radio show (Kyoto Broadcasting System), and open lectures.

February 2008
Kyoto Japan

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Project Leader of FR2-4
Research Institute for Humanity and Nature (RIHN)

RIHN Research Project 2-4

"Human Impacts on Urban Subsurface Environments"

Progress Report 2007

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Human and climate impacts on subsurface environments in Asia

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Abstract

Global environmental problems have been considered only above the ground, however, subsurface environments are also affected. Global warming and heat island effects penetrate into the subsurface, then creates subsurface thermal anomaly in many Asian cities. Land cover/use changes due to urbanization alter the groundwater quality and management of subsurface environment. Contaminants in groundwater and soil water are stored in subsurface environment and then been discharged by groundwater into the coastal zone. RIHN (Research Institute for Humanity and Nature) project "Human impacts on urban subsurface environments" and UNESCO-GRAPHIC (Groundwater Assessment under the Pressures of Humanity and Climate Change) project, which are now on going, suggest better future developments of subsurface environment for human well- being under the pressures of human activities and climate change. Water, heat, and material environments in subsurface are evaluated by investigating changes in groundwater resources using remote gravity measurements and satellite data, reconstructions of climate changes and urbanization using subsurface thermal regimes, and evaluations of contamination from preserved subsurface indexes.

1. Introduction

Subsurface environmental problems such as land subsidence due to excessive groundwater pumping, groundwater contamination, and subsurface thermal anomalies have occurred repeatedly in large Asian cities with a time lag depending on the development stages of urbanization (Taniguchi 2005, 2007a). Therefore, we may be able to assess future scenarios if we can evaluate the relationships between subsurface environmental problems and the development stage of the city. RIHN (Research Institute for Humanity and Nature) project "Human impacts on urban subsurface environments" has started to evaluate these relationships to suggest better future developments of subsurface environment for human well- being (http://www.chikyu.ac.jp/USE/).

In addition to the effects of urbanization on subsurface environment, the effects of climate change should be incorporated in an integrated management of urban groundwater. UNESCO-GRAPHIC (Groundwater Assessment under the Pressures of Humanity and Climate Change) project, which is now on going, advances the sustainable groundwater management in the face of climate change and linked human impacts. GRAPHIC provides a platform for exchange of information through case studies, thematic working groups, research, and communication. GRAPHIC serves the global community through providing scientifically-based recommendations that are policy relevant. GRAPHIC uses regional and global networks to improve capacity to manage groundwater resources (http://www.chikyu.ac.jp/USE/GRAPHIC/GRAPHIC.htm).

The purpose of this study is to evaluate both climate and human impacts on subsurface environments in Asia, for integrated management of the urban groundwater under the condition of various subsurface environmental problems, such as extreme subsidence, groundwater contamination, and subsurface thermal anomalies.

2. Groundwater uses and land subsidence

Land subsidence due to excessive groundwater pumping occurred in many sedimentary aquifers near the coast such as delta in the coastal cities in Asia. For instance, the land subsidence in the Osaka plain had been observed since 1930's due to excessive groundwater pumping for industrial water uses, then local government regulated the pumping after 1960's. On the other hand in Bangkok, land subsidence has been found in 1970', and the government regulated the pumping in late 1990's.

According to the changes in groundwater pumping rates and groundwater levels in both Osaka and Bangkok (Taniguchi 2005), .the groundwater pumping rate in Osaka decreased after 1960' (with the highest peak on 1963) due to regulation of groundwater uses. On the other hand, the groundwater pumping rate increased since 1960's in Bangkok with the peak on 1999. After then, the groundwater pumping rate decreased due to regulation of the groundwater use by Thailand government. The time lag of maximum groundwater pumping rate between Osaka and Bangkok was 35 years (1999-1963).

The lowest peak of the groundwater level at Osaka due to groundwater pumping was found on 1971, which was 8 years after pumping peak (1963). On the other hand, the lowest groundwater level in Bangkok was found around 1997-1999, which shows no time lag between the maximum of groundwater pumping rate and minimum of the groundwater level. The time lag of minimum groundwater level between Osaka and Bangkok was 26-29 years (1997/1999 – 1971).

According to the records of land subsidence in both cities, the land subsidence generally ceased around 1978 in Osaka, and 1999 in Bangkok, though the subsidence is still going on I some areas. The time lag between these years between Osaka and Bangkok was 19 years (1999 – 1978). According to these comparisons of groundwater pumping rate, groundwater level, and the amount of land subsidence between Osaka and Bangkok, the responses of decrease in groundwater level and amount of land subsidence due to pumping was fast in Bangkok rather than Osaka.

The time needed for compression (land subsidence) depends on mainly hydraulic conductivity and thickness of the clay layer. In the case of Osaka, the hydraulic conductivity and the thickness of the clay layer is smaller and thicker than those of Osaka, respectively. Therefore t in Osaka is larger than that of Bangkok. This may be the reason the time difference between groundwater depression and land subsidence is smaller in Bangkok than that in Osaka.

3. Groundwater contamination and loads to the ocean

Another important aspect of the subsurface environment concerns material (contaminant) transport to the coast. Research over the last few years has shown that direct groundwater discharge to the coastal zone is a significant water and material pathway from land to ocean (Moore, 1996; Taniguchi *et al.*, 2002; Burnett *et al.*, 2003). We hypothesize that many water quality and associated problems influencing coastal environments around the world today are related to past and on-going contamination of terrestrial groundwater because that groundwater is now seeping out along many shorelines. For instance, chronic inputs of fertilizers and sewage on land over several decades have resulted in higher groundwater nitrogen, and the slow yet persistent discharge along the coast, may eventually result in coastal marine eutrophication. Such inputs may contribute to the increased occurrences of coastal hypoxia, nuisance algal blooms, and associated ecosystem consequences. Since most Asian cities are located along the coast, material and contaminant transport by groundwater is a key to understanding present and future coastal water pollution and its effects on associated ecosystems (Capone and Bautista, 1985).

While investigations of groundwater discharge into the coastal zone have increased dramatically over the last several years, few studies were performed in and around the urban centers and very few were conducted in Asia except Japan (Taniguchi *et al*., 2002). A multidisciplinary approach was recently taken to assess the potential importance of groundwater seepage to nutrient inputs into Manila Bay, The Philippines (Taniguchi *et al.*, 2007a). Three lines of seepage meters were installed in transects along the coast at Mariveles, Bataan Province during the period between 8 - 10 January 2005. The seepage rates along the northern most line showed the highest submarine groundwater discharge (SGD) at rates of 7.1-10.9 cm day^{-1}. The overall average seepage flux was 5.1±5.4 cm/day with a range of 0-26 cm/day. Additional methodologies employed included automatic seepage meters, resistivity measurements, and use of natural radon as a groundwater tracer. Seepage meter and tracer results provided consistent results of estimates of SGD into Manila Bay. Both methods also showed that seepage fluxes are not steady-state but are modulated by the tides. Resistivity profiles show that the saline-freshwater interface moves on a tidal time scale. Our results show that dissolved inorganic nitrogen (DIN) fluxes via SGD are comparable in magnitude to DIN fluxes from each of the two major rivers that drain into Manila Bay.

4. Subsurface thermal anomaly

Global warming is considered a serious contemporary environmental issue, and the discussion of the phenomena is limited to the issues above the ground. However, subsurface temperatures are also affected by surface warming (Huang *et al*., 2000). In addition, the “heat island effect” due to urbanization creates subsurface thermal anomalies in many cities (Taniguchi and Uemura, 2005). The combined effects of these two processes may reach up to more than 100 meters below the surface, and can have potential consequences on groundwater system. The effect of heat island due to urbanization and global warming on subsurface temperature is one of the global groundwater quality issues because increased subsurface temperature alters groundwater system chemically and microbiologically through geochemical and geobiological reactions (e.g., Knorr *et al*., 2005) that are temperature sensitive, which may increase degradation of groundwater resources.. Subsurface temperatures in four Asian cities (Tokyo, Osaka, Bangkok and Seoul) have been evaluated to estimate the effects of surface warming due to urbanization and global warming, and the developmental stage of each city (Taniguchi *et al.*, 2007b). Mean surface warming in each city ranged from 1.8^{o}C to 2.8^{o}C. The depth of deviation from the regional geothermal gradient was deepest in Tokyo (140m), followed by Osaka (80 m), Seoul (50 m), and Bangkok (50 m). The analysis of the timing of the start of surface warming showed that the depth of 0.1^{o}C deviation from a constant geothermal gradient in subsurface temperature was deeper when the elapsed time from the start of surface warming due to urbanization was larger. This trend was confirmed by air temperature records in the study areas during the last 100 years (Taniguchi *et al.*, 2007b). The heat island effect due to urbanization on subsurface temperature is an important global groundwater quality issue, because it may alter groundwater systems geochemically and microbiologically. Many cities in the world have the same problem, particularly in Asia, where population is increasing rapidly.

5. Conclusions

Both human and climate impacts on subsurface environments are evaluated from the points of views of water, material and thermal transports in subsurface environment of Asian cities. Comparisons of changes between groundwater pumping rate and groundwater level in both Osaka and Bangkok showed that the time needed for compression (land subsidence) depends on mainly hydraulic conductivity and thickness of the clay layer as well as pumping rate. Material transport by groundwater was considered as one of important pathways from the land to the ocean. The evaluations of groundwater discharge by seepage meter, resistivity and radon as a tracer are have been made in Asian cities. Global warming and heat island effects as human and climate impacts on subsurface environment are evaluated in Asian cities. The analysis of the timing of the start of surface warming showed that the depth of deviation from a constant geothermal gradient in subsurface temperature was deeper when the magnitude of surface warming is larger and the elapsed time from the start of surface warming due to urbanization was larger.

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Research Achievements of the Socio-economic group

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Abstract

The Socio-Economic research group aims at providing overall causal relations between urban development processes and subsurface environmental changes from a longer term perspectives while compiling and synthesizing the research achievements of the project. The initial results of the research group are presented during the symposium and workshop in Bali. In the symposium, the presentation focused on the urbanization process in Asia and the cause and effect relationships of urban development and subsurface environmental issues through the DPSIR framework. This framework is also extended to include the social capacity (C) to perceive and evaluate subsurface environmental issues and to formulate appropriate responses and strategies to solve these environmental problems.

The presentation during the workshop highlighted the group achievements as well as the individual member's initial research outputs. For the last year, major research achievements are summarized into the following four items: (1) with a comprehensive review of the existing studies, the overall causal relations are summarized in reference to the DPSIR framework; (2) with the survey in Bangkok, rich datasets and relevant information are obtained; (3) longer term statistical database for the selected seven cities in Asia on demography and water use are developed, and (4) methodological progress in individual researches including comparative study on the changes in nitrogen balance of city with substance flow model, estimation of stock and thermal capacity of underground structures of cities, sewerage systems of Osaka and Bangkok and social capacity of city to cope with subsurface environmental issues. The three major dimensions for the direction of the research achievements are (1) increase in number of cities to be compared which finally covers seven selected Asian cities; (2) extension of period to review which finally covers the last 100 years; (3) examination of three issues of groundwater quantity and quality and subsurface thermal environment and their interactive relations.

In sum, tentative results and achievements show that the continued efforts of the research activities currently conducted will lead us to the expected outcomes in the initial research plan and proposal.

1. Introduction

The overarching functions of the Socio-economic group are to collect and organize various information on urban development and subsurface environmental challenges with the DPSIR framework and to improve our basic understanding on a broader scale the complex causalities of multi subsurface environmental issues.

This article contains a summary of the presentations conducted during the symposium and workshop in Bali. During the symposium the cause and effect relationships between urban development and subsurface environmental changes were analyzed in a DPSIR framework.

On the other hand, the workshop presentation focused on the research achievements by highlighting the initial research results of individual members. At the start of the year, the members of the group have formulated research plans, given in the table below.

Table 1. Research Issues in FY 2007

	Quantity	Quality	Thermal
Kaneko	DPSIR Framework Urbanization – USE Nexus with DPSIR framework (August, 2007)		
Zhang	Index、Model Sustainability Indicator with Focus on USE (August, 2007)		
Karen	City development model（population, economy） (1) Urban Demographic Growth Pattern (April, 2007), (2) Wealth of Cities (March, 2008)		
Fujiwara・Lee	Urban policies, land use Historical Review of Urban Policies: Comparison among Cities (October, 2007)		
Tanikawa	Material stock Underground Material Stock in Tokyo (October, 2007)		
Matsumuto	Lifestyle, Food consumption SFA of Household Consumption in Tokyo, Seoul and Taipei (October, 2007)		
Fujikura	Environmental burden, pollution abatement Sustainability of Edo: Nitrogen and Phosphorus Perspectives (August, 2007)		
Imai	Water and sewerage technology, Infrastructure Historical Review of Technologies on Water in Cities: Comparison among Cities (October, 2007)		
Tanaka	SWAT (Soil & Water Assessment Tool) Preliminary Application to Tokyo and Jakarta (TBD)		

II. Application of the DPSIR to analyze subsurface issues

DPSIR Framework

DPSIR is a general framework for organizing information about causal relations between human activities and the environment. The idea of the framework was originally derived from social and policy studies in organizing a system of indicators in the context of environmental issues where complex causal relations are not completely elucidated in number; as a simultaneous process with scientific researches. The challenge is to deal with differential dimensional issues in socioeconomic systems and natural environmental systems.

This systems view of analysis states that economic and social development, such as industrial production, which are common driving forces (D) exert pressure (P) on the environment, and as a result, the state (S) of the environment changes, such as depletion of natural resources, decrease in biodiversity and degradation of environmental quality. These changes then have impacts on the ecosystems, human health and other materials. Due to these impacts, society responds (R) to the driving forces, or directly to the pressure, state or impacts through preventive, adaptive or curative solutions.

III. Research Achievements

This year's group research topics are mainly focused on the driving forces and pressure components of the DPSIR. We have only shown here some of the presentation materials from the members of the group but more of these figures are included in the powerpoint slides.

The driving forces include population growth, economic growth in terms of GRDP and changes in industrial structure, and the patterns of land use and urban sprawl during the last few decades. The pressure components include groundwater abstraction, nitrogen emissions and heavy metals and heat flux due to the change in surface temperature.

Population data covers a hundred years of population change from 1905-2005.

The population in the seven case study areas (Tokyo, Osaka, Seoul, Taipei, Jakarta, Bangkok and Manila), has grown rapidly, especially during the latter half of the century. This high population growth of urban areas after reconstruction from the WWII until the 1990s was caused by the natural increase in population, massive influx of people from the surrounding areas and countryside and the expansion of administrative boundaries leading to increased population size.

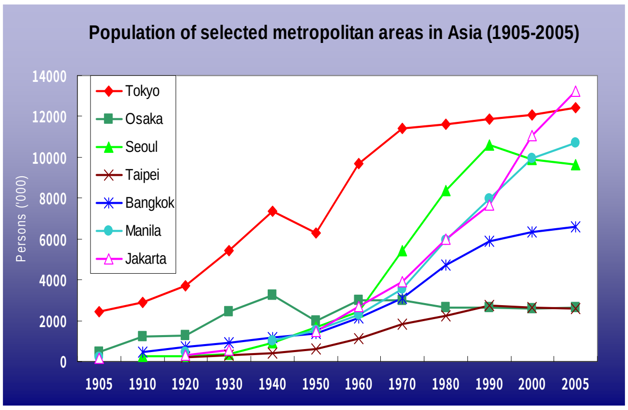

Fig.1. Growth of the population in selected urban areas in Asia (1905-2005)[1]

The increase in population and economic activities has affected the demand for water supply, which comes from surface water and groundwater sources. As an important element of the subsurface environment, we tried to illustrate the trend of groundwater abstraction in these urban areas as shown in the figure below:

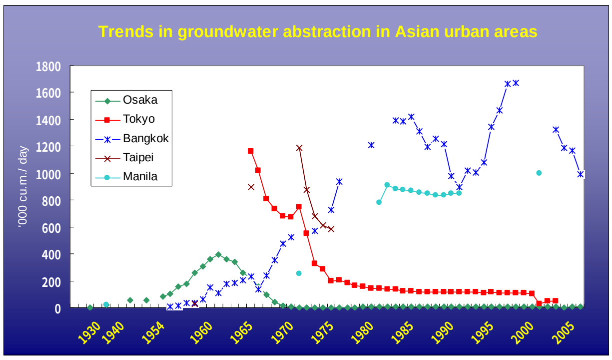

Fig. 2. Trends in groundwater abstraction in Bangkok, Manila,

Osaka, Taipei and Tokyo[2]

Major quantity of groundwater has been used for industrial production, followed by domestic consumption.

Another pressure component that the group is nitrogen from human food consumption and waste disposal. One study traced back to the Edo Period and examined how the human waste of a million population was used and recycled as agricultural fertilizer. A supply and demand balance has been created for nitrogen and phosphorus.

As cities developed, sewerage systems and waste water treatment plants were built to systematically dispose solid waste, industrial waste and runoff. The capacity development and diffusion rates of sewerage systems in Tokyo, Osaka, Taipei and Bangkok were also studied by the group.

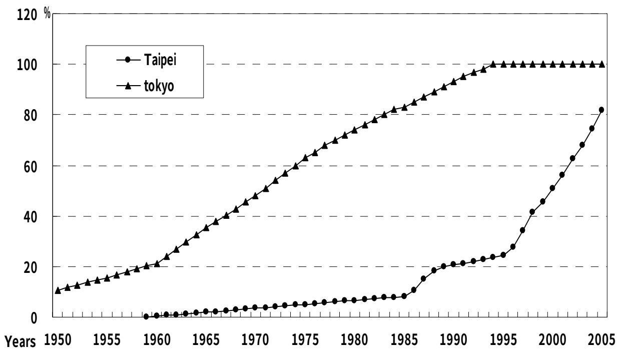

Fig. 3 Diffusion rates of sewerage systems in Tokyo and Taipei

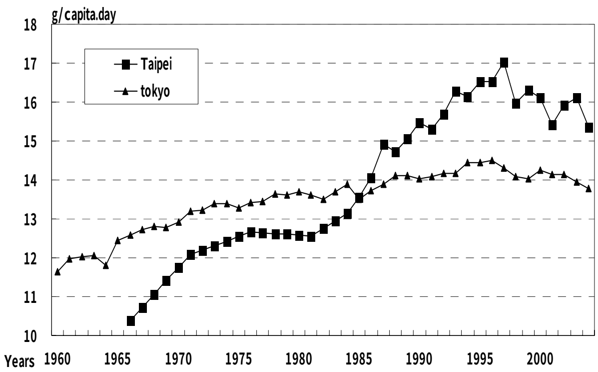

Fig.4. Trend in quantity of supply of nitrogen

Fig.5. Establishment of waste water treatment plants in Bangkok (Dept. of Drainage and Sewerage, BMA, Thailand).

The changes in nitrogen balance of the city have been analyzed using substance flow model (Fig.6). This model has been applied for Tokyo and Taipei in 3 periods: 1960, 1980, 2004 (Tokyo) and 1970, 1980 and 2004 (Taipei).

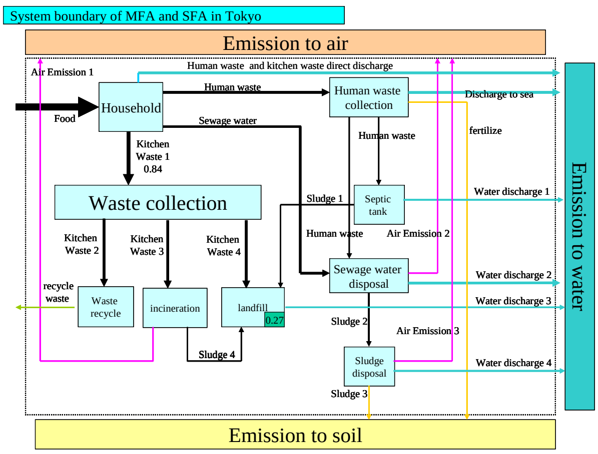

Fig.6. System boundary of material and substance flow analysis

Another aspect of the group's research is the estimation of stock and thermal capacity of underground structures of cities. Below are figures of stock quantity and stock density in the cities of Osaka, Tokyo and Yokohama.

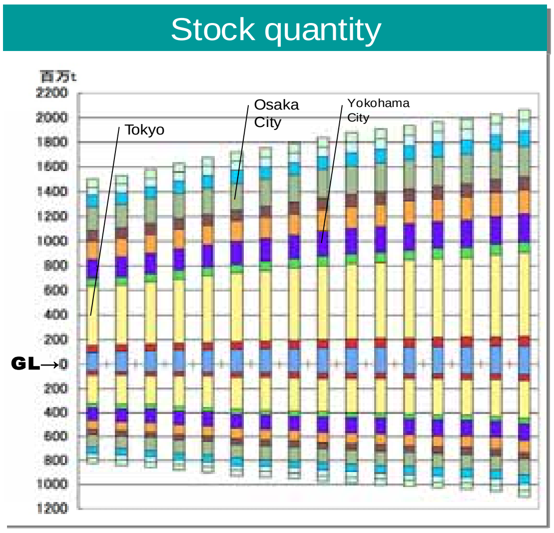

Fig. 7 Stock quantity in Osaka, Tokyo and Yokohama

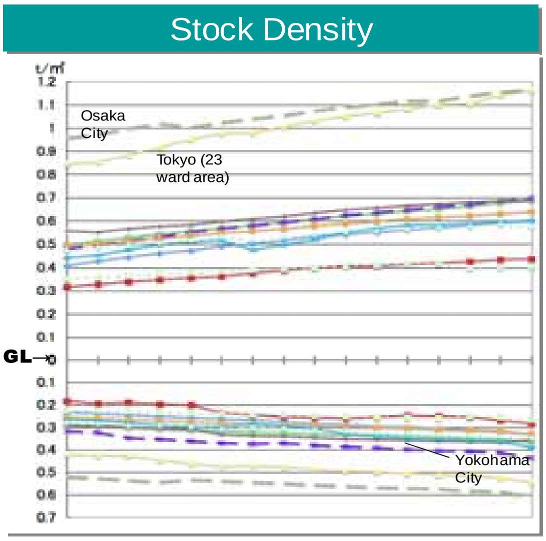

Fig.8. Stock density in Osaka, Tokyo and Yokohama

After a review of groundwater issues in the selected urban areas, we illustrate the interrelationship of the components of DPSIR as shown in Figure 9. The focus of our discussion, groundwater quantity and groundwater quality, are shown here as two sides of the DPSIR diagram. Although there are several problems and issues in groundwater resources, we only show here some components which are common among the study areas.

Taking from the experiences of these urban areas, we have common driving forces, population growth and industrialization, that exert pressure and cause changes in the environment.

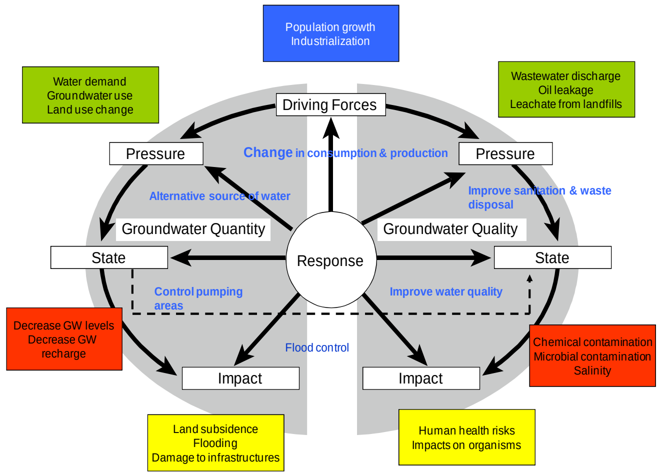

Fig. 9 Application of DPSIR framework in analzying subsurface environmental issues

Pressures on groundwater quantity include increasing groundwater demand from population and industries and land use changes. Examples of pressures for groundwater quality are discharges from wastewater, fuel leakage and landfill leachates. There are situations wherein the changes in groundwater quantity affect the quality of the groundwater (i.e. saline intrusion, artificial recharge) and have shown the link between the changes in the state of groundwater quantity to the change in groundwater quality. The response (R) component in the center means that the responses to the subsurface environmental problems have been varied and directed either to driving forces, pressure, state or impacts, or to a combination of these components.

We tried to extend the DPSIR framework to include the concept of social capacity. We now refer to it as the DPSIR+C framework (Figure 10). The concept of capacity development has evolved from the different approaches such as institutional building in the 1950-60s, institutional strengthening in the 1970s, and institutional development in the 1980s. This concept of capacity development was extended to determine the social capacity in environmental development.

We applied the DPSIR+C framework in analyzing the interrelationships among the factors of DPSIR and the capacity of different actors in the issue of water quality using national level data.

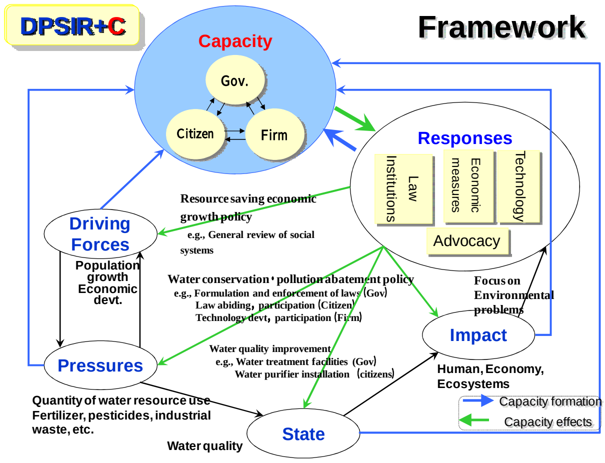

Fig.10 DPSIR+Capacity Framework

Society-wide capacity in environmental management includes the analysis of roles and capacity of each stakeholder such as government (national, local), firms, civil society (citizen, NGO), academe, mass media. This involves interactive relations among the stakeholders to exert society-wide capacity. We need to identify the factors that promote capacity-building including financial resources, technology, institutional arrangement, legal framework and environmental awareness. This leads to an effective environmental cooperation among actors in society.

IV. Concluding remarks

The group's achievements during the past year include the following items: (1) Summary of overall causal relations in reference to the DPSIR framework through a comprehensive review of existing studies; (2) Acquisition of rich data sets and information during the survey in Bangkok; (3) Development of long-term statistical database for the selected seven cities in Asia on demography and water use; and (4) methodological progress in individual researches including comparative study on the changes in nitrogen balance of city with substance flow model, estimation of stock and thermal capacity of underground structures of cities, sewerage systems of Osaka and Bangkok and social capacity of city to cope with subsurface environmental issues.

In applying the DPSIR framework, we have reviewed existing materials for 7 target cities and synthesized the related evidences. Most of the information are related to groundwater quantity issues. At a later stage in the project, we will try to incorporate the findings from the project and organize them into the DPSIR framework again to see the improvement of our understanding of subsurface environmental issues. We have created an image for the final output using this framework (Figure 11).

To sum it up, the tentative results and achievements show that the continued efforts on the research activities currently conducted will lead us to the expected outcome described in the initial research plan and proposal.

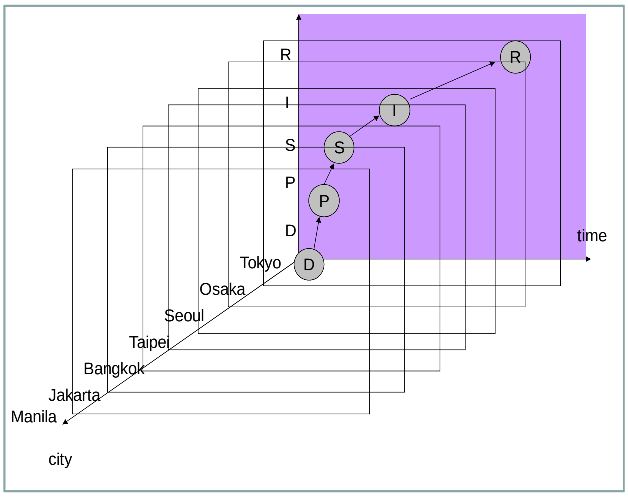

Fig. 11. Image of the final output using DPSIR

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Notes:

[1]Compiled from Abeyasekere 1987, JICA 1992, Magno-Ballesteros 2000, NSO 2004, NSO 2006, Taipei City Government 2004, UN 2006, Wilson 1983

[2]Source of basic data for Bangkok: Department of Groundwater Resources, MONRE, Thailand; Osaka: Osaka Bureau of Waterworks; Tokyo: Tokyo Metropolitan Government Waterworks Bureau. The data for Manila are compiled from JICA 1992, Rodolfo and Siringan 2006. The data for Taipei are compiled from Wu 1992, Wu 1976.

Summary of fieldwork achievements and future research needs

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Abstract

This presentation describes the fieldwork and research that we conducted in the case study cities in Asia, such as Seoul, Taipei, Manila and Bangkok. Based on the initial research framework and database requirements, the Socio-Economic research group visited several government offices, research institutes, universities and public works utilities. Although there were some limitations in data availability on a city scale and for a longer time period, our fieldworks have been smoothly undertaken due to the kind assistance of our foreign counterparts in these cities, and from the researchers and government staff who kindly help us in our data gathering.

1. Introduction

Since the start of the full implementation of the project, the Socio-economic group has conducted field surveys in Seoul, Taipei, Manila and Bangkok. In this presentation, we would like to give a summary of the fieldwork activities, the feedback we got from the visits in different institutes and agencies, and our future research plans. Based on the initial research framework and data needs, we conducted the fieldwork to gather historical, socio-economic and physical data of the urban areas. During the fieldwork, we were also able to some facilities such as the waterworks company, waste water treatment facilities and waste disposal facilities.

II. Fieldwork sites and Institutions visited

The group conducted the field surveys in Seoul from May 23-26, 2006: in Taipei from September 11-15, 2006; in Manila from December 12-21, 2006 and in Bangkok from May 27-31, 2007. Except for Manila, around 5-6 members of the group participated in these field surveys.

Most of the offices that the group visited were government agencies, research institutes, universities, waterworks companies, wastewater treatment and waste disposal facilities.

Aside from basic data gathering, we also had discussions, especially with the faculty members and researchers of the universities and research institutes that we visited.

III. Data and Information Acquired during the Surveys

The following tables shows examples of the relevant information that we have gathered during our fieldwork

Table 1. Example of Socio-economic data

Cities	Population	Economic	Land Use	Food	Waste
Seoul	**1915-2005**	GDP (country level) from 1960s; GRDP (1960-1998)	**1900-2000**		
Taipei	**1920-2003**	GDP (country level) from 1960s	**1900-2000 (ppt)**	Taiwan Food supply and Utilization Yearbook 2004	1968-2003
Manila	**1903-2005**	GDP (country level) from 1960s	**1996, 2003**	Phil. Food Balance Sheets 1987-2001	1985-2006
Bangkok	**1855-2005**	GDP (country level) from 1960s	**1960, 1992, 2006**	Thailand Food Statistics 2003-2007	1985-2006

Table 2. Example of subsurface and water data

Cities	Groundwater Use	Groundwater Levels	Groundwater Quality	Land subsidence	Waterworks
Seoul			1998-2005		1908-2003
Taipei	1954-1974	1970s-Present		1950-1969	1968-2003
Manila	1930-2000 (some are estimates)			1991-2003	1984-2005
Bangkok	1954-2006	1978-2006	1978-2004	1978-2006	1984-2006

IV. Assessment and Lessons Learned from Fieldwork

The fieldwork surveys were conducted smoothly due to the kind assistance and cooperation of our project counterparts in Seoul, Taipei, Manila and Bangkok. We would like to extend again our gratitude to Dr. Backjin Lee (Seoul), Dr. Chung-Ho Wang (Taipei), Prof. Fernando Siringan (Manila) and Dr. Somkid (Bangkok). We are also assisted by our contact persons in the offices that we visited and by the local researchers from some universities. Aside from the actual data gathering, our project counterparts were very helpful in making the arrangements for our visits to the offices and in establishing research networks in the universities and research institutes. Access to some offices and to some information was not easy to obtain and sometimes we need research networks and personal connection to get to these places and to have the data that we needed.

During the fieldwork, we were able to discuss the objectives of the project and the ways which we can contribute to the research aims of the institution. During the discussion however, there were suggestions to clarify on the scope of our research, whether it would be on a city-level, metropolitan area, basin level or would it even include peri-urban areas. City-level boundaries may not be appropriate enough to evaluate the impacts of human activities on the subsurface environment.

Although the fieldworks were quite successful, there were still constraints when it comes to data availability. There was a difficulty in getting city –level data. Data on population and other demographic characteristics are available on a city-level but some socio-economic and environmental data are still on a country-level and only the recent years there are available city-level data.

Except in Manila, language was also a constraint as some of the relevant materials are written in the local language and not in English.

V. List of Offices and Institutions Visited in Seoul, Taipei, Manila and Bangkok

Offices and Institutions Visited in Seoul

Seoul National University
Seoul Development Institute
Cheong Gye Cheon Restoration Project Headquarters
University of Seoul
Gyeonggi Research Institute
Korea Research Institute for Human Settlements

Offices and Institutions Visited in Taipei

Institute of Earth Sciences, Academia Sinica
Society of Urban Planning
National Taiwan University
Department of Statistics, Ministry of Interior
Water Environment Research Center, Taipei University of Technology
Council of Agriculture, Executive Yuan
National Taipei University of Technology

Facilities

Pei-tou Incinerator Facilities
Nangkang Landfill Facilities
Bali Wastewater Management Plant

Offices and Institutions Visited in Manila

Metro Manila Development Authority
Manila Water Company
National Water Resources Board
Philippine Atmospheric Geophysical and Astronomical Services Administration
Housing and Land Use Regulatory Board
National Statistics Office
National Statistical Coordination Board
Department of Environment and Natural Resources
National Solid Waste and Management Commission
University of the Philippines- Diliman and Los Banos
Philippine Institute of Development Studies
Asian Development Bank
Japan International Cooperation Agency

Offices and Institutions Visited in Bangkok

Bangkok Metropolitan Administration
Pollution Control Department, MONRE
Department of Groundwater Resources, MONRE
Metropolitan Waterworks Authority
Office of Agricultural Economics
Department of Town and Country Planning
Office of Transport and Traffic Policy and Planning
National Statistics Office
Mass Rapid Transit Authority

Hydro-environmental changes and their influence on the subsurface environment in the context of urban development

Akihisa Yoshikoshi, Itsu Adachi, Tomomasa Taniguchi, Yuichi Kagawa, Masahiro Kato, Akio Yamashita, Taiko Todokoro , Makoto Taniguchi

1. Introduction

The purpose of this research was to qualitatively analyze the relationship between urban development and hydro-environmental change and to examine the influence of these factors on the subsurface through comparative studies of Asian megacities, the development of which have varied with respect to speed, timing and form.

Substances such as water, heat and pollutants move about the atmosphere, the hydrosphere and the lithosphere through the earth's surface. Therefore, the earth's surface plays a very important role in mass transfer phenomena, which are greatly influenced by surface conditions. Surface and subsurface environments are more influenced by human activities than natural conditions.

Identification of the connection between surface changes and water transfer is one of the major themes in hydrology. Scholars have made numerous attempts to demonstrate the relationship between urbanization and hydro-environmental change. The first and most effective of those attempts (Hall, 1984) clarified the idea that water pollution, flooding and water shortages arise in the process of urbanization. We have also studied this hydro-environmental theme (Yoshikoshi, 1989; Yoshikoshi, 1998; Taniguchi, 2005; Yamashita, 2001).

Many of these efforts have focused on short-term hydro-environmental changes in a specific area. Little attention has been given to examining long-term hydro-environmental change, with a focus on differences in the urbanization process.

Comparative studies on megacities in different stages of urban development can help solve problems anticipated by other Asian cities.

2. Research Cities and Method

We selected three coastal cities affected by Asian monsoons for our research: Tokyo and Osaka in Japan, and Bangkok in Thailand. We selected these cities because of the availability and comparability of topographical maps and statistical data.

Tokyo, on Tokyo Bay, is the capital of Japan. Its 23 metropolitan wards have a total land area of 621.5 km^2 and a population of 8.319 million as of 2007. Osaka, on Osaka Bay, is the capital of the Kinki region. Osaka has a land area of 222.1 km^2 and a population of 2.637 million as of 2007. Bangkok, located near Thailand Bay, is the capital of Thailand. Bangkok Metropolitan Administration covers 1,569km^2 of land and has a population of 7.36 million.

Tokyo and Osaka represent cities whose urbanization started relatively early, in the middle of the 18th century; we considered Tokyo to be largely urbanized and Osaka to be less so. We selected Bangkok as representing a city whose urbanization started later.

The method of research was as follows. We first surveyed literary documents, statistical data and topographical maps to obtain a chronology and a clear view of urban growth. We then looked at hydro-environmental changes in the respective cities and undertook comparative analyses of how chronological changes in urban development and in the hydro-environment influenced each urban subsurface environment. The period covered by this research was the past 100 years. Larger scale topographical maps are the most appropriate research tools, and we used these whenever they were available. The study areas for statistical analysis were limited to each city's administrative districts or wards; however, comparative discussions sometimes include mention of surrounding urbanized areas.

3. Urban Development

3.1. Tokyo

Tokyo started its modern urbanization in the Meiji Era, after 1868. The urban area in those days covered only the area within a 7 to 8km radius of Edo Castle, located in the center of Tokyo (almost the same area as in the late pre-modern Edo stage). After the Meiji Era, improvement of modern roads and railways led to the expansion of the urban area. By 1910, the urban area had increased to include the Musashino Plateau and lowland on the right bank of the Edo River, covering about the same area as today's 23 metropolitan wards. The periphery, however, remained verdant countryside. The Great Kanto Earthquake hit the Tokyo metropolitan area in 1923, leaving Tokyo completely destroyed. In the meantime, the population decreased and urban development stagnated.

Around the end of the Second World War, the urban area in Tokyo expanded to a 15km radius. On the Musashino Plateau in particular, residential areas developed along railway lines, resulting in a rapid decrease in agricultural land. Along the coast of Tokyo Bay, industrial zones were built, primarily for heavy and chemical industries, following a massive land reclamation project after the period of high economic growth in the 1960s. As the capital of Japan, Tokyo has expanded its urban area to a current 50km radius.

3.2. Osaka

Osaka also started its modern urbanization process in the Meiji Era. Initially, however, pre-modern structures such as roadside canals could be seen alongside urban ones. Osaka's urban area expanded and railways were constructed in the process of modernization. In this way, Osaka transformed itself from a commercial to an industrial city. In the Taisho Era, industrial districts in Osaka began to expand outward from the periphery of the old urban area.

During the Second World War, Osaka made a rapid shift from light to heavy industry. The ravages of war interrupted manufacturing activities and stalled urban development. The high economic growth of the 1960s, however, reinvigorated urban expansion. In the 1970s, urban land use (including residential, industrial, commercial and business districts) was prominent, although there remained a lot of agricultural land use in the northern, eastern and southern suburbs. In the 1990s, suburbanization meant further expansion of urban land use. In northern, eastern and southern Osaka, forests were transformed into urbanized residential areas. Conversion of agricultural land to urban use occurred all over Osaka in a concentric fashion. The urban area of Osaka has now extended to cover a 20 to 30km radius.

3.3. Bangkok

Bangkok had its start as a city in 1782 when the Royal Palace, known as the Grand Palace, was built in Rattanakosin Island and the nearby district. By 1920, Bangkok already had a channel network centralized at Rattanakosin Island with the Royal Palace. The network grew toward eastern Bangkok on the left bank of the Chao Phraya River. This channel network has become the symbol of Bangkok's urban landscape, which for a time governed the course of the city's urban development. Urban expansion in Bangkok was brought about not by the extended new channel network but by the construction of roads for automobile transportation.

As a result of the industrialization started in the 1960s, Thailand had remarkable economic growth in the 1970s and 1980s. Further urbanization with population inflows from surrounding areas has made Bangkok one of the biggest cities in Asia. Rice paddies, vegetable fields and orchards have been transformed into industrial areas. While agricultural production has decreased, residential areas have increased. Bangkok's population had grown to more than 2million by 1960, and it is still increasing at a remarkable rate. Compared with Tokyo and Osaka, Bangkok's suburban population growth occurred later, although the designated urban ranges differ from city to city. The landscape of the downtown area along the Chao Phraya River stands in contrast to that of the commercial district in the newly established city center along the main road. Transportation by way of the channel network continues to play an important role even today because railways barely functioned as a means of daily transportation until the late 20th century. The urban area in Bangkok has come to cover a 10km radius.

4. Hydro-Environmental Changes in Urban Areas

4.1. Tokyo

Several rivers run through Tokyo, such as the Tama and the Ara Rivers originating in the Kanto Mountains, and the Kanda and the Shakujii Rivers originating in springs of the Musashino Plateau. Many kinds of water formations exist, including springs, streams for water supply and agricultural use, channels, the Inogashira Pond, and the Tama josui (aqueducts). These rivers and canals have been used for various purposes including domestic, agricultural, and industrial water supplies, water power from water wheels, and parks and spaces for recreation and relaxation.

Over the past 100 years, these urban hydro-environments have been dramatically altered by water pollution, river improvement works, and the covering over of rivers, among other things. In the 1930s, water formations existed across all of Tokyo, with a few exceptions on the Musashino Plateau. Those used for city canals in central Tokyo remained until the 1950s. At this time, irrigation ditches ran across networks of canals on the lowland, and there remained many streams originating in springs on the Musashino Plateau (Arai, 1996).

Around the time of the Second World War, however, the infrastructure of the sewage system was improved, and the canals that had played a role in drainage were made into culverts. These improvements were promoted, in particular, in densely populated downtown and residential districts suffering from serious water pollution (Taniguchi, 1997). The decrease in water formations has become increasingly marked since the period of high economic growth in the 1960s. This has been due to, among other things, improvements in (a) irrigation ditches as a result of the conversion of farmland into residential areas, (b) water transportation and the reclamation of rivers as a result of the progress of motorization, and (c) culverts as a result of the maintenance of water and sewage systems. Rapid urbanization led to an expansion of impervious surface areas on the Musashino Plateau. This resulted in a depletion of springs caused by a decrease in groundwater infiltration and the running dry of many rivers caused by the decrease of river flows. Recently, previous approaches to water-related development have been reconsidered, and new waterfront environments have been created through the restoration of rivers and canals and through the construction of artificial canals in some parts of Tokyo. Nevertheless, these changes have so far failed to stop the decrease of water formations due to the depletion of springs.

4.2. Osaka

In the pre-modern Edo Era, Osaka was called "the aquapolis" and had a channel network based primarily on roadside canals. Osaka's current civic center is located in the area surrounded by the Dohjima River to the north, the Dohtonbori River to the south, Osaka Castle to the east, and the Kizu River to the west. This almost matches the same area of the Edo Era. In 1927, roadside canals were maintained exactly as they had been during the Edo Era. The area between the Dohjima River and the Tosabori River was called Nakanoshima and was the economic center of Osaka in the pre-modern era.

Even now, the Nakanoshima area is home to central management functions such as the Osaka City Hall and the Osaka branch of the Bank of Japan, and it serves as the political and economic center of Osaka. The area surrounded by the Yokobori River, the Dohjima River and the Nagahori River was called Senba (dockland), and wholesale industry and brokerage businesses accumulated there. The Senba area became a flourishing physical distribution base, as occurred with the Nakanoshima area, through the use of water transportation that took advantage of roadside canals.

Dramatic changes took place in the aquapolis, which were related to the advancement of motorization, accompanied by the high economic growth of the 1960s. At this time in central Osaka, roadside canals were filled in and converted into motorways, as the number of automobiles had increased. Only a portion of roadside canals remained along the Dohtonbori and the East Yokobori Rivers by 2001. In the suburbs, irrigation ditches ran in every direction, and there were many reservoirs in the southern part of Osaka around the time of 1927. By the 1970s, these water formations had become useless as a result of the conversion of farmland to urban use (such as for residential areas).

In this way, the situation relating to water formations dramatically changed in Osaka from the 1920s to the 1960s, as symbolized by the disappearance of roadside canals in the civic center and the waterway network and reservoirs in the suburbs.

Since the 1960s, the major changes have occurred in coastal regions rather than in the interior. One change has been the expansion of land area due to landfill construction.

Osaka used to be called "the aquapolis" because of its history and landscape. New fields had been developed by the reclamation of bay areas in the pre-modern era, and the coastal industrial zone, formed after the Meiji Era in 1868, was also developed by further reclamation. Consequently, the unstable ground of the costal industrial zone in Osaka is vulnerable to sinking due to the excessive pumping of groundwater.

4.3. Bangkok

The urban development of Bangkok is closely linked to the expansion of the channel network. The meandering Chao Phraya River has created varying watercourses (Beek, 1982). The many and variously sized channels connecting to these watercourses constitute the necessary infrastructure that supports daily life and industrial activity in Bangkok. Maps created before motorization show channel networks twisting and turning through urban areas.

The fact that some of these roads were used for waterways in the rainy season and for roads in the dry season makes Bangkok unique with respect to the Asian monsoon. There are bridges at the intersection of roads and channels. Bridges were constructed to cross channels; however, some bridges gradually fell out of use with motorization (Narumit, 1977). Since the 1980s, some of these unnecessary channels have been filled in and the bridges spanning these channels removed.

At the same time, water use among the Bangkok people changed. Channels had been utilized not only as traffic ways but also as sources of drinking water, places to wash and drains. The channels that had played so many roles, however, came to be regarded as inconvenient and fell out of use in the course of urban transformation. Although many houses now stand on the waterfront, the present utilization of channels differs considerably from that of the past. Improvements in public health, such as the development of water and sewerage systems, was another reason people turned away from using waterways and canals.

One factor that must not be overlooked, however, is the fact that the merits of the channel networks have once again been recognized from the point of view of tourism and environmental preservation. An urban redevelopment project is currently underway in a subcenter of Bangkok. In this area, many renewed buildings stand along the Chao Phraya River, and many waterparks have been developed alongside canals.

These places have been useful in reviving the relationship between the people and the hydro-environment. A close relationship between waterways and houses remains in the suburbs of Bangkok. For example, people use liner ships running along the channel networks as a means of commuting from the suburbs to the civic center in Bangkok. Recently people have utilized existing channel networks effectively, and the government has also tried to embed hydro-environments in future city plans.

5. Influences of Urban Development on Subsurface Environments

5.1.Tokyo

Urban development in Tokyo has advanced not only horizontally but also vertically. Urbanization has sprawled over into suburban areas. Inner-city areas have intensified the use of integrated land, such as densely built-up districts and the vertical use of space. Above the ground, high-rise buildings, skyways, and elevated railroad tracks have been built. Under the ground, subways, roadways, underground stations and underground shopping areas have been developed. Tokyo has experienced a fair degree of subterranean railway construction. Newer lines have had to be built deeper under the ground, as was the case for the Ueno Station for the Shinkansen (Super Express Trains), which required 30m deep subterranean development.

Changes in underground use of space have heavily influenced both subsurface and surface hydro-environments, including rivers, canals and aqueducts. Huge underground construction projects, such as shopping areas and subway lines, can get in the way of groundwater flow. Water leakage from aqueducts and drains can cause groundwater increment and contamination. According to a report by the Tokyo Metropolitan Government (TMG,1998), the groundwater balance in Tokyo showed 44×10^4 m^3 leakage from aqueducts and drains per day, which was estimated to be nearly equivalent to one third of the daily supply of groundwater.

The increased demand for water as a result of the growing population and industrialization has triggered the construction of reservoir dams on rivers in the far-off prefectures and the pumping of more and more groundwater. Use of groundwater began early on because of its low cost and easy access. In the Koto Ward alone (one of the industrial districts in Tokyo), for example, 15×10^4 m^3 of groundwater was piped up per day in the late 1950s.

Excessive pumping of groundwater has seriously influenced the subsurface environment in many ways, leading to subsidence and rapid drops in water level. The Tokyo Metropolitan Research Institute reported (Tokyo Metropolitan Research Institute for Environmental Protection,1970) that Koto Ward experienced land subsidence of 17 to 18 cm for the year 1957 to 1958 . To make matters worse, excessive pumping induced groundwater failures related to oxygen-deficient air and saline water.

To address these subsurface environmental problems, regulations and controls on groundwater pumping have been in effect since the late 1950s. These measures have been effective in gradually restoring the level of groundwater. According to a 2006 report by the Bureau of Environment of the Tokyo Metropolitan Government(Bureau of Environment, Tokyo Metropolitan Government, 2006), even in Minamisuna 2-chome in Koto Ward, where subsidence integrated to more than 4.5 m since the government began to measure subsidence in 1918, subsidence there has been checked to within 2 cm per year in recent years.

Two other kinds of problem, however, have been drawing attention. First, the rising groundwater level has increased the buoyancy of groundwater in relation to existing buildings. This has forced Ueno Station for the Shinkansen, for one, to take necessary countermeasures. Second, developers have had to deal with a massive groundwater discharge in the course of underground development. In short, groundwater failures are no longer only about dropping water levels but about rising ones.

5.2. Osaka

Osaka has experienced similar kinds of groundwater failures. Deep subterranean areas in Osaka, however, have not been developed as much as those in Tokyo; therefore, Osaka's failures have been fewer and less serious than those of Tokyo.

Osaka Bay areas have witnessed the construction of many factories and businesses that belong to water-consuming industries and use a large amount of industrial water. Until 1950, the water supply for these industries has depended mainly on groundwater, which led to excessive pumping, lower groundwater levels, and subsidence.

Subsidence in Osaka began in the Meiji Era, just as in Tokyo, and eventually showed an integrated 57cm drop in the 35 years from 1886 to 1921. In the late 1930s, Osaka had its worst level of subsidence. Around 1943 and 1944, subsidence in Osaka almost stopped, primarily because excessive pumping of groundwater ceased due to decreased industrial activity during the war. After the Second World War, the rapid increase in industrial production brought about accelerated subsidence. The worst occurred in Kujo in the Nishi Ward and in Torishima in the Konohana Ward, which were home to several large factories. In Kujo and Torishima, the groundwater level decreased by 20 cm in the 10 years from 1950 to 1960, and some points recorded subsidence of 40 cm in the same period of time. Such subsidence meant that the Bay area ground level was lower than the highest sea level. This resulted in floods with high tides and heavy rains.

Residents constructed breakwaters and raised banks as countermeasures. However, these measures were not enough to prevent vast damage from a large storm surge from Typhoon Jane in 1950. To address subsidence problems caused by the excessive pumping of groundwater, the Osaka Prefectural Government began in 1950 to build waterworks for industrial use with source water from the Yodo River as a substitute for groundwater.

The enactment of ordinances regulating groundwater pumping occurred in the late 1950s and early 1960s. As early as 1962, groundwater levels began to show signs of recovering. The rapid rise continued until the 1970s; today, the rise in groundwater levels has slowed down and stabilized.

Subsidence was slower to respond to measures than were groundwater levels. Subsidence in Osaka, which continued to worsen little by little from 1965 to 1970, has now stopped.

5.3. Bangkok

The influences of urban development and hydro-environmental changes on the Bangkok subsurface environment are very different to those in Tokyo and Osaka. In Bangkok, the existence of subways, underground roadways, and underground shopping areas is relatively limited and, as yet, there has been no deep subterranean development there.

Therefore, there are few physical blocks to groundwater flow.

After the Second World War, and especially after the 1970s, population growth has given Bangkok status as a primary city in Southeast Asia. In the course of the economic growth in Southeast Asia, industrial complexes were developed along the Chao Phraya River, which has enabled Bangkok to grow as an industrial city. The rapid population growth and factory construction have increased the pumping of groundwater, which is less expensive than building waterworks and related facilities.

The development of groundwater started in 1954, with only a total amount of pumping 8×10^3 m^3 per day. It increased to 45×10^4 m^3 per day in 1982. Excessive pumping of groundwater has led to lowering water levels, subsidence, and groundwater contamination with domestic wastewater and industrial sewage. Subsidence, in particular, has caused serious damage from floods in rainy seasons because urban areas in Bangkok are located along the Chao Phraya River.

To address these problems, the Thai government implemented regulations on groundwater pumping after the 1970s. These regulations made it possible for Bangkok's groundwater level to recover immediately because it was recharged with abundant rainfall and water from the Chao Phraya River. The number of water wells increased from about 1,300 in 1995 to 1,900 in 2001. In addition, the total amount of groundwater pumping, which had at one point decreased to about 30×10^4 m^3 per day, soon reached 60×10^4 m^3 per day. The government's measures do not seem to be working effectively at present. Groundwater levels increased a little in the years from the 1980s to 2000 but have not recovered to their former levels. According to United Nations Environment Programme (UNEP, 2005), subsidence in Bangkok slowed from 5 to 10 cm per year in the 1980s, to 2 cm per year in the 1990s. Peripheral areas of Bangkok, however, have experienced worse subsidence. These problems will require further time to solve.

6. Discussion

Fig. 1 shows the results discussed above through a comparative study of Tokyo, Osaka, and Bangkok in the early, mid, and late 20th century.

"Land use composition" indicates the ratio of surface area for urban land use covered with impervious pavement. The higher the ratio, the harder it is for surface water to move to the subsurface in natural conditions. "Area of water surface" indicates the ratio of water formations on the surface, "groundwater level" shows the change in groundwater level, and "land subsidence" represents the amount of land sinkable. Fig. 1 shows relative changes based on values in the early 20th century.

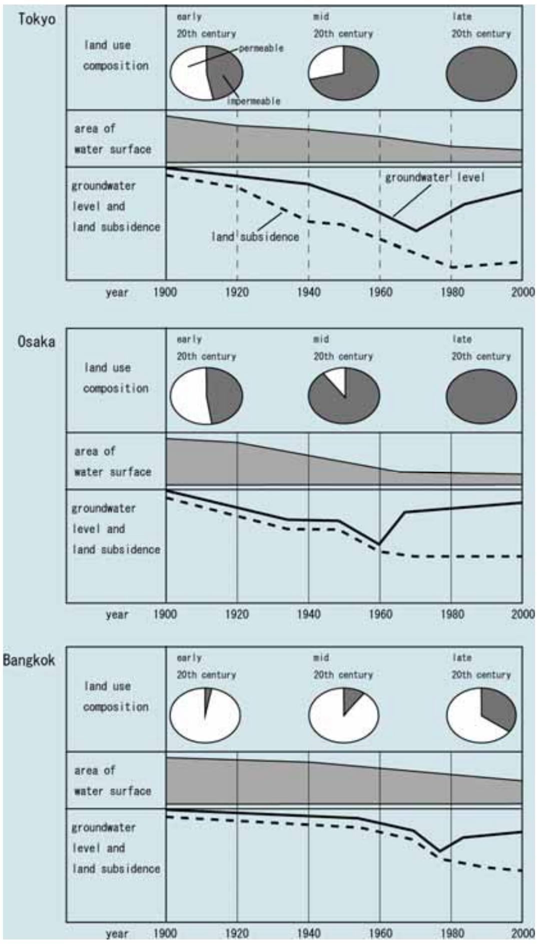

Fig.1 Changes of "land use composition","area of watrer surface","groundwater level"and"land subsidence"in Tokyo,Osaka and Bangkok in 20th century

The increase in urban land use in Osaka occurred rather earlier than it did in Tokyo; however, in Tokyo this process proceeded quickly, and today most parts of both cities manifest urban land use. By contrast, in Bangkok, even in the late 20th century, the ratio of urban land use accounts for less than 50%. Bangkok has a superior ability to move surface water to the subsurface, compared with Tokyo and Osaka. The total area of water surface has decreased over time in each city; however, the timing varies according to the stage of development. Bangkok was the last city of the three to experience a great decrease in water surface. This makes it possible for the city to retain a considerable number of water formations within urban areas.

The lowest groundwater levels were from the 1950s to the 1970s in Tokyo, in the 1950s in Osaka, and during the 1970s in Bangkok.

Groundwater levels increased in stages after the 1970s in Tokyo; however, in Osaka they made a rapid recovery in the 1960s and have remained on the same level since. In Bangkok, although groundwater levels increased rapidly in the late 1970s, this recovery has slowed down and, recently, has shown a downward trend. In the late 20th century, Tokyo and Osaka experienced a slowing in land subsidence, and the recovery of previous land levels has been confirmed in some parts of Tokyo and Osaka. In Bangkok, the speed of land subsidence has declined but has fallen short of stopping. In Bangkok, despite the government's efforts to halt the pumping of groundwater, the total amount of pumped water increased in the late 20th century. It is noteworthy, however, that groundwater levels have recovered and the speed of land subsidence has slowed under these adverse conditions.

These facts show that differences in the size of the cities, urban structures, and stages of urbanization promote distinct hydro-environmental conditions on both the surface and the subsurface.

7. Conclusion

In this paper we discussed hydro-environmental changes during the process of urban development and their impact on the subsurface environment, making a comparative study of three cities of different sizes and stages of urbanization.

Fig. 1, which shows the interrelationship between subsurface environment, city size, urban structure and stage of urbanization, shows that major differences in subsurface changes among the cities are closely related not only to the natural environments in which the cities are located but also with city size; urban structure; and the timing, stage and extent of urbanization. This paper provides general observations from qualitative analyses, but much more remains to be done as far as quantitative analysis.

However, given that urban development has not affected the Bangkok subsurface hydro-environment in a manner similar to that of Tokyo and Osaka, we suggest three reasons for such a difference. The first lies in meteorological conditions, in particular Bangkok's abundant annual rainfall. The second is based on surface conditions: Bangkok has the smallest ratio of impervious pavement surface area, meaning that surface water can more easily infiltrate underground. The third reason lies in the degree and extent of urbanization. Bangkok's subsurface hydro-environment has not been heavily affected because underground development has not yet reached deep subterranean areas.

By researching still more cities, at different stages of urbanization to those of Tokyo, Osaka and Bangkok, we plan to examine quantitatively urbanization and its influence on the subsurface hydro-environment. This research will help to limit damage to developing cities that have not yet experienced subsurface failures but which are expected to address them in the future. Further quantitative studies will also help determine which of the three reasons outlined above is the most influential.

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Report on Subgroup of Urban Climate
“Analysis on Surface Temperature Trends”

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Abstract

In this study, long term trend of surface temperature in Asian large cities is analyzed for the purpose of estimating the effect of urban warming. Index of estimated heat island intensity is suggested as the value which subtracts the grid reconstructed temperature data around the city from observational temperature data in the city. This value is lower than the actual temperature difference of urban and suburban observatory, but indicates averaged tendency of heat island intensity. Indicating this kind of index calculated by unified method is necessary for understanding general situation of urban warming in several Asian cities.

1. Introduction

Surface temperature affects subsurface temperature. Therefore, urban warming due to urbanization is serious issues not only for surface environment but also subsurface environment. In this study, long term trend of surface temperature in Asian large cities is analyzed for the purpose of estimating the effect of urban warming for 100 years. This kind of analysis is necessary in our project, "Human Impacts on Urban Subsurface Environment," for discussing the trend of subsurface temperature and thermal contamination duet to the urbanization.

Target cities are Seoul, Tokyo, Osaka, Taipei, Manila, Bangkok and Jakarta. Some of cities do not have enough observational meteorological data in term of its period, spatial resolution, and quality to discuss the long-term trend. Then, not only observational data but also reconstructed grid data are used for the study. Observational data has no homogeneity adjustment. Therefore, the data is untouched and leaves even small change. On the other hand, reconstructed grid data is adapted homogeneity adjustment. Therefore, time and spatial scale of data is uniform and easy to analyze, but data is smoothened and small change is omitted. For observational data, official record of meteorological department in each country is used. For reconstructed grid data, 0.5 grid temperature data from CRU TS 2.1 (Mitchell and Jones 2005) is used.

2. Change of temperature in the East-Asia during the 20-century

2-1. Heat island intensity of Tokyo

Temperature increase due to urbanization in Japan is of great concern and many of studies have been conducted (Kusaka *et al* 1998; Fujibe 1998). In many studies, Heat island intensity (hereafter, HII) index is used for analysis (Nakagawa 1996).

HII is popular index of urban warming. There are a lot of styles for calculating HII. Oke (1973) defined the HII as temperature difference between maximum temperature of city centre and temperature in suburban surrounding the city. Sometime, temperature difference of two observatories in urban and suburban area is used for calculating HII (Sakakibara and Owa 2005). Difference in average temperature of several observatories in urban and suburban area is also used (Sakakibara and Kitahara 2003). In addition to this difference, Sakakibara and Owa (2005) used both hourly and monthly temperature for discussing temperature differences.

In the past studies concerning HII, temperature difference of short time period was mainly focused on. Yamazoe and Ichinose. (1994) compared the hourly temperature difference when clouds exist and not exist. Yamashita (1996) conducted mobile observation. They are the studies for investigating mechanism of heat island. In this study, we focus on the long-term trend using yearly average temperature.

Fig. 1 shows meteorological observatories and their yearly mean temperature around Tokyo in a) 1897 and b) 2005. Observatories of AMeDAS (Automated Meteorological Data Acquisition System) are not included since it started the observation at 1970s.

As shown in these figures, the number of observatory at the early year is quite few compared with current number of observatory. Mito is considered to be adequate suburb observatory for calculating HII.

Fig. 2 a) shows variation of yearly mean temperature at Tokyo and Mito. Currently, meteorological observatory "Tokyo" is located at 35˚41' N and 139˚46' E. This observatory is relocated three times. It was firstly relocated from Toranomon (period: 1875-1882) to Kitahanebashi (period: 1882-1922). Then, it was relocated again to Hitotsubashi (period: 1923-1964) and to Otemachi (period: 1964-). There seems to be a small gap when the observatory was relocated from Kitahanebashi to Hitotsubashi at 1922. This might to be the result of relocation. Mito observatory is located at 36˚23'N and 140˚28'E and not relocated from the year when its observation began.

HII of Tokyo, temperature difference of Tokyo and Mito, is shown in Fig. 2 b). HII of Tokyo has increased approximately 2 ˚C from 1 ˚C to 3 ˚C during 20 century.

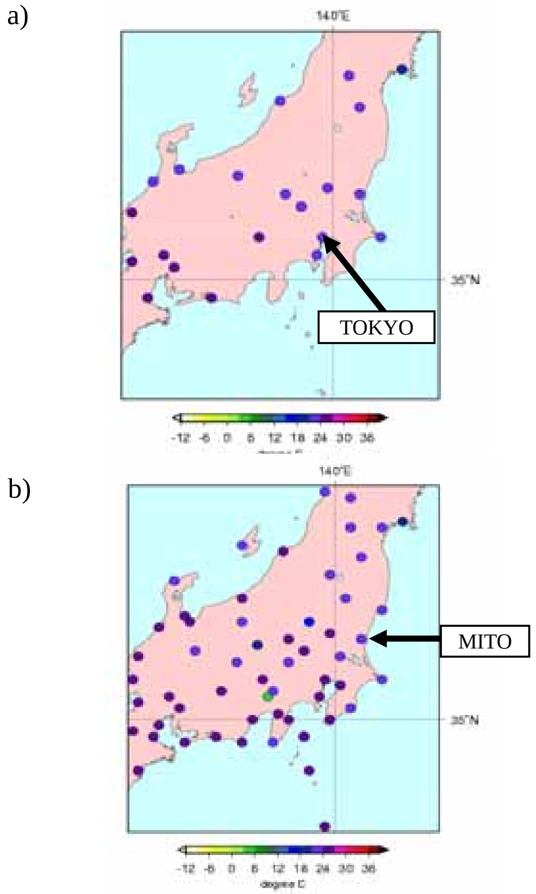


Fig. 1 Meteorological observatories and their mean temperature around Tokyo a) in 1897 and b) in 2005

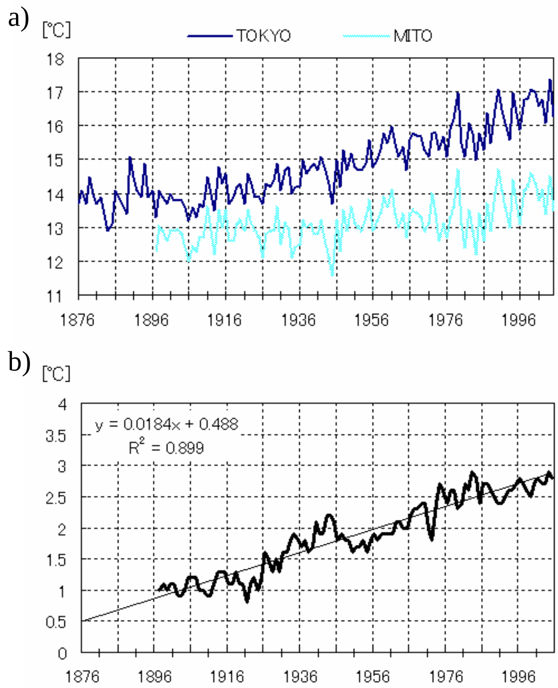


Fig. 2 Variation of a) yearly mean temperature at Tokyo and Mito, and b) heat island intensity of Tokyo

2-2. Heat island intensity of Bangkok

There are few studies focused on heat island in Bangkok. Pichakum and Maruta (1995) and Niitsu (2000) confirmed that high temperature area appeared in urban area.

Fig. 3 shows meteorological observatories and their yearly mean temperature in Thailand in a) 1951 and b) 2005. Same as Tokyo area, the number of observatory at the early year is few compared with current number of observatory. Lop Buri is selected as a suburb observatory for calculating HII.

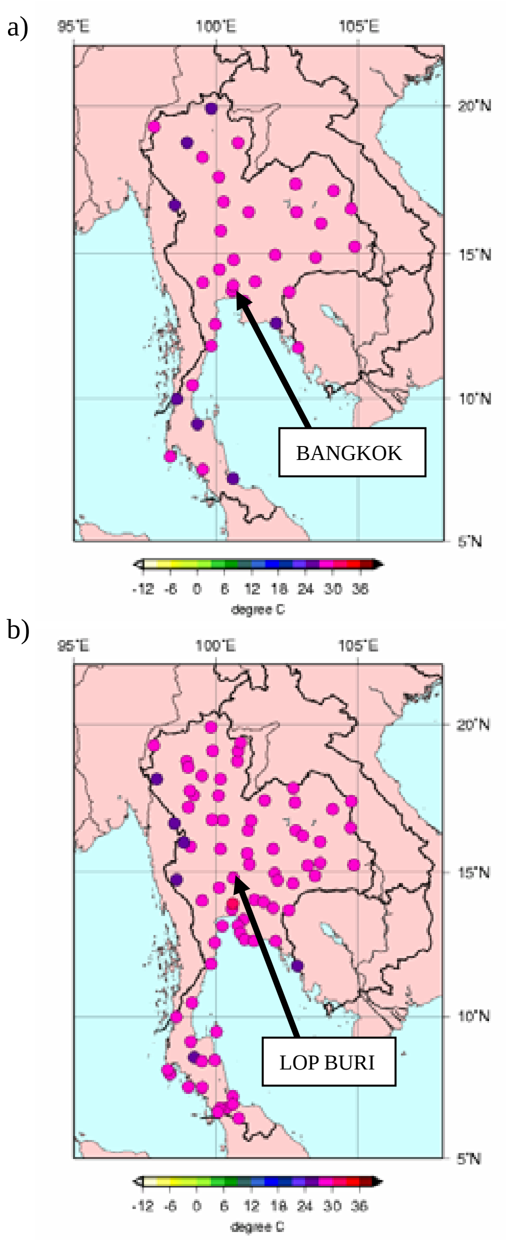


Fig. 3 Meteorological observatories and their mean temperature in Thailand a) in 1851 and b) in 2005

Fig. 4 a) shows variation of yearly mean temperature at Bangkok and Lop Buri. Representative observatory of Bangkok is called "Bangkok Metropolis." Current "Bangkok Metropolis" is located at 13 ° 44' N and 100 ° 34' E. This observatory was relocated twice in the past. Firstly, it was relocated from Sukhumvit (period: 1951-1991) to Bang Na (period: 1992-1993). It was relocated again, and moved to Chaloemprakiet (period: 1994-). There seems no large gap when the observatories were moved. Regarding Lop Buri, it is located at 14° 48' N and 100° 37'E. There is no detail information available related to relocations.

HII of Bangkok shown in Fig. 4 b) has increased approximately 2 ˚C from -1 ˚C to 1 ˚C per 50 years.

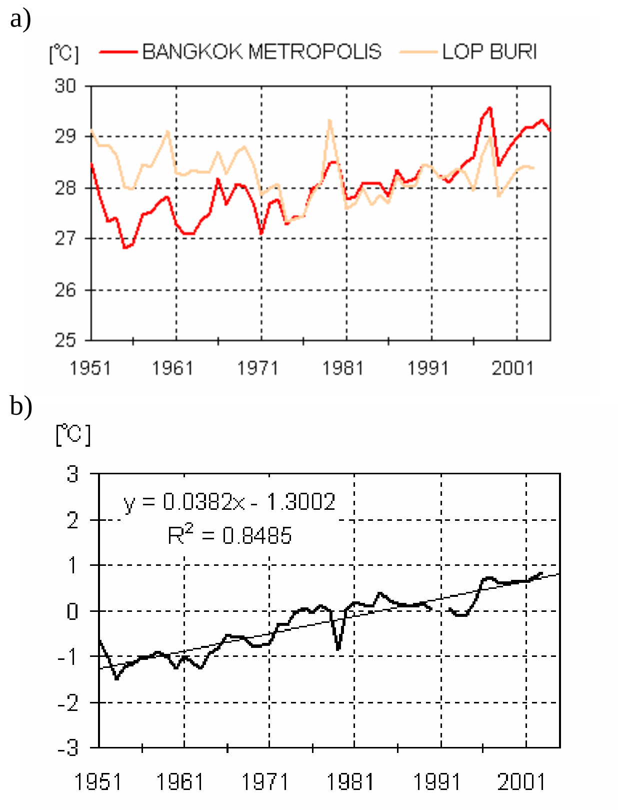
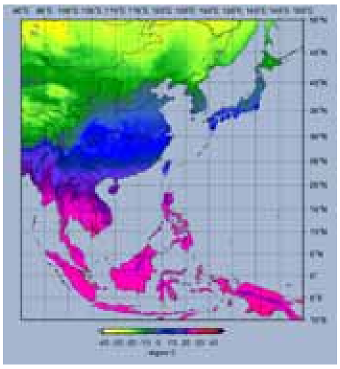


Fig. 4 Variation of a) yearly mean temperature at Bangkok and Lop Buri, and b) heat island intensity of Bangkok

2-3. Temperature trend of the East-Asian region

Fig. 5 a) and b) show average temperature distribution in January and July from 1901 to 2002 using the CRU TS 2.1. Average temperature of East-Asian region where our target cities exist is from -15˚C to 30˚C in January, and temperature difference of each city is large. On the other hand, average temperature in July is approximately 30˚C in large area, and temperature difference of each city is small.

a)



b)

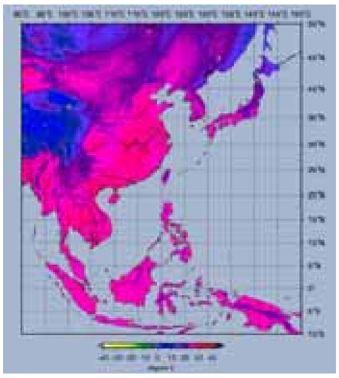


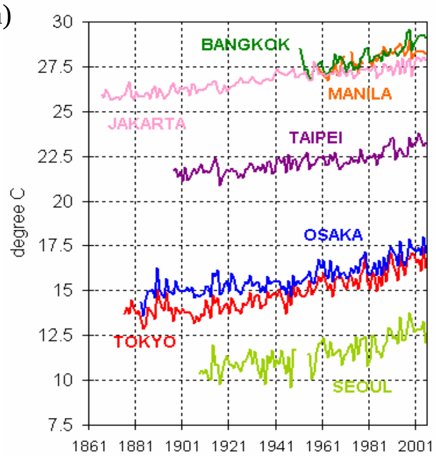
Fig. 5 Monthly average temperature in a) January and b) July during 1901-2002

2-4. Temperature trend of Asian large cities

Trend in yearly mean temperature of our target cities using observational temperature data is shown in Fig. 6 a). Meteorological observation of each city has begun in around 1900. The period of average yearly temperature data available is as follows; Seoul is from 1908. Tokyo is from 1876. Osaka is from 1883. Taipei is from 1897. Manila is from 1956. Bangkok is from 1951. Jakarta is from 1866. In most of these cities, temperature has increased by approximately 2.5 ˚C during 20 century. These increasing are considered to be effects of both urban warming and global warming.

Fig. 6 b) shows yearly mean temperature trend of the areas surrounding our target cities using CRU TS 2.1. They are the values averaging four grids data around the target cities exit. They seem to be slightly increasing, but their increase trend is smaller than that of observational temperature in the cities shown in Fig. 6 a). The city which has the largest number of population in 2000 is Tokyo, and the next is Osaka. The city which has the smallest number of population in 2000 is Taipei. Seoul shows largest increase ratio of population from 1950 to 1990. Population is often used as an index of indicating city size and comparing it with temperature (Park 1986; Sakakibara and Kitahara 2003).

a)



b)

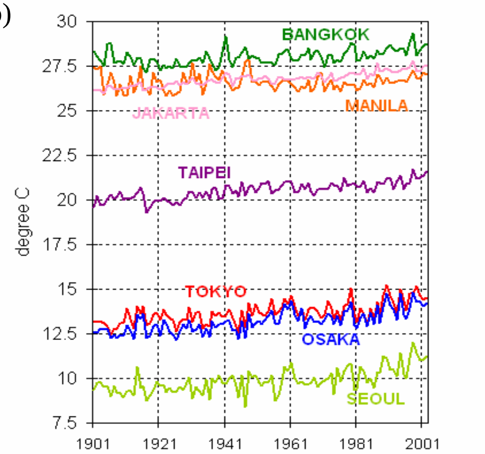


Fig. 6 Variation of yearly mean temperature a) at the Asian large cities using observational temperature data and b) at the areas of around the large cities using CRU TS 2.1 temperature data

3. Urban warming in the Asian large cities

In our project, long term trend of HII is necessary. Then, in this study, estimated HII (hereafter, E-HII), which is the value subtracting the reconstructed temperature around city shown in Fig. 6 b) from observational temperature in the city shown in Fig. 6 a), is advocated. Since long term trend is important, yearly mean data is used for calculating E-HII. This E-HII is quite simple index and not considered the detail situation of each city such as topography, city size, population and so on. However, indicating this kind of index calculated by unified method is necessary for understanding general situation of urban warming in several cities for long period and comparing it with other environmental data such as subsurface temperature.

Fig. 7 shows variation of E-HII at the target Asian large cities. Osaka shows largest E-HII and it almost 3 ˚C after 1981. Seoul, Tokyo, Taipei and Manila show between 1 ˚C and 2 ˚C after 1981. Jakarta and Bangkok show lower E-HII, but E-HII in Bangkok is rapidly increasing. The values of E-HII at 1951 and 1952 in Bangkok seem unusual. These values are result that original yearly average temperature values shown in Fig. 6 a) were high. In Bangkok, temperature data are manually recorded and digitalized later (from field survey at March 2006). Then, there is a possibility some unexpected mistake was happened when the data is edited.

The increase of HIl of Tokyo (Fig. 2) is larger than that of E-HII shown in Fig. 7 which has increased approximately 1.5 ˚C from 0.8 ˚C to 2.2 ˚C. This difference is considered to be a result of the way when suburb observatory was selected. Some of area used for data shown in Fig. 6 b) could be considered not to be enough suburbs. On the other hand, Mito is complete suburbs where not to be affected by Tokyo at all.

The increase fo Hll of Bangkok (Fig. 4) is also larger than that of E-HII which has increased approximately 1.0 ˚C from -0.5 ˚C to 0.5 ˚C shown in Fig. 7. This difference is also considered to be a result of how to select the suburb observatory same as Tokyo case.

E-HII is lower than the actual temperature difference of urban and suburban observatory in the both Tokyo and Bangkok case, and it indicates averaged tendency of heat island intensity.

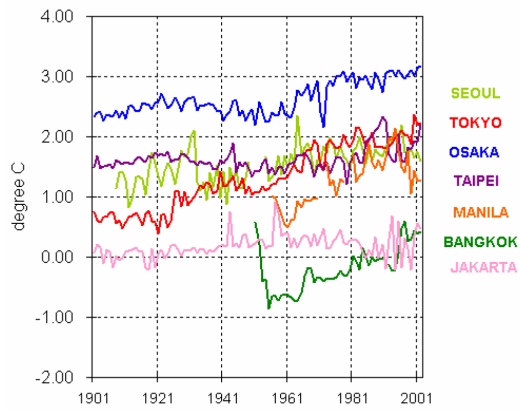


Fig. 7 Variation of estimated heat island intensity at the Asian large cities

4. Discussions and conclusions

In this study, long term trend of surface temperature in Asian large cities is analyzed for the purpose of estimating the effect of urban warming. E-HII index is advocated as the value which subtracts the grid reconstructed temperature data around the city from observational temperature data in the city. E-HII value is lower than the actual temperature difference of urban and suburban observatory, but indicates averaged tendency of HII. Indicating the index calculated by unified method such as E-HII is necessary for understanding general situation of urban warming in several cities for long period and comparing it with other environmental data such as subsurface temperature.

Regarding Taipei, Manila and Jakarta, there is no study result available for comparing with E-HII in this study. In Seoul, there are some studies focusing on the HII (Chung et al. 2004; Sugawara et al. 2005). Kim and Baik. (2002) shows trend of averaged maximum temperature deviation between Seoul and Yangpyeong, and it has increased approximately 0.5 ˚C from 3 ˚C to 3.5 ˚C during 1973 - 1996. This increase is larger than that of E-HII shown in Fig. 7 which has increased approximately 0.5 ˚C from 1.5 ˚C to 2.0 ˚C during same period. This reason is also considered to be the result same as Tokyo and Bangkok.

Due to the expansion of urbanization, urban warming became world wide problem (Tayanc amd Toros 1997) such as global warming. Expansion of time and spatial scale of analysis for heat island become necessary. Currently, reconstructions process, such as checking the quality and digitizing, of historical meteorology data before 20 century have making rapid progress (Ichinose 2003; Mikami 1996; Zaiki et al. 2006). Hung et al. (2006) used satellite data for evaluating heat island effect in large area. These new data should be used for analysis.

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Groundwater Management from the Viewpoint of Law and Institution -Japanese Experience-

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Abstract

The purpose of this paper is to review groundwater management in Japan from the viewpoint of law and institution. In Japan, groundwater is regarded as private property of landowner. This is called the theory of private water. In contrast, there is another argument that groundwater is (should be) regarded as not private property but public property and should be subject to governmental control like surface water. This is the theory of public water. Related to this problem, a lot of studies pointed out the necessity of unified law for surface and underground water. In this paper, we are concerned with the legal analysis of groundwater management in general and concrete problems that are caused by the different legal status of surface and ground water in Japan.

1. Introduction

The purpose of this paper is to review groundwater management in Japan from the viewpoint of law and institution. In Japan, groundwater was once used for a variety of purposes, such as irrigation and drinking water. But, after 1950, as a lot of dams were built and the rate of surface water dependence increased, the rate of groundwater dependence decreased. It is now only 12.5 %[1]. Nonetheless, groundwater is still important in that it plays an important role as a source of water supply in some regions and it works as an alternative water supply in case of drought. That's why there has been renewal of interest in groundwater management.

So far, a lot of investigations have been made about the legal status of groundwater. According to Ogawa or Takemoto, who published excellent reviews on the topic, one of the basic controversies in previous works is about "the theory of private and public water"[2].

In Japan, groundwater is regarded as a part of its land above and landowner, basically, can make free use of it. In other words, groundwater is situated as private property of landowner. This is called the theory of private water. In contrast, there is another argument that groundwater is (should be) regarded as not private property but public property and should be subject to governmental control like surface water. This is the theory of public water[3].

Numerous arguments have already been made about whether groundwater is private water or public water. But there are also opinions that the controversies do not mean a lot, because the classification is not absolute one, but relative one, depending on the situation where groundwater problems are taking place. Those works insist that what is more important is not to make fixed categories, but to think how we can justify public regulation on groundwater use, if there is need[4].

Related to this problem, a lot of studies pointed out the necessity of unified law for surface and underground water. What happens if groundwater is treated as private water and surface water is treated as public water, while those are connected with each other in one hydrological unit? Although this question was often posed by many researchers, almost all of them dealt with it in abstract way and failed to show concrete problems caused by the different legal status[5].

In this paper, we are concerned with the legal analysis of groundwater management in general and concrete problems that are caused by the different legal status of surface and ground water. We may consider the subject under the following heads; the next chapter deals with the necessity of water law in general. In the third chapter, we will discuss the theory of private and public water in detail. In the fourth chapter, we will think the necessity of unified law for surface and underground water with four kinds of concrete problems. In the fifth chapter, attempts will be discussed that have been made for the solution against the different legal status of surface and groundwater. And the sixth chapter is conclusion.

2. Why do we need water law?

Before moving to the main task, it is helpful to confirm the reason why we need groundwater law or water law in general. One of the important reasons is hydrological cycle. A river flows from headwater to ocean. Where a lot of people use water in the river, those people are connected by water. If water use by person A (typically, upstream user) put undesirable effects on person B, C etc (typically, downstream users), a conflict of interest will take place. Preventing or solving the conflict is a big reason why we need water law. So the focus of water law is not relationship between human and water, but relationship between humans connected by water[6].

It is often said that, although surface and underground water is a unit from a viewpoint of hydrologic cycle, water management is often schemed in fragmented way. In other words, hydrologic unit is often ignored when water management plan is implemented.

To take a simple example, water resource is managed by a lot of ministries in Japan. River itself is under jurisdiction of the Ministry of Land, Infrastructure and Transport. But irrigation water is managed by The Ministry of Agriculture, Forestry and Fisheries and drinking water is subject to regulation of the Ministry of Health, Labor and Welfare. Moreover, a single river was once divided in the different legal positions and the different rules were applied to each part, depending on the importance of the parts for a society as a whole. Those fragmentations were now amended in current legal system (the river law). But it still has room for improvement. For example, current river law deal with a surface water system as a whole, but little attention is paid to land uses in upstream areas[7]. And the third example is that the legal status of surface and groundwater is divided. While surface water is regarded as public water, but groundwater is regarded as private water. In the next chapter, let us look closely at the last point.

3. The theory of “private water” and “public water”

As mentioned before, groundwater is regarded as private water. It means that groundwater use is based on land ownership. It is said that this notion was based on a Japanese Supreme Court decision in 1896[8]. The case was about a conflict between a person who made rice in downstream area and a person who pumped groundwater in the mountain. The former appealed that the latter’s pumping had caused harm by decreasing the river flow from which the former had taken irrigation water. The judge rejected the appeal and said that right of use groundwater belonged to the ownership of land and the landowner could make free use of groundwater that lies below its land[9]. Moreover, Japanese civil law went into effect just one year after this judge. Its civil code section 207 said that, subject to limitations by laws and ordinances, the ownership of land extends both above and below its surface. This rule reinforced a theory of private water even more and the influence still remains today[10].

The theory of private water may lead to an over exploitation problem especially when groundwater is shared a lot of landowners. A lot of academic attempts have been made to mitigate the potential but undesirable effect of a theory of private water. For example, Takeda asserted that groundwater could be classified into three groups, such as soaking, unmoved and flowing. And he insisted that flowing groundwater should be subject to the same rule as applied to surface water. In other words, we may say he tried to pull out a part of groundwater from a theory of private water by making fine distinctions[11]. In another example, Endo tried to limit free pumping by asserting that groundwater was a "special" part of land in that over-pumping destroyed the crust itself. This opinion was made in the social context of a severe land subsidence problem [12] . Moreover, Minobe argued that groundwater might turn into public water through customary practices[13]. And the last, while these are attempts by scholars, amendment came from judicial decisions, too. Some decisions limited free pumping by using a theory of right abuse[14].

Although these assertions tries to limit free pumping, it does not deny the notion itself that groundwater is basically a part of surface land. Against these opinions, there is a school that asserts that groundwater is (should be) regarded not a part of surface land, but as a part of hydrologic cycle. This is called the theory of public water. In this theory, the necessity of public regulation on groundwater uses is strongly recommended[15].

Like this, so far, a lot of arguments have been made about whether groundwater can (should) be classified into private water or public water. But recently, as mentioned before, it is widely recognized that the controversies do not mean a lot and some point out that more attention should be paid to the status quo where surface and ground water is divided *in legal sense*. These arguments also tend to assert the necessity of integrated management of surface and underground water on the standpoint that both are a unit *in physical sense*. But just because surface and ground water connects with each other, it does not follow that integrated management is necessary [16] . It is because, for example, those two kinds of water are quite different in its flowing speed. Should we establish a law that covers surface and ground water paying attention to the physical unity? Or should the law be kept separated due to the difference of the characteristics? Of course, the answer depends on circumstances and differs in case by case. But if we knew the concrete problems that may be caused by the different legal status of surface and groundwater, we would be a step closer to answer the question. Then, we will turn to those problems in next chapter.

4. The different legal status of surface and ground water and its problems

In this chapter, we are concerned with four problems that are caused by the lack of the integrated management of surface and ground water.

Case 1: Land subsidence

The first example is land subsidence. Cities such as Tokyo, Osaka experienced the problem even in 1920's. But the problem got severe especially during economic development period (1950~1970). The main cause was over pumping by industrial sector that had been allowed to make free use of groundwater then. This is a typical example of "tragedy of commons." As a measures against problem, Japanese government enacted laws which regulated groundwater pumping. Those are Industrial Water Law in 1956 and Law concerning control of groundwater extraction for building use in 1962. And at the same time, Japanese government promoted an industrial sector to use surface water instead of groundwater by constructing industrial waterworks. It is widely accepted that these measures were very effective to stop severe land subsidence[17].

Case 2: Water banking

The second example is a case of water banking. Water banking is an artificial recharge of groundwater for future use[18]. In some regions like Kumamoto, Japan, paddy fields played a big role in recharging groundwater[19]. In other words, rice farmers unconsciously, voluntarily, recharged groundwater there. They produced a spillover of benefit and groundwater users could enjoy the benefit without paying to the farmers.

Now, rice industry in Japan is no longer the main economic sector. As the number of paddy fields decreases, groundwater recharge decreases in Kumamoto area, too. Water banking is a management tool for increasing groundwater recharge. In the case of Kumamoto, water banking takes a form of keeping water in paddy field. One possible way to realize this situation is to establish groundwater funds by collecting groundwater charge and give the farmers a financial incentive to keep paddy fields.

Here again, the legal status of groundwater will hinder the attempt. It is very hard for government to persuade groundwater users to pay its charge, while everyone thinks groundwater is their own private property. But it would be fallacious to think that establishing groundwater funds is impossible where groundwater is regarded as a part of surface land. But if possible, the funds are likely to be small, because it is difficult for government to collect high charge.

Case 3: Water conciliation part 1

The third example is a case of a river named the Pecos that flows in the state of New Mexico, U.S. First, the early settlers found large springs in the northern parts of the Roswell Basin and the water from the springs was quickly appropriated by them. That is, they began to use the water after applying and getting permissions for water use to the state government.

But then, such a governmental regulation did not reach to groundwater. So the late settlers were allowed to make free use of groundwater and this led to the diminishment of the surface flow. In other words, groundwater was a tributary of the Pecos River. From a legal perspective, this situation meant coexistence of pumps with permission and without permission along the same river. In this case, the benefit of the former was violated by the latter. This example shows the difficulty of securing water rights without paying attention to the physical unity of surface and underground water.

Against this situation, government of the NM state introduced a permitted water right system for not only surface water but also groundwater. It is widely known that this was one of the earliest applications of appropriative water right system to groundwater in the Western United States.

Case 4: Water conciliation part 2

The last example can be observed in Saijo city, a small city in Shikoku Island, Japan. Saijo is very famous for richness of groundwater. It is said the groundwater is recharged from a river named The Kamo. Recently, Saijo city has been very anxious about the preservation of groundwater because an adjacent city (Matsuyama) is trying to divert water the Kamo River for their domestic use[20].

From a legal perspective, this conflict raises an interesting problem. First, if Saijo took water from surface water for their own uses, they would have to get permission from the government that was in charge. It is because water in Kamo-river is public water and nobody is allowed to use without the permission. Then Saijo city would be regarded as a water right holder and the benefit would be protected by a law named the River law[21].

But, in reality, citizens in Saijo do not divert water from surface water, but pumps groundwater. Because the legal status of groundwater is private water, they don’t need any permission for pumping. That means they are not a water rights holder in strict legal sense. So, even if Matsuyama appears as a potential competent for water in Kamo-river, they can not enjoy the protection written in the river law.

First of all, groundwater that is used by citizens in Saijo is originated from water in Kamo-river and they are same thing physically. So it can be said that they use same water, irrespective of whether they take it from surface or underground. But in one case, citizen in Saijo can enjoy the protection of the River law and in the other case, they can not. This problem takes place because surface and groundwater is divided into two in legal sense. The measure that Saijo city can take against this problem remains to be seen.

Although these four problems seem completely separate, all of them are caused by the different legal status of surface and ground water. Moreover, there are another common features among these problems; the existence of spillover effects. While the effect is undesirable one to others in cases of land subsidence and water diversion, the effect is desirable one in case of groundwater banking. The problem is that we do not always have a mechanism for making people pay for desirable spillovers / compensate undesirable spillovers. Creating such a mechanism is the very role government should do. It can take a variety of form. It can be done by resolving the different legal status of water resources or introducing public limitation on groundwater uses while admitting the legal status of groundwater as private water.

5. Groundwater management without national groundwater law

Some attempts have once been made to establish national groundwater law. All of them were planned around the mid 1970's when land subsidence problem was officially regarded as one of the typical public nuisance by government.

The plans are summarized as figure 1.

Those plans were various in the purposes, the definition of the legal status of groundwater. While some plans were what focused on land subsidence, others tried to set up a more comprehensive rule that dealt other problems than land subsidence, such as groundwater pollution and salt intrusion. There was, however, a common feature in that the necessity of permitted water right system had been mentioned in all proposals. Some proposals even insisted that groundwater should be regarded as public water.

But none of the proposals were put into practice. Ogawa pointed out some reasons. First, it was hard to establish quantitative estimates on groundwater. Secondly, at that time, there have already been too many drills for government to get exact data on the pumping volume. Thirdly, the number of groundwater users was so large that coordinating their pumping was a difficult task. Fourth, Many groundwater users regarded groundwater as private

Figure 1: Four Plans for Groundwater Law

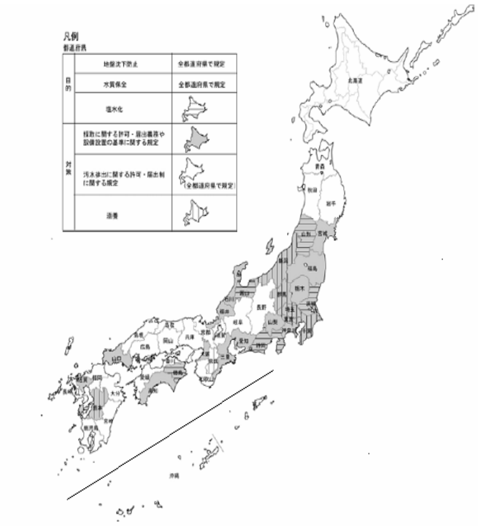
Planning body	Purpose	Regulation	Levying ground water fee	Legal status of groundwater
Central Council for Environment Pollution （Environment Agency）	Prevention of land subsidence	・Designation of critical areas ・Permitted system	○ （Long term goal）	Public water
Special Committee in Liberal Democratic Parity	Prevention of land subsidence	・Designation of critical areas ・Permitted system		
Study group of groundwater management institution （Ministry of Construction）	Comprehensive management （land subsidence, over-pumping, salt intrusion, pollution）	Permitted system	○	Public water
Resource research group (Agency of Science and Technology)	Comprehensive management	Permitted system		Public water

（Source: *Jurist*,No.582,1975）

property[22].

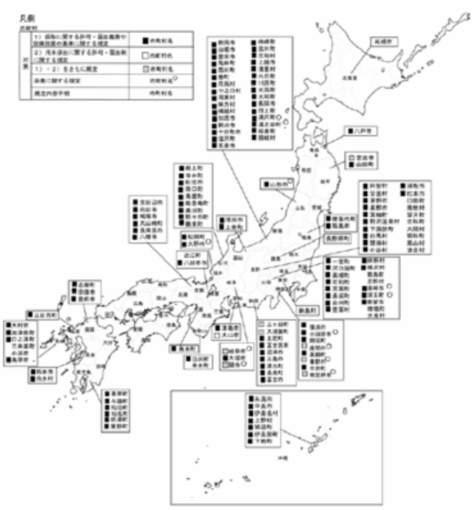
Due to these reasons, there is not a comprehensive groundwater law in Japan. This fact promoted local governments to establish their own groundwater rule and ordinances to cope with groundwater problems in their jurisdictions (Figure 2, 3). Much of ordinances were made as a part of general rule on environmental protection. And some include not only groundwater quality standard but also orders and regulations about artificial recharge and salt intrusion. Not only prefecture governments but also city governments have their own groundwater rules. It is said there are 330 examples and among them, 181 cases are a part of general ordinances for environmental protection.

Figure 2: Prefecture Ordinances



資料)佐藤邦明編著「地下水環境・資源マネージメント」埼玉大学出版会(2005年)

Figure 3: City Ordinances



注)市町村名は2004年7月現在のもの
資料)佐藤邦明編著「地下水環境・資源マネージメント」埼玉大学出版会(2005年)

6. Conclusion

The concept of hydrologic cycle has significance not only to natural science but also social science. Due to the cycle, typically, a water user in upstream may put negative influence on another water user in downstream. Then a conflict of interest will take place at that time. Prevention or solution of such a conflict is a main function of water law.

In Japan, while surface water law is regarded as public water, groundwater is treated as private water. In other words, while those who want to use surface water needs to get permission from government that is in charge of the river, those who wants to use groundwater don't need to get permission, but need to be an owner of the surface land. Where there is strong connection between surface and ground water, this means that water resource of a hydrological unit is fragmented in terms of law. Although a lot of arguments have been made about the legal status of groundwater, little attention was paid to the effects caused by the different legal status of surface and ground water. In this paper, it is shown that the difference provokes problems such as land subsidence, weak protection of existent water use in diversion, environmental flow problem and weak incentive for groundwater banking.

And the last, we showed that there was not comprehensive groundwater law of national level in Japan. Due to the lack of such a law, many ordinances established by each prefecture or city play a role as the substitute.

The legal structure of groundwater management has not been changed basically. So it seems reasonable to say that the risks mentioned above still exist potentially in many parts of Japan. Although we are concerned with an overall situation of groundwater management here, more and more specific case studies are necessary if we try to handle with the risks.

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Use of groundwater age tracers to understand the effect of urbanization in Asian cities
- Progress report of water group –

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I. Groundwater problems in Asian cities

Excessive groundwater use caused by human concentration to city areas and their land use change has created large impact on the groundwater environment in and around city areas not only for their quality but also for their quantity. Most of Asian big cities are developed over the alluvial sediments and the groundwater aquifer in these unconsolidated materials has easily induced the huge groundwater disaster; such as land subsidence, groundwater salinization, dry-up wells, oxygen-deficit air troubles.

In the big city area of Japan; Tokyo, Nagoya, and Osaka, has experienced these groundwater disasters in 1970's and they have succeeded to compensate the problems by regulating the groundwater use. While many Asian big cities have been suffered from these disasters during recent 10 to 20 years and some cities have not yet been taken any measures until present. Development stage, their geographical size, population, geology and hydrology of each city must influence the level of groundwater disaster. Also the recovery of the groundwater by regulating the water use must be mostly affected by the hydrological condition of the location of the problem cities. The success of groundwater recovery by pumping regulation in Japan must be caused by the positive natural groundwater recharge rate (800-900mm/yr) in the humid temperate climate of Japan.

II. Paleo hydrology (paleo-information extracted from urban groundwater aquifer)

The one major purpose of groundwater hydrology is to make clear the flow system in the groundwater aquifer. The use of environmental isotope is very helpful to understand this system because of their isotopic tracer characteristics such as age and origin. The recent development of those isotope hydrology study has create another aspect of research purpose which is called paleo hydrology. This is the study to extract the paleo information from groundwater aquifer by using isotopes. In the case of isotope hydrology study, we will create the change of chemistry along the groundwater flow line which is the distance from recharge area and also the groundwater age. Major chmical component in the aquifer shows evolutional trend along this line as shown in Fig.1.

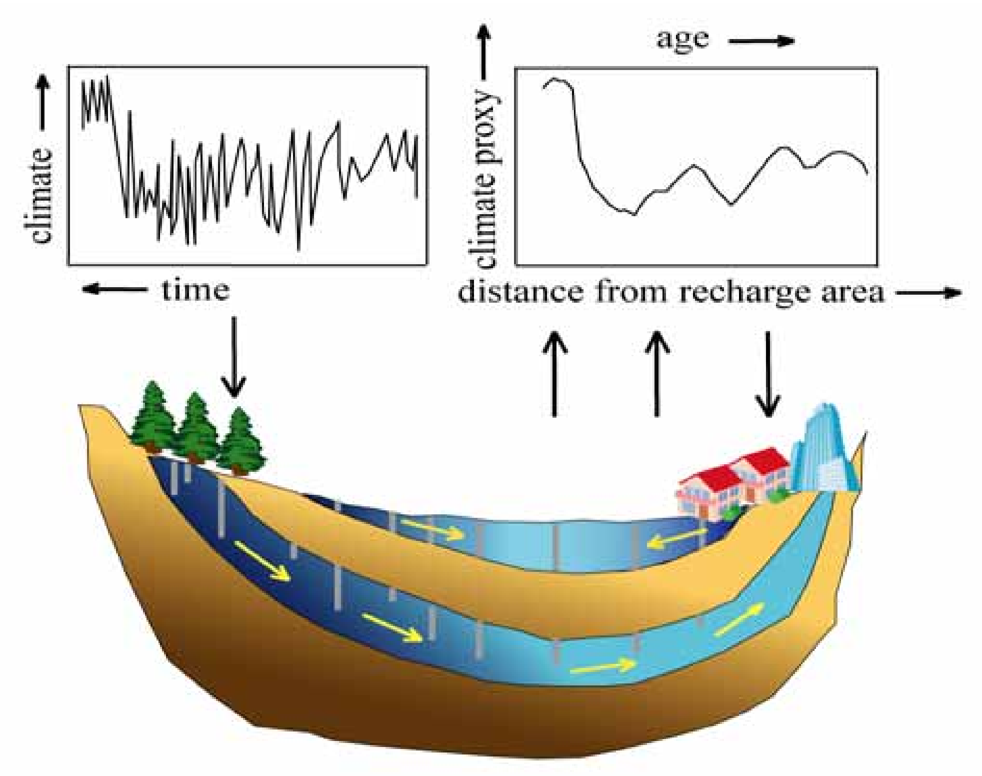
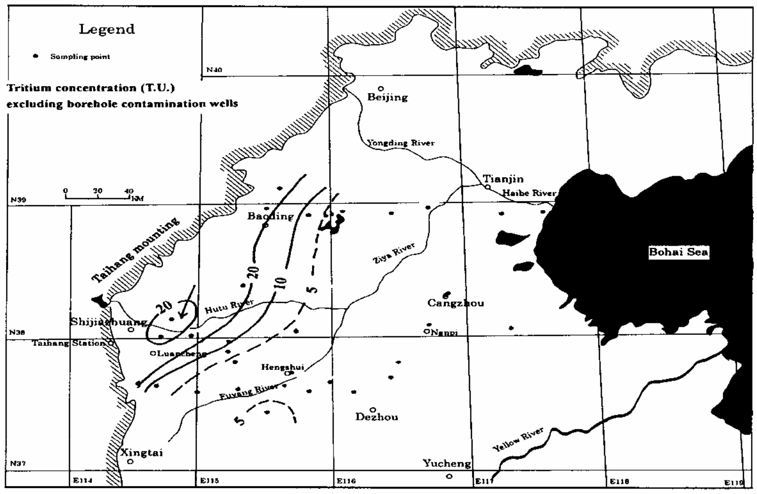


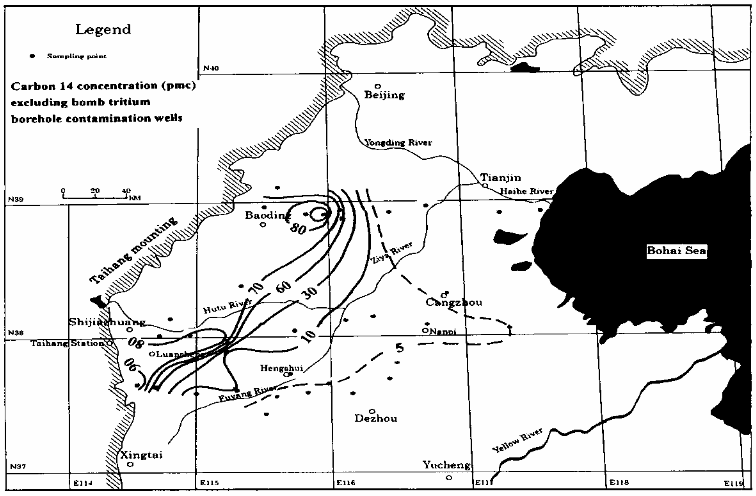
Fig. 1 Paleo hydrology (paleo-information extracted from groundwater aquifer) EOS.No.24,1998

As mentioned previously, the excessive pumping in the urban area has created huge groundwater drawdown in many Asian cities. This drawdown could be considered as the kind of man-made groundwater flow system over the natural flow system. Because of the very steep hydraulic gradient, this man-made flow is much faster than the natural condition in most case. Fig.2 shows the tritium and ^{14}C content in the groundwater of the western part of the North China Plain. This area has relatively modern tritium and ^{14}C content, and this is the evidence of man made induced groundwater flow caused by regional over pumping (Shimada *et al*, 2002).

Thus if we select the sampling line carefully, I believe that it is possible to extract the effect of urban growth from the groundwater aquifer by using the man-made induced groundwater flow.



Distribution of Tritium content for the sampled groundwater



Distribution of Carbon 14 content for the sampled groundwater

Fig. 2 The distribution of ^{3}H and ^{14}C content in NCP groundwater. (Shimada *et al*, 2002)

III. Development of the modern groundwater age tracer technique

The recent tritium concentration in precipitation has been decreased almost natural level (less than 10 T.U.) and the age resolution by using tritium has become lower year by year. After 1990's the development of the new young groundwater age tracer technique has been appreciated. The Cloro-fluoro Carbons (CFCs), the refrigerant liquid which has been widely used in 1980's and stopped to use because of the global ozone hole problem. The atmospheric CFC has been introduced to the groundwater through recharge process and could be used as the shallow aquifer age tracer like tritium. Also another anthropogenic substance, Kr-85 which is the artificial production through nuclear reactor or reprocessing plant of used nuclear fuel, is also thought to be the useful young age tracer after tritium. Because the use of those age tracers has not been recognized in the hydrological study in Japan, we would like to introduce those young age tracers to detect the groundwater age in the induced groundwater flow caused by the over pumping in the urban area.

Ⅳ Present status of the development of CFCs and Kr-85 age methods and some results of field observations at Kanto and Bangkok area.

In 2006, CFCs method has introduced from USGS CFCs lab. and established the extraction and analysis line by the end of 2006. The method have preliminary tried at Kanto aquifer and Bangkok aquifer in 2007. However the result does not shows clear age trend because of the effect of the biological degradation in the confined aquifer. We will consider this reason more precisely and also consider the possible use of CFC’s as contaminant tracer by human activity in those aquifers instead of age tracers. In 2007, groundwater sampling for CFCs analysis is planed at Jakarta area.

Kr-85 method has developed separately for on-site rare gas extraction system and LSC measurement for Kr-85. Since the activity of ^{85}Kr is very low (1×10^{-4} Bq/L) in the present shallow groundwater, we have to collect 0.5~1.0 ccSTP of Kr from an approximate 10,000 L groundwater sample. We have assembled the hollow-fiber membranes, which is made of poly-4-methyl-1-pentene, into the proto-type degassing system. We conducted the tests to investigate the degassing performance of the system and the results of performance tests suggest that more than 99 % of dissolved gases including Kr was continuously collected from groundwater by using the assembled prototype degassing system. As for LSC measurement, we develop the analytical method similar to that for Kr-85 in air and have established the recovery method of Kr from a large volume of air, separation of N_2 and O_2 from Kr and complete isolation of Kr by gas chromatography. The material of a counting vial for Kr-85 was examined and we determine to use synthesized quart. Presently we are developing a method for Kr transfer to organic solution based scintillator in the synthesized quart vial. Both system has been completed within FY2007, and hope to try application of on-site Kr sampling and its LSC measurement in March 2008 at Kumamoto area.

In the Kanto area, long term groundwater levels data were collected and compiled for to provide a history of groundwater flow changes in the central region of the Kanto plain, which supports the largest urban area in Japan, the Tokyo Metropolitan Area. These results suggest that the groundwater flow affected by urbanization continued to change over several decades, even after the regulation of pumping. In addition, the recovery of groundwater levels has resulted in the resumption of demand for groundwater. Since increased groundwater withdrawals will have a marked effect on groundwater flow changes, the continued monitoring of the groundwater environment, including groundwater levels and groundwater quality, is important for the sustainable use of groundwater resources. The selection of the groundwater sampling line for CFC's analysis has been determined depends on these results and also these results will be issued in the Special Issue of STOTEN.

To reveal the confined groundwater flow system in and around Bangkok Metropolitan Area (BMA) and its recharge mechanisms under human impacts, field surveys were carried out in June 2006 and August 2007. Hydraulic head and isotopic compositions of groundwater were measured using totally 120 boreholes within eight confined aquifers down to a depth of 600 m. Hydrometric measurements clarified horizontal flow system in each aquifer and showed that groundwater pumping disturbs the flow lines at three areas. These results correspond to regionality in groundwater withdrawals. Isotopic data suggest that vertical flow between aquifers is non-negligible especially in BMA and saline waters remaining in upper aquiclude(s) move downward and mix with flesh groundwater, although in the three areas mentioned above the main body of groundwater appears to be supplied by horizontal flow rather than vertical flow. Thus, there is a possibility that the groundwater pumping at the areas enhances recharge of the deep groundwater. Based on both hydraulic head and isotopic data, a principal recharge zone is estimated to be a hilly region to the northeast of BMA. On the other hand, such an enhancement of groundwater recharge cannot be induced at the central part of BMA under the present conditions of spatial pattern of hydraulic head.

A part of these findings was presented at JGU (Japan Geoscience Union) meeting 2007 and 4th annual meeting of AOGS (Asia Oceania Geosciences Society).

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Tracing Deep Groundwater Underneath the Bangkok Metropolitan Area

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Abstract

To reveal recharge properties (e.g., sources, flowpath, velocity, etc.) of deep groundwater underneath the Bangkok Metropolitan Area both before and after drastic piezometric depression/restoration events, the spatiotemporal variations in piezometric water level and water quality (including environmental tracer concentration) were investigated. The results imply that for shallow aquifer groundwater recharged at the plain, terraces, and fans dominates in almost of plain area. In contrast, for deep aquifer such a groundwater can be observed only at the central area, while at the other area groundwater are mainly recharged by precipitation fallen onto hills and mountains. Owing to groundwater abstraction, recharge of modern fresh groundwater might be accelerated, and the young water is transported into lower aquifers with ancient sea water stored within and pressed out the Bangkok Clay layer.

1. Introduction

Bangkok, the capital of Thailand, is one of the Asian mega cities, which suffer various water problems due to urbanization. Population increase and economic growth in the city since 1950's have introduced excessive groundwater withdrawal for meeting drastic increase in water demand for public water supply and industrial use. As the results, piezometric level dramatically lowered inducing groundwater salinization, and land subsidence occurred and enlarged damage of flood disaster (Ramnarong and Buapeng, 1991). To cope with the problems, Thailand government has taken several measures: enactment of Groundwater Act in 1977, Groundwater Use Charge in 1985, Groundwater Preservation Charge in 2005, and water source change for public water supply (IGES Freshwater Resources Management Project,|2006). Owing to the measures, the piezometric level now comes to be restored.

A number of investigations on such groundwater and land subsidence problems have been carried out (e.g., Asian Institute of Technology, 1981; Ramnarong and Buapeng, 1991; Kokusai Kogyo Co. Ltd., 1995; Sanford and Buapeng, 1996; Phien-wej et al., 2006; Klaus et al., 2007), whereas none of them has addressed on restoration processes after mid-90s. Our goal is to elucidate deep groundwater recharge and flow systems in terms of their disturbance/restoration processes due to human activity. This paper mainly focuses on (1) changes in piezometric level, water quality and flow system during past 30 years, and (2) origins and flow paths of deep groundwater revealed by environmental tracers.

2. Area description and methodology

Bangkok metropolitan area (BMA), which is composed of Bangkok province and adjacent 5 provinces (Fig. 1), is located in the deltaic flood plain of the Chao Phraya River, called the Lower Central Plain (LCP). The plain has an extent of 25,000 km^2 and is surrounded by terraces, fans, hills and mountains. Elevation of the most part of the plain is lower than 20 m a.m.s.l. Annual precipitation within LCP ranges from 1000 to 1500 mm.

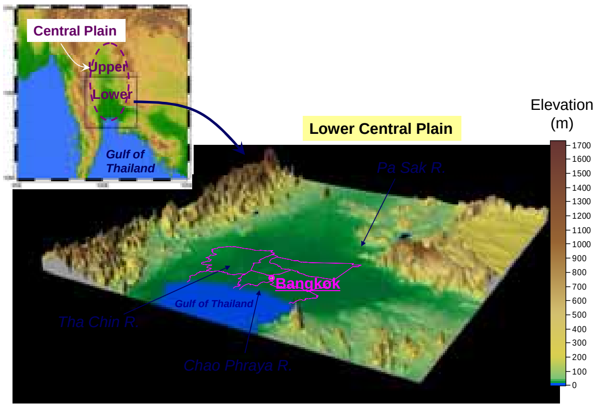

Fig. 1 Topography map of study area

Bangkok (or Thon Buri) sedimentary basin situated beneath LCP is conventionally divided into eight aquifers. The top confined-aquifer (BK) is overlain by soft to stiff clay layer known as “Bangkok Clay” with a thickness from 20 to 30 m, and other aquifers are also intervened by compact clay layers acting as aquitard. Groundwater is mainly exploited from Phra Pradang (PD), Nakhon Luang (NL) and Nonthaburi (NB) aquifers.

We conducted analysis of groundwater monitoring data compiled and provided by Department of Groundwater Resources, Ministry of Natural Resources and Environment, Thailand. In addition, field investigations including measurements of hydrogen and oxygen stable isotopic compositions (δD and $\delta^{18}O$), major ions, and chlorofluorocarbon (CFC) are carried out.

3. Historical change in piezometric level

For PD aquifer, moderate decline of piezometric level was observed at eastern/southern areas of BMA. At both western and central areas the level holds constant or rise moderately. Only at well no. 26, the decline is very remarkable with a maximum depression of 16 m for a period from 1980 to 1996, whereas the restoration after late 1990’s is also remarkable.

For NL aquifer, at many sites tentative restoration was observed in mid-80. The piezometric level depression is most remarkable at northeastern area, and the maximum depression reaches 25 m. Since 1997, the level came to be restored at all the sites more or less.

For NB aquifer, noisy and drastic change in piezometric level has occurred mainly at northern area. At the other areas variation pattern is similar to that for NL. At well mo. 3 the maximum depression of 25 m was recorded.

Horizontal distribution of hydraulic head for PD shows that its depression first has formed at the center of BMA then moved eastward. The strong depression at eastern area observed in 2000 is considerably restored up to 2006. Although we have no hydraulic head field covering all over LCP except for 2006, weak depression can be seen at western suburban area, forming groundwater ridge. Gradient of hydraulic head indicates that groundwater flows from north or northeast to south or local depression.

In contrast to PD, the hydraulic head depression in NL has been formed in earlier stage (i.e., 1980), and the magnitude of the depression in 2000 was greater. However, the depression weakened up to 2006. Another depression observed at western area in 2006 might continue from 2000. Groundwater is estimated generally to flow southward or southwestward at the northern half of LCP, and then flow to the two depressions: one is formed at eastern side of the Bangkok and another at western side.

The distribution pattern of hydraulic head in NB is almost similar to that in NL with minor difference in exact location of the depression.

4. Water isotopes, Cl^- and CFC

Stable isotope composition of water is capable of providing valuable information of the water source. The δD observed in 2006 is lower at the northern half of LCP and higher at the southern half, particularly at central Bangkok. Comparing the results with that observed in 1980’s by Sanford and Buapeng (1996), we cannot find clear difference between them. Spatial variation of the isotopic composition in NL is similar to that in PD. For NB aquifer, δD in 2006 is higher at the central area and lower at the eastern and western depressions. As compared to 1980’s, the values at the central area appear to slightly increase.

The δ-diagram shows data obtained in 80’s are not different from the present data very much, as for variation range and *d*-excess. An important point is that a part of the groundwater samples has values lower than long-term (30 years) mean value for precipitation, suggesting the waters has recharged at higher elevations. Another point is that many samples have δ value higher than precipitation value, indicating mixing with sea water and/or evaporative enrichment during recharge process. Among the isotopic alternation processes posed, effect of mixing with sea water can be addressed by using chloride data.

The Cl- concentration at the central area clearly shows an increase trend. High values of Cl^- are not restricted at costal area but found at inland areas. In addition, the Cl- value is lower at the northern half of LCP, whereas it is high at the southern half of BK aquifer, which is underlain by PD aquifer and its southern half is overlain by Bangkok Clay. These facts strongly suggest that the chloride ion is originated from Bangkok Clay and transported to aquifers PD through BK. In contrast to PD, Cl^- values are not so high even at the central part of BMA, and its difference between 1980's and 2006 is not clear. Eliminating only one exception, chloride concentration holds low levels in NB, same as in NL. These results indicate that groundwater abstraction induces downward movements of water and Cl^- from Bangkok Clay to the underlying aquifers, though the effect is major in PD and minor in NL and NB.

Assuming the present groundwater as a mixture of fresh groundwater preexisting in the aquifer and ancient sea water pressed out of Bangkok Clay, one can estimate isotopic composition of preexisting fresh groundwater by extrapolating the mixing line displayed in δ-Cl diagram.

Groundwater isotopic composition that corrected considering mixing with ancient sea water is plotted right-hand side of local meteoric water line (LMWL), indicating the groundwater was affected by not only mixing with sea water but also evaporative enrichment. If we assume relative humidity of 80% as a condition under which evaporation goes on, then the slope of evaporation line is estimated to be approximately 5. Thus, the intersection point of LMWL and the evaporation line gives original isotopic composition.

The Cl^- correction reduces number of samples having δD values higher than -35 permil, while the data were not influenced at low δD domain (Fig. 2). On the other hand, $\delta^{18}O$ correction reduces number of samples having δD values higher than -45 permil and lowered over entire δD domain. As a result, variation range of groundwater δD became in agreement with that of precipitation falling onto the plain and adjacent terraces, fans, and hills. These

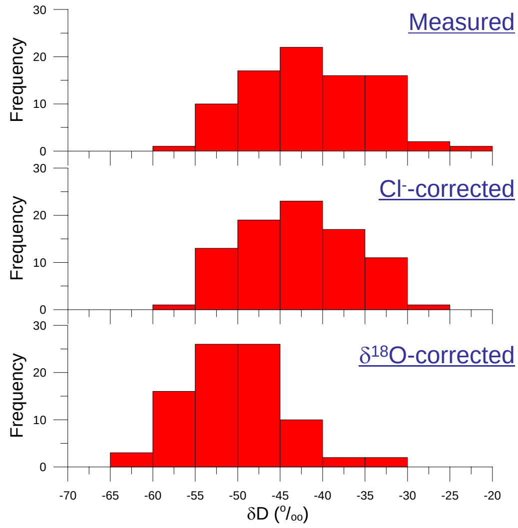

Fig. 2 Histogram of corrected/uncorrected δD

results partly support validity of the corrections. In other words, we can expect that (1) the original isotopic composition reflects altitude of recharge area, (2) the change in δD caused by the $\delta^{18}O$ correction reflects a magnitude of evaporative enrichment, and (3) the change due to Cl^- correction reflects relative contribution of sea water.

Assuming global average of the isotopic lapse rate for δD (2.24 permil/100 m), we can convert δ value to the altitude of recharge area. For instance, a value of -50 permil indicates that the groundwater recharged at an altitude of 230 m, and a value of -65 permil implies recharge at 900 m. Spatial distribution of full-corrected δD suggests that

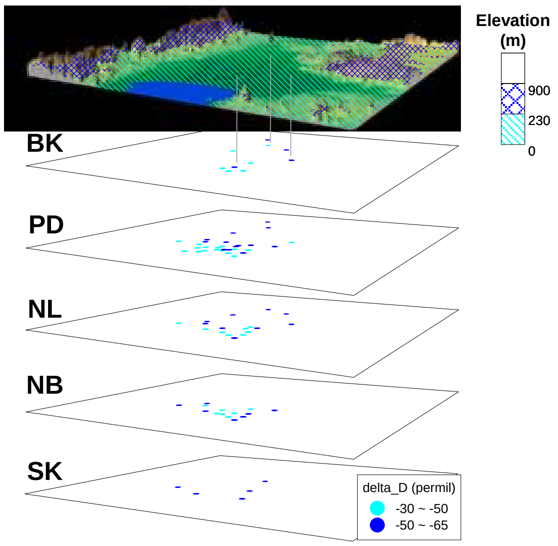

Fig. 3 Spatial distribution of δD indicating groundwater recharge areas

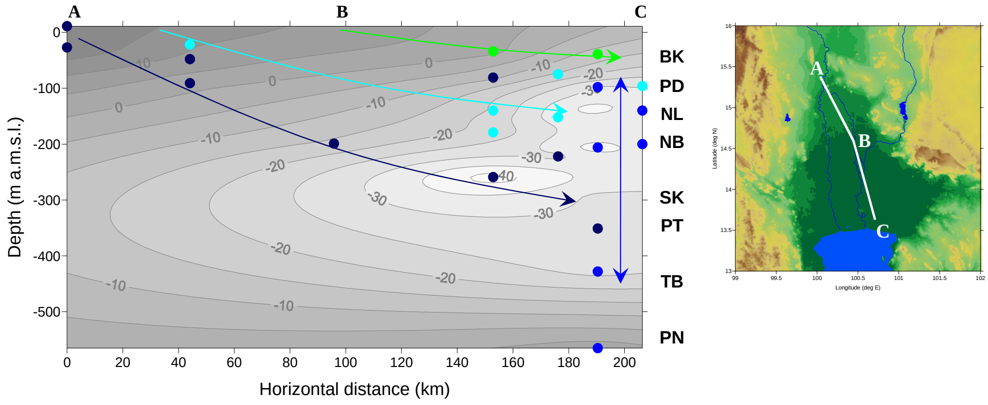

Fig. 4 Vertical cross section of distributions of hydraulic head and δD indicating flow paths

groundwater being recharged at the plain, terraces, and/or fans (sky blue hatched in the top panel; Fig. 3) dominates in upper aquifers and southern part of LCP (especially in central BMA). On the other hand, groundwater recharged at higher regions (e.g., hills and/or mountains; blue hatched; Fig. 3) can be found northern suburban areas and lower aquifers underneath BMA.

Vertical cross section of hydraulic head and full-corrected δD fields shown in Fig. 4 indicates groundwater flow paths. The figure also suggests vertical mixing probably due to groundwater pumping.

Surprisingly, most of samples had relatively high CFC-12 concentration ranging from 50 to 300 pptv. This fact indicates hat paleo-groundwater with age from 5000 to 20,000 years (Sanford and Buapeng) might be replaced by modern groundwater within past 30 years. Although the CFC results should be carefully reexamined, recharge of deep groundwater underneath the BMA can be accelerated by its use by human being.

5. Concluding remarks

Recharge areas of confined groundwater could be identified using environmental tracers. The flow paths estimated are disturbed by human activity at around the central Bangkok, and the residence time of deep groundwater may be shortening because of its use. On-going research should increase the reliability of these findings.

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Overview of the gravity group activities
and
GRACE application for monitoring terrestrial water storage

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Abstract

We investigated the applicability of the GRACE (Gravity Recovery and Climate Experiment) satellite gravity data and precise in-situ gravity measurements in order to establish a new technique for monitoring groundwater variations in urban areas.

Using the GRACE data, we estimated regional scale water mass variations in four major river basins of the Indochina Peninsula. The estimated variations were compared with Soil-Vegetation-Atmosphere Transfer Scheme (SVATS) models with a river flow model of 1) globally uniform river velocity, 2) river velocity tuned by each river basin, 3) globally uniform river velocity considering groundwater storage, and 4) river velocity tuned by each river basin considering groundwater storage. Model 3) attained the best fit to the GRACE data, and the model 4) yielded almost the same values. This implies that the groundwater plays an important role in estimating the variation of total terrestrial storage. It also indicates that tuning river velocity, which is based on the in-situ measurements, needs further investigations in combination with the GRACE data.

A new scheme for in-situ measurements that combines absolute and relative gravity measurements as well as GPS measurements is proposed for monitoring groundwater variation and associated land subsidence as well. The relationships among GRACE data, SVATS models, and in-situ measurements are also discussed briefly.

1. Introduction

The gravity group of RIHN Project 2.4 is mainly conducting the following two research subjects; 1) Estimation of terrestrial water storage (TWS) variations by combining the GRACE satellite gravity data and TWS variations obtained from a Soil-Vegetation-Atmosphere Transfer Scheme (SVATS) model implemented in a global climate model, 2) in-situ measurements that combines absolute and relative gravity measurements as well as GPS measurements for detecting groundwater level changes and associated land subsidence in Bangkok, Thailand, and Jakarta, Indonesia.

Regarding the first subject, we estimated regional scale water mass variations in the Indochina Peninsula from the GRACE data, and then, compared the variations with SVATS models with different river flow/ground water flow assumptions. The result shows the importance of groundwater flow and river velocity in estimating the total terrestrial storage.

The second subject is still in a preparation period, and we conducted preliminary surveys in Bangkok and Jakarta last year for selecting gravity points, estimating urban noise levels for gravity measurements, GPS test measurements and so on.

In this paper, we first introduce the basic concept and the research plan about the in-situ measurement, and then describe the results using the GRACE data.

2. In-situ Precise Gravity measurement

Local hydrological variations crucially affect precise gravity measurements, for instance, relative gravity observations (*e.g.*, Lambert and Beaumont, 1977), superconducting gravity observations (*e.g.*, Abe *et al.*, 2005), and absolute gravity measurements (*e.g*., Bower and Courtier, 1998). However, practical application of the gravity method for hydrological studies is very limited. One of the successful applications of this kind of study may be for geothermal power stations (Allis and Hunt, 1986). It is necessary to monitor the mass balance in geothermal reservoirs to produce geothermal fluid (steam and hot water) over a long period. For instance, Nishijima *et al*. (2006) conducted repeated gravity measurements at Takigami geothermal field located in central Kyushu, Japan. In general, the expected gravity change signal at the geothermal field varies significantly, reaching several tens of micro gals (10^{-8} m/s^2) or more. Nishijima *et al*. (2006) employed Scintrex CG-3 and CG-3M gravimeters to measure precise gravity change around the Takigami geothermal power station and attained an observation accuracy of ±10 micro gals, which is sufficiently accurate to detect the signals.

Not many studies have been conducted to monitor groundwater variations or to investigate hydrologic problems, primarily because the expected signals are small compared with the geothermal applications. However, the basic principle of the hydrological application is rather simple; the gravity changes due to groundwater mass movements are measured as gravity changes by means of precise gravimeters. An infinite water table of one meter thickness causes about a 40-micro gal gravity change. Thus, an accuracy of 10 micro gals or better is required for the hydrologic problems. It is not easy to achieve an accuracy of 10 micro gals by means of a spring-type relative gravimeter, for instance Schintrex or LaCoste & Romberg gravimeters. We therefore propose a new method to combine absolute gravity measurements and relative gravity measurements. For this purpose, we intend to employ a portable absolute gravimeter A-10, which is currently available from Micro-g LaCoste, for the measurements at some control points, and employ relative gravimeters of superior portability for the measurements at most points around the control points. We think this type of hybrid gravity measurements, which employ both absolute and relative gravimeters, can strike a balance between accuracy and efficiency of the measurements.

Another source of the gravity changes is vertical land movements. The rate of gravity change versus height change depends on the mechanism of height change and associated gravity change. If we assume mass movement or density change $\delta\rho$ of underground material (soil or sedimentary layers) and groundwater level changes (δgw) causes gravity change (δg) as well as height change (δh), then

$$\delta g=(-0.3086+2\pi\delta\rho G)\delta h+2\pi G P_e \delta gw \qquad (1)$$

where G is the Newton's gravitational constant and P_e is effective porosity.

If δgw causes height change of δh, but no density change is associated, *i.e.*, no compaction occurred, then a 1m vertical movement causes about a 0.3 mgals gravity changes. Therefore height changes at the gravity points should be measured with an accuracy of a few centimeters to ensure the equivalent accuracy of a 10 micro gals (0.01 mgals).

For monitoring height changes, we employ GPS measurements. Precision of height measurement by static or rapid static GPS survey is about ±5mm+1 ppm. Therefore about 3cm precision can be achieved within 30km survey area. For a wider survey area, we simply set up additional reference stations to ensure the precision.

Figure 1 shows the configuration of the combined measurements described above. A cross-shape with a circle shows a control point, where absolute gravity measurements should be conducted. Note that gravity and GPS measurements should be occupied at the exactly same mark to ensure the accuracy of a few cm in height or a 10 micro-gals of gravity, whereas groundwater level is not necessarily measured at the same point as long as the measurements well represents the neighboring groundwater level.

As test areas, we selected Bangkok, Thailand, and Jakarta, Indonesia, where excess groundwater pumping is still going on. We plan to monitor the aquifer balance changes by combining absolute and relative gravity measurements with GPS surveys. We expect that repeated gravity measurements with an interval of one year will reveal secular groundwater changes in both cities.

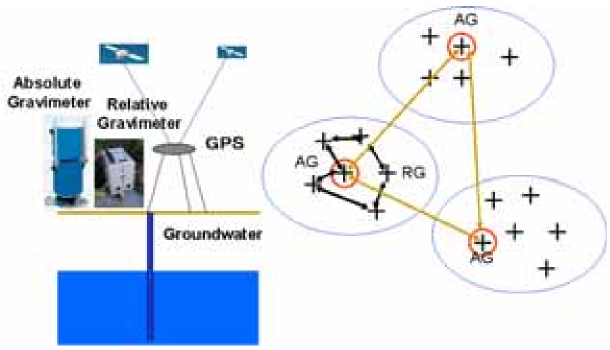

Fig. 1. Conceptual illustration of the method for monitoring groundwater variations. Absolute gravity measurements are conducted at selected control points, and relative measurements are conducted at the points around the control points to strike a balance between accuracy and efficiency of the measurements. Rapid static GPS measurements are conducted at all the gravity points to detect the vertical movements, and groundwater levels are monitored as selected points.

3. GRACE data processing

3.1 Data sets

In our previous work, Yamamoto *et al*. (2007) employed the GRACE Level 2 monthly gravity field solutions of the University of Texas at Austin, Center for Space Research Release 02 (UTCSR RL02), GeoForscheungsZentrum Potsdam Release 03 (GFZ RL03) and Jet Propulsion Laboratory Release 02 (JPR RL02). Recently, new data sets have been released from each of these three data centers, and UTCSR RL04 (Baettadpur, 2006), GFZ RL04 (Flechtner, 2007) and JPL RL04 (Watkins, 2007) are currently available as the most updated GRACE level 2 solutions. In these data sets, the data periods are expanded to Feb. 2007, and data accuracies have been improved by employing a new data processing algorithm, new ocean corrections, and a more reliable background global gravity field model (*e.g*., Bettadpur, 2006). In the current versions, the differences between the solutions of different data centers are not significant. Therefore, in this study, we employed UTCSR RL04, which provides the longest data period (from Apr 2002 to Feb 2007).

The hydrological model used in this study includes SVATS (Soil-Vegetation-Atmosphere Transfer Scheme), river flow routing, and groundwater models. The SVATS outputs are obtained from Japan Re-analysis 25-year data (JRA-25; Onogi *et al*., 2007). The river flow routing and groundwater models were run in offline mode forced with the total runoff in the JRA-25 dataset. Table 1 summarizes different data versions. Data version 1.b.x was obtained using this full model. Data version 1.a.x was obtained without groundwater models, and no groundwater storage; however, this storage is implicitly included in river channel storage for this version. In data versions 1.a.1 and 1.b.1, we used a globally uniform current velocity of 0.4m/s. This simple treatment has often been used but causes differences in the river discharge phase between observations and model outputs (*e.g*., Nakaegawa *et al*., 2007). We therefore performed current speed tuning and obtained the same phases for 66 of 70 rivers. Data 1.a.2 and 1.b.2 are obtained with the calibrated velocity.

3.2 Data processing

The procedure to estimate the mass variations or TWS variations in the four major river basins in the Indochina Peninsula is basically the same as that in

Table 1. Data version of TWS used in this study. SM:Soil moisture, SW:Snow Water Equivalence, RC: River channel storage, GW: Groundwater storage, CS: Current Speed tuning

Data version	SM	SW	RC	GW	CS
1.a.1	X	X	X		
1.a.2	X	X	X		X
1.b.1	X	X	X	X	
1.b.2	X	X	X	X	X

Yamamoto *et al*. (2007). We first designed Swenson-type optimal regional filters (Swenson *et al*., 2003) for each of the river basins and the four-river combined area. We next applied the filters to the GRACE data to extract the mass variations associated with the river basins. The locations of the river basins and their borders are depicted in Fig. 1 of Yamamoto *et al*. (2007).

The optimal design of the regional filter directly depends on the amplitudes of the satellite measurement errors. As described above, the measurement errors of RL 04 data sets have been reduced considerably compared with the previous versions. Consequently, the newly designed optimal regional filters can suppress the leakage errors more effectively and ensure more accurate estimation of the hydrological signals.

Figure 2 depicts the amplitudes of the filtered and non-filtered UTCSR RL04 GRACE data together with the hydrological model (1.b.2) amplitudes for the combined area of the four rivers. Figure 2 is the

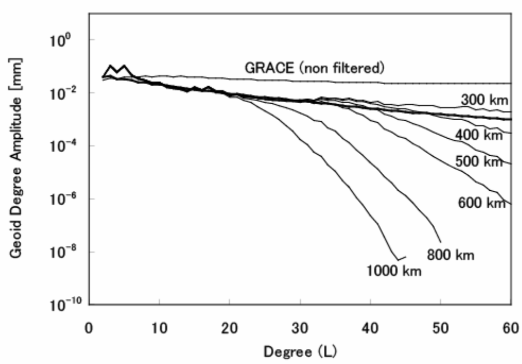

Fig. 2. Degree amplitude for the combined river area of the four rivers calculated from the filtered GRACE data with different correlation lengths (from 300km to 1000km). Degree amplitudes of non-filtered GRACE data and the land water model are also shown.

same as Fig. 3 of Yamamoto *et al*. (2007) and can be directly compared with it. Clearly, the GRACE amplitudes in Fig. 2 are much smoother than those in Fig. 3 of Yamamoto *et al*. (2007). Nevertheless, we selected 600km as the correlation length of the optimal filter because Fig. 2 shows the best fit between the hydrological model and the curve of the correlation length with 600km.

3.3 Comparison of the results

Figure 3 illustrates the estimated mass variations for the combined area of the four rivers from the hydrological models listed in Table 1. There are some differences in both amplitudes and phases. The amplitudes increase in the order of 1.a.1, 1.a.2, 1.b.2 and 1.b.1, and the phase delay increases in the same order. Figure 3 indicates that the difference between 1.a.1 and 1.b.1 (blue lines) is larger than the difference between 1.a.2 and 1.b.2 (red lines). This means that inclusion of groundwater storage in the model is significant if the current speed is not tuned. It also means that current speed tuning partially compensates for the groundwater storage. For further evaluation of the model fitting the GRACE data, we calculated annual signals of the estimated mass variations for both GRACE and the model data sets. Large improvements have been attained in 1.b.x models that include the groundwater storage. However, model 1.b.1 provides the best fit to the GRACE data, although model 1.b.2 produces almost the same values. In this study, the current speed was tuned based on in-situ measurements of the river runoff data, which is independent from the GRACE data. In addition, the residence time of groundwater is assumed to be 60 days for all land areas, which could degrade the mass variations. Considering these points, achieving a proper balance is a good subject for further investigations. For the present, we use model 1.b.1 for later comparisons because it gives the best fit to the GRACE data.

Figures 4 (a)-(e) present the estimated mass variations from GRACE and model 1.b.1 for the combined area of the four rivers (the Mekong, Irrawaddy, Salween, and Chao Phraya river basins). The GRACE estimations in these figures exhibit basically good agreement with the model estimations, although the GRACE estimations in Salween and Chao Phraya basins are noisier than the others. This is a huge improvement in RL04 data sets compared to the previous versions, in which the noise in

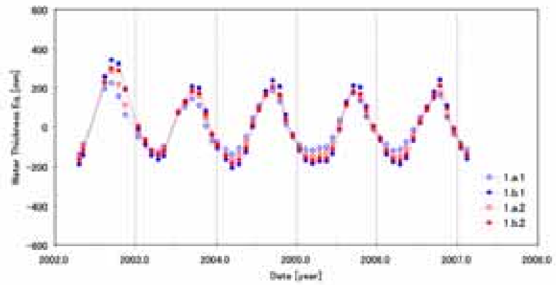

Fig.3. Comparison between TWS models. Temporal mass variations are calculated for the combined area of the four rivers using the models listed in Table 1.

Salween and Chao Phraya basins was so large as to mask almost all useful signals there (Yamamoto *et al*., 2007).

4. Conclusion

The RIHN project 2.4 “HIUSE” seeks to assess the effects of human activities on the subsurface environment. The various subsurface environmental problems include extreme subsidence, groundwater contamination, and subsurface thermal anomalies. Of these, the sustainable use of groundwater is a key issue for future urban development, and the main

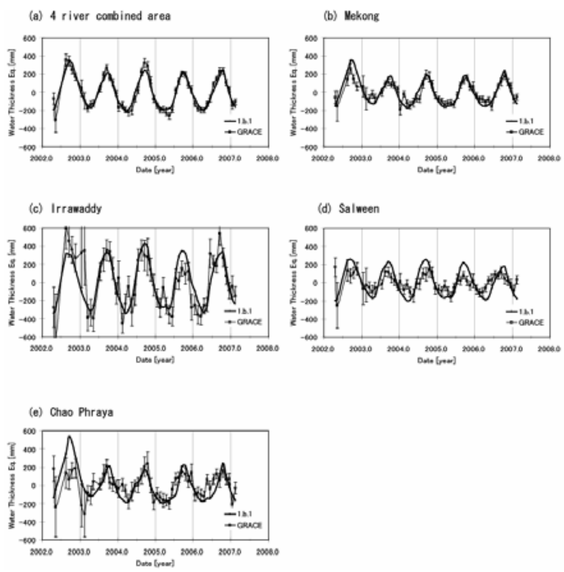

Fig. 4. Estimated mass variations from UTCSR RL04 (thin lines). (a) Combined area of the four rivers. (b) Mekong river basin. (c) Irrawaddy river basin. (d) Salween river basin. (e) Chao Phraya river basin. The mass variations estimated from the model (1.b.1) are also shown (thick lines).

objective of this study was to propose new techniques for monitoring the groundwater variations. The spatial resolution of the GRACE data is far from satisfactory for discussing urban scale groundwater variations. However, we have to determine regional or even global scale variations precisely to discriminate the phenomena caused by human activities in urban areas from phenomena due to climate change or larger scale processes. From this point of view, GRACE provides very good constraint conditions for hydrological models in terms of total mass variations or mass balance. It should be noted that only gravity measurements give such high precision constraints as the total sum of the variations, while hydrological models are necessary for understanding the processes of the variations.

For more direct monitoring of the groundwater variation in urban areas, we proposed using absolute and relative gravity measurements combined with GPS measurements. We are now preparing to conduct the first test measurement in Jakarta and Bangkok within a year. A key point is that an absolute instrument will be employed for the gravity measurements. Relative gravimeters are usually employed for these studies because absolute gravimeters have not been widely used yet. However, relative measurements always include some uncertainties in interpretation processes, and we anticipate the use of absolute gravimeters will yield more accurate and unambiguous interpretations. It should again be noted that even in-situ gravity measurements only give a kind of constraint in terms of mass balance. Therefore, a model is necessary for better understanding the processes. In this study, we used only global SVATS models, but in the future, we need more detailed models to deal with urban scale phenomena.

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Gravity and GPS preliminary survey at Jakarta and Bangkok

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Abstract

We carried out the preliminary gravity and GPS survey at Jakarta and Bangkok. We conducted the about 2km interval gravity survey to make clear the underground structure. The ground deformation survey using GPS has been started by Institute of Technology Bandung (ITB). Many benchmarks are established by ITB, and we went to some benchmark to check the benchmark size and noise level. We selected the four benchmarks in order to measure the gravity using the A10 absolute gravimeter in 2006. In Bangkok, We constructed the GPS base station on the top of the building of Chulalongkorn University. We will start the relative and absolute gravity measurement from 2008.

1. Introduction

Using a large amount of ground water causes serious environmental problems. This large amount of pumping up causes mass fluid movement and mass redistributions, which can cause measurable gravity changes and ground deformation at the ground surface (Fig.1). It is necessary to monitor the balance of aquifer between the production and recharge to use the ground water for a long term.

Repeat gravity measurements have been applied at the geothermal power plant and the erupting volcano. The first report of the in-situ gravity monitoring was the observation around the Wairakei geothermal power plant, New Zealand. Gravity decreases of up to 1000 micro gal have been measured after 30 years of production from the Wairakei geothermal field (Allis and Hunt, 1986). In Japan, the observed gravity changes depend significantly on changes in shallow groundwater level change. Nishijima (2006) applied a multivariate regression model and eliminated the effect of shallow groundwater level change in order to extract the gravity change associated with the production and injection of geothermal fluid.

These studies suggest that repeat gravity measurements are an effective method to monitor underground water flow. But there is no study for the application of the repeat gravity measurements for urban water resources problems. We are planning to make a repeat gravity and GPS survey at Jakarta and Bangkok to monitor the aquifer balance changes.

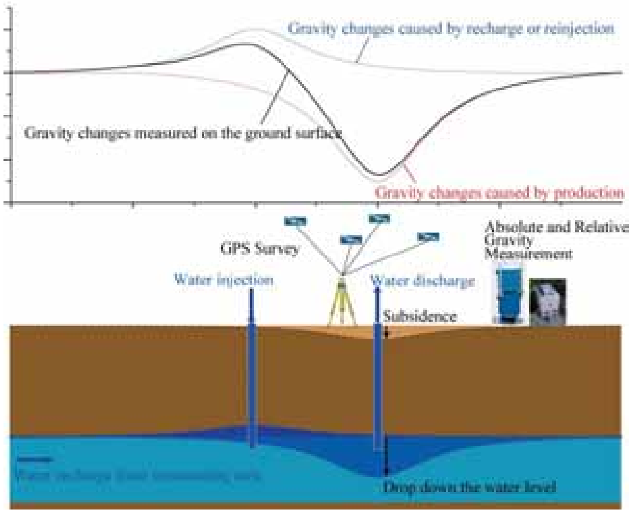

Fig.1 Concept of repeat gravity measurements.

2. In-situ gravity measurement for groundwater level monitoring

There are two methods to measure the gravity. We will combine the Absolute gravity measurement and the relative gravity measurement. The instruments are relative gravimeter (CG-3M gravimeter: Scintrex Ltd. and LaCoste and Romberg gravimeter: Micro-g LaCoste, Inc.) and absolute gravimeter (A-10 gravimeter: Micro-g LaCoste, Inc.).

Recently there are some satellite gravimetry missions. GRACE mission is one of them. GRACE data can evaluate the global mass movement include ground water flow. We will also use the satellite GRACE mission data to evaluate the wide area ground water flow, because the spatial resolution is not enough (about several hundred km).

Fig. 2 Relative gravimeter
(LaCoste and Romberg gravimeter).

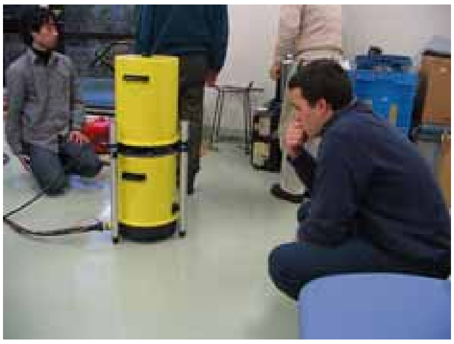

Fig. 3 Absolute gravimeter
(A10 gravimeter).

Fig 4 shows the concept of repeat gravity and GPS survey. We will establish the some reference station for absolute gravity measurement. And we will place the stations for relative gravity measurements around the reference stations. We will divide some areas using the pattern of the ground water level changes (For example, water dropping area, water recover area, and so on). We will place the reference station and 5 or 6 relative gravity stations in each area.

Observed gravity values are included some gravitational effects (Table 1). We have to remove these effects in order to separate the effect of groundwater level changes. There are very precise model to predict the effect of earth tide, we can remove this effect easily. Since the effect of the station height changes is very large, we will measure the station height using GPS at the same time.

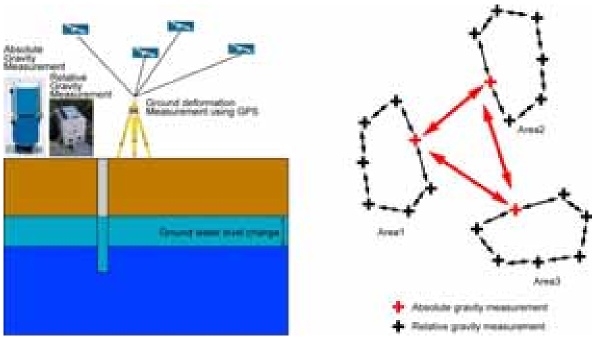

Fig. 4 Concept of repeat in-situ gravity measurements loop.

Table 1 Gravitational effects of temporal gravity changes.

Station height changes	308.6μgal/m
Earth tide	±250μgal
Atmospheric pressure changes	4μgal/10hPa
Ground water level changes	10 ~100μgal

3. Preliminary survey in Bangkok

We carried out the preliminary survey at Bangkok since 2004, and we checked the observation wells to plan the repeat gravity and GPS survey. Each observation wells drilled to the 2 or 3 aquifer called PD, NL and NB (Figure 4), and the depth of aquifer is about 100m, 150m and 200m respectively. And we will check the gravity change between each reference stations using the absolute gravimeter.

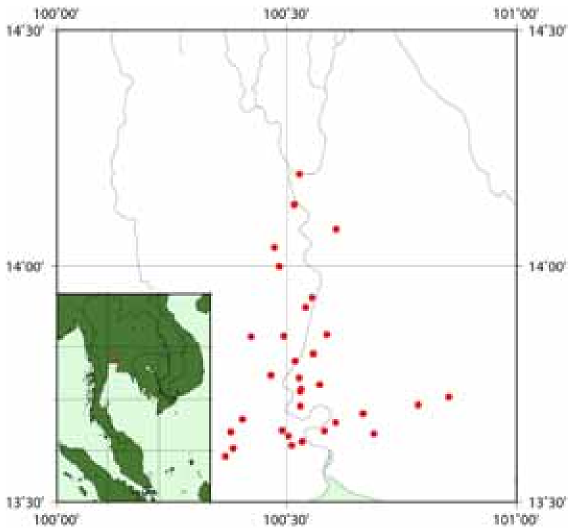

Fig. 5 Distribution of groundwater monitoring wells.

We established the reference station in the Thai Meteorological Department and measured the gravity using FG-5 absolute gravimeter (Micro-g solutions, Inc.) in September 2005(Fig. 6). And we constructed GPS reference station on the top of the building of Chulalongkorn University in March 2007 (Fig. 7).

Fig. 6 Absolute gravity measurement at the Thai Meteorological Department

Fig. 7 GPS reference station at Chulalongkorn University.

4. Preliminary survey in Jakarta

We carried out the preliminary gravity and GPS survey in Jakarta since 2006. We got cooperation from Institute of Technology Bandung (ITB) and BAKOSURTANAL to conduct the ground subsidence survey and repeat relative gravity measurements.

The ground subsidence survey using GPS has already been started by ITB (Hasanuddin, 2008). Many benchmarks are established by ITB, and we went to some benchmark to check the benchmark size and noise level. Fig. 8 and 9 show the benchmark and the picture of GPS survey respectively. We selected the four benchmarks in order to measure the GPS and gravity using the A10 absolute gravimeter. We will choose 5-6 stations for relative gravity measurement around the each absolute gravity station. Some relative gravity station will place near the observation well for monitoring the groundwater level in order to compare the groundwater level with the gravity changes.

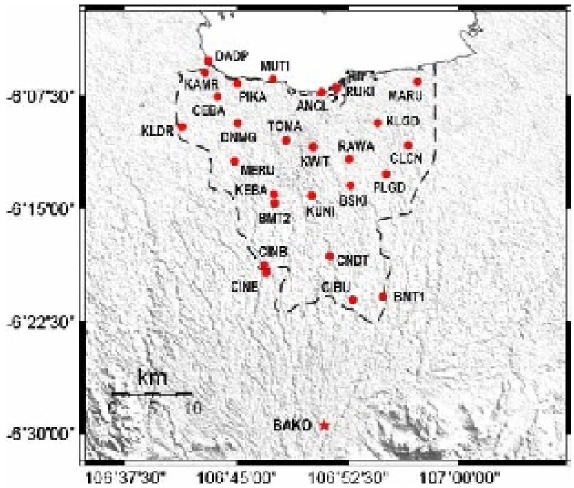

Fig. 8 Location of benchmarks for GPS survey. (Hasanuddin, 2008)

Fig. 9 GPS survey at Kunigung benchmark. We selected one of reference station for absolute gravity measurement.

We also carried out the 2km interval gravity survey to make clear the underground structure (Fig. 10). We surveyed 87 points along the N-S, E-W direction street.

The gravity anomaly, that is difference between observed gravity and normal gravity estimated by the homogeneous density earth model, reflects the depth of high density rocks. Fig. 11 shows the relation between the gravity anomaly and the underground structure. If the depth of high density rocks is shallow, the gravity anomaly indicates high. On the other hand, if the depth of high density rocks is deep, the gravity anomaly indicates low. In the fault zone, the gravity anomaly changes high to low rapidly. We can estimate the shape of the basement rocks and the location of the fault.

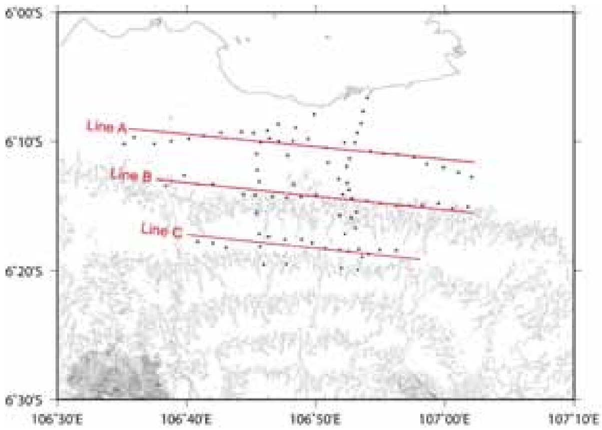

Fig. 10 Distribution of gravity survey points.

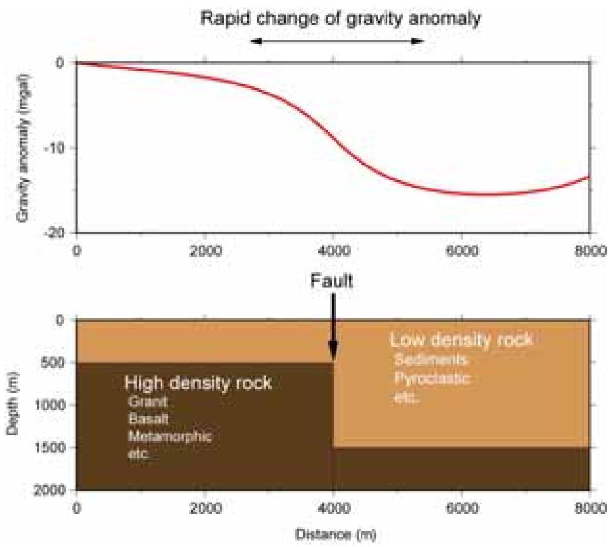

Fig. 11 Relation between the gravity anomaly and the underground structure.

Fig. 12 shows the contour map of the gravity anomaly. There are two high anomaly areas at the center and northern part of Jakarta. And the gravity low anomaly is located eastern part of survey area. We can not see the fault zone, because there is no high gradient zone of the gravity anomaly

We applied two dimensional modeling method (Talwani et al., 1959) to the gravity anomaly in order to estimate the depth of the basement rocks. This model consists of two layers. One is the marine tertiary deposits (basement rock); the other is the non-marine sediments. The density contrast is decided from the average density (Schön, 2004).

Fig. 13 shows the result of two dimensional analysis. In line A and B, the depth of the basement rock is getting shallower at the center of each line. The deepest depth (about 200m) is almost same at all lines. We can not detect the vertical displacement fault.

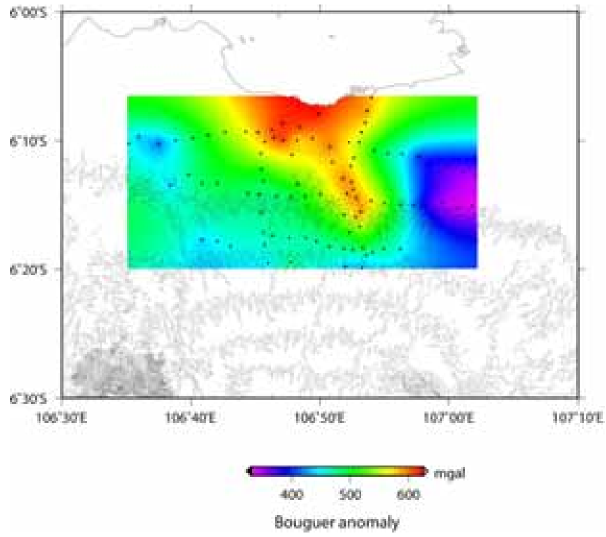

Fig. 12 Contour map of gravity anomaly.

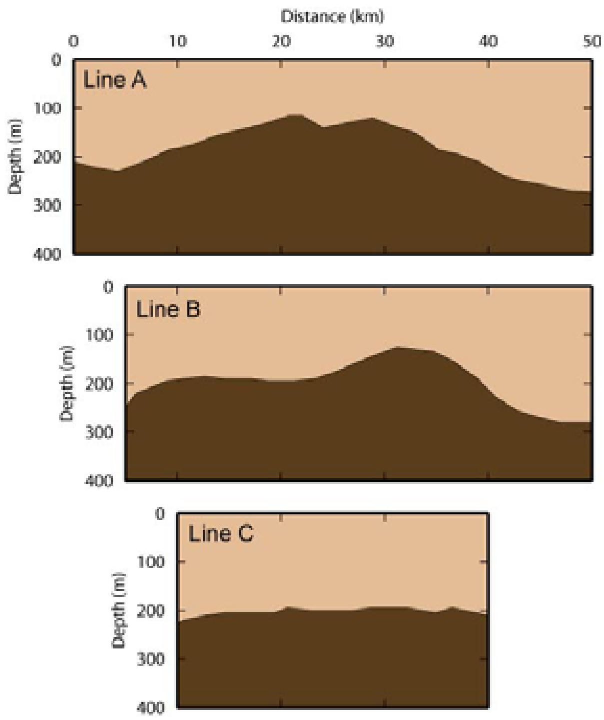

Fig.13 Estimated boundary of basement rock and sediments at each lines. We assumed the density contrast as o.3 g/cm^3

5. Summary

We started preliminary gravity and GPS survey at Jakarta and Bangkok since 2004, and we checked the observation wells and GPS benchmarks to evaluate the noise level for the in-situ gravity measurement. We will start the relative and absolute gravity measurement from 2008.

We reported the preliminary result of the estimation of the depth of basement rock. We will improve the more precise model using the other geological and geophysical data, and we will evaluate the underground structure.

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Role of sediment discharge and submarine groundwater discharge as contaminant discharge process to ocean at coastal mega-cities

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Abstract

To confirm contaminant discharge process to ocean at coastal mega-cities, we conducted the review of research papers in regarding to the pollution in Osaka, Japan and application of the multi-methods. Our hypothesis is composed of two stage of the process. First is large contaminant discharge stage by sediment and solute load with river runoff during rapid increasing period of population. Second is delayed discharge stage by contaminant groundwater discharge and dissolution of deposited material on the seabed by recirculated seawater during the stable period of population after the first stage. The deposited material was supplied from land during the first stage. The large contaminant discharge was reported by some researches at Osaka. Both of solute load in a river and sediment deposit increased with population and ocean quality became degradation. But the ocean environment had not recovered even though the contaminant load by river decreased. One of the reasons was suggested as the delayed contaminant discharge by groundwater. The evidence to that is not enough directly. Other reason is dissolution of contaminant from the deposited sediment on the sea bed. The leaching from marine deposit was accelerated by advection process of recirculated seawater. Some researches indicated this possibility. In our future research, these hypothesis will be confirmed more.

Key words: contaminant, discharge, ocean, sediment, solute, river, groundwater, mega-cities

1. Introduction

Ocean pollution had occurred near megacities. Because the large quantity of mass generally converges on the mega-city (World Bank, 1997; Tsunekawa, 1998), a part of consumed mass had been leached into river, groundwater and ocean. The most of mega-cities in the world exist in Asia, and the most of them are located on the coastal area (Jiang et al., 2001). Growing Asian mega-cities have the some severe pollution problems such as those in Tokyo or London about 30 years ago. To prevent the expansion of these problems, it is necessary to find the relationship between water pollution characteristics and growing stage of mega-city, and to propose the possible problems in future and the measure to them for Asian mega-cities intensive growing.

The objective of this research is to confirm contaminant discharge process to ocean at coastal mega-cities. Especially, we conducted the review of research papers in regarding to the pollution in Osaka, Japan and application of the multi-methods.

2. Hypothesis of contaminant discharge process to ocean

In many previous studies, the delay of ocean pollution had been reported. But the mechanism had not been clarified. We are challenging to the confirmation of delay process of contaminant discharge in the RIHN project as well as the quantification of subsurface contaminant accumulation at the mega-cities. We have a hypothesis to this problem. Our hypothesis is composed of two stage of the process.

(1) First is large contaminant discharge stage by sediment and solute load with river runoff during rapid increasing period of population.

(2) Second is delayed discharge stage by contaminant groundwater discharge and dissolution of deposited material on the seabed by recirculated seawater during the stable period of population after the first stage. The deposited material was supplied from land during the first stage.

3. City growing and groundwater situation of Osaka city

City population

Fig.1 shows Osaka city and the around areas, Japan. The area shown by dark color in Fig.1 is Osaka city, and colored area is Osaka Metropolitan district. The later one includes Kobe city and Kyoto city. Population of Osaka Metropolitan district is more than 10 million. This area is characterized by relatively small suburban area.

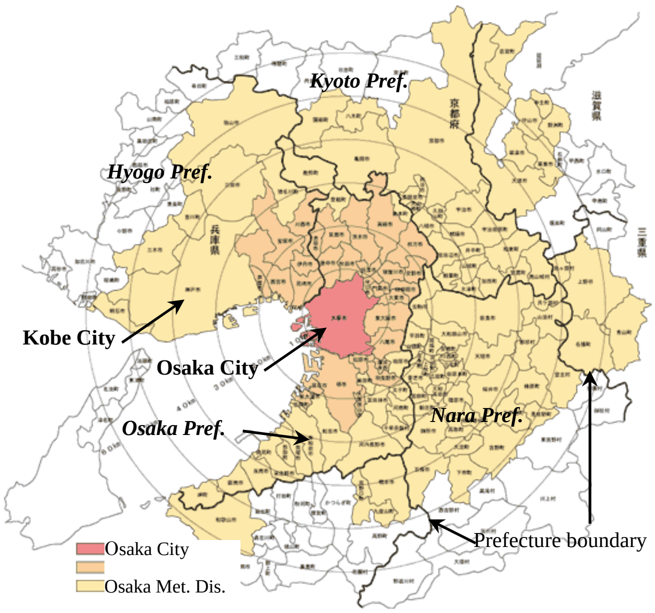

Fig.1 Location of Osaka city and Osaka Metropolitan district.

Fig.2a shows the variation of population and industrial production index of Osaka prefecture. Both of population and industrial production index increased significantly from 1920s to 1970s. Population was less than 3 millions in 1945, but it became more than 8 millions in 1970s. The urban area expanded from the center city to around area shown by medium color in Fig.1 with increase of population. Consequently, suburban area narrowed in these areas. Since 1970s, the prefecture

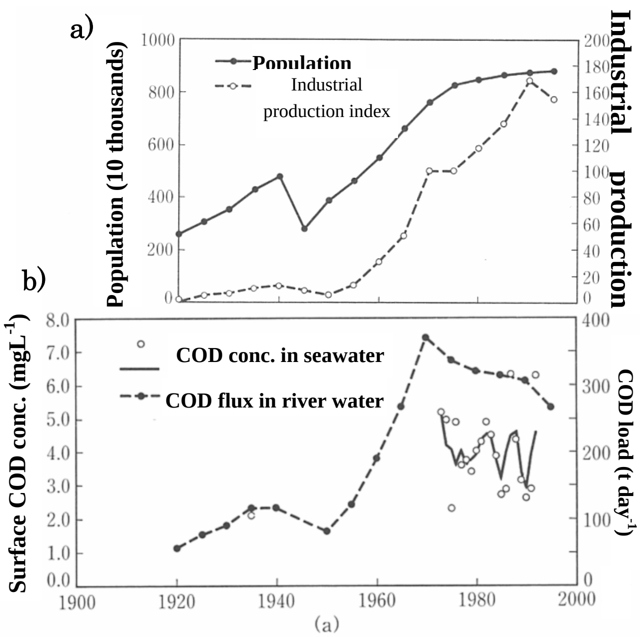

Fig.2 Variation of a) population and industrial production index, and b) surface COD concentration in Osaka bay and COD flux from river (Nakatsuji, 1998).

population increased slightly less than 1 million for 30 years. But Industrial production index kept increasing 1.5 times of that for 20 years.

Intensive groundwater pumping caused the decrease of hydraulic head and land subsidence during 1960s. The hydraulic head was less than -25m below the sea level, and land subsidence rate was about 10m in annual in around 1960, respectively. But the government regulation of pumping brought back the hydraulic head after 1970s. The land subsidence also stopped.

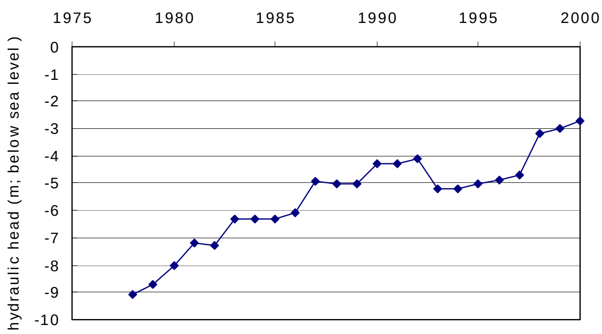

Fig.3 Variation in hydraulic head of deep groundwater of Osaka.

Fig. 3 shows the 20 years variation of hydraulic head of coastal deep groundwater. The hydraulic head in deep groundwater increases but it still keep less than sea level, that is, seawater intrusion has occurred and groundwater has not discharged into the ocean.

Coastal pollution

Fig.2b shows the variations of surface COD concentration in Osaka bay and COD load from river to the sea for more than last 30 years (Nakatsuji, 1998). But surface COD concentration in Osaka bay is only since 1970. The COD concentration and COD load were a maximum in around 1970. The COD load from river to the sea was a minimum in around 1950. It was approximately constant before 1950. The COD load in river became 4 times for 20 years from 1950 to 1970. This period coincides with rapid increasing period of population. These results suggest the effect of urbanization on the quality of river water and seawater.

Since 1970s, population increased gradually and industrial production index also increased, however the COD concentration and load decreased. This downward trend suggests to be originated in the development of sewage treatment system. However, even if river water pollution decreased, the impact of pollution before 1970s would be reflected in subsurface environment. Burt et al. (1993) introduced the example of sluggish transport of contaminant accumulated for 30 years in unsaturated zone of upland in England. It means that we need to notice the groundwater contamination and contaminant transport after the peak of river water pollution. In fact, the COD in seawater had relatively constant trend with some variations. It suggests the effect of contaminant groundwater discharge as well as the buffer effect by its large volume. Since 1990s, the industrial production index decreased with the removal of industries to suburban area and developing countries. Consequently, the COD concentration and load in river also decreased more.

Groundwater pollution

Fig.4 shows the condition of groundwater contamination in Osaka prefecture from 1993 to 2003 (Environment Council, Osaka Prefectural Government, 2004). The contaminant species include Br, B, Hg, As, nitrate, Pb and VOC in this figure. This result indicates that various contaminants are detected in groundwater in last decade.

In the coastal mega-cities in Japan, not only the water pollution but also the seawater intrusion or decline of groundwater level occurred. Therefore, we also have to consider the effect of them on the subsurface contamination.

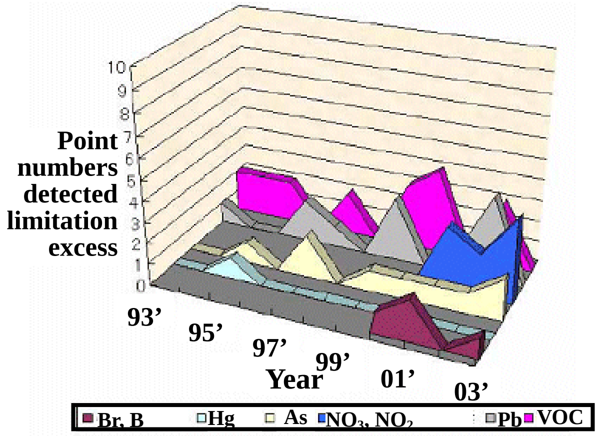

Fig. 4 Variation in contaminant species of groundwater from 1993 to 2003 in Osaka.

4.Pollution problem in Indonesia

Table 1 Air pollution in Mega-cities (modified from Jiang et al., 2001).

Mega-city	population (million)	Mean annual (ug/m^3) TSP	SO_2
Osaka	10.61	43(1993)	19 (1994)
Tokyo	26.96	49(1993)	18 (1995)
Jakarta	8.62	271(1990)	No data
Manila	9.29	200(1995)	33 (1993)
Bombay	15.14	240(1994)	33 (1994)

Air pollution is one of the sources of groundwater pollution. Table 1 shows the air pollution in some Asian mega-cities (Jiang et al., 2001). Mean annual TSP in Osaka and Tokyo are one order lower than those in Jakarta, Manila and Bombay. Mean annual SO_2 in Osaka and Tokyo are a half of those. These results suggest that the pollution load to groundwater by rainfall and dry fall in Jakarta is larger than that in Osaka. The population of all cities is approximately more than 10 million. But the growing situation is different. The population of Osaka is decreasing a little bit, as described above. On the other hand, Jakarta continues the increase of population still. The growing situation of city population would support the pollution intensity to groundwater.

Table 2 shows the variation from 1890s to 1990s in trace metal flux into Jakarta bay by using sediment core analysis from the depth of 40cm below the sea bed to the surface. The peak of flux is in 1990s in case of Cu and in 1980s in case of Zn and Pb, respectively. These results indicate that the pollution peak agrees with the intensive increasing period of population.

Table 2 Trace metal flux into Jakarta bay estimated by using sediment core analysis. ($ugcm^{-2}yr^{-1}$) (Williams et al., 2000)

Depth(cm)	Age(yr)	Cu flux	Zn flux	Pb flux
0-1	0-2.6	1.68	3.51	1.12
5-6	16	1.15	4.96	2.59
10-11	29	0.58	4.09	1.95
20-21	56	0.83	1.40	1.94
30-31	82	1.05	1.83	1.57
40-41	109	0.79	0.48	0.24

5. Dissolution from seabed by recirculation of sea water

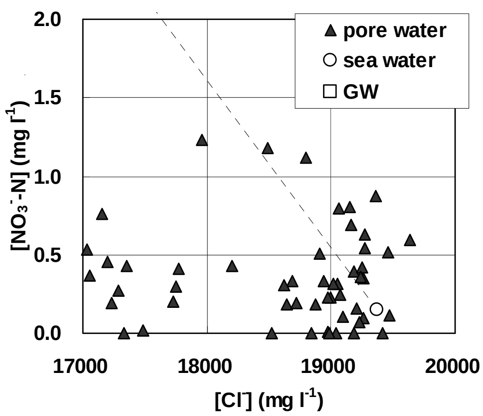

Fig.5 relationship between Cl- and NO3- concentration of sea water, terrestrial groundwater and pore water below the tidal slope (Onodera et al., 2007)

Based on the observations at Osaka and Hiroshima in Seto Inland Sea, Japan and Thailand (Ishitobi eto al., 2007; Onodera et al., 2007; Umezawa et al., 2007), the recirculation of sea water and dissolution of nutrient were indicated with submarine groundwater discharge at the offshore near coasts. Fig.5 shows the relationship between Cl^- and NO_3^- concentration of sea water, terrestrial groundwater and pore water below the tidal slope (Onodera et al., 2007). This indicates both of the attenuation and dissolution process of nitrate, because most of pore water samples under the tidal slope were plotted below and above the mixing line of groundwater and seawater. The attenuation process occurred from terrestrial area to the tidal slope, but the dissolution process occurred at the offshore. The dissolution rate was accelerated by the recirculation of seawater. Generally, a part of seabed sediment is supplied from terrestrial area. Especially, the sedimentation rate increases at mega-cities. In our future research, these hypothesis will be confirmed more.

6. Conclusions

Our hypothesis is composed of two stage of the process. First is large contaminant discharge stage by sediment and solute load with river runoff during rapid increasing period of population. Second is delayed discharge stage by contaminant groundwater discharge and dissolution of deposited material on the seabed by recalculated seawater during the stable period of population after the first stage. The deposited material was supplied from land during the first stage. The large contaminant discharge was reported by some researches at Osaka. Both of solute load in a river and sediment deposit increased with population and ocean quality became degradation. But the ocean environment had not recovered even though the contaminant load by river decreased. One of the reasons was suggested as the delayed contaminant discharge by groundwater. The evidence to that is not enough directly. Other reason is dissolution of contaminant from the deposited sediment on the sea bed. The leaching from marine deposit was accelerated by advection process of recirculated seawater. Some researches indicated this possibility. In our future research, these hypothesis will be confirmed more.

Acknowledgments

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Result of Material Group study (terrestrial part): Pollution status and mechanism in each Asian mega city

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Abstract

Material Group has conducted extensive groundwater and coastal sediment core sampling at each Asian mega city during the period of 2005 and 2006: Osaka in 2006, Seoul in 2005, Taipei in 2005 and 2006, Bangkok in 2006, Jakarta in 2006, and Manila in 2006. On the other hand, in 2007, our group has been focused our research activities on laboratory work such as sample processing, elements concentration measurements, and isotopic analysis, except a small scale of groundwater sampling at Taipei city at October in this year. According to the analytical results which data are available until now, the general view of groundwater pollution status is becoming clear for each target city. Detailed pollution cause(s) and pollution history including coastal sediment core samples would be investigated in the future research. Several research articles are under the reviewing for publishing in the next year. Most outstanding research results are presented in this report.

1. Introduction (purpose, methods, samples, and research activity status)

Primary aim of the Material Group is to elucidate pollution status and mechanism in groundwater at major Asian mega cities (Osaka, Seoul, Taipei, Bangkok, Jakarta, and Manila), which are situated in different developing status each other. Our main methods to solve these issues are (1) to find out the critical pollution with its concentration levels by analyzing all possible elements and (2) to understand the source and process of these pollutions by using multiple isotopic methods, which is the powerful geochemical tracers originally developed in earth science filed and now getting used as the environmental tracers. The main sampling target is groundwater; however, we collected river waters, rain waters (monitoring samples from June 2006 to October 2007 in each city), waste water, geological constituents, as well as pollution source materials (detergents and fertilizers) for source comparison. We also collected three coastal sediment core (~80 cm in lengths) samples at representative points in a bay in each city, which nutrients and metals data are used to reconstruct pollution history (1900~2007). This sediment core study is very important to understand the total pollutant input from the city to neighbor environments because some pollution metals (Cu, Pb, Zn, and Cd) are not dissolved into the waters, but rather, present as an adsorbent form in particles in waters, which will be finally transported in metropolitan coast.

Our group has dedicated in water and coastal sediment core sampling at all target Asian mega cities in 2005 and 2006: Osaka in 2006, Seoul in 2005, Taipei in 2005 and 2006, Bangkok in 2006, Jakarta in 2006, and Manila in 2006. On the other hand, in 2007, we concentrated in our research activities on laboratory work such as sample processing, elements concentration measurements, and isotopic analysis, except a small scale of groundwater sampling at Taipei city at October in this year. The data were fairly accumulated to prepare the several articles for publications especially for groundwater research (Hosono et al., 2008a,b; Onodera et al., 2008; Ymezawa et al., 2008). This report selected from these articles the most important results as well as unpublished data. According to these, the most important elements that have to be considered for Asian city environments are nitrate (NO_3), arsenic (As), and lead (Pb) as well as major ions dissolved in the waters. Concentration levels, sources, and pollution mechanisms are presented for rain waters, river waters, and groundwater. A part of results of sediment core study are presented in the separated reports.

2. Results and discussion

Major ions

In trilinear diagram, water chemistries are divided into four types, A, B, C, and D. The origin of dissolved elements in water samples are traditionally categorized as followings; A: river and shallow groundwater, B: deep groundwater, C: marine component and hot spring water, and D: pollution, hydrothermal, and fossil water. Water samples for five Asian mega cities (Seoul, Taipei, Bangkok, Jakarta, and Manila) plot broadly in trilinear diagram. There are two important points to note, (1) some water samples from Bangkok, Jakarta, and Manila plot in a field of C type, suggesting the seawater intrusion around the coastal area and (2) some water samples from Bangkok and Jakarta plot in a field of B type, suggesting the presence of human impact.

Water types for all samples (river water, shallow groundwater, and deep groundwater) at each sampling site are superimposed in the land use map for Jakarta and Bangkok except ones collected at geothermal area (Fig. 1). For Jakarta city, water samples collected at the forest area are classified as A type and it evolved through the flow direction to B type in agricultural farm area. D type water is predominates in urbanized area. Finally, groundwater tends to become C type at coastal area, suggesting the occurrence of sea water intrusion by groundwater pumping in the city. Water type distribution in Bangkok city is also corresponding well with land use data; B type water is predominant in the farm area, whereas, water in urbanized area is characterized by C type. Later phenomenon suggests that marine components contribute to deep groundwater. C type waters also distribute in upstream area which salt components might be derived from rainwater with oceanic Na and Cl.

Strontium (Sr) has a similar chemical property to Calcium, one of the major elements in natural water, and Sr isotopic ratios can be used as the excellent tracer for mineral elements such as Ca and Mg. Fig. 2 shows that the Sr isotopic ratios of groundwater vary according to the difference of geology at each Asian mega city. For example, groundwater in Jakarta and Manila developed at volcanic environment show the Sr isotopic ratio that is typical values for volcanic rocks, whereas, groundwater in Bangkok and Taipei (at sedimentary environment) and Seoul have Sr isotopic affinity to each host rocks (sedimentary rocks and old continental rocks, respectively). This clearly suggests that mineral components in waters are largely derived from geological materials. By contrast, some groundwater samples collected near the coastal zone in Jakarta and Bangkok show narrow Sr isotopic range between 0.707-0.710 with high Ca concentrations, indicating the contribution of sea water components. This may suggests the sea water intrusion near the

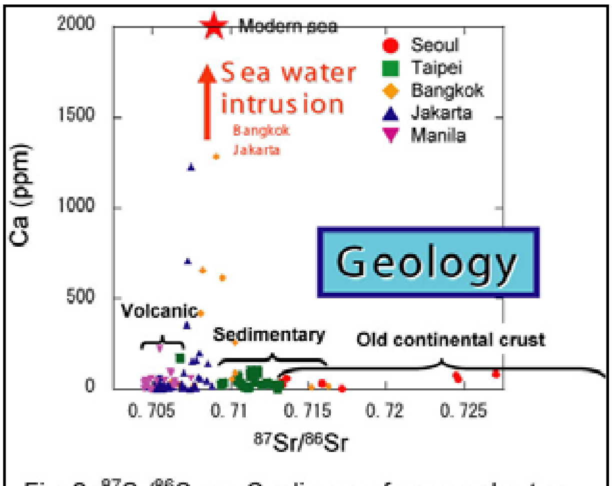

Fig. 2: $^{87}Sr/^{86}Sr$ vs. Ca diagram for groundwater at each Asian mega city.

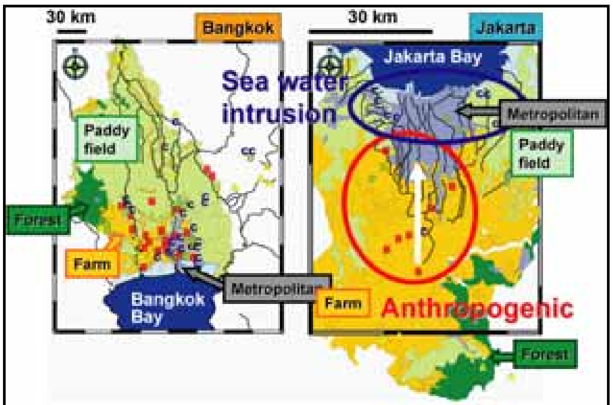

Fig. 1: Major ion type distribution (Jakarta and Bangkok)

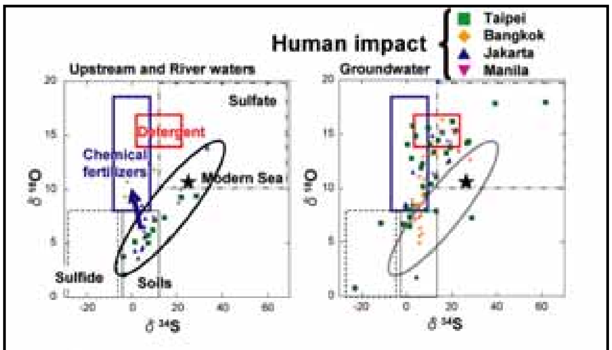

Fig. 3: $\delta^{34}S$ vs. $\delta^{18}O$ diagram for upstream and river waters (left-hand) and groundwater (right-hand) at each Asian mega city. Isotopic compositions for sources materials are after Vitoria et al. (2004).

coastal area, corresponding well with major ion signatures.

In general, sulfate (SO_4), one of the major anions in natural water, are derived from both natural (marine water components, sulfate, sulfide, and soils) and anthropogenic materials such as air pollution (originated by coals and crud oils), fertilizers, and detergents. $\delta^{34}S$ and $\delta^{18}O$ in SO_4 of water samples from each city plot on $\delta^{34}S$ vs. $\delta^{18}O$ diagram (Fig. 3) and compared with those of potential source materials (Vitoria et al., 2004). Majority samples of upstream water with no-human impact and river water plot within the compositional field between soil sulfur and sea water sulfate except some river samples at Bangkok. On the other hand, most of the groundwater samples plot much closer to the compositional fields of fertilizers and detergents than do upstream and river water samples. Therefore, it is suggested that sulfate in groundwater was largely derived from anthropogenic origin.

Nitrate

Nitrate is one of the major compounds of environmental concern. We analyzed nitrate concentrations for more than 300 samples collected from each city (Onodera et al., 2008; Umezawa et al., 2008). Considering the Japanese environmental standard for nitrate (10 ppm N in NO_3), all rain and river water samples are under the limitation level. However, some groundwater samples (Seoul and Jakarta) are high in NO_3 concentrations and needs a continuous investigation. NO_3 pollution distribution in Jakarta city is consistent well with major ion results, whereas, groundwater in Bangkok is generally ammonium predominant and NO_3 is just minor component (Fig. 4). Umezawa et al. (2008) analyzed $\delta^{15}N$ and $\delta^{18}O$ in NO_3 of water samples from each city and compared them with those of potential source materials (Kendall, 1998) in order to elucidate the NO_3 source(s) and nitrogen status through transformation process. They found from these isotopic comparison the three important things (Fig. 5): (1) NO_3 pollution via precipitation is not important for groundwater pollution, (2) NO_3 in both river and groundwater was largely derived from sewages and manure, and (3) NO_3 concentration decreases due to the reducing reaction in groundwater, proceeding the groundwater purification with respect to NO_3 pollution. It is revealed from our research that NO_3 pollution in Asian mega city situated in reducing condition is not a serious status such like the European counties situated in oxidative condition with crystalline crustal environment.

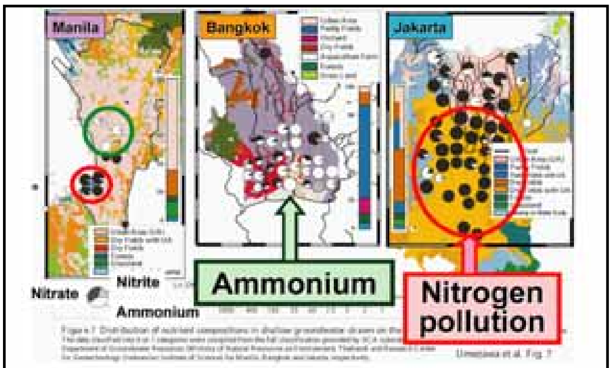

Fig. 4: Groundwater nitrate concentration in Manila, Bangkok, and Jakarta.

Arsenic

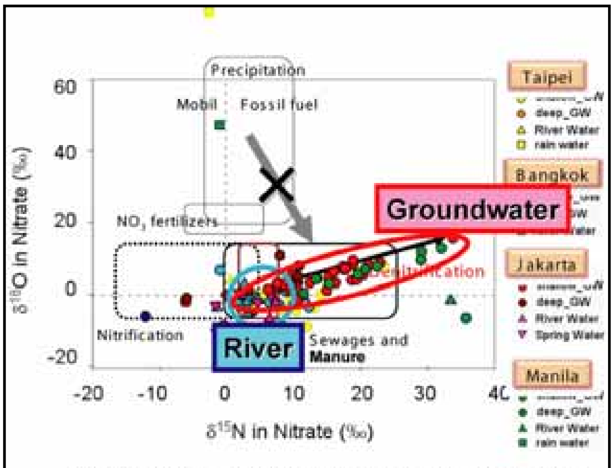

Fig. 5: $\delta^{15}N$ vs. $\delta^{18}O$ diagram for river and groundwater at each Asian mega city. Isotopic compositions for sources materials are after Kendall (1998).

Reducing condition in groundwater is good for NO_3 pollution purification. However, arsenic (As) dissolved into groundwater as redox condition shifts to reducing environment. Fig. 6 clearly shows that As concentrations increase with decreasing of NO_3 concentrations in groundwater. Some groundwater samples are above Japanese environmental standard revel (10 ppm). Although the source of As in groundwater appears likely of natural origin, we have to pay attention to As concentration level especially in the condition where reducing environment predominant such as Bangkok and Manila. Some samples in Taipei show extremely high As concentration (~120 ppm). More detailed analysis is needed to understand this problem.

Lead

Lead is low in concentration in groundwater as well as in river water because of its absorption property to suspended particles in waters or sediments through water-soil (river suspended

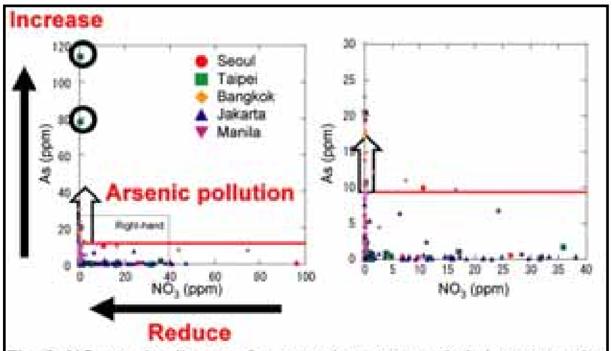

Fig. 6: NO_3 vs. As diagram for groundwater at each Asian mega city.

particles) interactions. However, lead contains substantially in rain water. Most of the lead in precipitation might be derived from air pollution originated from gasoline and coal combustion and waste incineration. According to the rain water monitoring research from June 2006 to October 2007 at some Asian mega cities (Taipei, Bangkok, Jakarta, and Manila) (Fig. 7), we found two important facts that (1) rain water lead in Jakarta is higher level than Japanese environmental standard level of 10 ppb especially at rainy season and (2) Taipei rain in winter season is characteristically enriched in lead probably due to pollution transportation from China. More monitoring investigations are needed to confirm the seasonal pollution patterns with its mechanism in each city. The river suspended particles with lead will be transported and deposited in the coastal area near the city. The pollution history deduced by coastal sediment core analysis will be reported in the separated report sheet.

3. Summary: Pollution status comparison in each Asian mega city

The summary of pollution (NO_3, As, and Pb) status in each city is shown in Table 1. Rain water is concentrated in Pb in high level in some season at Jakarta and Taipei compared to the other cities and NO_3 is moderately enriched in Taipei rain water. Additional rain water analysis has to be done for the other cities. River water is generally depleted in all pollution (NO_3, As, and Pb) elements concentrations, however, pollution materials might exist as an absorption form on sediments or suspended particle materials in river. These pollutions suggest to be transported into the coastal zone as suspended particles to deposit into the coastal sediments. These sediments core analysis among each city clearly revealed the different pollution levels and patterns in each Asian mega city. Groundwater NO_3 concentrations are high in Seoul and Jakarta where oxidative condition develops, whereas, As concentrations are high in Bangkok and Manila where reducing environment develops. It is summarized that groundwater NO_3 and As pollutions are largely depending on geological setting which controls the redox condition in groundwater.

Table 1: Pollution status comparison in each Asian mega city

	Rain water			River water			Groundwater			Sediment	
	NO_3^-	As	Pb	NO_3^-	As	Pb	NO_3^-	As	Pb	N, C	Pb
Osaka	In preparation	In preparation	In preparation	In preparation	In preparation	In preparation	In preparation	In preparation	In preparation	Higher	Higher
Seoul	In preparation	In preparation	In preparation	Lower	Lower	Lower	Higher	Medium or Occasionally higher	Lower	In preparation	In preparation
Taipei	Medium or Occasionally higher	Lower	Higher	Lower	Lower	Lower	Medium or Occasionally higher	Higher	Medium or Occasionally higher	In preparation	In preparation
Bangkok	In preparation	Lower	Lower	Lower	Lower	Lower	Lower	Higher	Lower	In preparation	In preparation
Jakarta	In preparation	Lower	Higher	Lower	Lower	Lower	Higher	Lower	Lower	Lower	Lower
Manila	In preparation	Lower	Lower	Lower	Lower	Lower	Medium or Occasionally higher	Higher	Lower	Lower	Lower

Compared to environmental standard... Higher / Medium or Occasionally higher / Lower / In preparation

4. Future study

Additional field survey for water and sediment core sampling, isotopic analysis for potential source materials, and sedimentation age determination (with Dr. Su in National Taiwan University) have to be done within the research activities of the Material Group. We also plan to investigate the material transportation mechanism with groundwater age data in cooperation with the Water Group. Relationship between pollutions and land use has to be made clear in Osaka, Manila, and Taipei, in addition to Bangkok and Jakarta with the discussion of Urban Geography Group. Finally, we are interesting in reconstructing the sediment core pollution history by using chemical evidence in combination with economic data which will be collected by the Social Economy Group. Thus, we consider enhancing the interdisciplinary research with other research groups.

Acknowledgments

We thank all peoples who help water and sediment core sampling in each Asian city. Only the name of speaker is shown in the title page, however, this report is based on the research results done by the all members in Material Group (both Japanese and

foreign members).

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Evolution of the Subsurface Thermal Environment in Urban Areas

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Abstract

The ground surface temperature (GST) variation in the past can be estimated from temperature profiles measured in boreholes. This "geothermal method" of GST history reconstruction is applied to studies of thermal environment evolution in urban areas. Most of the temperature profiles measured in the Taipei, Bangkok, and Jakarta areas have apparently been affected by recent surface warming. Preliminary results of inversion analysis of the temperature profiles show significant increase in GST during the last century. Long-term monitoring of borehole temperatures and soil temperatures has also been conducted at selected sites to investigate the heat transfer process and the relationship between GST and surface air temperature.

1. Introduction

Since temporal variation in the ground surface temperature (GST) propagates into subsurface sediments and basement rocks, GST variation in the last several hundred years has been recorded in the underground temperature distribution in the upper several hundred meters. It is therefore possible to estimate the history of GST, which should be closely related to surface air temperature (SAT), from vertical temperature profiles measured in boreholes (e.g., Lachenbruch and Marshall, 1986; Wang and Lewis, 1992). The reconstruction of GST using this "geothermal method" has been conducted extensively since the 1980s, mainly in North America and Europe, and the analysis techniques have been well investigated.

GST histories estimated using the geothermal method may reflect both large-scale climate changes, including global warming, and more local phenomena. In urban areas, it is expected that the subsurface temperature distribution has been disturbed by various local anthropogenic factors, e.g., the formation of "heat islands," changes in land use, land development for housing and industry, and the pumping of groundwater. Measurements and analyses of borehole temperatures in large cities and their surrounding areas will therefore allow the reconstruction of the evolution of the thermal environment near the ground surface associated with the development of cities.

As part of the project "Human Impacts on Urban Subsurface Environments" by Research Institute for Humanity and Nature, (RIHN) we have been studying the subsurface thermal anomalies in urban areas caused by human activities mainly through measurements of borehole temperature profiles and long-term temperature monitoring. The obtained data will be used to reconstruct GST histories in the target areas; these GST histories can be compared with meteorological data and integrated with other information on urbanization processes collected through different approaches.

2. Method of GST history reconstruction

In large cities in East Asia, which are the target of the subsurface environment project, wells for groundwater monitoring are generally suitable for measurement of vertical temperature profiles because they are well maintained and basic geological and hydrological information on the surroundings is often available. It is necessary to conduct repeated temperature measurements (logging) in these wells at some time interval to examine the stability of the temperature profiles.

Logging in boreholes in which temperature profiles were measured previously (e.g., 10 to 20 years ago) would be very useful because simultaneous analysis of old and new temperature profiles provides more reliable GST histories (Wang and Lewis, 1992).

Measurements and analyses of borehole temperatures need to be made not only within large cities, but also in the surrounding suburban areas, where reference data can be obtained. Taniguchi and Uemura (2005) analyzed the shapes of borehole temperature profiles measured in the Osaka plain and inferred that the magnitude of the recent surface warming was much larger in the middle of the city than in the area surrounding Osaka. We may be able to conduct similar and more detailed studies of some of the target cities, e.g., Tokyo, Osaka, and Bangkok, where boreholes are widely distributed in the surrounding areas.

Most of the target cities are coastal and have been developed on alluvial plains, and the formations around the boreholes are expected to have layered structures consisting of alternating coarse and fine deposits. Therefore, reconstruction of GST history needs to be made using a multi-layer model in which the best-fitting thermal conductivity is estimated for each layer.

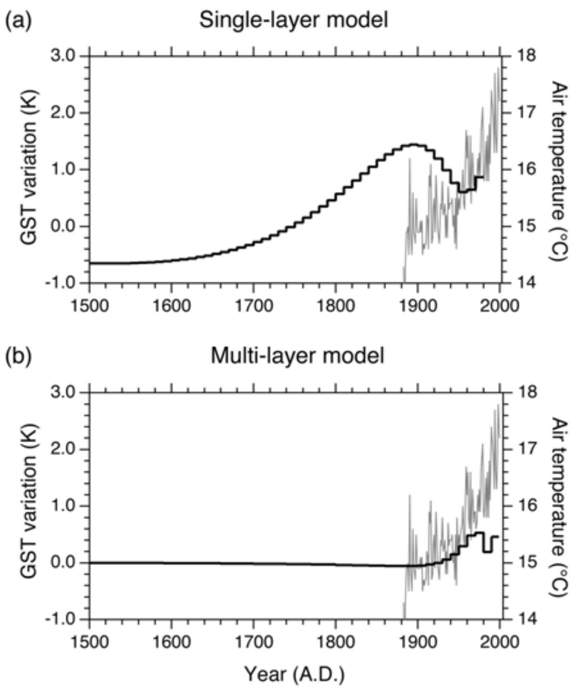

Fig. 1 GST histories at a site on Awaji Island reconstructed using a uniform model (a) and a multi-layer model (b) plotted with the SAT time series at a nearby meteorological station (Goto and Yamano, 2005).

An example of analysis of temperature data in a borehole penetrating through a layered formation (a hole on Awaji Island, Japan) is shown in Fig. 1 (Goto and Yamano, 2005). The GST history obtained using the multi-layer model is much different from that obtained by assuming a uniform thermal conductivity through all of the layers. The former is more consistent with the SAT records at nearby meteorological stations.

Another important factor in temperature data analyses is the effect of groundwater flow. Most of the target cities are underlain by some highly permeable formations and in rather humid environments with annual precipitation of 1000–2000 mm/yr. Taniguchi et al. (1999) analyzed borehole temperature profiles from the Tokyo metropolitan area, taking both recent surface warming and groundwater flow into consideration. They found that the penetration depths of the effect of surface warming varied systematically from the uplands in the west to the lowlands in the east and attributed the variation to differences in the vertical flow rate in a regional groundwater flow system. Similar studies of the propagation of surface warming in the presence of groundwater flow systems have been made in other areas of Japan (e.g., Miyakoshi et al., 2003; Uchida et al., 2003).

Effects of temporal changes in groundwater flow must be taken into account as well. Most of the target areas have both a dry and a wet season because of the monsoons, which may cause large annual variation in groundwater flow. Furthermore, the decrease and recovery of groundwater levels as a result of pumping and the regulation of water use, respectively, have been prominent in the last several decades. We should cooperate with the research group studying the temporal variation in groundwater flow systems for more reliable reconstruction of the evolution of thermal environment.

3. Preliminary results of temperature profiles measurements

Since 2004, we have conducted measurements of temperature profiles in boreholes in Seoul, Taipei, Bangkok, Jakarta and their surrounding areas. The total number of measurement sites as of December 2007 is 102 (14, 21, 41, and 26 in the Seoul, Taipei, Bangkok, and Jakarta areas, respectively). Most of the holes are observation wells used for groundwater level monitoring, and the depths are generally 100 to 250 m.

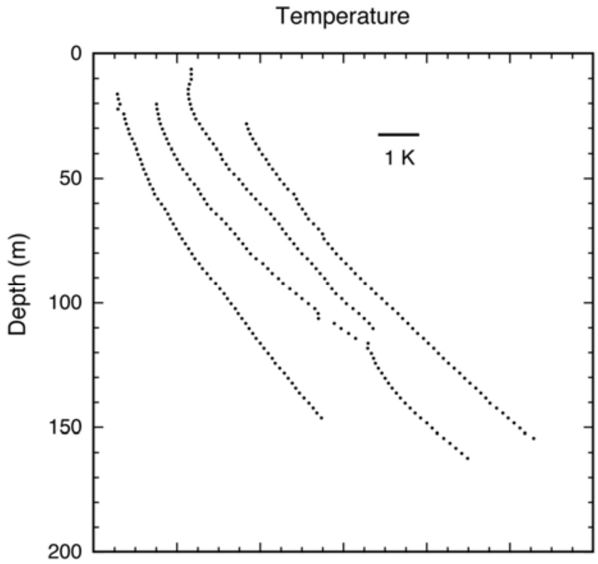

Fig. 2 Examples of borehole temperature profiles measured in the Jakarta area.

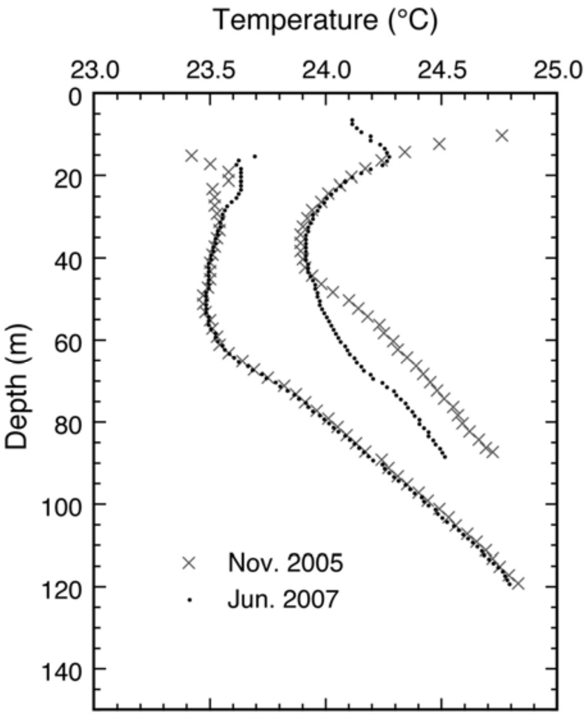

Fig. 3 Temperature profiles in two boreholes in the Taipei area measured in November 2005 and in June 2007.

In Seoul, the obtained temperature profiles appear to have been severely disturbed by groundwater flow and could not be used for analysis. In the other areas, many of the measured profiles showed negative (or close to zero) temperature gradients in the upper parts of the holes, indicating a recent increase in the GST due to global warming, the "heat island" effect, or both, whereas some of the profiles were distorted, probably by groundwater flow (Fig. 2).

Temperature logging was repeated to test the stability of temperature profiles at 22 sites. The temperature profiles measured at two different times were almost identical at most of them, but quite different at some sites as shown in Fig. 3. The shapes of the temperature profiles at the two sites are similar, whereas the stability of the profile is very different. These examples demonstrate the necessity of repeated temperature logging.

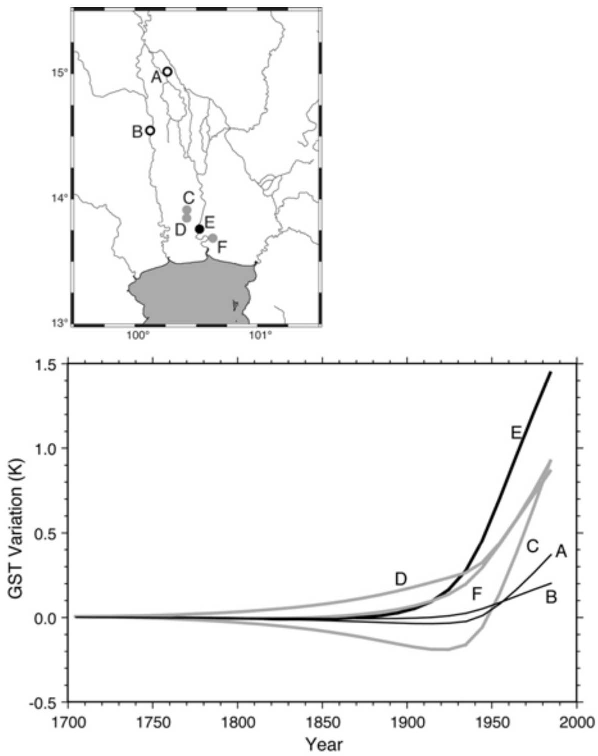

Fig. 4 GST histories reconstructed from the temperature profiles in the Bangkok area.

We attempted the reconstruction of GST histories from some of the temperature profiles measured in the Taipei, Bangkok, and Jakarta areas. Preliminary results obtained for the Bangkok area are shown in Fig. 4. Temperature logging was conducted in July 2004 and June 2006 in the city of

Bangkok, the surrounding suburban area, and a rural area to the north of Bangkok. The estimation of GST history was made on temperature profiles from six sites that seemed to be least affected by groundwater flow through inversion analysis using the multi-layer model. All of the reconstructed GST histories show surface warming in the last century (Fig. 4). The amount of the temperature increase ranges from 0.2 to 1.5 K and is greater in the city than in the northern rural area. The higher warming rate in the city may be attributed to the heat island effect, although further analyses of temperature profiles from these and other stations are needed, as well as repeated measurements in the same boreholes to check for stability.

4. Long-term temperature monitoring in boreholes

In reconstructing the GST history from underground temperature distributions, it is usually assumed that the past GST variation has been propagated downward by thermal diffusion. If subsurface temperatures at some different depths are continuously measured for a long period, the data will show how the temperature signals are actually transferred through the formations. Cermak et al. (2000) carried out long-term monitoring of temperature in boreholes in the Czech Republic. They observed monotonous temperature increases at a very constant rate at depths of about 40 m and interpreted them as the penetration of long-period components of GST variation (i.e., surface warming). These types of data may provide evidence to support the results of GST reconstruction from borehole temperature profiles. We will also be able to obtain information on the mechanism of heat transfer (conduction, advection, or both) and estimate the thermal diffusivity from long-term temperature data at multiple depths (e.g., Smerdon et al., 2004; Goto et al., 2005).

We have begun monitoring borehole temperatures at selected stations; two in Taiwan, three in Bangkok, and three in Jakarta. At each station, three water temperature recorders were hung in the upper part of the borehole at intervals of 5 or 10 m (Fig. 5). The first recovery of the temperature records was made in 2007 at the stations in Taiwan and Jakarta, and data for 11 months to 1.5 years were obtained.

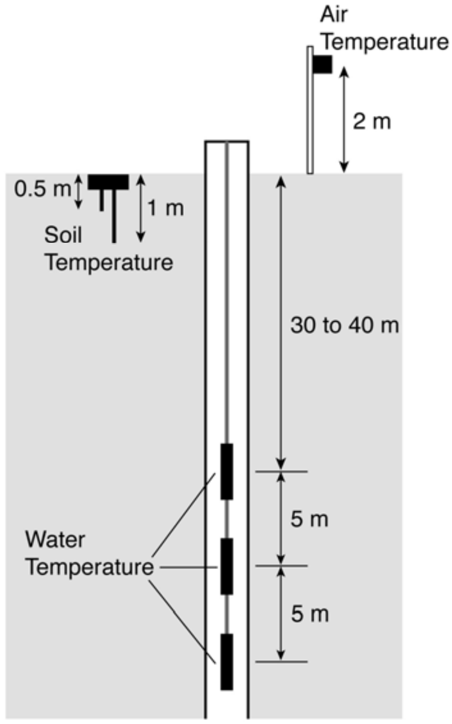

Fig. 5 Typical configuration of temperature monitoring systems.

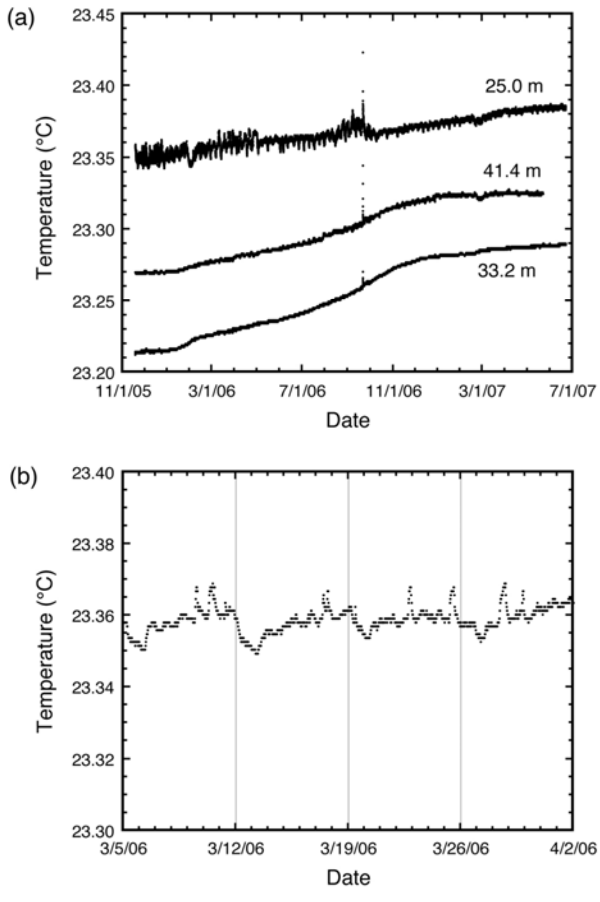

Fig. 6. (a) Long-term temperature records in a borehole in the Taipei area. (b) Blowup of the temperature record at 25.0 m.

In a hole in the vicinity of the city of Taipei, temperature records for 1.5 years were obtained at depths of 25.0, 33.2, and 41.4 m (Fig. 6a). All the records show gradual temperature increase and a quick event was observed at the same time on September 20, 2006. Peculiar short-period variations can be seen at 25.0 m. A blowup of the 25.0 m record demonstrates that it apparently contains one-day and one-week components (Fig. 6b), which is supported by the result of spectrum analysis. It strongly suggests that the short-period variations are related to some human activity near the hole.

5. Future work

For the vital study of the effects of human activities on the subsurface environment in urban areas, we must combine the obtained information on GST history and the heat transfer process with the products of other research groups of the project. One important factor in such integration, especially for the investigation of heat island development, is the relationship between GST and SAT. GST, which can be estimated through the analysis of borehole temperature data, must differ in general from SAT, though GST and SAT are thought to be closely coupled (e.g., Gonzalez-Rouco et al., 2003).

Measurements of soil temperatures near the ground surface provide useful information on the GST–SAT relationship (e.g., Smerdon et al., 2003; Bartlett et al., 2006). We have begun to monitor shallow soil temperature to estimate the GST in Taiwan, Bangkok, and Jakarta, mainly at the stations used for borehole temperature monitoring. Temperature sensors were buried at depths of 0.5 and 1.0 m just beside the boreholes (Fig. 5). At some stations, air temperature recorders were also installed 2.0 m above the ground. Time series data of soil (and air) temperatures at these stations will be analyzed in combination with other meteorological data from the vicinities to investigate the relationships between GST and SAT.

Another important component of the next stage of our study is the use of the existing temperature profile data in and around the target cities of the project. Temperature profile measurements in groundwater observation wells were conducted extensively in the Tokyo metropolitan area and in the Osaka plain (Taniguchi et al., 1999; Taniguchi and Uemura, 2005). Temperature profiles obtained in a large number of boreholes throughout the Republic of Korea are also available (e.g., Kim and Song, 1999). Analysis of selected data from these profiles will provide valuable information on the surface warming associated with the urbanization of the three cities. Repeated measurements in the same boreholes will better constrain the GST histories, especially in the Tokyo area where the previous measurements were made over 15 years ago.

6. Summary

The reconstruction of GST histories from borehole temperature profiles can be a useful tool with which to investigate thermal environment evolution in urban areas. We have conducted temperature profile measurements in boreholes at 102 sites in the Seoul, Taipei, Bangkok, and Jakarta areas. Most of the profiles, except for those in Seoul, show effects of recent surface warming. Inversion analysis of selected profiles showed that the GST increased in the last century and the amount of the temperature increase seemed to vary by site. For further discussion of the warming process, we need to make analyses taking account of the effect of groundwater flow.

Long-term monitoring of temperatures at multiple depths in the upper part of boreholes and soil temperatures within 1 m of the ground surface is being conducted at selected sites in the Taipei, Bangkok, and Jakarta areas. The obtained data will show how GST variation is actually propagated through subsurface formations and provide evidence to support the estimation of GST history from the subsurface temperature distribution. The relationship between GST and SAT at each station will be derived from the soil temperature records.

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Reconstruction of the thermal environment evolution in Jakarta

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Abstract

Temperatures in boreholes can be an important source of information on recent climatic changes. The normal upward heat flow from the Earth's crust and interior is perturbed by the downward propagation of heat from the surface. Subsurface temperatures in Jakarta city, where population and density increase rapidly, were analyzed to evaluate the effects. Temperature-depth profiles and groundwater levels were measured on three observation wells in the area. This is the preliminary results of inversion analysis of the temperature profiles show significant increase in ground surface temperature (GST) during the last century in Jakarta city.

1. Introduction

The variation of surface temperature is recorded in the distribution of subsurface temperature. Since temporal variation in the ground surface temperature (GST) propagates into subsurface sediments and basement rocks, GST variation in the last several hundred years has been recorded in the underground temperature distribution in the upper several hundred meters.

Huang (2000) says that the thermal regime of the uppermost continental crust is determined in part by the outward flow of heat from the deep interior of the Earth and in part by fluctuations of temperature at the surface. In homogeneous rock and in the absence of changes at the surface, the temperature in the subsurface increases linearly with depth, at a rate which is governed by the magnitude of the terrestrial heat flow and the thermal conductivity of the rock. Fluctuations of surface temperature propagate downward into the rock as attenuating thermal waves superimposed on the temperature profile associated with the deeper heat flow. The depth to which disturbances can be observed is determined by the amplitude, duration and spectral composition of the temperature change at the surface.

The long-term variation of air temperature is classified by their scale, such as global warming and urbanization. From the view point of the global warming, the increase of 0.5–0.7K during the past a century was showed from the global meteorological data (Hansen and Lebedeff, 1987) and conformed by Huang et al. (2000). On the other hand in the urban area, the increased surface temperature was higher than that of global warming (Taniguchi et al., 2005).

The objectives of this study are to reconstruct ground surface temperature (GST) histories in Jakarta city. These GST histories will be compared with meteorological data and other information on urbanization processes collected through different approaches.

2. Borehole Temperature Data

Jakarta city which is the capital of the Republic of Indonesia is located within the basin, with an elevation which ranges between 0 – 1000 m above sea level, lies on the coastal plain of the Java Sea (to the north) and is bordered by Jakarta Bay in the north, West Java province in the south, east and Banten province in the west. It is located between 106^o 33’ - 107^o ’E longitude and 5^o 48’ 30” - 6^o 10’ 30” ’ S latitude with an area around 652 km^2 (Figure.1). This area has a humid tropical climate season, dense population and there is hardly environmental impact by human activity.

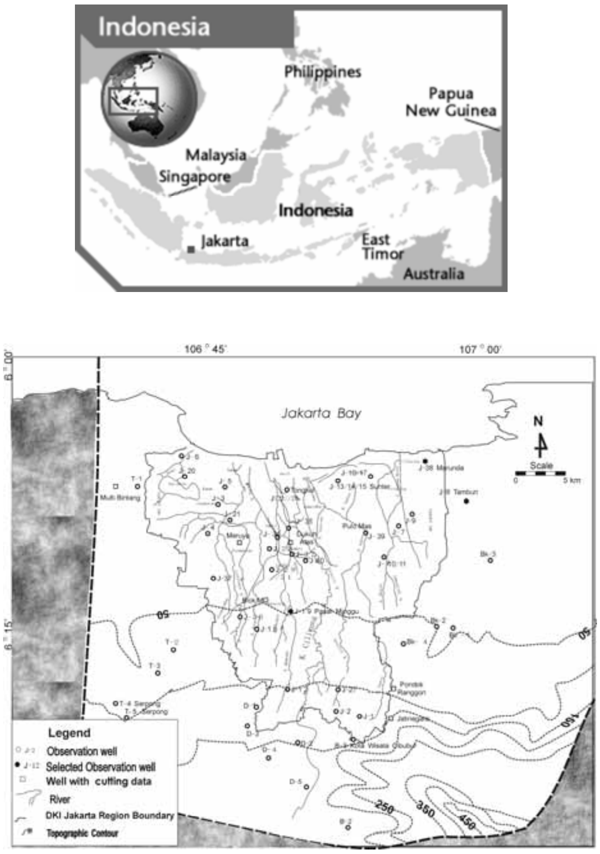

Figure 1. Location of study area and selected observation well

Temperature-Depth (T–D) profiles were measured in three observations well in September, 2006 (Figure 2). The measurements were made at 2-m intervals from the water level to the bottom of the hole with a digital thermister thermometer of 0.01 °C precision Selected boreholes are observation wells, therefore ideal for thermal studies. Due to the time elapsed since their construction, they can be considered to have attained thermal equilibrium conditions between water in a borehole and surrounding subsurface temperature.

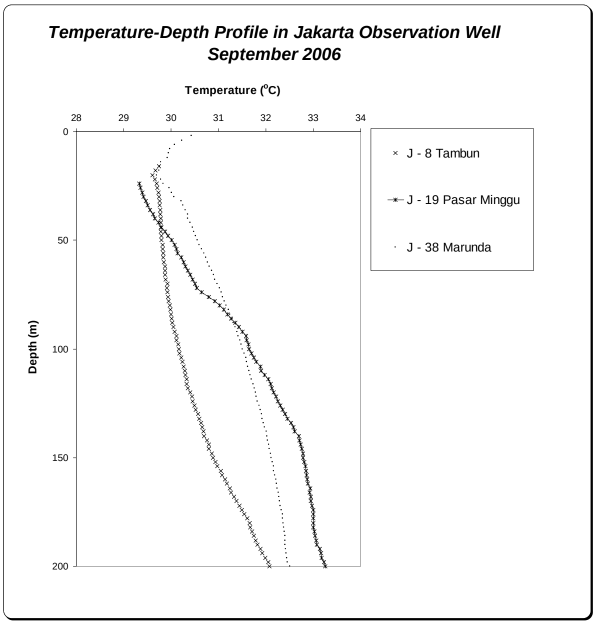

Figure 2. Temperature-depth (T-D) data in selected observation well

3. Air Temperature and Population Data Analysis

Air temperature record in Jakarta areas are shown in Figure 3. As can be seen, air temperature increased during the last 100 years by 1.4 ^{0}C (R^2=0.93). According to the analyses of global trends of air temperature change by Hansen and Lebedeff (1987), the magnitude of global warming is about 0.5 K/100 years. Therefore, the increased air temperature includes not only global warming but also other factors.

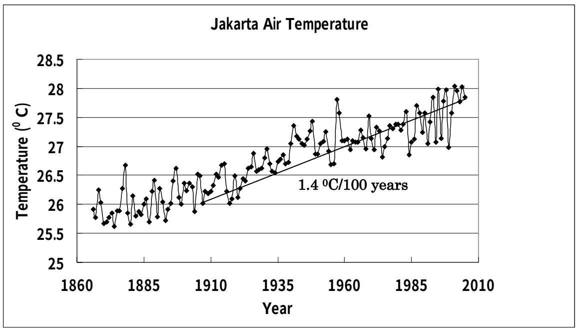

Figure 3. The long time air temperature variation in Jakarta

These cities are developed and urbanized rapidly in particular after 1950`s period (Figure 4). The most reasonable explanation for the increase in air temperature greater than global warming is the urbanization of this city.

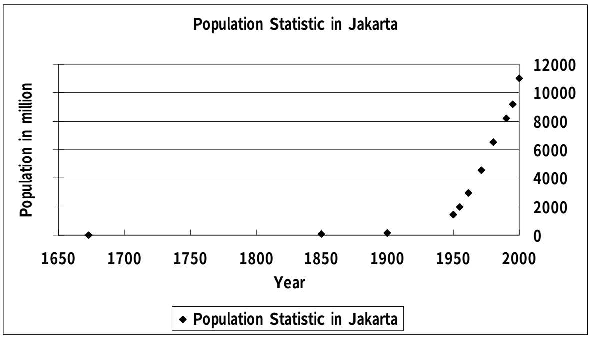

Figure 4. Population statistic in Jakarta city

2. Method and Result

In order to reconstruction of the ground surface temperature history from the borehole temperature data, analytical solution obtained the analytical solution for temperature using a one-dimensional heat conduction–advection equation under the condition of linear increase in surface temperature on the T–D profile has been made (Goto et. al, 2005). Assuming a semi-infinite homogenous material and the heat transfer in the material is only by one-dimensional heat conduction. At the surface (depth z = 0), the temperature fluctuates as a series of step function:

$$T(z = 0, t_{i-1} < t < t_i) = \Delta T_i \qquad (i = 1, 2, \ldots, M) \quad ..(1)$$

Where t is the time before the temperature measurement and ΔT_i is the temperature change at time between t_{i-1} and t_i. The subsurface thermal response to the surface boundary condition at the time of the borehole temperature measurement (t = 0) is given as (Carslaw and Jaeger, 1959):

$$T(z, t = 0) = \sum_i^M \Delta T_i \left[erfc\left(\frac{z}{2\sqrt{kt_i}} \right) - erfc\left(\frac{z}{2\sqrt{kt_{i-1}}} \right) \right] \ldots (2)$$

Where erfc is the complementary error function and k is the thermal diffusivity of the surrounding material defined as:

$$k = \frac{K}{\rho C_p} \qquad \ldots (3)$$

Where K, ρ and C_p are the thermal conductivity, density and specific heat of the material, respectively. To reconstruct the GST History from the borehole temperature data, it uses the Bayesian inversion method based on Tarantola (1987). The calculated T–D profile shows the relatively good agreement that the increased surface temperature after 1950`s period (Figure 5).

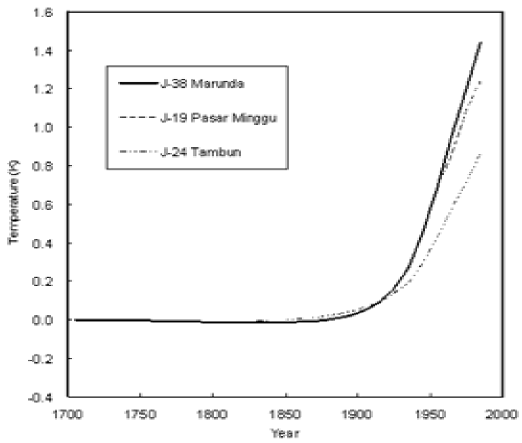

Figure 5. Result of GST history from individual borehole temperatures in Jakarta

4. Conclusion

The reconstruction GST history in Jakarta city showed that the surface temperature increased estimated to be 1.4 ^{0} C which agree well with the air temperature records during the last 100 year. The combined effects of heat island and global warming reaches up to more than 100 meters below the surface, and the increased rate of subsurface temperature by the heat island effect is much larger than that of global warming. It shows that subsurface thermal contamination occurs in this city due to urbanization in addition to global warming.

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Groundwater Discharge and Nutrient Fluxes off Metro Manila, Philippines Based on ^{222}Rn Measurements

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Abstract

We are examining material (contaminant) transport between urban groundwaters and surface waters in several Asian megacities. Manila, with one of the highest population densities of any city in the world, has experienced very rapid growth resulting in some severe environmental and social problems. We ran multi-detector radon surveys along the shoreline of the city for a qualitative assessment of where groundwater seepage might be highest. These results agreed well with the known hydrology as the highest radon activities in Manila Bay nearshore surface waters appeared in areas where the groundwater pieziometric surfaces were also highest. We next ran a 48-hour radon time-series in coastal waters off Cavite (southern part of Metro Manila) to evaluate tidal-scale temporal fluctuations. The results showed a large increase in ^{222}Rn at low tide together with a distinct freshening of the water, characteristics indicating groundwater seepage. When we model these results, we obtain estimated groundwater flow rates that varied from 0 to 12.5 cm/day with an overall average of 2.9 cm/day. These data, combined with nutrient analyses from nearby piezometers, allowed us to make nutrient flux calculations. While the fluxes of inorganic nitrogen (DIN ~5 mmol/m^2 day) and PO_4 (0.16 mmol/m^2 day) were about two times higher than a less-impacted site studied earlier on the opposite side of the bay, they were 1-2 orders of magnitude higher than most other embayments. We suspect that the DIN fluxes would presumably be even higher without the denitrification that apparently occurs in these sediments.

Key words: groundwater, urban setting, nutrient fluxes, radon

1. Introduction

Perhaps the most dramatic and obvious subsurface environmental problem occurring in Asian coastal cities today is the subsidence and related issues due to excessive pumping of groundwater. This has occurred repeatedly in major cities throughout Asia with a time lag depending upon the developmental stage of urbanization in each city. Subsidence not only results in dangerous structural problems within cities but has also resulted in a serious danger of flooding in many low-lying coastal cities of Asia. Entire sections of Bangkok, for example, now flood during each spring tide. Government-mandated changes in the reliable use of water resources from groundwater to surface water supplies have typically been initiated to address the over pumping and subsidence problems. However, even when land subsidence has ceased due to regulation of groundwater pumping, the resulting <u>increase</u> in groundwater level has caused other types of damage by flooding and exerting buoyant forces to underground infrastructures (e.g., subways) that were constructed during the drawdown period. What is somewhat surprising is that this same scenario (groundwater over pumping → subsidence/flooding → withdrawal restrictions → groundwater level rising) has been repeated several times in different cities over the past several decades without any obvious collective wisdom. We continue to make the same mistakes.

We address here what may be one of the most important aspects of the subsurface environment, i.e., material (contaminant) transport to surface waters. Research over the last few years has shown that submarine groundwater discharge (SGD) to the coastal zone is a significant water and material pathway from land to sea (Bokuniewicz, 1980; Capone and Bautista, 1985; Valiela et al., 1990; Church, 1996; Moore, 1996; Li et al., 1999; Charette et al., 2001; Taniguchi et al., 2002; Burnett et al., 2003a; Boehm et al., 2004; Garrison et al., 2003; Paytan et al., 2006; Kroeger et al., 2006). This flow may occur through the surficial aquifer or through breaches in deeper semi-confined coastal aquifers (Moore, 1999). While the overall flow of fresh groundwater into the ocean is likely no more than about 6% of global runoff, it has been estimated that the total dissolved salt contributed by terrestrially-derived SGD may be as much as 50% of that contributed by rivers (Zektser and Loaiciga, 1993). This process will thus affect the biogeochemistry of estuaries and the coastal ocean through the addition of nutrients, metals, and carbon (Moore, 1996). High dissolved N:P ratios in contaminated coastal groundwater relative to surface waters may drive the coastal ocean towards P-limitation within the coming decades, perhaps changing the present N-limited coastal primary production (Valiela et al., 2002; Slomp and Van Cappellen, 2004; Hwang et al., 2005). In addition to inputs of terrestrially-derived groundwaters, recirculation of seawater through sediments by tidal pumping and other processes also can provide significant biogeochemical inputs and is also considered "SGD" (Burnett et al., 2003a).

While coastal scientists now recognize that groundwater often can be a major contributor to coastal nutrient budgets, most studies to date have been performed in rural, and in many cases, pristine environments. This approach reflects the understandable desire to deal with "natural" systems. While there certainly have been a number of contamination studies in and around urban waterways of the world, few have addressed the issue of interaction between urban groundwaters and surface waters. Exceptions include Charette and Buesseler (2004; urban area of Chesapeake Bay), Rapaglia (2005; Venice Lagoon), Beck et al. (2007; Jamaica Bay, NY); and Nakayama et al. (2007; Tokyo Bay). In light of the trend towards accelerating global urbanization, it now seems prudent to turn our attention to evaluating such impacts in some major urban areas. We report here on an SGD investigation off Metro Manila, Philippines, an Asian megacity.

2. Study site and methodology

Manila Bay

Manila Bay is a semi-enclosed bay located on the southwestern part of Luzon Island (**Fig. 1**).

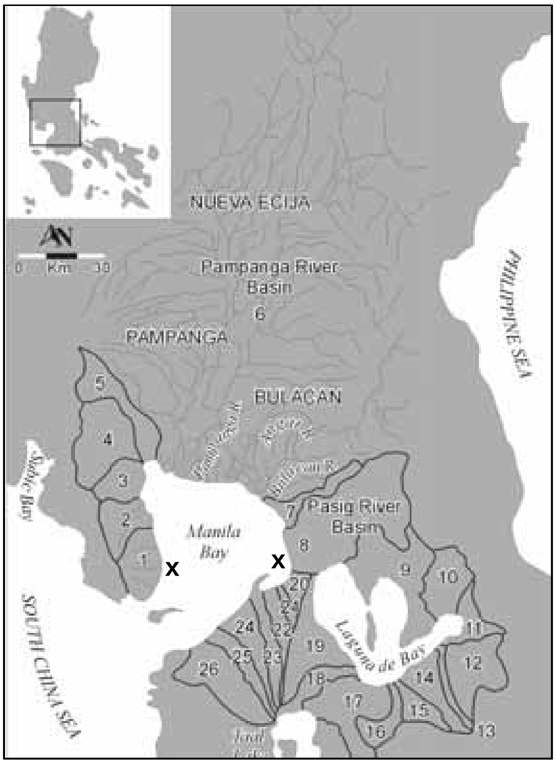

Figure 1. Index map of Manila Bay (Philippines) showing the different drainage basins in the area. We were part of a group that performed fieldwork along the southeast coast of the Bataan Peninsula (basin #1) in 2005 (Taniguchi et al., 2007) and off Metro Manila in 2006. The x's mark the approximate locations.

It has a surface area of 1800 km^2 with a coastline of approximately 190 km. The bay has an

Table 1. Characteristics of Metro Manila relevant to this study.

Population/Urban Environment	Climate/ Rainfall	Topography/ Proximity to Ocean	General Geology	SGD Characteristics
11.3 million (as of 2005); Serious water pollution, subsidence from over-pumping of groundwater	Tropical marine, SW monsoon May-Oct; rain=2200 mm/y	Moderate slopes; Metro Manila directly on Manila Bay	Various volcaniclastics and a thin veneer of coastal and alluvial dep.	Hydraulic gradient and tidal pumping; strong fresh water SGD signal seen in Manila Bay

average depth of 25 m and is approximately 52 km long, with widths varying from 19 km at its mouth to 56 km inside the bay. Tides along the coast of Manila Bay are diurnal and within the microtidal range. During an earlier study in January 2005, we investigated an area along the southeastern coast of the Bataan Peninsula, on the opposite side of the bay from the city of Manila. The steep gradients and abundance of artesian wells along that coast suggested that there could be high levels of SGD. In addition, the harmful algal blooms that occur in Manila Bay were often initiated in this area (Bajarias and Relox, 1996). Our results from that initial study suggested that DIN fluxes via SGD are comparable in magnitude to DIN fluxes from each of the two major rivers that drain into the bay (Taniguchi et al., 2007). This is significant as Bataan is clearly less contaminated than the Metro Manila area that is the focus of the present study.

The city of Manila, one of the municipalities that comprise Metro Manila lies at the mouth of the Pasig River on the eastern shores of Manila Bay. The city sits on top of century's worth of prehistoric alluvial deposits built by the waters of the Pasig River and on land reclaimed from Manila Bay. The layout of the city was haphazardly planned during the Spanish Era as a set of communities surrounding the original walled city of Intramuros, one of the oldest walled cities in the Far East. Beginning in 1898, the United States occupied and controlled the city (except for the Japanese period during WWII) and the Philippine archipelago until 1946. During World War II, much of the city was destroyed and thus most infrastructures are relatively recent.

Manila has one of the highest population densities of any city in the world (10,550 people/km²; compare to Tokyo at 4,750 people/km² or New York at 2,050 people/km² according to http://www.citymayors.com/statistics/largest-cities-density-125.html). The very rapid growth and relatively poor economy has resulted in some very unfortunate environmental and social problems. It is estimated, for example, that over 150,000 people make a living by scavenging for resale goods through the ~6,700 tons of garbage produced each day in Manila. The most famous of several dumps is called "Payatas," a 30-meter mountain of garbage. This dump collapsed during monsoon rains in 2000 and buried more than 200 squatters in their shacks. The urban collapse of the slums around Manila has clearly led to many environmental disasters. Some of the physical and urban characteristics germane to our SGD study are provided in **Table 1**.

The expanding population of Manila (~11.3 million as of 2005) has put serious pressure on the available water resources. Even with the tropical climate and high rainfall (~2.2 m/yr) in the Manila area, groundwater levels dropped dramatically until the early 1980's when restrictions became necessary and levels in some areas have now been restored (**Fig. 2**).

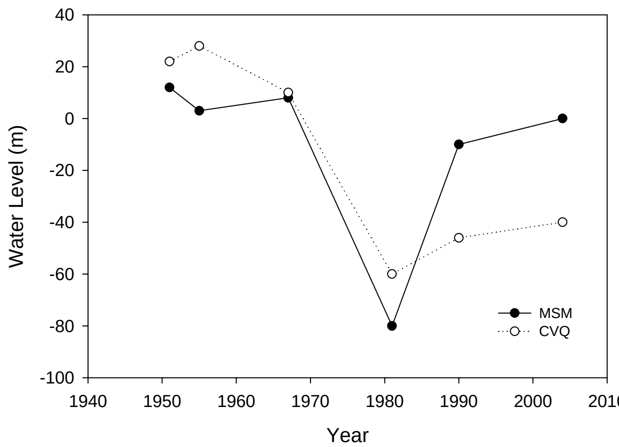

Figure 2. Groundwater levels over the past several decades interpolated from piezometer measurements made in two areas of Metro Manila: MSM = Manila - San Juan - Mandaluyong; and CVQ = Caloocan - Valenzuela - Quezon City.

Radon measurement

Several studies have now shown that radon is an excellent tracer of groundwater discharge (Cable et al., 1996; Hussain et al., 1999; Corbett et al., 1999; Kim and Hwang, 2002; Burnett and Dulaiova, 2003; Garrison et al., 2003; Burnett et al., 2006). Radon works as a tracer because it is greatly enriched in groundwater relative to ocean water, behaves conservatively in seawater, and is relatively easy to measure. An automated radon system (Burnett et al., 2001) was used to analyze ^{222}Rn from a constant stream of near-surface water (driven by a submersible pump) passing through an air-water exchanger that distributes radon from this running flow of water to a closed air loop. The air stream is fed to a commercial radon-in-air monitor (Durridge RAD-7) that determines the activity of ^{222}Rn by collection and measurement of the α-emitting daughter, ^{218}Po. Since the distribution of radon at equilibrium between the air and water phases is governed by a well-known temperature dependence, the radon activity in the water is easily calculated.

We first used radon and conductivity in a qualitative manner at the study site by performing a survey of the area's coastline (May 27-28, 2006) with a multi-detector radon analysis system (Dulaiova et al., 2005). We ran the radon system together with a YSI temperature-conductivity probe and logging gps navigation and depth sounding while underway along the shoreline off Metro Manila at slow speed (~5-6 km hr^{-1}) from a small fishing boat.

Individual radon measurements from grab samples collected from offshore piezometers and groundwater wells on land were performed using an attachment to the RAD-7 analyzer called a "RAD-H_2O." This device allows one to sparge a 250-mL sample with air, which is then directed through a drying tube and measured for radon by the RAD-7. We found that some of the piezometer samples were very gas-rich and bubbles would rush up the RAD-H_2O tubing and flood the desiccant. This problem was solved by installing a simple trap consisting of a second small drying tube without any desiccant immediately below the actual drier.

After the survey, we selected a site about 300 m off Cavite (one of two high areas defined by the survey) to conduct a time-series experiment. This was done from May 28-30, 2006 using a small submersible pump connected to an exchanger and a single radon detector. Measurements of radon, as well as temperature, conductivity (salinity), and water depth were made over the same period. Wind speed data were recovered from a local meteorological station for purposes of calculating radon exchange across the air-sea interface. Atmospheric radon measurements over the same time period were made with a separate RAD-7 set up nearby.

The main principle of using continuous radon measurements to decipher rates of groundwater seepage is that we can monitor the inventory of ^{222}Rn over time, making allowances for losses due to atmospheric evasion and mixing with lower activity waters offshore. Any changes observed in these inventories can be converted to fluxes required to maintain the observed quantity of radon. Although changing radon inventories in coastal waters could be in response to a number of other processes (sediment resuspension, long-shore currents, etc.), we find that the advective transport of groundwater (Rn-rich pore water) through permeable sediment is usually the dominant process. Thus, if one can measure or estimate the radon activity in the advecting fluids, we can convert the ^{222}Rn fluxes obtained by a mass balance approach to water fluxes by dividing the radon fluxes by the radon activity of the groundwater. The principles and equations for gas exchange, mixing corrections, and discharge estimates have been described in detail in Burnett et al. (2003b) and Burnett and Dulaiova (2003).

Nutrient Analyses

Piezometer and monitoring well samples were collected in acid-washed and sample-rinsed polyethylene bottles, and filtered through o.45 μm cellulose filters immediately upon sample collection. The samples were returned shortly after collection to the hotel where they were frozen and then shipped back to Japan with dry ice and kept frozen until analysis. We analyzed for nitrate (actually nitrate + nitrite), ammonia, and inorganic phosphate analyses following recommended procedures (Grasshoff et al., 1999). Dissolved inorganic nitrogen (DIN) reported here is the sum of NO_3 (and any NO_2) and NH_4.

3. Results and Discussion

Radon Survey

The results from the radon survey (**Fig. 3**) show that there are two areas with higher than average radon concentrations: an area off Pasay City near Central Manila; and a second area near Cavite in the southern part of the city. These results should be considered qualitative in terms of groundwater discharge as many other factors can influence radon concentrations. For example, different mixing rates in different areas could result in various amounts of low-radon offshore water being present locally. Different sediment types would likely have variable radium concentrations, affecting contributions from diffusion. Finally, there are likely temporal changes on time scales as short as tidal cycles (see next section).

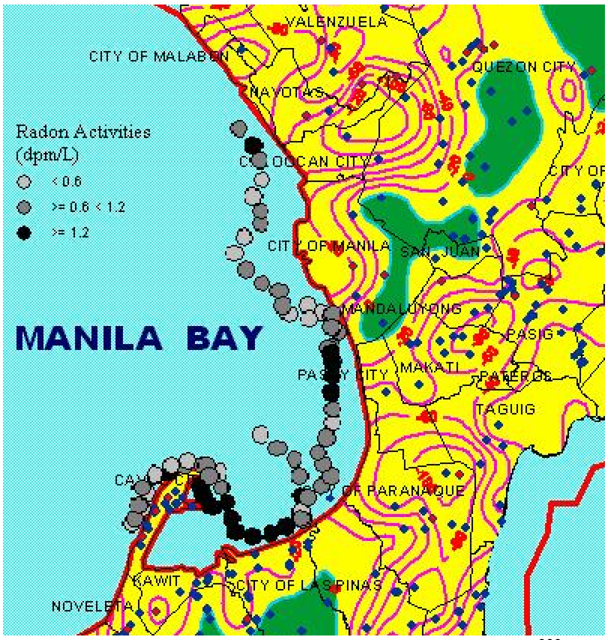

Figure 3. High, low, and medium concentrations of ^{222}Rn in surface waters off the shoreline of Metro Manila together with piezometric surface contours from 2004.

In spite of these considerations, we still feel that the survey approach is a useful tool for identifying potential areas of interest in a relatively short time. For example, we used this approach successfully during an SGD intercomparison study held in Ubatuba, Brazil in 2003 (Burnett et al., 2006). In fact, the two areas identified in the survey as potential sites of groundwater seepage do correspond to areas with the relatively highest pieziometric surfaces in Metro Manila. While most groundwater surfaces are shown below sea level in Figure 3, government restrictions have resulted in steadily increasing water levels (Fig. 2). Thus, the actual piezometric surfaces during our 2006 survey would likely be higher than those indicated. This would be especially true in the Manila - San Juan - Mandaluyong (MSM) area, nearby the central zone of high radon. We chose the southern area near Cavite for the time-series experiment since it was near temporary piezometers installed offshore and there were monitoring wells available for sampling groundwaters on-shore.

Radon Time-Series Experiment

After the survey was completed, we anchored the boat about 300 m offshore in an area near Cavite where several piezometers and seepage meters had been installed. We set a submersible pump about 0.5 m below the surface and began taking radon measurements using one RAD-7 detector running at 1-hour intervals. We also deployed a YSI multi-probe and HOBO water level meter at the same station to measure temperature, salinity, and water depth variations. A separate RAD-7 was set up on the deck of the boat to measure atmospheric radon. This time-series experiment was run from 15:00 May 28 to 14:00 May 30, 2006.

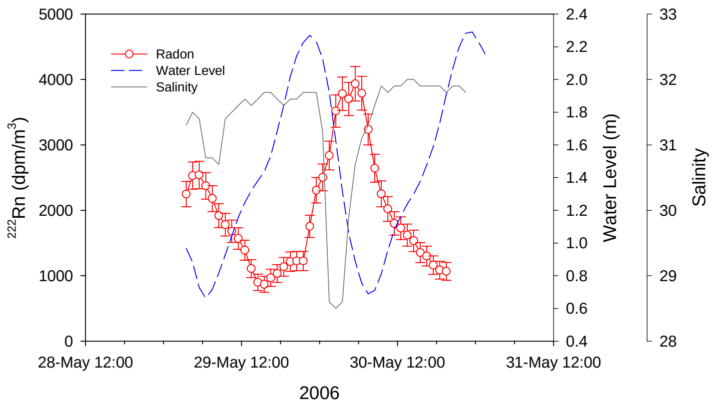

Figure 4. Time series experiment performed in surface waters off Metro Manila in May 2006 showing systematic variations in ^{222}Rn activities, salinity, and water level.

The radon results show a large increase in ^{222}Rn at low tide together with a distinct freshening of the water, characteristics of groundwater seepage (**Fig. 4**). When we model these results following a non-steady-state mass balance approach (Burnett and Dulaiova, 2003), we obtain estimated groundwater flow rates that fluctuate from 0 to 12.5 cm/day with an overall average of 2.9 cm/day. These rates overlap but are at the low end of the average values for the 3 seepage meters deployed in the area. Those rates were 9, 24, and 5.4 cm/day at 70, 170, and 220 m offshore, respectively (Ishitobi, pers. comm.). Since the radon measurements are taken in the water column, the tracer signal is integrated over a larger area than that covered by a single seepage meter (~0.25 m^2). Presumably, the radon results should thus be more characteristic of the entire area.

Estimates made by the radon model depend critically upon the end-member choosen, i.e., the radon concentration in the waters flowing into the study site. Fortunately, we had access to several piezometers that allowed us to sample pore waters from 0.5 m below the sea bed. It is also fortunate that the results from 8 samples collected from 6 different locations fall into a relatively tight grouping (**Table 2**). Our selected groundwater ^{222}Rn end-member of 288±41 dpm/L represents a standard deviation of only about 14%. If we plot the time-series radon versus salinity, on the other hand (**Fig. 5**), it appears that there could be more than one end-member. Simple linear mixing between a high groundwater end-member and low offshore values cannot explain the observed distribution. However, we feel that this may be due to low-radon water inputs from a nearby stream. We made some measurements in this stream and found the radon in the stream water to be very low, near the detection limit. Thus, any contributions from this stream would likely lower the salinity without a resulting rise in radon at the time-series location. Since the radon model applied does not depend on salinity, this effect should be minor.

Table 2. Radon activities for 4 monitoring well samples and 8 piezometer samples collected from the study site.

Sample	Distance Offshore (m)	Salinity	Date/Time Sampled	^{222}Rn (dpm/L)
GW-6	0	29.9	May 28 10:10	185 ± 70
GW-7	0	10.3	May 28 11:00	289 ± 85
GW-8	0	11.3	May 28 13:00	677 ± 41
GW-9	0	4.7	May 28 15:30	371 ± 28
Piez-A	70	34.4	May 29 9:36	317 ± 52
Piez-B	120	35.1	May 29 9:46	352 ± 17
Piez-C	170	34.8	May 29 9:57	257 ± 13
Piez-D	220	36.4	May 29 10:07	307 ± 24
Piez-X1	30	30	May 29 16:59	223 ± 33
Piez-X2	30	29.8	May 29 17:03	264 ± 37
Piez-Y1	40	31.1	May 29 17:09	274 ± 24
Piez-Y2	40	31.2	May 29 17:11	307 ± 34

Mean of 8 piezometer samples = 288±41 dpm/L

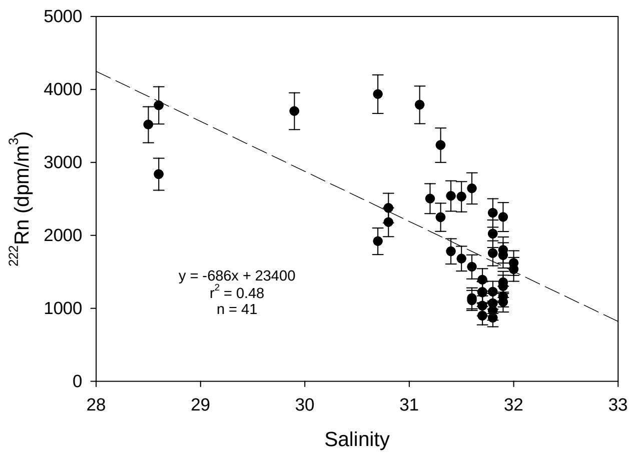

Figure 5. Radon versus salinity variations as measured during the time-series experiment.

Nutrient Fluxes

The radon-derived discharge estimates, combined with nutrient analyses from the same piezometers used for the radon measurements, allow us to make nutrient flux calculations (**Table 3**). As expected, the Metro Manila site shows higher DIN and PO_4 fluxes compared to the less impacted site off the Bataan Peninsula that was investigated in 2005. Both sets of estimates based on measurements made in Manila Bay are thought to be conservative and are relatively well-constrained as we were able to confidently assess end-member values for radon and nutrients at the two sites. In addition, the SGD fluxes were also evaluated by automatic seepage meters. The agreement between the radon and seepage meter rates was excellent at Bataan and reasonably good (within a factor of two for the closest seepage meter) at the Metro Manila site. The calculated nutrient fluxes fall within the worldwide range of SGD nutrient fluxes compiled by Slomp and Van Capellen (2004), although these ranges are extremely broad. The fluxes are significantly higher than those reported from other less impacted embayments. For example, the DIN and PO_4 fluxes at the Manila Bay sites are 1-2 orders higher than those reported for Waquoit Bay, Massachusetts (Charette et al., 2001), Florida Bay (Corbett et al., 1999), and Kahana Bay, Hawaii (Garrison et al., 2003). The Kahana Bay site has a somewhat similar volcanic geology but is in a low-density setting of northeastern Oahu, Hawaii.

Perhaps most surprising about the Metro Manila data is that the nutrient fluxes are not even

Table 3. Estimated SGD fluxes of inorganic N-species and PO_4 into 2 sites in Manila Bay and 3 sites from the literature. The Bataan results are from January 2005; and the Metro Manila measurements were made in May 2006.

Location	NH_4	$NO_3 + NO_2$	DIN	PO_4	Reference
	Nutrient Fluxes (mmol/m^2 day)				
Manila Bay: Bataan Peninsula*	2.4	0.02	2.4	0.07	Taniguchi et al., 2007
Manila Bay: Metro Manila**	5.3	0.002	5.3	0.16	This study
Waquoit Bay, Massachusetts	0.44	0.11	0.55	--	Charette et al., 2001
Florida Bay, Florida	0.28	0.2	0.3	0.001	Corbett et al., 1999
Kahana Bay, Hawaii	--	--	0.16 - 0.92#	0.001 - 0.004	Garrison et al., 2003

*Fluxes based on radon-derived seepage rate of 4.0 cm/day (av. seepage meter rate = 5.1 cm/day); end-members: ^{222}Rn = 240 dpm/L; NH_4 = 59.3 μM, NO_3 = 0.6 μM, PO_4 = 1.8 μM.
**Fluxes based on average advection of 2.9 cm/day based on radon measurements (av. seepage meter rate = 5.4 cm/day); end-members: ^{222}Rn = 288 dpm/L; NH_4 = 177 μM, NO_3 = 0.6 μM, PO_4 = 5.3 μM
#Total dissolved nitrogen

higher in this extremely contaminated environment. A fresh water monitoring well on land very close to the Cavite site had a NO_3 concentration of 1200 μM and 130 μM NH_4, yet the porewaters discharging just offshore have DIN values <200 μM. PO_4 was about the same (~5 μM) in the fresh groundwater as in the offshore piezometers. Denitrification may be an important process in these sediments.

4. Conclusions

A radon survey along the shoreline of Metro Manila identified two areas of relatively high radon, indicating potential sites of groundwater seepage into Manila Bay. These two areas also correspond to areas identified as having the highest piezometric surfaces in the region. In addition, the water level around the districts of Manila - San Juan - Mandaluyong has been rising significantly over the past several years due to government-imposed water supply restrictions. This area is thus identified as a likely zone of enhanced discharge of terrestrial groundwaters.

A time-series experiment at the southern site identified in the radon survey showed clear evidence of groundwater seepage with enhanced flow and freshening during low tide. Good end-member values for radon and inorganic nutrients were obtained from piezometers installed in the same area. Calculated nutrient fluxes showed that the Metro Manila site was higher by about a factor of two than a less impacted site off the Bataan Peninsula on the opposite side of Manila Bay. The DIN and PO_4 fluxes in Manila Bay are about one and two orders of magnitude higher, respectively, than embayments in other areas investigated recently. Although these fluxes are high, concentrations of inorganic nitrogen species in the sediment pore waters are relatively low compared to some contaminated groundwater on the adjacent shoreline. Thus, denitrification may play a role in maintaining DIN fluxes.

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Warming Effects on Surface and Subsurface Thermal Environment of Taipei, Taiwan

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Abstract

The objective of this study is to analyze surface and borehole subsurface temperature records of the Taipei Basin, Taiwan for a better understanding of the warming history (global plus urban heat island effects) in this RIHN project target site. The annual surface air temperature time series from the meteorological station show that Taipei has been warming since early 20th century. The mean warming rate in Taipei surface air temperature is about 1.5 °C/100a over the period from 1897 to 2006, at least half of which can be attributed to the urban heat island effects. A clear rising trend after 1980 is also observed in the surface temperature trend. Regarding the diurnal variations, both day and night temperatures display a distinct rising trend with the night temperature slope showing a factor of 2-3 higher than that of the day temperatures. Borehole temperature profiles (down to 300m; measured in the 2005 winter and 2007 summer) exhibit a general decrease-and-then-increase tendency with a thermal gradient of about 2.7°C/100m. The anthropogenic thermal impacts on the subsurface of Taipei Basin will be the focus study of the next phase. This work is an updated presentation for the thermal study of Taipei Basin in our RIHN project.

Keywords: surface air temperature, diurnal temperature range, borehole temperature, urban heat island effects, subsurface thermal environment

1. Introduction

The warming effect over big cities has been documented first in mid-latitude urban areas and later in the tropical environment. The nocturnal heat island results from diverging cooling rates between the urban and rural environments often produce a sharp increase in intensity soon after sunset to a maximum of about 4 hours later in temperate climate cities (Oke, 1982). The thermal performance of an inner city is usually affected by land area, massing and surrounding buildings (Golany, 1996) and becomes the main concerns in recent research. Taipei Basin (including Taipei city and part of Taipei County; Figure 1) has been the fastest expanding metropolitan area of Taiwan for the past five decades with approximately 6 million inhabitants (WRPC, 1992; EPA, 2006). In addition to dense population, the Taipei Basin itself is very dense and dominated by high-rise buildings across all public, industrial, commercial sectors. Accordingly, Taipei Basin has been experiencing a regional scale heat-island effect along with global warming. These changes, in turn, induce significant changes to other important meteorological parameters in this study area. The impact of the urban climate in the subtropical Taipei Basin is thus alarming. The temperature records (surface and subsurface) between the inner urban and rural sites are the primary objectives of this study. This work seeks to document the thermal history of the surface and subsurface environments of Taipei Basin in collaboration with similar endeavors performed in other study sites of RIHN project.

2. Site, Data and Methodology

Taipei Basin is located at the northern Taiwan (25.1° N, 121.3°E) and surrounded by mountains/hills on all sides with an area of 380 Km^2 (Figure 1).

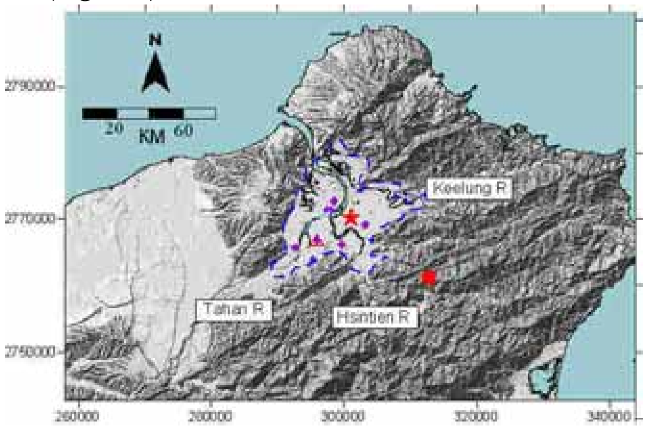

Figure 1. Location of Taipei metropolitan area (circled by blue dashed line). Red solid star is the Taipei meteorological station; red solid dot is the Wenshan station; red open triangle is the groundwater monitoring well of the Tenth River Management Office. Solid diamonds are the borehole locations. Three major rivers are shown as Keelung (east), Hsintien (southeast) and Tahan (south).

Its climate is hot and relative low humidity in summer, cool and relative high humidity in winter (Wan, 1973; Wu, 1993; Wang et al., 1994). Winter (northeast) and summer (southwest) monsoons are the main factors controlling the climate of Taipei Basin. Three rivers that come from east (Keelung), southeast (Hsintien) and south (Tahan) catchments, respectively, merge into one major stream (Tanshui) in the middle of Taipei Basin and flow northwesterly toward the Taiwan Strait (WRA, 2005). The unique topography of Taipei contributes to the city's high levels of air pollution and enhancement of warming. In this study, all surface temperature records are provided by the Central Weather Bureau of Taiwan. The borehole temperatures were measured in November 2005 and June 2007 for 8 sites in the Taipei Basin according to the methods in Miyakoshi et al. (2005). One site (the Tenth River Management Office) was selected for a continuing temperature measurement for three different levels (25.0m; 33.2m; 41.4m) from November 2005 through June 2007.

3. Results and Discussion

The ground thermal history of Taipei Basin can be viewed from the annual temperature records of Taipei meteorological station (25° 02' 23" N, 121° 30'24" E; altitude = 5.3m above mean sea level; Figure 1, red solid star) from 1897 to 2006 (Figure 2A). These temperature records are expressed as anomalies relative to their long-term averages (yearly mean = 22.2°C) which are shown as the zero reference line. The general feature of the temperature trend agrees well with the global average trends (IPCC, 2007). It is evident that Taipei has a linear rising rate of 0.15°C per decade for the annual records (Figure 2A), that is a factor of 2 higher than the world average and consistent with a previous study (Wu, 1993). A faster speed (0.38°C/decade) than the linear rate for the past century can be deduced and suggests the recent acceleration of climate warming in the Taipei Basin. This feature is also observed in other metropolitans (IPCC, 2007).

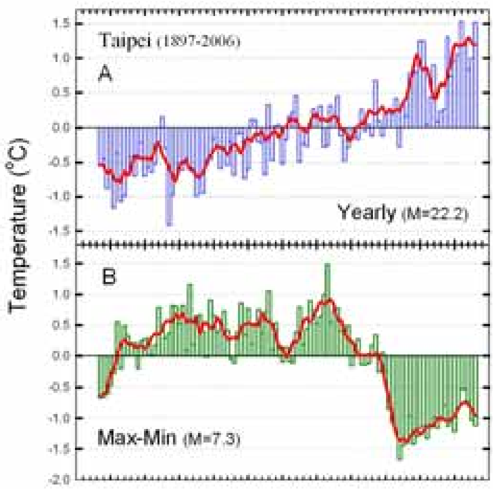

Figure 2. (A). The long-term annual temperature trends of Taipei meteorological station (yearly data). (B). The long-term annual temperature trends of Taipei meteorological station (difference between maximum and minimum means). Long-term temperature averages are served as reference lines. Five-year running means are illustrated as red dashed lines. The long-term temperature means are shown in the respective parentheses.

Regarding the diurnal variations, Figure 2B shows the annual time series temperature records for the difference between maximum and minimum temperatures in the Taipei Basin. Because the mean minimum temperature expresses a fast rising rate (0.21°C/decade) than the mean maximum (0.09°C/decade), the diurnal difference between maximum and minimum temperatures show a decreasing trend (-0.12°C/decade) and the negative anomalies mainly occurred after 1980, which is coincident with the onset of annual temperature accelerating in Figure 2A, as well as the fast city expansion in Taipei Basin. One of the principle reasons for the decrease in diurnal temperature difference is attributed to an increase in clouds/cloud albedo resulting from anthropogenic aerosols (Liu et al., 2002) and is highly related the Taipei development pace in recent decades. This feature demonstrates that the warming does accelerate its rate in recent decades and has an observable impact on the diurnal temperature pattern at the Taipei Basin. Figure 3 illustrates the temperature distribution of Taipei during the mid-night. It is evident that the basin centers where are the beginnings of the urban development areas display the highest temperature relative to the surrounding rural regions.

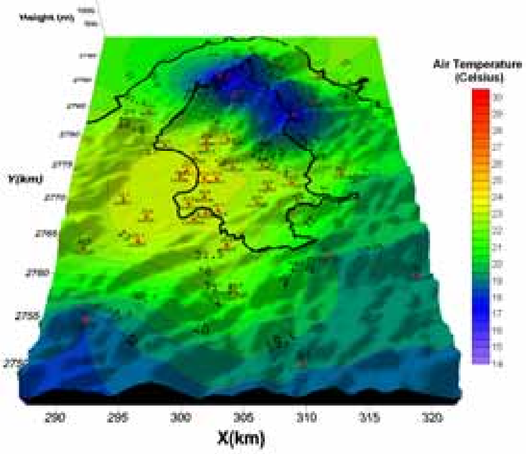

Figure 3. Temperature distribution at 00:00 am from stations inside Taipei basin shows a higher thermal area (old downtown) in the central region and implies that it was the beginning of the urban development.

The Urban Heat Island effect (UHI) index is a good measurement of heat distribution and normally represented by a comparison between the temperature differences of city center with those of rural sites (Oke, 1974; Landsberg, 1981). In this work, a rural station (Wenshan, 121.621° N, 24.95° E, altitude 410m; Fig. 1, red solid dot) located at the southeastern side of Taipei Basin was chosen for the comparison from 1994 to 2006 due to the data availability (hourly data provided by CWB). The average monthly means of air temperature from 1994-2006 in the Taipei meteorological station are about 1.7 °C higher than those of Wenshan. The observation is similar to many other cities (Oke, 1987). The monthly time series variations of these two sites from January 1994 through December 2006 were calculated by the established technique (Oke, 1974; Landsberg, 1981) and are shown in Fig. 4. The UHI intensity clearly reveals an increasing trend with 0.011 °C in monthly average for the study period. In the latest five years (2002~2006), the UHI anomalies show the most significantly increasing in positive mode. This observation indicates that the Taipei city center has experienced more temperature rising than the surrounding rural region for the last decade and would likely continue this tendency to the future.

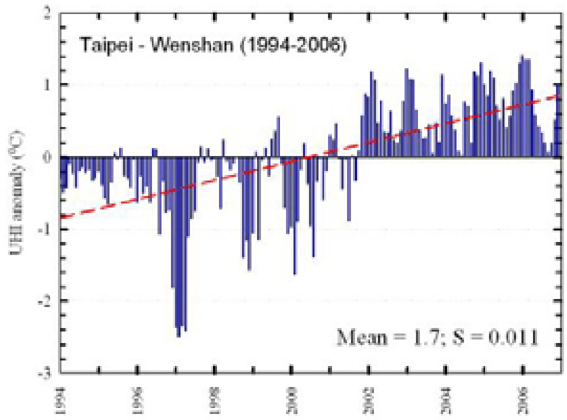

Figure 4. The anomaly and linear trend of monthly mean daily maximum UHI between Taipei station (urban) and Wenshan site (rural) from 1994~2006. The long-term temperature mean and linear fitting slope are shown in the parentheses. The anomalies and linear trends of monthly mean daily maximum UHI in the pair of Taipei-Wenshan in 1994~2006. This plot indicates an increasing trend with exclusive positive anomalies during the latest four years.

Figure 5 shows the temperature-depth profiles of eight boreholes measured in June 2007 at the Taipei Basin. The site locations of these boreholes can be found in Figure 1 (shown as solid diamonds). The subsurface temperature variability is relative large (0.2°C ~ 6.7°C); apparently groundwater pumping and flow play major roles. One of the subsurface temperature profile (Flood Diversion Park) shows a sampling depth down to 307m. According to this relative long record, the geothermal gradient at the Taipei Basin has a rate of 0.026°C/m which is comparable to that of Osaka area (Taniguchi & Uemura, 2005).

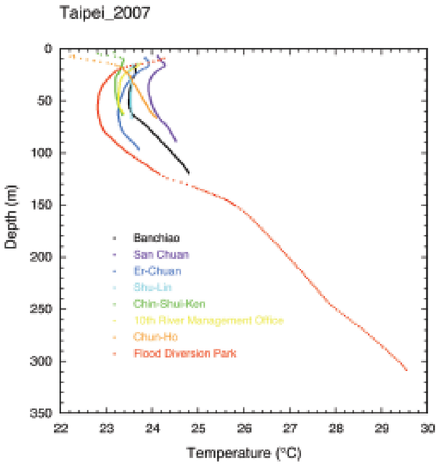

Figure 5. Temperature-Depth profiles of eight boreholes measured at the Taipei Basin in June 2007.

A continuous temperature monitoring work was carried for the site of the Tenth River Management Office for the depths of 25.0m, 33.2m and 41.4m from November 2005 through June 2007 (Figure 6). The temperature trends of these three levels all show a rising tendency though with different rates for various levels. This observation provides the first evidence for the subsurface warming effect in the Taipei Basin; though it is only a preliminary result. Obviously, a lot of work needs to be pursued in the next phase of our study.

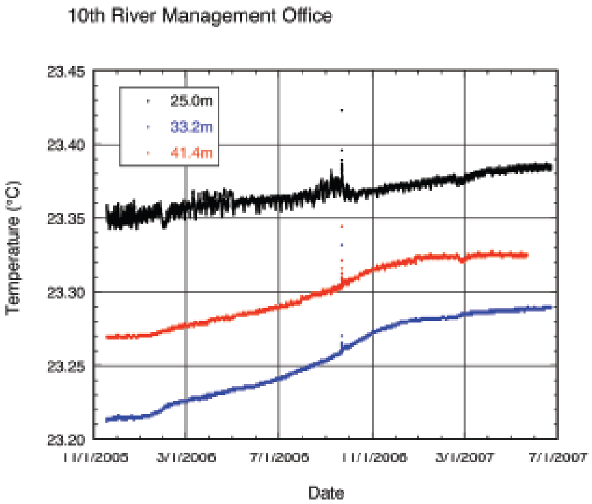

Figure 6. Time-series temperature records of the groundwater well at the Tenth River Management Office for three different levels (25.0m; 33.2m; 41.4m) during the period of November 2005 through June 2007.

4. Conclusion

A strong warming trend (2 times higher than that of the world average) has been observed in the period from 1897 to 2006 with acceleration after 1980. Certain unfavorable phenomena and trends (such as rapid warming in the city center and at night; hydrological extremity) are very evident and become the major factors in generating the recent environmental problems in Taipei metropolitan area. The change in the climate variability and the persistence of high temperatures in the future will certainly have an impact on many aspects, for example, public health (increase in heat-wave mortality), ecosystems, agriculture (particularly during high temperature with drought) and water resources. Preliminary result also indicates a warming trend in the subsurface temperature of groundwater. A multidisciplinary effort is certainly needed to compile inventory lists regarding important environmental parameters in addition to temperature and hydrological factors (such as air and water pollutions, sunshine hours, etc. both for surface and subsurface environment), and uncover the linkage among these parameters with the development of Taipei metropolitan area through years. In addition, an appropriate strategy for the effective management of water resources and living environment in Taipei metropolitan area is urgently needed in perceiving these persistent and gloomy trends in the future.

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The Status and Outlook of Land Warming as Part of Global Warming

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Abstract

This project will assess the effects of human activities on the subsurface environment, an important aspect of human life in the present and future but not yet evaluated. This is especially true in Asian coastal cities where population numbers and density have expanded rapidly and uses of subsurface environment have increased. The primary goal of this project is to evaluate the relationships between the development stage of cities and various subsurface environmental problems, including extreme subsidence, groundwater contamination, and subsurface thermal anomalies. We will address the sustainable use of groundwater and subsurface environments to provide for better future development and human well-being. It has been recognized that climate change on a global scale is accompanied by changing heat content of the continental lithosphere. But less certain are the extent of the ongoing continental lithosphere warming and its outlook. This study shows that the recent global climate warming has led to a significant heating in the continental landmasses and the climate induced lithosphere warming is most likely to be further intensified in the 21st century. With respect to the baseline of the mean 1851-1900 temperature, the landmasses of Asia, Africa, Australia, Europe, North America, and South America together have accumulatively absorbed 12 ZJ (10^{21} Joules) of thermal energy from the atmosphere over the period from 1851 to 2005, over sixty-five percent of which was acquired during the most recent warming phase since 1970. If the observed global warming trend over the 1971-2005 period is to continue, an additional 50 ZJ of heat will be trapped underground by the end of the 21st century, and there will be a subsurface temperature anomaly of about 1.5 K at a depth of around 50 meters. Even if the global surface temperature is to stabilize at the current state throughout the rest of the 21st century, the continental landmasses will continue to acquire extra energy from the atmosphere. An overall 0.7 K cooling at the global ground surface between now and 2100 is required to avoid further heating of the continents.

1. Introduction

The recent increase in the global surface air temperature (SAT) is well documented in the instrumental records. Any global scale change in SAT is accompanied by a change of the thermal state of all major climate system components. Several efforts [*Barnett, et al.*, 2005; *Levitus, et al.*, 2005; *AchutaRao, et al.*, 2006; *Beltrami, et al.*, 2006; *Huang*, 2006a; *AchutaRao, et al.*, 2007; *Cheng and Wu*, 2007] have been devoted to detecting and attributing the changes in the heat content, or thermal energy, of various climate system components including the continental landmasses. However, there has been no discussion so far on the outlook of the continental thermal state. In this study I examine the history and the outlook of subsurface thermal aspects of the world continental landmasses over the period from 1851 to 2100, except for the ice-covered Antarctica. I address the problem by examining the heat content change of the continental subsurface through analyzing the heat flux at the atmosphere-lithosphere boundary and by studying the transient temperature anomalies in the subsurface.

I examine the annual heat content change of the continental landmasses over the period from 1851 to 2005 based on meteorological [*Brohan, et al.*, 2006] and borehole temperature [*Huang, et al.*, 2000] records, and extend the analysis to year 2100 under three climate scenarios. The first scenario assumes that the global warming trend is to continue at the rate of 0.29 K per decade as we have experienced over the last 35 years from 1971 to 2005. The second scenario assumes the five-year mean temperature between 2001 and 2005 as the steady ground surface temperature for the rest of the 21st century. In the third scenario, I investigate the ground surface temperature condition required for the continental heat content to remain unchanged in near future.

2. Heat Content and Heat Flux Analysis

In a continental area, the distribution of subsurface temperature is influenced in part by the ground surface temperature, and in part by the terrestrial heat flowing outward from the deep interior of Earth. Ground surface temperature change is part of climate change ultimately driven by the radiative energy flux from the Sun. The solar energy flux instancing on Earth [*Lean*, 2005] is three to four orders greater than the mean terrestrial heat flow over world-wide continents [*Pollack, et al.*, 1993]. Additionally, terrestrial heat flow varies notably only on geological time scales from millions to hundreds of million years. Therefore, on annual to centennial time scales, the change of the thermal state of the continental landmasses is controlled by the temperature at the ground surface.

According to the theory of heat conduction [*Carslaw and Jaeger*, 1959], a temperature change at the ground surface is associated with energy exchange between the air and the land. Given an annual ground surface temperature anomaly time series (T_i, i=1,2,…,n), the time series of the heat flux (q_i, i=1,2,…,n) across the atmosphere-lithosphere boundary can be estimated [*Huang*, 2006a] by

$$q_i = \frac{2\lambda}{\sqrt{\pi \cdot \alpha \cdot \Delta t}} \sum_{j=1}^{i} [T_{j-1} - T_j] \cdot [\sqrt{i-(j-1)} - \sqrt{i-j}] \quad \text{, ………… (1)}$$

where Δt is one year, λ is thermal conductivity of the rocks, and α the thermal diffusivity. In this study, λ and α are respectively taken to be 2.5 W/m/K and 1.0 10^{-6} m^2/s, which are typical of the upper layer of the lithosphere [*Clauser and Huenges*, 1995].

I approximate the change in ground surface temperature with the surface air temperature anomaly time series assembled from the global database of the land-only meteorological records hosted at the Climate Research Unit (CRU) of the University of East Anglia [*Brohan, et al.*, 2006]. Based on global climate modeling, a recent study [*Mann and Schmidt*, 2003] initially suggested that air and ground surface temperatures might substantially be decoupled on a regional scale due to snow cover. But a revisit [*Chapman, et al.*, 2004; *Schmidt and Mann*, 2004] of the model shows that the original study [*Mann and Schmidt*, 2003] is indeed a confirmation of a good air and ground temperature coupling on global and regional scales. Although the ground is usually warmer than the air above it, and some degree of air-ground temperature decoupling exists in certain geographical settings [*Pollack and Huang*, 2000; *Majorowicz, et al.*, 2005], ground surface temperature generally tracks the surface air temperature variation very well at annual and longer temporal scales [*Bartlett, et al.*, 2004; *Chapman, et al.*, 2004; *Pollack and Smerdon*, 2004; *Smerdon, et al.*, 2004; *Gonzalez-Rouco, et al.*, 2006].

The CRU database contains records from meteorological observatories located on main-lands and on islands, including some scattered observatories in Antarctica. Antarctica is excluded from the analysis in this study because of insufficient data coverage and because it is widely covered by glacial ice where thermal energy storage is governed by different processes [*Jeffries, et al.*, 1999] with different thermo-physical properties. SAT time series from isolated islands far away from a continent are also excluded from the analysis because those island records are more representative of oceanic climate change than of continental change.

The selected SAT records cover 722 5°×5° girded boxes. The ensemble of the selected land-only meteorological data shows that superimposed on the inter-annual temperature variations are a slight cooling trend over the second half of the 19th century and a two-phase warming in the 20th century. The first phase warming was moderate at about 0.12 K per decade and spanned roughly the first four decades of the twentieth century. The second warming phase started at around 1970 and has progressed into the twenty-first century. This ongoing warming phase is much stronger than the earlier one, at a pace of 0.29 K per decade on average. In between the two warming phases was a slight cooling for about three decades.

Corresponding to the observed surface temperature time series is an annual heat flux that swings between positive (downward into the ground) and negative (upward to the air) 0.25 W/m^2 at the atmosphere-lithosphere boundary. Over the second half of the 19th century, the continents nearly made an even in the thermal energy budget. Afterwards, the annual heat flux became mostly positive. Consequentially, there has been a significant amount of thermal energy being deposited into the worldwide continental landmasses since the beginning of the 20th century. With respect to the baseline of the mean 1851-1900 temperature, the cumulative continental heat content change for Asia, Africa, Australia, Europe, North America, and South America landmasses over the past 155 years from 1851 to 2005 is about 12 ZJ. Over sixty-five percent of this thermal energy was acquired by the lands during the most recent warming since 1970.

I extend the continental heat content analysis to 2100 under three different scenarios. The first scenario of continuous warming appears to be "business-as-usual" to the surface temperature change; but the response of the continental heat content will not be as usual. If the global surface warming is to continue at the current pace, the heating of the continental landmasses will be greatly accelerated. The 21st century will see an addition of over 50 ZJ of heat deposited underground, five times the amount trapped during the 20th century.

The second scenario assuming a steady ground surface temperature is much more conservative than the first scenario. Nevertheless, even if the global surface temperature is to be pinned at the 2001-2005 mean, the lands will continue to acquire extra heat from the atmosphere, at a gradually slowed pace though. Under the second scenario, the six continents are expected to add to their heat content 8 ZJ and 6 ZJ of heat respectively over the first and the second halves of the 21st century.

The heat content of the continental landmasses is a state variable tied to their surface temperature history. The second scenario analysis shows that at this stage of global climate change, stopping ground surface warming is not sufficient to prevent the lands from gaining extra heat from the atmosphere. If the continental landmasses are to have their heat content stabilized at the current level, the global surface temperature will need to drop over 0.7 K by the end of the 21st century, as shown by the third scenario analysis.

3. Subsurface Temperature Anomaly

For any given time, the heat content of a substance is a product of its specific heat and temperature. When a large amount of heat comes in or out of the ground, the temperature of the rocks must change accordingly. Therefore, the climate induced change in the heat content of the continental landmasses will lead to abnormal subsurface temperature distribution.

Temperatures beneath the Earth's surface comprise two principal components: a steady-state component related to the flow of heat outward from the deeper interior, and a downward-propagating transient component related to the perturbations from changes at the ground surface. In a steady-state, subsurface temperature is expected to increase linearly with depth in a uniform geothermal gradient proportional to the terrestrial heat flow. However, if the surface temperature is not steady but changes with time, subsurface temperature will depart from the linear distribution [*Pollack and Huang*, 2000]. A progressive cooling at the surface will increase the temperature gradient at shallow depths. On the other hand, a progressive warming will result in a smaller even negative gradient at shallow depths.

In a semi-infinite solid medium, the present-day subsurface temperature anomaly ΔT_z at a given depth z due to a past surface temperature history $T_0(t)$ is given by [*Carslaw and Jaeger*, 1959]

, $$\Delta T_z = \frac{z}{2\sqrt{\pi\alpha}} \int T_0(t) t^{-3/2} e^{-z^2/(4\alpha t)} dt$$ ………… (2)

where t is time. The 1851-2005 temperature history is expected to be responsible for a subsurface temperature anomaly progressively diminishing with depth and detectable down to a depth of about 150 m. This expected subsurface temperature anomaly from the past 155 years, however, is smaller than what is recorded in many borehole temperature records [*Huang, et al.*, 2000; *Huang*, 2006b]. The borehole observed temperature anomaly extends to a greater depth and is substantially greater in magnitude than what the 155-year climate history can possibly generate.

Under all three future surface temperature scenarios, the depth of transient perturbation will increase to around 200-250 meters by the end of the 21st century. However, the magnitudes and the distributions of the subsurface temperature anomaly will be different from scenario to scenario.

With the first “business-as-usual” scenario of continuous surface warming, the positive subsurface temperature anomaly throughout the entire perturbed depth range will grow dramatically. The extended 1851-2100 surface temperature variation will result in a +1.5 K increase in the subsurface temperature at a depth of 50 m, as opposed to the +0.2 K temperature anomaly at the same depth that the observed 1851-2005 surface temperature history is responsible for.

Under the second scenario of stabilized surface temperature at the 2001-2005 mean, the near surface temperature will remain the same. At greater depths within the perturbed range, however, the subsurface warming is expected to continue to develop. The projected temperature anomaly at the 50 m depth of the world continents would be +0.6 K by year 2100.

The third scenario analysis shows that an overall 0.7 K decline in the global surface temperature by 2100 at a progressively slowed rate is required to keep the continental heat content remaining at the current level. Under this scenario, the thermal energy of the continental landmasses will be redistributed towards greater depths. At the end of the 21st century, the projected subsurface temperature will be 0.1 K cooler at around 30 m depth, 0.5 K warmer at 50 m, and 0.1 K warmer at 100 m than the present day. While the uppermost layer of the rocks will become cooler, the rocks at greater depths will continue to warm up moderately.

4. Conclusions and Discussion

This study shows that the impact of global climate change is not restricted to the Earth’s surface. The recent global warming has led to a substantial heating of the continental landmasses, and the continental lithosphere warming is most likely to be further intensified in the 21st century. Collectively the landmasses of Asia, Europe, North America, Africa, Australia, and South America have absorbed about 12 ZJ of heat from the atmosphere over the period from 1851 to 2005. Over 65% of this continental heat gain occurred over the 35 year period from 1971 to 2005.

If the global warming trend of 0.29 K per decade over the 35 year period from 1971 to 2005 is to continue, an additional 50 ZJ of heat will be deposited to the continents by the end of the 21st century. Even if the ground surface is to stop warming, the continents will continue to acquire thermal energy from the atmosphere in the near-future. An overall 0.7 K cooling at the global ground surface between now and 2100 is required to prevent the continents from gaining more heat from the atmosphere.

The change in the continental heat content is reflected in the change in subsurface temperature. The surface temperature history over the past 155 years from 1850 to 2005 should be responsible for a positive subsurface temperature anomaly down to a depth of about 150 m.

If the observed global warming trend over 1971-2005 is to continue over the rest of the 21st century, the subsurface temperature anomaly will extend down below 200 m depth with a projected temperature anomaly of 1.5 K at a depth of 50 m by the end of the 21st century, as opposed to the 155-year model projected current-day anomaly of 0.2 K at the same depth.

If the ground surface temperature is to stabilize at the current state for the rest of the 21st century, subsurface warming will continue. The subsurface temperature anomaly at 50 m depth is expected to be 0.6 K by year 2100 under this second scenario.

Even if the ground surface is to cool by 0.7 K by the end of this century to maintain a balanced continental heat budget, subsurface cooling will restrict to the top some 40 m rocks. A moderate warming of underlying rocks down to the depth of around 200 m will continue to develop. In the absence of any additional heat, the exiting abnormal continental heat content of the uppermost layer of rocks will be redistributed toward greater depths.

The climate system of Earth is a dynamic system encompassing interactions among various components including atmosphere, oceans, and lithosphere [*Trenberth and Stepaniak*, 2004; *Sen Gupta and England*, 2007]. A comprehensive understanding of the thermal regimes of various climate system components and the energy exchanges among these components on different spatial and temporal scales is of fundamental importance to our ability to predict future climate. However, no signal disciplinary data set carries full spatial or temporal coverage of climate change.

There have been significant efforts [*Harris and Chapman*, 1997; *Huang, et al.*, 2000; *Harris and Chapman*, 2001; *Huang*, 2004; *Beltrami, et al.*, 2005; *Bodri and Cermak*, 2005; *Majorowicz, et al.*, 2005] in retrieving long term trend information of climate change from borehole temperatures as a supplement to the climate information provided by relatively short instrumental records. This study shows, on the other hand, the wide-spread meteorological records are complementary to borehole temperature measurements in understanding the recent changes in the thermal regime of the continental landmasses at a higher temporal resolution. A meteorological data based geothermal analysis can overcome the low-temporal resolution of a typical borehole temperature based analysis, and offers new insights into the excursion of the changing lithosphere thermal regime.

Subsurface temperature is an important factor controlling various physical, chemical, and biological processes near the ground surface. For example, subsurface temperature variation may impact the life-span of soil organic matters, mobilize the subsurface carbon stock, and change the carbon cycle in the global climate system [*Davidson and Janssens*, 2006]. More subsurface environmental consequences associated with the continental landmass warming remain yet to be recognized.

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Reconstructing the metal pollution history of Metro Manila from depth profiles of sediments from three water bodies

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Abstract

Sediment cores were acquired in three water bodies in the Metro Manila area, Manila Bay, Laguna de Bay and La Mesa Reservoir, to characterize metal pollution due to urbanization. Rivers discharging into these three water bodies drain different portions of the metropolis that are in different stages of development. Sediments were micro-wave digested in a 2 ml HNO_3 and 4 ml HCl solution and analyzed for selected metals using ICP-AES and a Mercury Analyzer. The average concentrations respectively for Laguna de Bay, La Mesa Reservoir, and Manila Bay are: 10 mg/Kg, 13 mg/Kg and 9 mg/Kg for Cd; 84, 79 and 42 mg/Kg for Cu;11, 79, 17 mg/Kg for Cr; 77, 42 and 63 ng/Kg for total Hg; 13, 46, 17 mg/kg for Ni; 3, 3 and 6 mg/Kg for Pb; and 60, 75 and 78 mg/Kg for Zn. Upcore, in Manila Bay and Laguna Lake, Cu and Zn almost doubled while Pb increased by more than four times. Accelerated metal loading to the environment appears to have occurred after WW II. An apparent decrease in metal loading of Manila Bay after 1991 is better explained by sediment dilution due to elevation of sediment input. Increasing concentration of total Hg in recent years can be attributed to inputs from nearby dumpsites, Payatas for La Mesa Reservoir and Lupang Arenda for Laguna de Bay. Input of Hg from the Payatas Dumpsite to La Mesa Reservoir is likely to be via atmospheric transport.

1. Introduction

Trace metals occur naturally in the environment but may also be introduced through human activities. Numerous products utilized in urbanized centers contain metals such as Pb in fossil fuels and paints, Hg in fluorescent lamps and batteries and Zn in galvanized roofs, resulting into high metal loading to the environment. Trace metals being persistent pollutants due to their resistance to decomposition in the natural environment, has become a serious problem in urban areas because of their health implications.

The sediment record is useful in the reconstruction of pollution history and in providing baseline values that can be used to assess the degree of pollution in a given area. In this study, the history of heavy metal pollution in Metro Manila is reconstructed using the sediment record from three water bodies. Variations in the concentrations of Cd, Cr, Cu, Hg, Ni, Pb and Zn for each site and through time are described in this paper. Associations, timing and causes of changes in metal concentrations through time are explored.

Using a large amount of ground water causes serious environmental problems. This large amount of pumping up causes mass fluid movement and mass redistributions, which can cause measurable gravity changes and ground deformation at the ground surface (Fig.1). It is necessary to monitor the balance of aquifer between the production and recharge to use the ground water for a long term.

Repeat gravity measurements have been applied at the geothermal power plant and the erupting volcano. The first report of the in-situ gravity monitoring was the observation around the Wairakei geothermal power plant, New Zealand. Gravity decreases of up to 1000 micro gal have been measured after 30 years of production from the Wairakei geothermal field (Allis and Hunt, 1986). In Japan, the observed gravity changes depend significantly on changes in shallow groundwater level change. Nishijima (2006) applied a multivariate regression model and eliminated the effect of shallow groundwater level change in order to extract the gravity change associated with the production and injection of geothermal fluid.

These studies suggest that repeat gravity measurements are an effective method to monitor underground water flow. But there is no study for the application of the repeat gravity measurements for urban water resources problems. We are planning to make a repeat gravity and GPS survey at Jakarta and Bangkok to monitor the aquifer balance changes.

Figure 1. Map of Metro Manila which is comprised by 14 cities and three municipalities.

2. Study Area

Metro Manila the capital of the Philippines is comprised by 14 cities and 3 municipalities and includes Manila, Makati and Quezon City (Figure 1). Metro Manila has an area of 636 km^2 or 0.2% of the country`s land area. As of 2005, it hosts 11.29 million people or 12.9% of the country population (Figure 2). With an area of only 636 km$^2$ or 0.2% of the country`s land area, the population density of 17.9 thousand/km^2 is one of the highest in the world. In 1903, the political units of what now comprise Metro Manila had a population of 0.26 M. This grew to 1.54 M in 1950 and to 9.93 M by 2000 (Figure 2). The expansion of Metro Manila which is spilling rapidly over its boundaries emanates from Manila, the oldest city of the metropolis (Fig. 3).

Metro Manila is bounded by Manila Bay to the west and Laguna de Bay to the southeast with Pasig River cutting across the region (Fig. 4). Along its western side, Metro Manila is composed of coastal lowlands underlain by relatively thin veneer of coastal and alluvial sediments. The central portion is a plateau underlain by distal facies volcaniclastic materials with elevations mostly within 10 to 40 meters but exceeding 100 meters on its northeast end. The eastern flank is a lowland area underlain by fluvial and lake deposits.

Manila Bay is a semi-enclosed bay with a surface area of 1800 km^2 and a coastline of approximately 190 km. It is an important historical, cultural and economic resource of the Philippines contributing as much as 52.5 percent to the national GDP (PEMSEA 2006). It has an average depth of 25 m and is approximately 52 km long, with widths varying from 19 km at its mouth to 56 km inside the bay. The bay has a watershed area of 17,000 km^2 comprised of 26 catchment areas and is home to about 30% of the country`s population. The Pasig River, with Metro Manila within its watershed, discharges into the bay large amounts of waste from domestic sources since only 15% of the population is connected to the Metro Manila sewerage system (IMO 1994).

Laguna de Bay is the largest lake in the Philippines. Based on a 1963 chart, at mean lower lake level, which is equal to mean sea level, Laguna de Bay has a surface area of 929 km^2, a volume of 2.32×10^9 m^3 and an average water depth of 2.52 m. The lake has a total catchment area of 3,820 km^2 (Richter 2001) with 35 tributaries draining it (Zimmer and Bendoricchio 2001) but with only one outlet to Manila Bay, the 25.5-km long Napindan-Pasig channel. With lake levels only 1 m above mean sea level, the river flow reverses during some dry seasons, resulting in saltwater inflows into the lake (Santos-Borja 1994).

The La Mesa Dam, an earth dam that backstops the La Mesa Reservoir, is in the north eastern portion of Metro Manila. It was first constructed in 1929 with storage capacity of 45.36 Mm^3. It was raised in 1959 to a maximum storage capacity of 50.5 million cubic meters. The reservoir has watershed with an area of only 27 km^2 (JICA, 1992) however a fraction of the trans-basin water transfer from other dams pass through the reservoir before they are distributed to filtration plants that supply most of Metro Manila's water needs. In total, the reservoir accounts for about 11 percent of the surface water supply. Furthermore, the La Mesa Reservoir may account for more than 12 percent of the total recharge of Metro Manila`s aquifer system although the reservoir area is just a bit greater than 4% of the metropolis` land area.

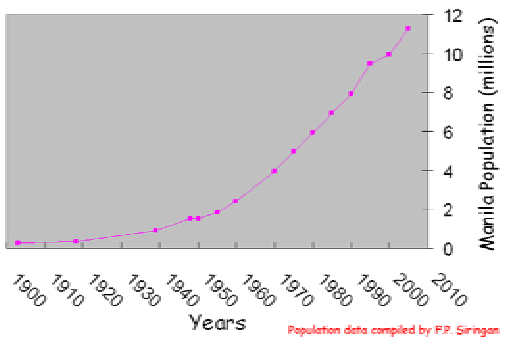

Figure 2. Population growth of Metro Manila from 1903 to 2005 (compiled from Magno-Ballesteros 2000; JICA 1992; http://books.mongabay.com/population estimates/full/Metro_Manila-Philippines.html; and NSO website).

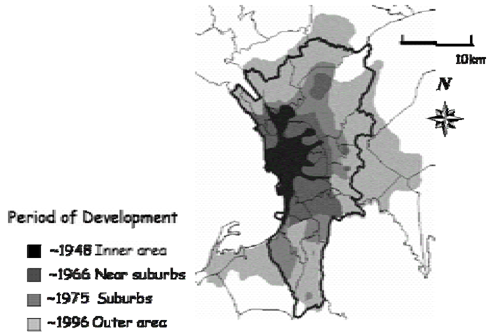

Figure 3. Expansion of Metro Manila from around 1948 to 1996 (modified from Midorikawa and Bautista (2002))

3. Methods

The Manila Bay and La Mesa Dam cores were acquired in 2002 and 2006, respectively using a gravity corer; a modified Livingstone corer was used in Laguna de Bay in 2003 (Fig. 3). The core site in Manila Bay lies along the path of the sediment plume of Pasig River and in an area likely to be undisturbed by trawling, which though not allowed in the bay is not uncommon. The Laguna de Bay core site is on the bayhead of the west lobe close to the mouth of the tributary to Pasig River where backflows occur during the dry season.

The sediments were oven dried at 60 °C until constant weight Since the sediments were mainly mud, no grain size fractionation was performed. However, shells of mollusks and gastropods that were large enough for picking were removed from the sub-samples prior to hand-grinding with an agate mortar and pestle. About 0.2 grams of ground sediment were placed in Teflon vessels and digested using 2 ml of HNO_3 and 4 ml of HCl. An hour after introduction of acids to the sediments, the Teflon vessels were sealed and microwaved with a step-wise increase in vessel pressure at 20, 30 and 40 psi`s at 5 minute durations. Digestant was filtered through a No. 6 quantitative ashless filter and diluted to 100 ml. Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Ni, Pb, Sr, Ti, and Zn were measured using a Perkin Elmer Optima 3000 ICP-AES.

A 5 ml aliquot added with 0.2 ml 10% $SnCl_2$, and 0.2 ml 1:1 H_2SO_4 was analyzed for total Hg using a NIC RA-3 Mercury Analyzer. A 10 ppb Hg standard solution was prepared using 10 mg L-Cysteine, 2 ml HNO_3 and 1000 ml H_2O.

Cluster analysis used the agglomerative hierarchical clustering with wards aggregation criterion and Euclidean distance. The entire suite of metals was used for the analysis but in this paper, the concentration trends for selected metals are presented. Timing of changes in the concentrations of these metals is inferred from likely sedimentation rates for each core site.

Figure 4. Location of cores in Manila Bay and Laguna de Bay are marked by a star. The La Mesa Reservoir, which is another core site, is indicated by an arrow.

4. Results and Discussion

Average concentrations, ranges and vertical trends.

Cd - The average Cd concentration is 10 mg/Kg, 13 mg/Kg and 9 mg/Kg for Laguna de Bay, La Mesa Reservoir and Manila Bay, respectively (Fig. 5). The widest range, at 7mg/Kg, is in Laguna de Bay, while the lowest, at 2 mg/Kg, is in Manila Bay. The wide range of Cd in Laguna de Bay is associated with a clear increasing trend upcore; Manila Bay and La Mesa Reservoir values are fluctuating but do not have a clear trend (Fig.6).

Cr - Cr concentrations in La Mesa Reservoir yield the highest value at 160 mg/Kg, average value at 79 mg/Kg and widest range at 133 mg/Kg (Fig. 5). Even its lowest concentration of 27 mg/Kg is higher than the highest concentrations in Laguna de Bay and Manila Bay which are at 14 mg/Kg and 19 mg/Kg, respectively. The range in LB is 7 mg/Kg and only 3 mg/Kg in Manila Bay. The wide range of concentrations in La Mesa Reservoir is associated with a strong decreasing trend upcore (Fig. 6). Cr concentrations define an overall increasing trend in Laguna de Bay while Manila Bay do not have a clear trend. Cr in Manila Bay surface sediments ranged from 12 to 44 mg/Kg; in Laguna de Bay it is 11 to 19 mg/Kg (Urase et al. 2006).

Cu - The average Cu concentration is highest in Laguna de Bay at 84 mg/Kg and lowest in Manila Bay at 42 mg/Kg (Fig. 5); at La Mesa Reservoir it is 79 mg/Kg. La Mesa Reservoir yields the smallest range of 13 mg/Kg, excluding the outliers, while Laguna de Bay gives the widest range of 45 mg/Kg. Cu concentrations have fluctuated but with no clear vertical trend in La Mesa Reservoir (Fig.6). In contrast, Manila Bay and Laguna de Bay show overall increasing trends Surface sediments in Manila Bay and Laguna de Bay yielded Cu concentrations ranging from 33 to 109 mg/Kg and 120 to 140 mg/Kg, respectively (Urase et al. 2006). In the region where the cores were taken, Cu ranged from 42 to 66 mg/Kg and 116 and 121 mg/Kg in Manila Bay and Laguna de Bay, respectively.

Hg - Laguna de Bay yielded the highest average concentration of total Hg at 78 ng/Kg, the highest concentration at 235 ng/Kg, but it also gave the lowest concentration at 18 ng/Kg (Fig.5). Manila Bay yielded an average value of 63 ng/Kg with the highest value at 89 ng/Kg and the lowest at 30 ng/Kg. The La Mesa Reservoir gave the lowest average at 39 ng/Kg and lowest highest value at 71 ng/Kg. Total Hg shows a clear increasing trend is exhibited in Manila Bay and in the upper parts of Laguna de Bay and La Mesa Reservoir (Fig. 7).

Ni - Average Ni concentration is highest in La Mesa Reservoir at 46 mg/Kg and lowest in Laguna de Bay at 13 mg/Kg (Fig. 5). The range in La Mesa Reservoir is also the widest at 53 mg/Kg and narrowest in Manila Bay at 3 mg/Kg where the average concentration is at 17 mg/Kg. Ni shows a very slight increasing trend in Laguna de Bay, a decreasing trend in La Mesa Reservoir and is fairly unchanged in Manila Bay (Fig. 7). Ni in surface sediments of Manila Bay and Laguna de Bay, ranged from 10-33 mg/Kg and 9-14 mg/Kg, respectively (Urase et al. 2006).

Pb - Manila Bay gives the highest value and highest average concentration of Pb at 14mg/Kg and 6 mg/Kg respectively. La Mesa Reservoir yields the lowest average of 3 mg/Kg (Fig. 5). Several samples from all sites had Pb concentration below detectable limits. Manila Bay shows an increasing trend starting at the base of the core while Laguna de Bay shows a relatively constant concentration upcore then shows an increasing trend starting at 64 cm. La Mesa Reservoir shows widely fluctuating values but an increasing trend occurs from 56 to 36 cm (Fig. 7). Pb in surface sediments of Manila Bay and Laguna de Bay ranges from 10-41 mg/Kg and 16-27mg/kg, respectively (Urase et al., 2006). Where the cores were taken, Pb ranged from 12-17 mg/Kg and 21-20 mg/Kg in Manila Bay and Laguna de Bay, respectively.

Zn - The highest average and highest value for Zn is from Manila Bay at 78 mg/Kg and 93 mg/Kg, respectively while the lowest average and value is from Laguna de Bay at 60 mg/Kg and 39 mg/Kg, respectively. Laguna de Bay yields the widest range at 50 mg/Kg, while Manila Bay yields the narrowest range (Fig. 5). All sites have increasing trends of Zn concentration upcore (Fig. 8). Zn in the surface sediments of Manila Bay and Laguna de Bay ranged from 59- 220 and 90-129 mg/Kg, respectively; in the core sites, the ranges are 81-89 mg/Kg and 102-129 mg/Kg, respectively (Urase et al. 2006).

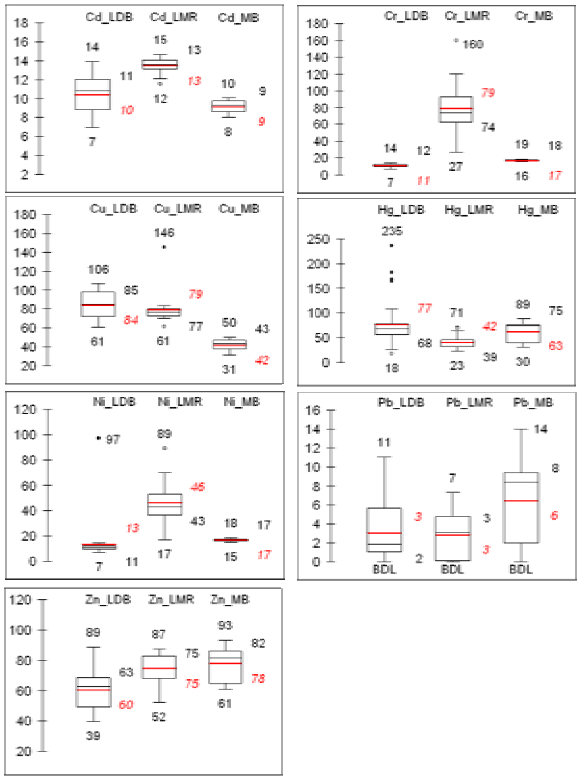

Figure 5. Box and whisker plots. Values underneath and above the box plots are the minimum and maximum concentrations, respectively, Values on the right side, in italics are the average concentrations and in black are the median concentrations corresponding to the red and black lines in the boxplots, respectively, LDB =Laguna de Bay, LMR = La Mesa Resrevoir, MB = Manila Bay, BDL = below detection limit. All concentrations are in mg/Kg sediment except for total Hg which is in ng/Kg sediment.

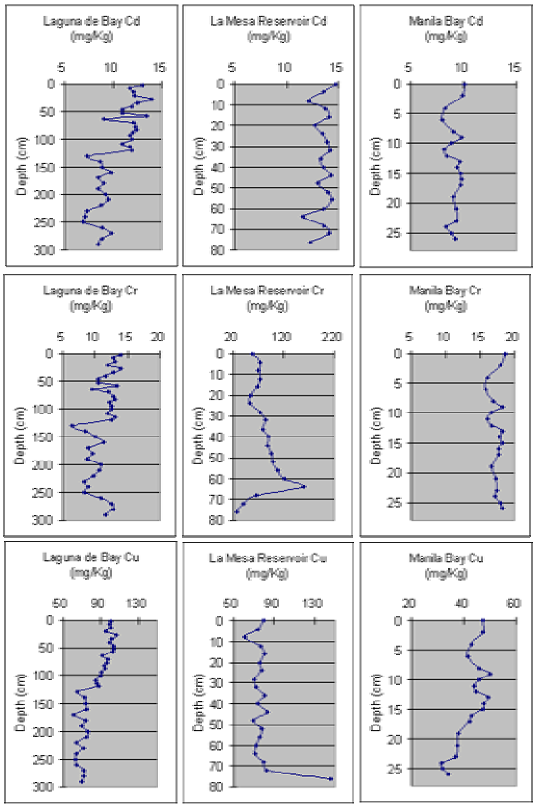

Figure 6. Concentration trends for Cd, Cr and Cu.

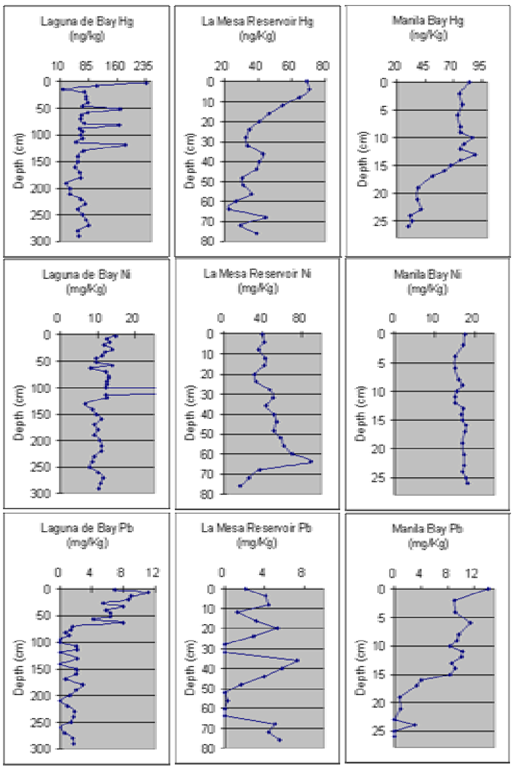

Figure 7. Concentration trends of Hg, Ni and Pb.

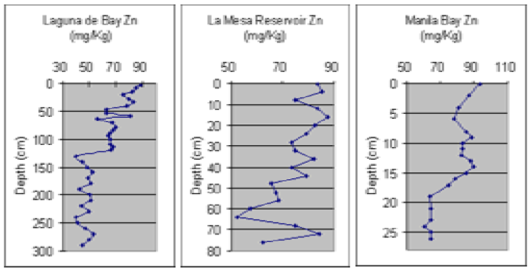

Figure 8. Concentration trends of Zn.

Associations

Cluster analysis of the Manila Bay core data, with all the metals included, grouped Cd, Cr, and Ni with Al, Ti and Fe while Co, Cu, Pb, Hg, and Zn formed another group. Al, Ti, and Fe are typically associated with lithogenic input while Pb, Hg and Zn are associated with human input. The two major groups are also exhibited by the Laguna de Bay core but Ni dissociated from the lithogenic group to form a higher order cluster. In the La Mesa Reservoir core, Cu and Cd forms a subcluster apart from the rest. The other elements splits into two groups with Cr and Ni clustered together. The other subgroup splits between Pb, Zn, Hg and the more lithogenic associated group of Fe, Cd, Al and Ti. The consistent grouping of Pb, Hg, and Zn and separated from lithogenically associated metals indicate that they are mainly from anthropogenic activity.

Possible Timing and Causes of Changes in Metal Concentrations

A core taken by Sombrito et al. (2004) near our Manila Bay site, based on Pb-210, was estimated to have a sedimentation rate of about1 cm/y after the eruption of Mt. Pinatubo in 1991 and about 0.25 cm/y prior to the eruption. Using these for our core, as we do not have age control, 1991 would be within 11 cm core depth; the base would be equivalent to late 1940s to early 1950s. Given that most of the development in Metro Manila took place after World War II, and that this period of development would lead to elevation of metal input into the environment, the late 1940s to early 1950s is a fairly reasonable timing for the base of the core. The decrease in metal concentration close to 1991 could be due to sediment dilution due to elevated sediment influx after the eruption of Mt. Pinatubo in 1991.

If the timing of increase of metals in Manila Bay is the same as in Laguna de Bay, then it would imply that the average sedimentation rate since the late 1940s and early 1950s is about 2.25 cm/y. This sedimentation rate is realistic given that previous estimates of sedimentation rates in Laguna de Bay ranged between 1 to 4 cm/y (NIGS-LLDA 1999; Sly et al. 1993). With sedimentation rate at 2.25 cm/y, the increase in Pb appears to have commenced in the early 1970s. The increase of Hg in recent years could be due to the commencement of dumping in 1995 in the Lupang Arenda dumpsite which presently occupies 40 to 80 hectares in Taytay, Rizal along the northeast shores of Laguna de Bay's West Bay.

The lowermost 10 cm of the La Mesa Reservoir core contained rootlets and slightly firmer nodular aggregations indicating a possible origin as an exposed or near exposed surface. In the area of the reservoir itself, the underlying lithology is dominated by Quaternary volcaniclastics. Sudden elevation of Cr and Ni above the lowermost 10 cm of the core may represent the initial influx of sediments washed down from possibly lateritic soils in the ophiolites upstream of La Mesa Reservoir watershed. The rise of the water table during the initial infilling of the dam possibly caused slope destabilization leading to landslides. The decreasing trend of Cr and Ni upcore may signify the eventual slope stabilization.

Since the La Mesa Reservoir is no older than 1929 and the core was acquired in 2006, the upper 65 cm of the core may have accumulated at an average sedimentation rate of 0.85 cm/y. However it is likely that sedimentation was faster during the early years of reservoir operation due to more frequent landslides during this period. Thus, the starting period of Hg increase at 25 cm depth could be in the late 1970s. The increasing trend of Hg might be due to atmospheric input from the 22 hectare Payatas dumpsite which was opened in 1973 (Fig. 9). The predominant wind in this area of Metro Manila is from the east and the dumpsite is less than 1 km east of the reservoir. Thus, emanations from Payatas dumpsite may be deposited directly on the La Mesa Reservoir and its watershed.

Conclusions

Variation in the concentration levels and temporal trends of metals in the three water bodies indicate differences in major sources of metals in the sediments. The consistent grouping of Pb, Hg, and Zn and separation from lithogenically associated metals indicate that they are mainly from anthropogenic activity. An elevated concentration of Cd, Cr, Cu, and Ni in La Mesa Reservoir is most likely due to the ophiolitic nature of rocks upstream of the reservoir. Accelerated increase of metal loading to the environment appears to have occurred after WW II. Recent increase in Hg in La Mesa Reservoir and Laguna de Bay is likely due to additional loading from opening of dumpsites close to these bodies of water. Direct deposition on La Mesa Reservoir of Hg-laden fumes from Payatas is highly probable due their proximity and predominance of easterly wind in the area. In the reconstruction of metal loading, changes in sediment flux should be considered as it can greatly influence concentrations of metals in the sediments.

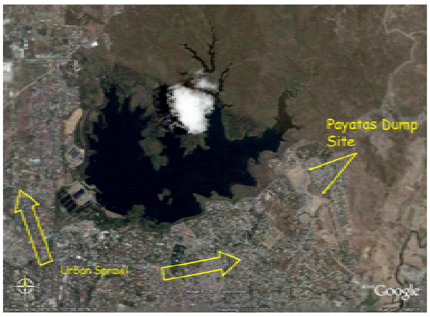

Figure 9. The La Mesa Reservoir and the Payatas Dumpsite. Star indicates location of core.

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Role of GIS working group – the progress in 2007 and future plan

Yu Umezawa
Research Institute for Humanity and Nature, Japan

Abstract

One year before, we established GIS working group to accelerate GIS works in our project. In this short paper, I'll briefly report 1) the benefit of forming GIS working group, 2) the progress of GIS works in 2007, 3) what is decided as technical matter to effectively share the results, and 4) our future plan.

1. Introduction

Currently geographical Information System (GIS) has been used even in scientific fields as an effective and common platform to synthesize various data sets together with the information of the location. This will facilitate us to 1) store the data, 2) understand the relations among the associated attributes, and 3) show the results to researchers and ordinary people in easily understandable format. In our project, Urban Geography group and Socio-economics group were mainly in charge of GIS studies, but it was hard for them to process various specific data sets collected by the other groups. For example, we need to treat groundwater quality data referring to the water sampling depth, groundwater flows and the time-lag in which surface environment affects on the subsurface environments. It was benefit for them to have the supports by the researchers, who are familiar with the specific data collected by each sub group, and who can know what is the best explanation to show the data using GIS. Therefore, we decided to organize GIS working group (hereafter GIS_WG), which consists of 1 or 2 representatives from each sub group (Table 1).

Table 1 Member of GIS working group

A.Yamashita, S. Kaneko, Y. Umezawa		
Urban Geogr. Y. Kagawa, T. Ichinose	***Socio-Economics*** H. Tanikawa, K. Tanaka, K. Jago-on	***Heat*** A. Miyakoshi, F. Lubis
Material Y. Umezawa	***Water*** T. Yamanaka	***Gravity*** J. Nishijima

GIS_WG has discussed the detail about data gathering and how to synthesize various data set of different resolutions in time and space, so that we can crystallize the rough ideas suggested at Group Leaders' meeting. As of September 2007, 15 members join in GIS_WG mailing list (gis_wg_24fr@ml.chikyu.ac.jp) and often communicate using e-mail. It automatically makes many chances where young researchers can communicate among the sub groups. In addition to the Group Leaders' meeting, such a tight connection by young researchers would be good for a big project. That is another unexpected benefit for forming GIS_WG. Following to the decisions at GIS_WG, actual working staff (e.g., Masaru Okuda, Y. Umezawa) are trying to gather statistical data from the network consisting of RIHN project members and other cooperative institutes (Table 2).

Table 2 Example of cooperative intsitutes for GIS works

* Center for Spatial Information Science, The University of Tokyo
* Foreign Counterparts
  - University of the Philippines
  - Indonesian Institute of Sciences
  - Ministry of Natural Resources and Environment
  - Academia Sinica
  - Japan International Cooperation Agency
* Governmental Offices

Since next year, GIS_WG will start communicating with the other working groups, such as "Simulation Modeling Working Group" and "Public Release Working Group". And finally, integrated results would be retuned back to the society and cooperative Institutes (see section 6).

A first half year after establishing GIS_WG, we had discussed about many of technical matters, and set up the server for the file sharing. In 2007, this year, we started to convert the statistical data and original data collected through our field surveys into the shp files on GIS format.

2. Decisions on Technical Matter

Though I mentioned that GIS is universal format and widely used over the world, application software, language, and coordinate system are different depending on individual and each laboratory. So first we needed to decide the rules to unite our data in same format.

ArcView was adopted as application software, so all of the given files written in the other format were converted to this format. Vector data and raster data were explained mainly using “shp file format” and “geotiff format”, respectively. The other file formats such as “jpg” and “tiff” are auxilarily accepted. Using same coordinate system is the most important rule to unite the GIS data of same areas, which were created by different groups. We decided to use WGS1984 as our coordinate system, and Universal Transverse Mercator (UTM) zones at each city were also confirmed (Table 3).

Table 3 UTM zone at the city surveyed in this projec

UTM 47:	Bangkok
UTM 48:	Jakarta
UTM 51:	Taipei, Manila
UTM 52:	Seoul
UTM 53:	Osaka, Tokyo

The decision on the classification for land use map, which we are originally creating, was one of important decisions. The priority was the difference of permeability for water group, while material group also wanted to put priority on the difference of nitrogen and phosphorus loadings, and the difference of redox conditions. The point to maximally meet both merit with limited budget and time were these eight classification: Forest, Grassland, Paddy fields, Fields, Industrial area, Residence area, Water body, Wetland and Others.

To organize many GIS data, we have also decided to prepare metadata file (inventory file). The format of metadata file was created by Dr. A. Yamashita (Rakuno gakuen Univ.). The researchers, who created and/or supplied GIS data, are requested to fill in file name, the name of administrator of the file, contents, keyword, date, coordinate information, data format, resolution, and the rules to cite the files. This metadata file is supposed to be uploaded regularly on the official web site of our project so that all members can access to the latest information of GIS data.

3. Creating land use map at each mega-city

First, we were a little reckless, and tried to convert all of data into GIS. But that was very time-consuming and laborious work. So we had decided our prior topics at the meeting in May 2007. The participants were A. Yamashita, S. Kaneko (Hiroshima Univ.) and Y. Umezawa (RIHN). We agreed that the information about land use, population, water system and water & sewer pipes are essential base, when we study about water related problems in subsurface environments at megacity. And such information can also contribute to decide the definition of the city boundary. With these base maps, we plan to compare the other important topics (e.g., water level, land subsidence, water quality, and surface & subsurface temperature), that each sub-groups are studying. Synthesis of the data set and analysis of the relations among associated attributes would be facilitated, if these base maps are prepared using GIS.

Creation of land use maps (0.5 km grid size) of 3 or 5 periods at each megacity have been conducted under the leadership of Urban Geography group and a support of EnVision (NPO, Sapporo, Japan). As of December 2007, the maps of 3 periods (1930, 1970 and 2000) at Osaka (Fig. 1a) and Tokyo (Fig. 1b) were completed. Furthermore, at least, latest map at the other 5 cities will be also completed until March 2008. Finally all maps will be completed until

March 2009, and they can help us to understand the trend of spatial expansion of city areas during an arbitrary period from pre-urbanization to present. Especially we want to insist that this is first trial to complete land use maps at several Asian mega-cities in same criteria. So we hope that many people will access our web site for long in future, to cite these maps for their studies.

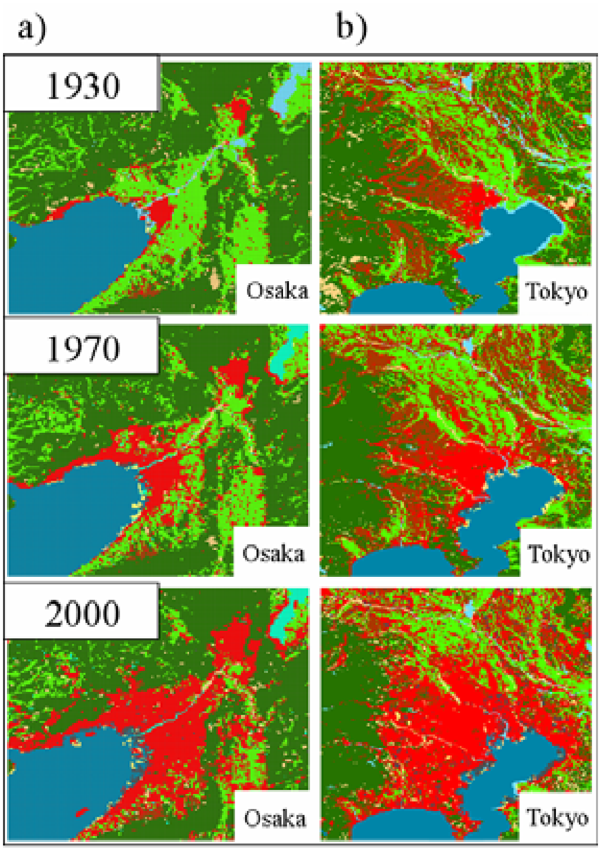


Fig.1 Land use-map at a) Osaka and b) Tokyo area.
The maps were created using 1/50,000 topographic map

The creation of these land use maps are based on the 1/50,000 topographic map collected at each city. With many of thoughtful supports by foreign counterparts and domestic project members, we have almost collected latest topographic maps (1/50000 resolution) at the targeted cities except for Jakarta (as of December 2007) (Fig. 2). On the other hand, old maps have been collected only at Tokyo and Osaka cities. We are still looking for the map indicated with black symbol (Fig. 2). So we would appreciate it if someone could give us any information about these maps. All of collected topographic maps are scanned, saved as TIFF format (300 dpi) and stored at FTP server for GIS purpose (2TB). The information of the maps owned by our project is put in the metadata list (Excel format), which Dr. M. Inoue (Ritsumeikan Univ., Japan) are managing. So all members can access the

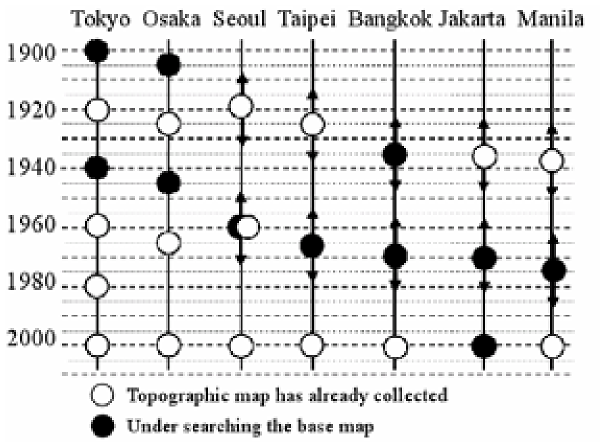


Fig.2 Progress of base-map gathering as of Dec. 2007

information and easily get the electric map with geo-reference from the server.

5. Example of GIS data

Material group converted all of the original water quality data to GIS files. Figure 3 shows an example of such data set; nitrate concentrations in groundwater and river water collected at Bangkok city and surrounded areas. Here different color indicates different water system such as river, shallow GW and deep GW. Concentrations of nitrate are explained with the size of the circle. We hope

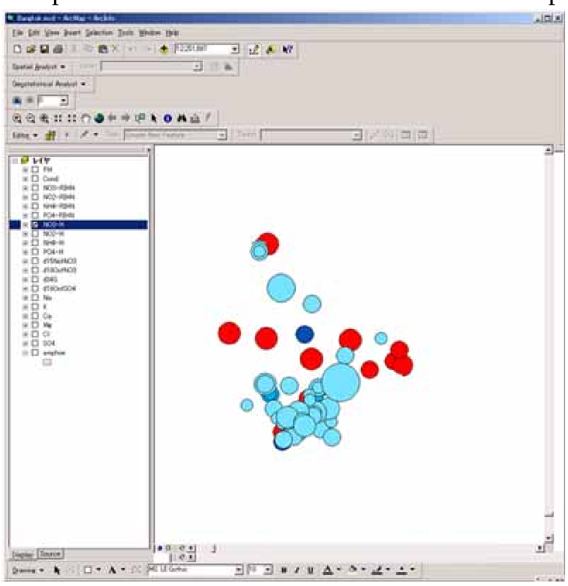


Fig.3 NO_3^- concentrations in each water system observed at Bangkok city and surrounded areas.

that these GIS maps would facilitate people to understand the situation of water environments.

In Tokyo, Osaka and Bangkok, many statistical data collected during last 20 or 30 years are available at national and municipal administration offices. Although we are trying to understand water quality condition in old time combining the chemical analyses in deep groundwater and age dating method, these statistical data are very valuable to compare the water environments before and after urbanization. You can easily understand that water quality in groundwater around Osaka area has drastically changed along the years (Fig. 4).

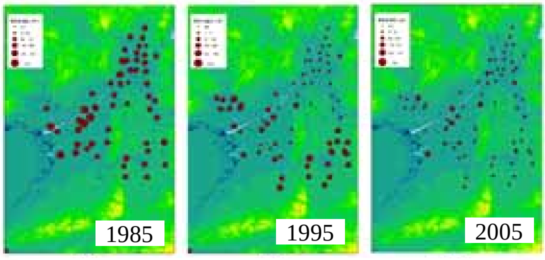


Fig.4 Historical shift of conductivity in well water in Kinki area (Osak, Kyoto and Nara). The maps were created using statistical data compiled by Ministry of Land, Infrastructure, Transport and Tourism in Japan

Many GIS data associated with economic, sociologic, geologic and hydrologic components are also individually prepared in many research institutes at each country. Thanks to the thoughtful understanding by foreign cooperative institutes, we are allowed to cite some of their GIS data for our presentations and papers. But we need to keep in mind that we should include their names in reference and acknowledgement. The instructions about how to use these data are available at the GIS server together with each data set. Most of the GIS data in Jakarta were supplied by LIPI (Indonesian Institute of Sciences) through Dr. Robert Delinom. The data in Manila supplied from local institutes and universities by Ms. Karen Jago-on's agency are too many to understand all of them. We really appreciate kind cooperation by Metro Manila Development Authority (MMDA), Greater Paris Regional Planning and Development Institute (IAURIF), Japan International Cooperation Agency (JICA) and Philippine Institute of Volcanology and Seismology (PHIVOLCS). As for the GIS data in Bangkok, Dr. Adisai Charuratna (Ministry of Natural Resources and Environment) is contact person, and kindly supports our studies (cf. Fig. 5).

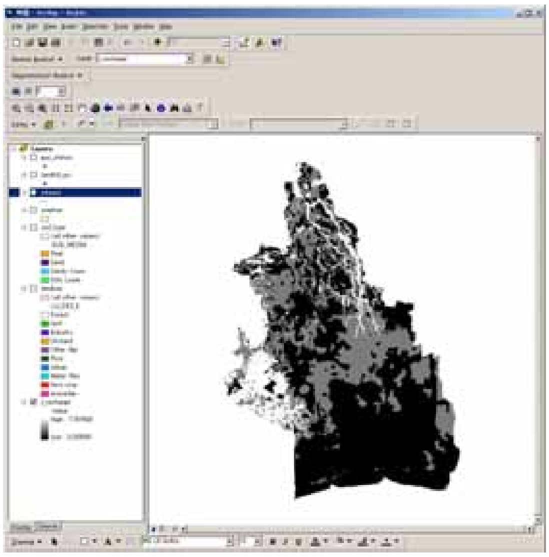


Fig.5 The mass of recharged water at Bangkok and surrounded areas. This is one of GIS data supplied by MONRE in Thailand.

6. Final output of the GIS working group

Basically any of GIS data originally collected and transformed to GIS format by members will be shared by the other project members after a given period, when the creator has priority to use the data for the papers. We, especially Urban Geography group, plan to have special symposium at annual meeting of the Association of Japanese Geographers (http://wwwsoc.nii.ac.jp/ajg/english/web/index.html) this March. They also plan to contribute to special issue in an academic journal in future to introduce our studies.

On the other hand, we plan to open some of our results on web site. Other than submitting papers in scientific journals, exhibiting the results on web site can effectively propagate the results of our project. That can raise the name of RIHN project, and collaborating institutes. We expect that ordinary people can also easily take a look at our results and may have more attentions to the sustainable use of subsurface environments. Because we also plan to distribute original data set, too, that can facilitate the secondary use of our data by other researchers. Furthermore, all of project will be finally evaluated two years after finishing 5 years project in our institute. So it would be worth to monitor how many times and from which areas it was accessed.

Last year, "Yodo River Basin PROJECT (Prof. Kaga, Osaka University, Engineering for Assessing the Sustainable Environment)" finished their 5 years study about expansion of human activities at Yodo River Basin and associated change of surface environments, including atmosphere, river and forests. They created well-organized web site to release the result of their research on GIS basis (http://db.see.eng.osaka-u.ac.jp/yodogawa/index.html) (in Japanese). I believe that their web site is good resource for us to consider about how we should release our results on web site. They supply many of maps showing the index of society development, ecological functions of forest, and pollutions in air, water and soils. And when user enter the GIS page, they can choose the topic which they want to see, at their will. These exhibitions are not necessarily effective, when we want to scientifically compare each factor. But it would be effective to attract attention of the people with various background level.

Currently many of GIS data created by governmental offices, NPO and private companies are available on browser basis (e.g., GIS portal site organized by Japanese government: URL: http://www.gis.go.jp/contents/about/internet/index.html (in Japanese)). However, they are not necessarily prepared at universal format using common language (e.g., English), and access to these data are often limited to the members. However, it should be important to share our experiences and results with many researchers and ordinary people at Asian countries for the sustainable development of developing countries. That would minimize various environmental health risks for the people living in these developing cities. So we plan to create GIS portal site to effectively show our results using ArcIMS server, wishing to complete it until mid of 2010 (Table 3). The data shown on this web site will be peer-reviewed. Free access to such a peer-reviewed data set would be benefit for further studies, management and educations.

Table 3. History and Tentative Schedule of GIS works

Date	Contents
Dec. 2006	• GIS working group was organized
Jan. 2007	• The FTP server (60MB) for GIS WG was preapred
Mar. 2007	• 1st GIS WG meeting was held at RIHN (Taniguchi M, Yamashita, Taniguchi T, Jago-on, Umezawa, Hosono, Yamanaka, Miyakoshi, Nishijima, Okuda, Inoue)
Apr. 2007	• A part-time technical staff for GIS study was hired at RIHN
May 2007	• Core group meeting was held at Rakuno Gakuen Univ. (Yamashita, Kaneko, Umezawa) • Core group meeting was held at Makuhari Chiba (Taniguchi M, Yamashita, Umezawa, Hosono)
June 2007	• Large volume FTP server (2TB) for GIS WG was installed
Nov. 2007	• Presentation at the conference, "CSIS DAYS ", the Tokyo Univ., Japan.
Dec. 2007	• Accomplishment of the land-use map of 3 periods at Osaka and Tokyo.
Dec. 2007	• 2nd GIS WG meeting will be held at Kumamoto, Japan • Presentation at the RIHN workshop held at Bali, Indonesia
Feb. 2008	• Accomplishment of latest land-use map at 7 mega-cities (Interim Evaluation for our Project)
Dec. 2008	• Accomplishment of the land-use map of 2 or 3 periods at 7 mega-cities
Mar. 2008	• Another technical staff for GIS study will be hired at RIHN
2009	• Preparation for the contribution to spatial issue
2010	• Releasing web site exhibiting our results.

Acknowledgement

I am grateful to GIS working group members, who contributed to the progress of GIS works in our project. Especially, Dr. A. Yamashita (Rakuno gakuen Univ.) and Dr. S. Kaneko (Hiroshima Univ.) gave me many constructive suggestions. The major financial support for GIS work is provided by the Research Institute for Humanity and Nature (RIHN) through their project on "Human Impacts on Urban Subsurface Environments."

International Symposium and Workshop on Current Problem in Groundwater Management and Related Water Resources Issues

Bali, 3- 8 December 2007

Program

Tuesday, 4th December

10.00 – 12.00 Bintang Ballroom

Opening Ceremony

Organizing Committee

Minister of Science and Technology : Dr. Kusmayanto Kadiman

Keynote Speech:

1. **Prof. Narifumi TACHIMOTO, Director General RIHN, Japan**
2. **Dr. Ir. M. Basuki Hadimulyono Inspector General Department of Public Works, Indonesia**

RIHN – KRIHS MOU SIGNING

Session 1 Pulau Flores Room: Groundwater Development
Moderator: Robertus W. Triweko

13.30 – 13.50	A Review on Urban Policies to Balance Between Environment and Development of Asian Developing Countries **Backjin Lee and Minho Suh**	ppt	**184**
13.50 – 14.10	Groundwater Development in Aceh Province Post Tsunami **Dian Budi Dharma**		
14.10 – 14.30	Replenishment of Bandung Basin of Groundwater, West Java, Indonesia **Djoko Mudjihardjo and Ahmad Taufiq**		
14.30 – 14.50	Urban Development and Groundwater Use in Asian Cities: Review of Issues and Responses **Karen Ann B.Jago-on and Shinji Kaneko**		
14.50 – 15.10	Water Resources Analysis in Small Islands (Case Study in Nusa Lembongan Island, Bali **I Wayan Redana, and I Wayan Suparta**		
15.10 – 15.30	Dewatering and Its Impacts to Groundwater Storage **Sunjoto S.**		

Session 1 Pulau Sumba Room: Groundwater Methodology and Modeling
Moderator: Jun Shimada

13.30 – 13.50	The Result of Preliminary Data Inventory During Schematization of Umbulan Groundwater Basin **Bambang Soenarto and Heni Rengganis**
13.50 – 14.10	Applying DPSIR-C Framework on Urban Subsurface Environmental Issues in Asian Cities **Shinji Kaneko and Karen Ann B. Jago-on**

14.10 – 14.30	Monitoring Groundwater Variations in Urban Areas Using Modern Geodetic Techniques **Y. Fukuda, K. Yamamoto, S. Uneo, J. Nishijima, and T. Nakaegawa**	
14.30 – 14.50	Long –term Temperature Monitoring in Boreholes for Studies of the Ground Surface Thermal Environment and Groundwater Flow, **Makoto Yamano, Hideki Hamamoto, Shusaku Goto, and Akinobu Miyakoshi**	
14.50 – 15.10	Modeling the conjunctive use of surface water and groundwater for irrigation in Limboto-Bolango-Bone River Basin **Waluyo Hatmoko**	
15.10 – 15.30	Urbanization effect on groundwater environment in the Jakarta groundwater basin, Indonesia **Rachmat Fajar Lubis; Yasuo Sakura; Robert Delinom; Makoto Yamano; Abdurahman Assegaf; Makoto Taniguchi**	

Session 2 Pulau Flores Room: <u>Groundwater Development 2</u>
Moderator: Peter Hehanussa

15.50 – 16.10	Effects of Groundwater on the Roof Coal Mine Stability **B. Sulistijo**
16.10 – 16.30	Concept of Series Water Trap on Natural Gully as Water Conservation Development to maintain Groundwater Surface in Small Islands Area **Sr. Susi PI**
16.30 – 16.50	The Study of Groundwater Abstraction by Deep Well Related to Discharge Stability of Umbulan Spring at Pasuruan, East Java **Dede Henly Rasyid**
16.50 – 17.10	Water temperature and electrical conductivity of springs on the volcanic slope in a tropical region: A case study on Lembang area, West Java, Indonesia **Hendarmawan**
17.10 – 17.30	Wonosari Groundwater Basin – A Case Study of Groundwater Basin Delineation **Untung Sudarsono**
17.30 – 17.50	Groundwater Optimalisation in East Java Province **I Made Sutarya**

Session 2 Pulau Sumba Room: <u>Groundwater Quality and Contamination</u>
Moderator: Robert Delinom

15.50 – 16.10	Hydro-environmental Changes and Their Influence on the Subsurface Environment in the Context of Urban Development **Akihisa Yoshikoshi, Itsu Adachi, Tomomasa Taniguchi, Yuichi Kagawa, Masahiro Kto, Akio Yamashita, Taiko Todokoro, and Makoto Taniguchi**
16.10 – 16.30	Human Impacts on the Environments at Asian Mega-cities, Evaluated by the Groundwater and Marine Sediment Samples **Yu Umezawa, Takahiro Hosono, Shin-ichi Onodera, Makoto Taniguchi**
16.30 – 16.50	Hydrodynamic Relationship Between River and Aquifer to Water Quality at Ciliwung River Banks. An Overview of Integrated Water management, **Deny Juanda Puradimaja, D. Erwin Irawan, Budi Brahmantyo, and Hendri Silaen**

16.50 – 17.10 The Ecological Hydrogeometeorogical Analysis for Bandung Basins, Based on the Rainfall Characteristics and Satelite Image Processing
Sri Hartati Soenarmo, Adjat Sudrajat, Ildrem Syafri, and Hendarmawan

17.10 – 17.30 The Accuracy of the Mise-a-la Masse Method in Groundwater Pollution Detection
B. Sulistijo and U.W. Widodo

17.30 – 17.50 Groundwater Quality in Vicinity of Bandar Gebang (Jakarta, Solid Waste Disposal Site
Ratna Hidayat

Wednesday, 5th December

08.30 – 10.30 Session 3 Pulau Flores Room: Groundwater Management
Moderator: Yu Umezawa

08.30 – 08.50 Groundwater Management in Indonesia Facts and Deals
Joyce Martha Widjaya

08.50 – 09.10 Transboundary Groundwater Management of Kumamoto Area, Japan – Sustainable Development of Groundwater Resources Support 700,000 Residents City Water
Jun Shimada

09.10 – 09.30 An Integrated Method on Groundwater Management Based on System Interrelationship Model
Priana Sudjono

09.30 – 09.50 Groundwater Management Model for Sustainable Irrigation in Wajo District, South Sulawesi
Suhardi, H. Pawitan, Budi I. Setiawan, and Roh S.B. Waspodo

09.50 – 10.10 Groundwater Management in Bangkok (Institution and Monitoring)
S.Buapeng ppt **176**

10.10 – 10.30 Systemic Approach on Dissemination of Groundwater Policy in Bandung Basin, West Java, Indonesia
Ismail Hasjim

Session 3 Pulau Sumba Room: Groundwater Recharge Process
Moderator: Hasanudin Z. Abidin

08.30 – 08.50 Infiltration on Canal as a Method for Recharging Groundwater Storage,
Sunjoto S.

08.50 – 09.10 Groundwater Recharge Into The Matano Crypto-Depression, South Sulawesi
Iwan Ridwansyah and P.E. Hehanussa

09.10 – 09.30 Fishponds Water Infiltration Related to Their Environment and Aquaculture Practices in Bogor, West Java
Tjandra Chrismadha

09.30 – 09.50 The Geological Factor of Flooding in Jakarta Area
Robert M. Delinom and Sudaryanto ppt **181**

09.50 – 10.10 An Outline of Water Resources in West Timor
Bogie Soedjatmiko

10.10 – 10.30 Tentative Groundwater Potential at Dana Island the Outer Small Island in Rote Ndao Regency, NTT
Wawan Herawan

Session 4 Pulau Flores Room: Land subsidence and Land-Ocean Interaction
Moderator: Yoichi Fukuda

10.50 – 11.10 Land Subsidence Characteristics of Bandung Basin as Estimated from GPS Surveys
Hasanuddin Z. Abidin, Heri Andreas, M. Gamal, Sumarwan, D. Darmawan, and Nancy Marilyn

10.50 – 11.10 Hydrodynamic Relationship Between River and Aquifer to Water Quality at Ciliwung River Banks. An Overview of Integrated Water management,
Deny Juanda Puradimaja, D. Erwin Irawan, Budi Brahmantyo, and Hendri Silaen

11.10 – 11.30 Groundwater Abstraction Contribution to Land Subsidence in Jakarta
Agus M. Ramdhan and Lambok M. Hutasoit

11.30 – 11.50 Over pumping of ground water as one of causes of sea water inundation in Semarang City
Dodid Murdohardono, Tigor MHL Tobing, Agus Sayekti

11.50 – 12.10 Variation in Contaminant Transport and Hydrological Situation at Asian Coastal Mega-Cities
Shin-ichi Onodera, Makoto Taniguchi, Mitsuyo Saito, and Yu Umezawa

12.10 – 12.30 Groundwater Discharge and Nutrient Fluxes off Metro Manila, Phillipines based on 222Rn Measurements
W Burnett, R.Peterson, F.Siringan, Y.Umezawa, and M.Taniguchi — paper **76**, ppt **165**

12.30 – 12.50 Metal Pollution History of Metro Manila from Sediment Cores from Three Water Bodies
Fernando P. Siringan, Kazuhiko Takeda, Shin-ichi Onodera, Makoto Taniguchi, Mitsuyo Saito, Takahiro Hosono, Karen Jago-on, and Yu Umezawa — paper **96**, ppt **173**

Session 4 Pulau Sumba Room: Groundwater related to Climate Change
Moderator: Shin-ichi Onodera

10.50 – 11.10 Human and Climate Impacts on Subsurface Environments in Asia
Makoto Taniguchi

11.10 – 11.30 Climate Changes and Phytoplankton Blooms as One of Their Indications in the Sea
Quaraisyin Adnan

11.30 – 11.50 The Status and Outlook of Land Warming as Part of Global Warming
Shaopeng Huang — paper **90**, ppt **170**

11.50 – 12.10 Warming Effects on Surface and Subsurface Thermal Environment of Taipei, Taiwan
Chung-Ho Wang, Wen-Zer Lin, Makoto Taniguchi, Makoto Yamano, and Haopeng Huang — paper **85**, ppt **167**

12.10 – 12.30 Fresh water in small island and coastal area in Indonesia: problem and thread under the global climate change
Hantoro W.S., Soeprapto T.A., Arsadi E.M., Airlangga A.Y., Suyatno

12.30 – 12.50 A Study of Meteorological Variations in Winter of Snowy Regions in Japan
Takeshi Ito, and Edi Prasetyo Utomo

Session 5 Pulau Flores Room: Related Water Resources Issues 1
Moderator: Lambok Hutasoit

14.00 – 14.20	Study of Rainfall and River Debit Interaction Using Rational Method to Determine Intrusion of Seawater in the Jakarta Bay Area **Atika Lubis and Yan F. Permadhi**
14.20 – 14.40	Types and Abundance of Meifauna at Lubuk Siam Lake, Siak Hulu District Kampar Regency, Riau Provicnce **T. Afrizal and Adriman**
14.40 – 15.00	Characteristics of Hydrometeorology in Citarum River Basin **Ruminta, Bayong Tjasyono Hanggoro Kasih, and Indratmo Soekarno**
15.00 – 15.20	Rainfall Infiltration During Last 10 Years **Joko Wiratmo**
15.20 – 15.40	Exploitation and Recharge Estimates using Groundwater Table Contour and Soil Moisture Balance for the evaluation of groundwater use in Bandung Basin **M. Djuwansah, R.M. Delinom, Arief Rahmat, Ida Narulita**

Session 5 Pulau Sumba Room: Related Water Resources Issues 2
Moderator: Hidayat Pawitan

14.00 – 14.20	Production of Natural Dew Drinking Water as one of Global Groundwater Crisis Solutions **Budhi Haryanto, A. Trianita, Arda R. Lukitobudi, Pramono, and LBS Kardono**
14.20 – 14.40	Estimation of Water Resources Components Using Spatial Monthly Soil Water Balance in Bandung Basin **M. Djuwansah**
14.40 – 15.00	Relationship Between Phytoplankton Abudance and Some Water Quality Parameters Around Penyengat Island, Tanjung Pinang Regency Kepulauan Riau Province **Eni Sumiarsih and T. Efrizal**
15.00 – 15.20	The New Indonesian Water Law With Special Reference to Groundwater Regulations **P.E. Hehanusa and Gadis S. Haryani**
15.20 – 15.40	Climate Modification Technology to Increase Groundwater Reserves in Recharge Area. Case: Recharge Area in BOPUNJUR Area[1] **F. Heru Widodo dan Samsul Bahri**

16.00 – 17.30 Plenary Session (Bintang Ballroom)

Closing Ceremony

RIHN Workshop

Human Impacts on Urban Subsurface Environments in Asian Megacities

Date: December 7 - 8
Venue: Ramada Bintang Hotel, Kuta, Bali, Indonesia

Program

Friday, 7th December

9:00 – 9:15 Bintang Ballroom
Opening Address
Chairman of LIPI: **Prof.Dr. Umar Anggara Jenie.**
Overview of the project "Human Impacts on Urban Subsurface Environments"
- What should be focused more especially in the project at RIHN?-
Makoto Taniguchi (RIHN) ppt **188**

<u>Session 1: Groundwater management: Laws, Religion and Nationality</u>
Moderator: Yu Umezawa

9:15 – 9:35 Groundwater managements from the viewpoint of law and institution
-Japanese experiences-
Takahiro Endo (RIHN) paper **29**
ppt **131**

9:35 – 9:50 Do the construction and events related to religion affect on groundwater management?
Makoto Taniguchi (RIHN) ppt **190**

9:50 – 10:10 Role of Religion in the Perspective of Water Utilization Culture in Indonesia
Robert Delinom (LIPI) ppt **192**

10:10 – 10:25 Discussion

<u>Session 2: Groundwater Management and Problematic Issues in Indonesia</u>
Moderator: Hidayat Pawitan

10:40 – 11:00 Groundwater development and management
<u>Joesron Loebis</u>, Peter Hehanusa and R. W. Triweko, ppt **195**

11:00 – 11:20 Groundwater modeling

<u>Hidayat Pawitan</u> and <u>Lambock Hutasoit,</u> ppt **198, 201**

11:20 – 11:40 Groundwater change and land subsidence

Hasanuddin, Assegaf ppt **205**

<u>Session 3: Urban geography group and Socio-economics group</u>

Moderator: Takahiro Endo

14:00 – 14:20 Research of Urban Geography Group

Akihisa Yoshikoshi (Ritsumeikan University, Japn) paper **14**
ppt **126**

14:20 – 14:40 The effect of climate change on urban subsurface temperature

Toshiaki Ichinose (National Institute for Environmental Study, Japan) paper **23**
ppt **128**

14:40 – 15:00 Discussion

15:00 – 15:20 Defining subsurface environmental issues: An attempt at DPSIR model application

Shinji Kaneko (Hiroshima University, Japan) paper **5**
ppt **119**

15:20 – 15:40 Long-term urban growth and its implications on water supply systems in Asian mega-cities

Karen Ann B. Jago-on (RIHN, Japan) paper **11**
ppt **123**

15:40 – 16:00 Discussion

<u>Session 4: Water group and Material group</u>

Moderator: Yu Umezawa

16:20 – 16:40 Age-dating of groundwater using multiple tracers

Jun Shimada (Kumamoto University, Japan) paper **37**
ppt **134**

16:40 – 17:00 Tracing deep groundwater underneath the Bangkok metropolitan area

Tsutomu Yamanaka (Tsukuba University, Japan) paper **42**
ppt **138**

17:00 – 17:20 Discussion

17:20 – 17:40 Land-Ocean Interactions: transport of land-derived materials
Shin-ichi Onodera (Hiroshima University, Japan) paper **56**
ppt **150**

17:40 – 18:00 Pollution status and mechanisms in each Asian mega city
Takahiro S. Hosono (Akita University, Japan) paper **61**
ppt **154**

18:00 – 18:20 Discussion

18:20 – 18:30 Announcement

Saturday, 8th December

Session 5: Heat group and Gravity group

Moderator: Karen Ann B. Jago-on

9:00 – 9:20 Evolution of the subsurface thermal environment in urban areas
Makoto Yamano (the University of Tokyo, Japan) paper **66**
ppt **157**

9:20 – 9:40 Reconstruction of the thermal environment evolution in Jakarta
Fajar Lubis (Chiba University, Japan) paper **72**
ppt **161**

9:40 – 10:00 Discussion

10:00 – 10:20 Terrestrial water storage estimated from GRACE and reanalyses data set
Yoichi Fukuda (Kyoto University, Japan) paper **46**
ppt **142**

10:20 – 10:40 Gravity and GPS surveys at Jakarta
Jun Nishijima (Kyusyu University, Japan) paper **51**
ppt **146**

10:40 – 11:00 Discussion

Session 6: Data management

Moderator: Takahiro Endo

11:10 – 11:20 Tentative schedule of the Project (2008 – 2010)
Makoto Taniguchi (RIHN, Japan) ppt **209**

11:20 – 11:40 Data base management

Tomotoshi Ishitobi (RIHN, Japan) ppt **211**

11:40 – 12:00 Introduction of GIS working group. How should we effectively store and share the data, and release the results?

Yu Umezawa (RIHN, Japan) ppt **214**

Session 7: General Discussion

Moderator: Yu Umezawa

13:30 – 15:00 Cross-cutting: What is current progress and future study plan at each study area?

-------- Advisory members from each targeted city -----------

Backjin Lee (KRIHS, Korea)
Chung-Ho Wang (Academia Sinica, Taiwan)
Fernando Siringan (University of the Philippines, Philippines)
Somkid Buapeng (MONRE, Thailand)
Robert Delinom (LIPI, Indonesia)

13:30 – 13:45 Overview and comments for the studies in Seoul

Backjin Lee paper **219**

13:45 – 14:00 Overview and comments for the studies in Taipei

Chung-Ho Wang paper **221**

14:00 – 14:15 Overview and comments for the studies in Manila

Fernando Siringan paper **223**

14:15 – 14:30 Overview and comments for the studies in Bangkok

Somkid Buapeng paper **225**

14:30 – 14:45 Overview and comments for the studies in Jakarta

Robert Delinom paper **227**

15:00 – 15:10 General comments 1 **William C. Burnett (Florida State University, USA)**

paper **229**

15:10 – 15:20 General comments 2 **Shaopeng Huang (University of Michigan, USA)**

paper **231**

15:20 – 15:35 What is current (potential) problems in this project?

15:35 – 15:50 Future cooperative studies in each city

15:50 – 16:00 Announcement about publications and conference

16:00 - 17.30 Plenary Session: Formulation of Recommendations
Closing Ceremony

Research achievements of the socio-economic group

IDEC, Hiroshima University,
Shinji Kaneko

Roles of socio-economic group

Overarching function:
to collect and organize the various information on urban development and subsurface environmental changes with DPSIR framework and to improve our basic understanding on broad picture of complex causalities of multi subsurface environmental issues.

In-depth analyses of human activities:
to identify the relative contributions of urban socio-economic activities and countermeasures for the long-term changes in subsurface environments.

Research Issues in FY2007

	Quantity / Quality / Thermal
Kaneko	DPSIR Framework Urbanization – USE Nexus with DPSIR framework (August, 2007)
Zhang	Index, Model Sustainability Indicator with Focus on USE (August, 2007)
Karen	City development model (population, economy) (1) Urban Demographic Growth Pattern (April, 2007), (2) Wealth of Cities (March, 2008)
Fujiwara･Lee	Urban policies, land use Historical Review of Urban Policies: Comparison among Cities (October, 2007)
Tanikawa	Material stock Underground Material Stock in Tokyo (October, 2007)
Matsumuto	Lifestyle, Food consumption SFA of Household Consumption in Tokyo, Seoul and Taipei (October, 2007)
Fujikura	Environmental burden, pollution abatement Sustainability of Edo: Nitrogen and Phosphorus Perspectives (August, 2007)
Imai	Water and sewerage technology, Infrastructure Historical Review of Technologies on Water in Cities: Comparison among Cities (October, 2007)
Tanaka	SWAT (Soil & Water Assessment Tool) Preliminary Application to Tokyo and Jakarta (TBD)

1

DPSIR?

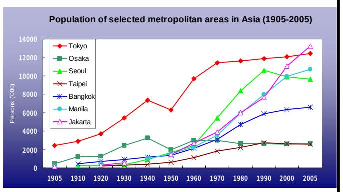
- DPSIR is a general *framework* for organizing information about causal relations between human activities and the environment.
- The idea of the framework was originally derived from social and policy studies for organizing a system of indicators in the context of environmental issues where complex causal relations are not completely elucidated in number, as a simultaneous process with scientific researches.
- The challenge is to deal with different dimensional issues in socioeconomic system and natural environmental system.

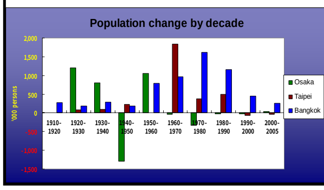
- **Driving forces to change the pressures (e.g. population growth, industrial production)**
- **Pressures on the environment (e.g. abstraction of groundwater, discharges of waste water)**
- **State of the environment (e.g. water quality in rivers and lakes)**
- **Impacts on population, economy, ecosystems (e.g. water unsuitable for drinking)**
- **Response of the society (e.g. watershed protection)**

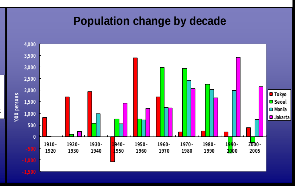
2

Key indicators for comparison

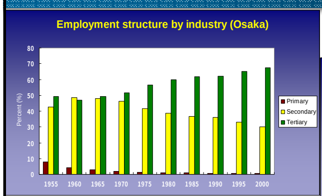
- **Driving forces**
  - Population
  - GRDP and industrial structure
  - Urban sprawl and land use
- **Pressures**
  - Groundwater abstraction
  - Nitrogen emissions (and heavy metals)
  - Heat flux due to change in surface temperature

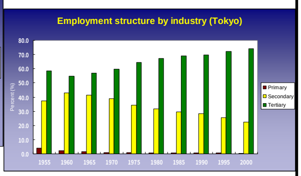


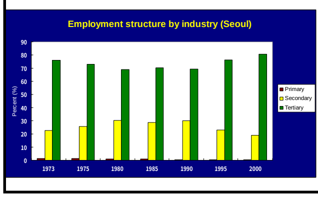




Economic structural change: Labor

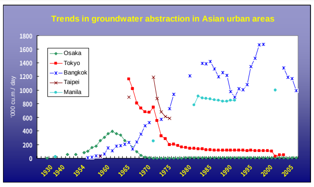






4

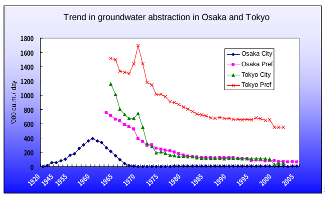
Groundwater abstraction and countermeasures



Peak of GW use

Osaka City (1960): 395000 m3/ day
Osaka Pref (1963): 755000 m3/day
Tokyo (1964): 1162000 m3/ day
Tokyo Pref (1970): 1515000 m3/day
Taipei (1970): 1192000 m3/ day
Bangkok (1997): 1671000 m3/day
Manila (2000): 1000000 m3/ day

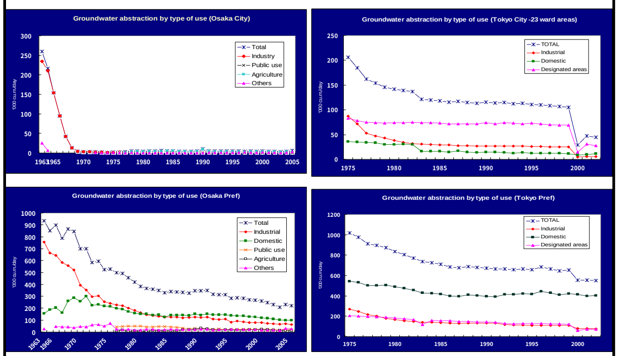
Sources of basic data for Bangkok: Department of Groundwater Resources, MONRE, Thailand; Osaka: Osaka Bureau of Waterworks 2004; Tokyo: Tokyo Metropolitan Government Waterworks Bureau. The data for Manila are compiled from JICA 1992, Rodolfo and Siringan, 2006. The data for Taipei are compiled from Wu 1992, Wu 1976.



Seoul: only from 1990s
Jakarta: only registered wells

5

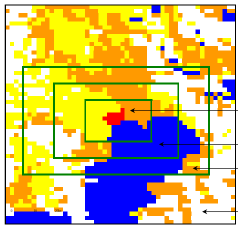
Groundwater abstraction by type of use



6

How human wastes of 1 million population in Edo (former Tokyo) in 1850 was used?

- Using land use map in 1850 (Arizono 1995) Edo (city) ■, rice paddy ■, other crop fields ■, area calculations.
- The farther from Edo, the lesser was the quantity of human waste generation (Watanabe 1983).
- There was a market in which human waste were recycled as agriculture fertilizer.
- Divided the area around Edo into A〜D zones.



Zone	Distance from Edo (origin)				Input share
	E	W	S	N	
A	3	2	2	1	25%
B	6	5.5	4	3	10%
C	9	9	6	5	5%
D	Outside C zone				0%

7

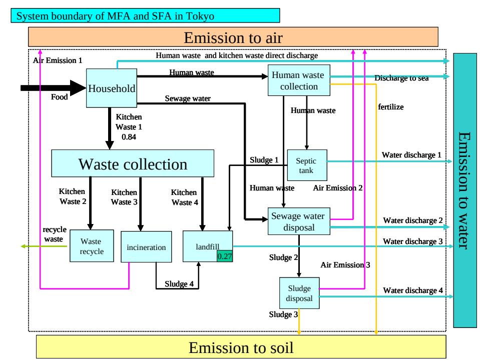
Results: Nitrogen balance

Zone	Supply ratio (%)	Nitrogen: Rice paddy: Unit (ton/km^2)	Fertilizer (ton/km^2)	Area (km^2)	Input (ton)	Field: Unit (ton/km^2)	Fertilizer (ton/km^2)	Area (km^2)	Input (ton)
A	25	6.0	1.50	240	360	18.0	4.50	144	648
B	10		0.60	444	266		1.80	368	662
C	5		0.30	592	178		0.90	568	511
D	0		0.00	1,488	0		0.00	1,744	0
Total	-	-	-	2,764	804	-	-	2,824	1,822

(Demand) Total N input (ton): 2,626
(Supply) N generated (ton): 2,774
Demand-Supply (ton): 148

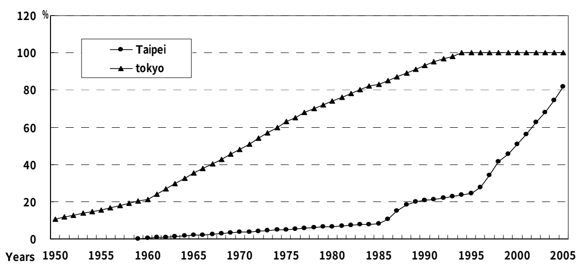
8

Substance Flow Analysis: System boundary of analysis



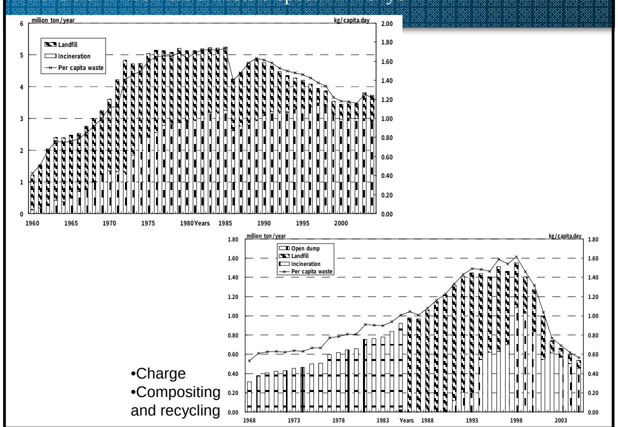
9

Diffusion rates of sewerage system in Tokyo and Taipei



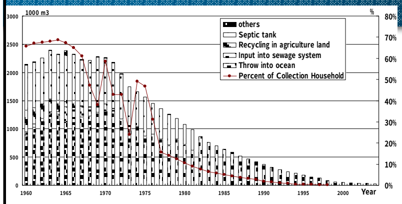
10

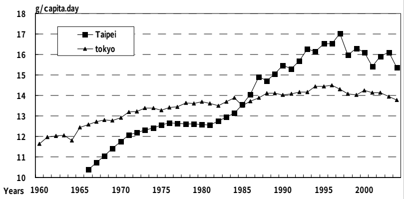
Transition in domestic waste disposal in Tokyo



- Charge
- Compositing and recycling

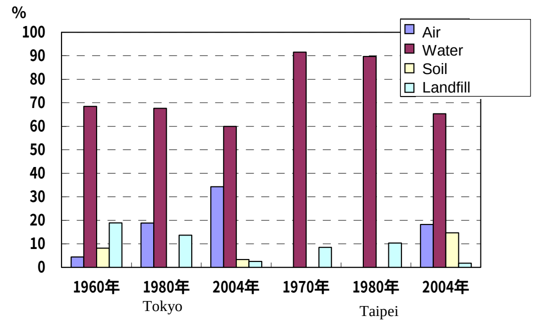
Treatment of human waste (night soil) in Tokyo





Trend in nitrogen supply quantity- Tokyo and Taipei

Discharge ratio



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Industrial wastewater treatment in Osaka City

1972：Start of periodic monitoring of industrial effluent by the Water quality survey department

Organization of full-time patrol group (2 persons/ group)

Establishment of Environmental Pollution Department at Osaka Prefecture Police. Coordination with the Sewerage and Wastewater Management Department in apprehending violators.

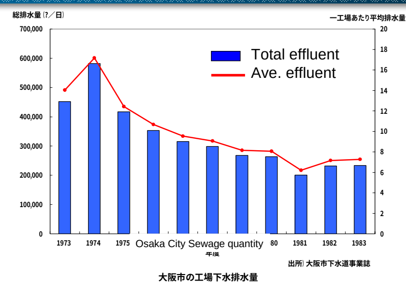
1973: 45 personnel，in1978 it increased to 57

On-site inspection during the same period increased from 3,165 to 6,172.

1970s: Rapid improvement of river water quality in the city

14

Environmental policy induced water saving



Total wastewater quantity from sewers in industries in the city was reduced to 40.2 per cent from 1974 to 1983.

- Because of the oil shock in 1973, business performance was reduced. --- Start of sewerage tax collection in 1972
- Start of water quality charges in 1973 (depending on the level of BOD, COD, SS in sewage)

15

Osaka City：Government cost of monitoring industrial effluent (2002)

Number of registered establishments: around 3,000

Annual inspection：8,600 times

Average inspection rate： 2.9 times/year and establishment

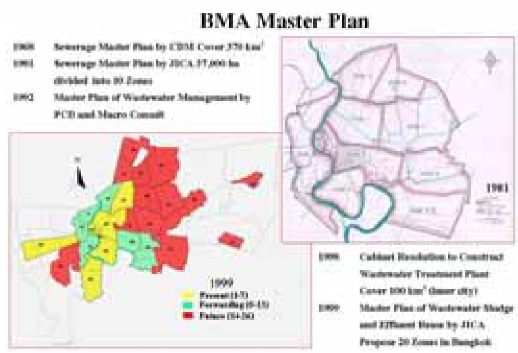
Number of personnel： 38 persons (14 inspectors)

2 persons/ team

Average number of inspections per team/year：452

16

BMA Master Plan (1968-1999)



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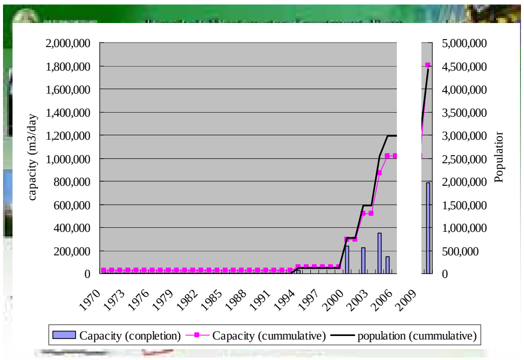
Present and Future WWTP in Bangkok

Water Environment Control Plant	Area (km^2)	Population	System/ Technology	Capacity (m^3/day)	Source of Fund	Cost (Million Baht)	Year and Month
Wastewater Treatment Project					BMA. : GOV.		
1. Si Phraya	2.7	120,000	Contact Stabilization A.S.	30,000	BMA 100 %	464	1994.1
2. Rattanakosin	4.1	70,000	Two Stage A.S.	40,000	GOV. 100%	883	2000.5
3. Din Daeng	37	1,080,000	Activated Sludge	350,000	25 : 75	6,382	2004.10
4. Chong Non Si	28.5	580,000	Cyclic Activated Sludge System	200,000	40 : 60	4,552	2000.12
5. Nong Khaem	44	520,000	Vertical Reactor A.S.	157,000	40 : 60	2,348	2002.2
6. Thung Khru	42	177,000	Vertical Reactor A.S.	65,000	40 : 60	1,760	2002.2
7. Cha Tu Chak	33.4	432,000	Cyclic Activated Sludge System	150,000	60 : 40	3,482	2005.3
8. Community Plant 12 Plants	-			25,700			1970s
Total	191.7	2,979,000		1,017,700		19,871	
Future BMA. Wastewater Treatment Project							
1. Bang Sue EECP	21	250,000	Step Feed A.S.	120,000	BMA 100 %	4,732	
2. Klong Toei	56	485,000	Activated Sludge	360,000	60 : 40	9,896	
3. Thon Buri	59	704,000	Activated Sludge	305,000		11,561	
Total	136	1,439,000		785,000		26,189	

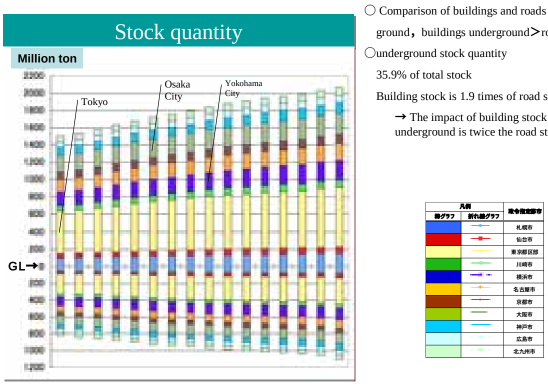
18

Bangkok Wastewater Treatment Plant



19

Ground - underground material stock estimates



○ Comparison of buildings and roads

ground, buildings underground＞roads

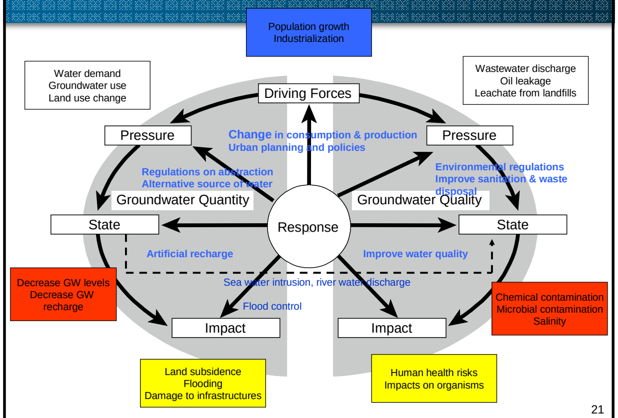
○underground stock quantity

35.9% of total stock

Building stock is 1.9 times of road stock

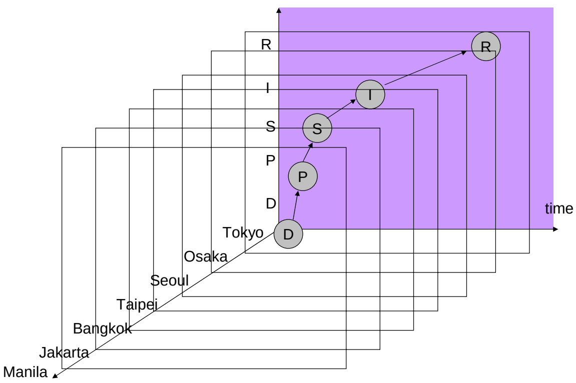
→ The impact of building stock on the underground is twice the road stock.

20



21

Image of final output



22

Progresses in DPSIR application

- Reviewed existing materials for 7 target cities and synthesized the related evidences into DPSIR framework (STOTEN paper).
- Most of information in the past are mostly concentrated on quantity issues of groundwater.
- At the later stage of the project, we will try to incorporate the findings from the project and organize them into DPSIR framework again to see the improvement of understanding.

23

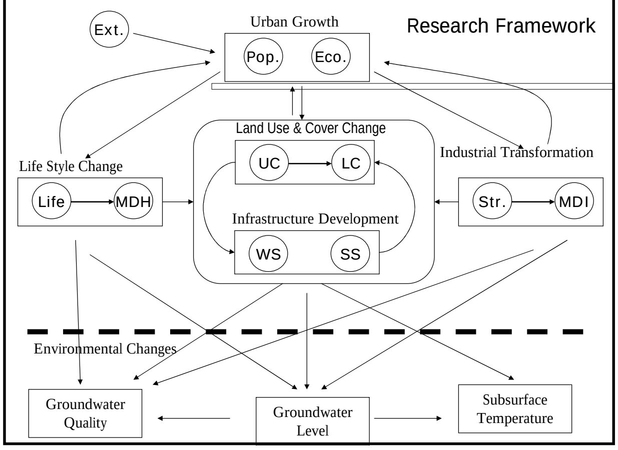
Summary of fieldwork achievements and future research needs

RIHN Workshop

Bali, Indonesia
December 7-8, 2007

Karen Ann B. Jago-on
IDEC, Hiroshima University

Research Framework



Database structure with examples

Nature condition(24)

- Temperature
  - Average temperature
  - Above earth's surface by 1m, 3m and 10m
  - Below earth's surface by 1m, 3m and 10m
- Water resource
  - Groundwater level
  - Rainfall
  - Water resource endowment
  - Surface water
- Area
  - Total area
  - Population density
  - Built-up area coverage
  - Agricultural area

Demographic(17)

- Population
  - Total population
  - Demographic structure
  - Total number of households
- Population change
  - Death rate
  - Birth rate
  - TFR
  - Life expectancy
  - Migrant population

(number of indicators, approx. 150 in total)

Economy and Infrastructure (54)

- Economic
  - GRP
  - Labor population
  - Employment by sector
  - Consumer price index
  - Gross income per household
  - Production of chemical fertilizer
  - Crop production
- Infrastructure
  - Number of incinerators
  - Final landfill disposal
  - Waste disposal
  - Total length of paved road
  - Household land area
- Infrastructure for water
  - Dam reservoir capacity
  - Pumped water level
  - Water supply pipelines
  - Well water temperature
  - Well water material residue
  - Users of tap water
  - Sewer treatment

Database structure with examples (cont.)

Material data(17)

- Electric power sales
- Gas consumption
- Coal consumption
- Biogas consumption
- Water consumption by sector
- Chemical fertilizer consumption
- Daily calorie intake per person
- Iron supply
- Cement consumption

Transportation(12)

- Users of public transportation
- Operating kilometer of railways
- Number of automobiles

Environment(17)

- Air
  - SO2 concentration
  - NO2 concentration
  - CO concentration
  - TSP
- Water
  - Ammonia nitrogen effluents
  - Wastewater discharge
- Material
  - Nitrogen flux
  - Phosphorous flux
  - COD
- Subsidence level
- Subsidence area
- Heat exhaustion

Government(4)

- Budget size
- Independent revenue source
- Number of personnel

Objectives of fieldwork

- To gather historical, socio-economic and physical data of cities such as demography, income, land use, food demand and supply, water demand and supply, groundwater data, sanitation systems, waste management facilities, and environmental laws and regulations relevant to the protection of the subsurface environment.
- To conduct field visits to:
  - Waterworks company
  - wastewater treatment facilities
  - waste disposal facilities
- To introduce the project and establish possible research contacts and collaborators
- To supplement data gathered in Japan

Fieldwork Sites 2006-2007

Seoul, Korea: May 23-26, 2006
(5 members)

Taipei, Taiwan: September 11-15, 2006
(5 members)

Metro Manila: December 12-21, 2006
(1 member)

Bangkok, Thailand – May 27-31, 2007
(6 members)

Offices/ Institutions Visited

- Government agencies – population, economic and environment statistics
- Research institutes - statistics, related studies
- Universities – discussions on related studies
- Waterworks, wastewater treatment facilities, waste disposal facilities.

Socio-Economic Data

Cities	Population	Economic	Land Use	Food	Waste
Seoul	**1915-2005**	GDP (country level) from 1960s; GRDP (1960-1998)	**1900-2000**		
Taipei	**1920-2003**	GDP (country level) from 1960s	**1900-2000 (ppt)**	Taiwan Food supply and Utilization Yearbook 2004	1968-2003
Manila	**1903-2005**	GDP (country level) from 1960s	**1996, 2003**	Phil. Food Balance Sheets 1987-2001	1985-2006
Bangkok	**1855-2005**	GDP (country level) from 1960s	**1960, 1992, 2006**	Thailand Food Statistics 2003-2007	1985-2006

Subsurface and Water Data

Cities	Groundwater Use	Groundwater Levels	Groundwater Quality	Land subsidence	Waterworks
Seoul			1998-2005		1908-2003
Taipei	1954-1974	1970s-Present		1950-1969	1968-2003
Manila	1930-2000 (some are estimates)			1991-2003	1984-2005
Bangkok	1954-2006	1978-2006	1978-2004	1978-2006	1984-2006

Assessment/ Lessons Learned from Fieldwork

Implementation/ Coordination
- Project/ Research counterparts are very important!
  - preparation of visit to offices
  - establish research networks
  - data gathering
- Roles of local researchers

Objectives of Project
- Clear understanding of the objectives of the project
- How and what we can contribute to the research aims of the institution

Scope of Research
- City level / metropolitan area / basin level/ peri-urban area
- area boundaries

Assessment/ Lessons Learned from Fieldwork (2)

Data availability

- Difficulty in getting long-term and city-level data
- Population and demographic data are mostly available in all areas
- Most socio- economic data are still on a country level; city level data are available in recent years
- industrial type/ structure data are minimal
- some language constraints

Future Research Needs

Explore other sources of information:
- economic data (city-level)
- industrial data (types, location, production inputs, effluents, etc.)
- government budget and revenues (city-level)
- water resources quantity and quality
- water, sanitation and sewer facilities and infrastructures

- government laws and regulations related to subsurface issues
- government and social cost of subsurface environmental problems

List of Offices/ Institutions Visited in Seoul, Taipei, Manila and Bangkok

Offices/ Institutions Visited in Seoul

- Seoul National University
-Seoul Development Institute
-Cheong Gye Cheon Restoration Project Headquarters
-University of Seoul
-Gyeonggi Research Institute
-Korea Research Institute for Human Settlements

Offices/ Institutions Visited in Taipei

Institute of Earth Sciences, Academia Sinica
-Society of Urban Planning
-National Taiwan University
-Department of Statistics, Ministry of the Interior
-Water Environment Research Center, Taipei University of Technology
-Council of Agriculture, Executive Yuan
-National Taipei University of Technology

Facilities:

-Pei-tou Incinerator Facilities
-Nangkang Landfill Facilities
-Bali Wastewater Management Plant

Offices/ Institutions Visited in Manila

-Metro Manila Development Authority
- Manila Water Company
-National Water Resources Board
-Philippine Atmospheric Geophysical and Astronomical Services Administration
-Housing and Land Use Regulatory Board
-National Statistics Office
-National Statistical and Coordination Board
-Department of Environment and Natural Resources
-National Solid Waste and Management Commission
-University of the Philippines
-Philippine Institute of Development Studies
-Asian Development Bank
-Japan International Cooperation Agency

Offices/ Institutions Visited in Bangkok

-Bangkok Metropolitan Administration
-Pollution Control Department, MONRE
-Department of Groundwater Resources, MONRE
-Metropolitan Waterworks Authority
-Office of Agricultural Economics
-Department of Town and Country Planning
-Office of Transport and Traffic Policy and Planning
-National Statistics Office
-Mass Rapid Transit Authority

Presentation Files

Bangkok

-Water quality management in Bangkok (DDS, BMA)
- Solid waste management in Bangkok Metropolis
-Groundwater Operations (DGR)
-Bangkok Bus Rapid Transit (BRT) Project
-Land Transportation in Bangkok

Manila

-Water Resources and Treatment Facilities (MWC)
-Water supply, sewerage and sanitation (MWC)
-The Manila Water Company (MWC)
-Solid waste management (NSWMC)

Research of urban geography group

Research project

"Human impacts on urban subsurface environment"

Akihisa Yoshikoshi

Ritsumeikan University

Purpose of research (1)

- **Collect the urban geographical data of seven Asian cities**

Research cities:
(Tokyo,Osaka,Seoul,Taipei,Manila,Bangkok, Jakarta)

Geographical data:
(Literary documents,Statistics,Maps,Aerial Photographs, Satellite Imageries)

Purpose of research(2)

- **Investigate the change of hydrological environment**

  Express the position of rivers, lakes, spring waters and swamps in a map as in detail as possible

- **Research for the relation between the surface hydrological environment and the subsurface environment**

Contribution of research

- **Research findings of the purpose(1)**

  contribute by providing the member of other groups of the project with the fundamental data about urban development

- **Research findings of the purpose(2)**

  contribute to development of academic circles. This contributes by urban hydrology as a regional research, and contribute by exchange of surface water and groundwater as contents of research.

Member of urban geography group

Akihisa Yoshikoshi, Prof.,Ritsumeikan Univ.
Itsu Adachi, Assistant Director,Japan International Cooperation Agency
Toshiaki Ichinose, Chief Researcher,National Institute for Environmental Studies
Manabu Inoue, Researcher,Ritsumeikan Univ.
Takahiro Endo,Assistant Prof.,Research Institute for Humanity and Nature
Yuichi Kagawa, Lecturer,Univ.of Shiga Pref.
Kumi Kataoka, Researcher,Univ.of Tsukuba
Masahiro Kato, Associate Prof.,Ritsumeikan Univ.
Kazuya Suzuki, Service Officer,Japan International Cooperation Agency
Tomomasa Taniguchi, Part-time Lecturer,Rissho Univ.
Yingjiu Bai,Lecturer, Tohoku Univ.of Community Service and Science
Akio Yamashita, Lecturer,Rakuno Gakuen Univ.
Taiko Todokoro, Graduate Student,Ritsumeikan Univ.

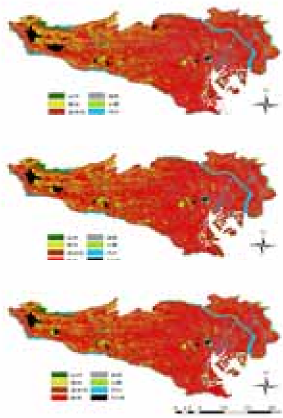
Prediction of research

Summary

- **If change of the waterway of various times in a city region are clarified, a urban water problem can be predicted.**
- **If land use of the earth surface is clarified, exchange of surface water and ground water will become intelligible.**

Method of research

Landuse of Tokyo

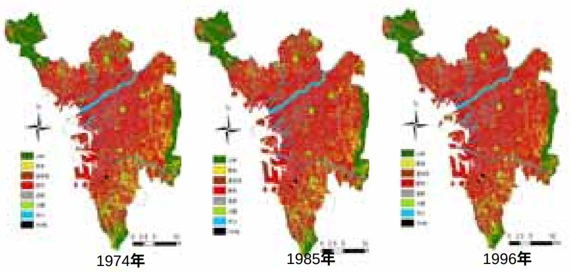


1974年

1985年

1994年

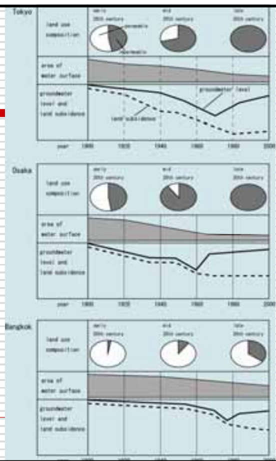
Landuse of Osaka



1974年 1985年 1996年

Change of Water Area in Osaka Plain

Changes of “land use composition”,”area of water surface”, “groundwater level” and “land subsidence” in Tokyo,Osaka and Bangkok in 20th century



Research program

(A part is comleted)

- 2005(Pre-research)
  Literay document list , Map list, Aerial Photo.list, Satellite imagery list
  Collection of data, Planned decision,Field survey(Tokyo,Osaka)
- 2006
  Literary document list,etc.,Collection of data,Hydrological environment research, Field survey(Bangkok,Seoul,Tokyo,Osaka)
- 2007
  Literary document,etc.,Collection of data,GIS display,Hydrological environment research,Field survey(Taipei,Manila,Seoul,Bangkok,Jakarta,Manila,Tokyo,Osaka)
- 2008
  Collection of data,GIS research, Hydrological environment research,Field survey(Tokyo,Osaka,Bangkok,Jakarta)
- 2009
  Collection of data, Urban development theory,Research of hydrological change,Field survey(Tokyo,Osaka,Seoul, Taipei)
- 2010
  Collection of data,Field survey(supplement),Conclusion

The effect of climate change on urban subsurface temperature

ICHINOSE, Toshiaki, Prof. Dr. Eng.

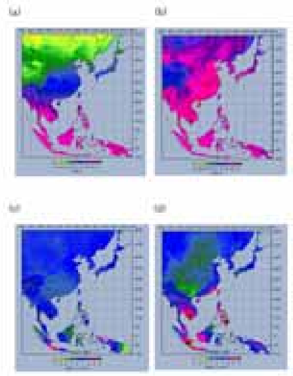
Senior Research Scientist,
National Institute for Environmental Studies, Japan

/ Assoc. Prof., Chiba Univ., Japan
/ Prof., East China Normal Univ., China

RIHN Workshop: Human Impacts on Urban Subsurface Environments in Asian Megacities

Surface climate change accompanied by urbanization

- The author proved mutual relations by collecting information on the changes in surface climatic factors, comparing to a vertical profile of subsurface temperature obtained from the subjected cities in Asia, information on the transition in land use and strength of human activity which enable to explain the changes in inter-annual surface climatic factors.
- He aimed to clarify the influence of urbanization in regard to the vertical profile of subsurface temperature.
- Especially he compiled and showed data of warming for more than 100 years in the subjected cities.

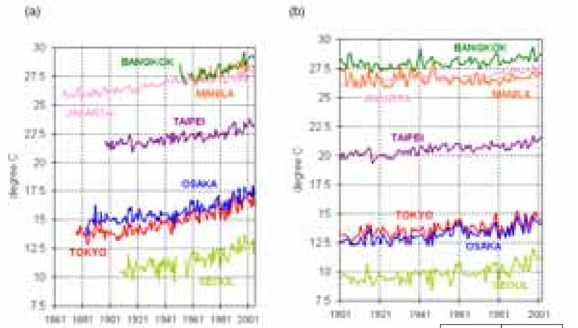


Average of 4 pixels data around the target cities: Defined as the rural temperature

UHII=T(urban)-T(rural)
Urban Heat Island Intensity

X

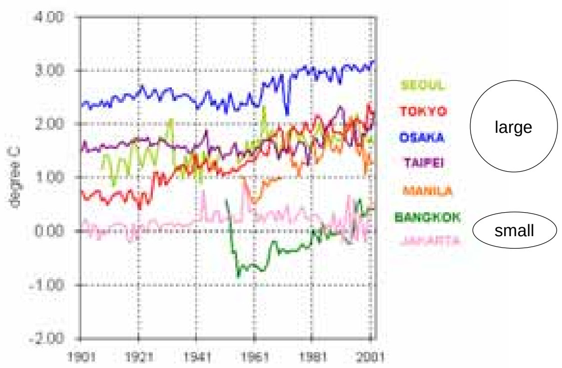
CRU TS2.1: 0.5 deg. temperature data (Mitchell *et al.*, 2005)
Monthly average temperature (a) JAN (b) JUL
Its trend of variation (1901-2002) (c) JAN (d) JUL



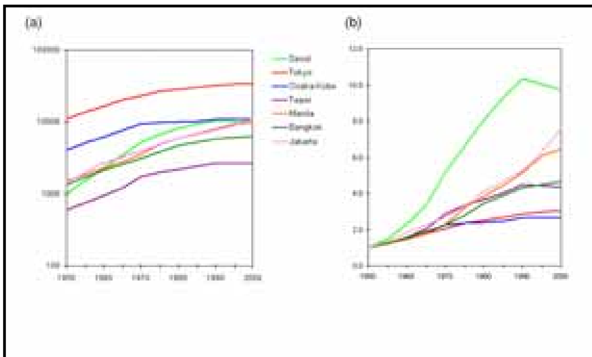
Variation of yearly mean temperature

(a) observed as T(urban): +2.5 deg. C / 100 years
(b) average of 4 pixels (TS2.1)
around obs. points as T(rural)

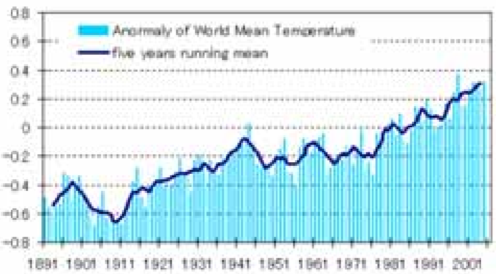
X



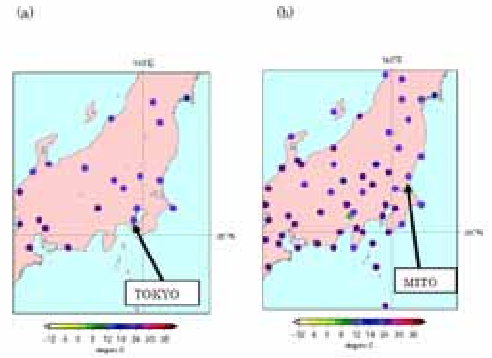
Variation of Estimated Urban Heat Island Intensity (EUHII)
EUHII = T(urban) (a) – T(rural) (b)



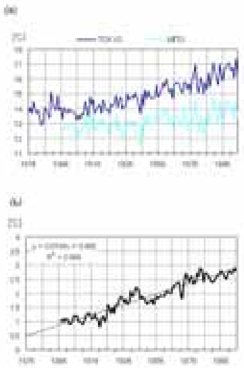
(a) Population
(b) Increase ratio based on 1950



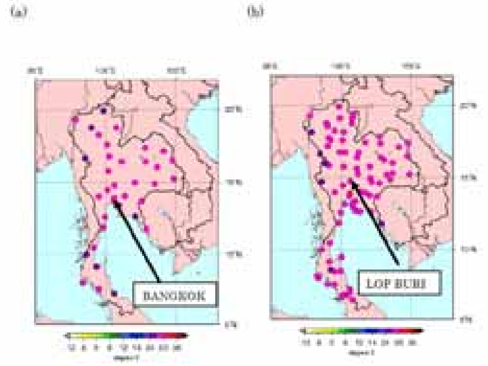
Anomaly of yearly mean temperature in the world from 1891-2005
+0.7 deg. C / 100 years



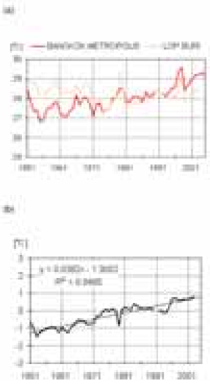
Meteorological observatories around Tokyo
(a) in 1897
(b) in 2005



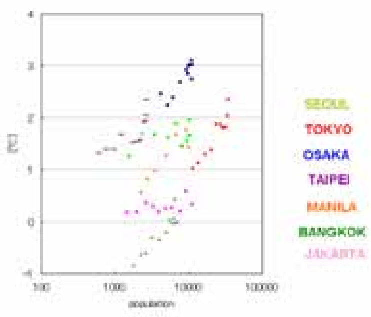
(a) Yearly mean temperature at Tokyo and Mito
(b) Heat island intensity of Tokyo (+2 deg. C / 100 years)
(EUHII: +1.5 deg. C / 100 years)



Meteorological observatories in Thailand
(a) in 1951
(b) in 2005



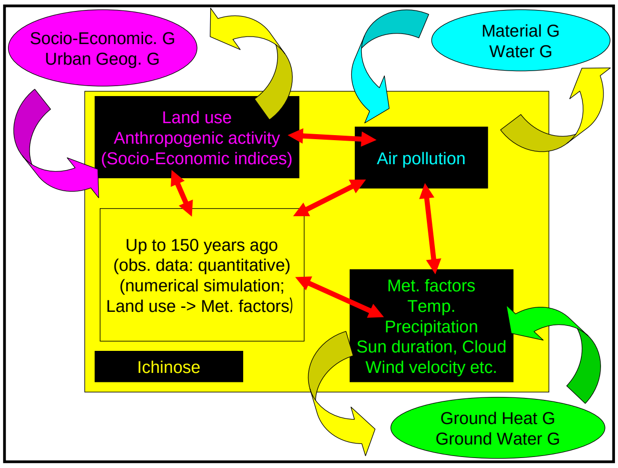
(a) Yearly mean temperature at Bangkok and Lop Buri
(b) Heat island intensity of Tokyo (+2 deg. C / 50 years)
(EUHII: +1.0 deg. C / 50 years)



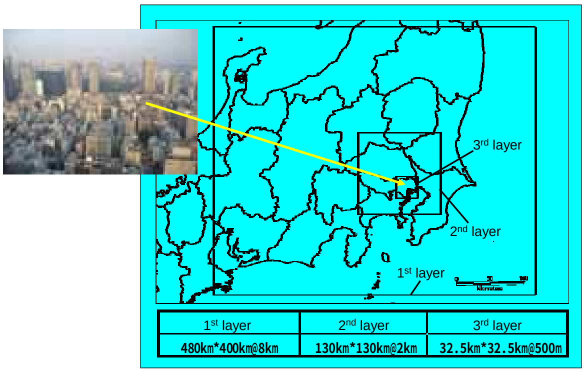
EUHII and population

On-going works

- The author mainly collected observation data up to the past 150 years, so now he started numerical simulation on both of historical sub-surface temperature (vertical profile) and surface climatic factors with meso-scale climate model in the subjected cities.
- Groups of urban geography and socio-economics prepared databases from collected data and they enabled him to input them to a climate model.



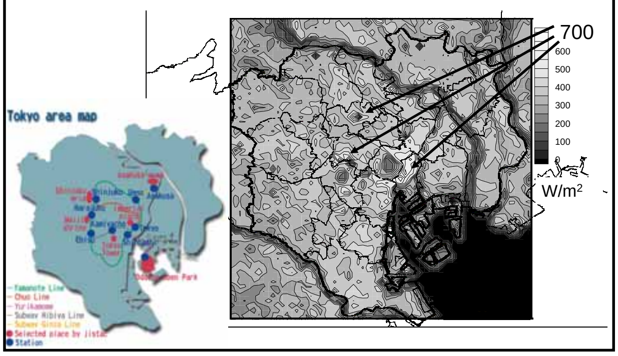
Numerical simulation by Ashie *et al.* (around Tokyo)

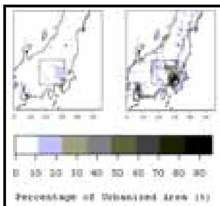


Numerical simulation by Ashie *et al.*

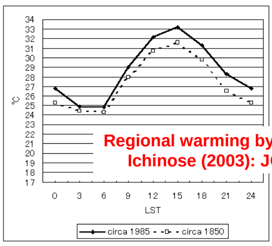
Sensible heat flux (14:00 in late July)

around Tokyo (30 km x 30 km)

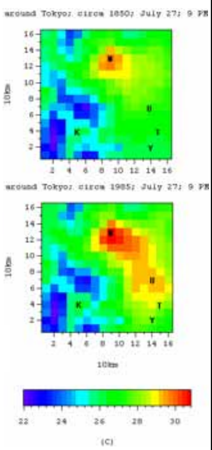




	dTmax	at	dTmin	at	Tmax1985
Tokyo	1.8	9PM	0.5	6AM	33.2
Osaka	2.2	9PM	0.4	6AM	33.0
Sapporo	0.5	0AM	0.2	9AM	24.0
Fukuoka	0.8	9PM	0.1	6AM	31.4
Sendai	0.9	9PM	0.0	6AM	27.4



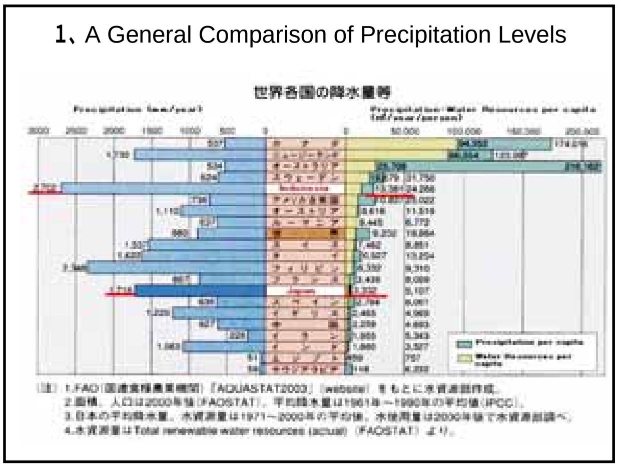
Regional warming by urbanization
Ichinose (2003): JGEE, Vol.9

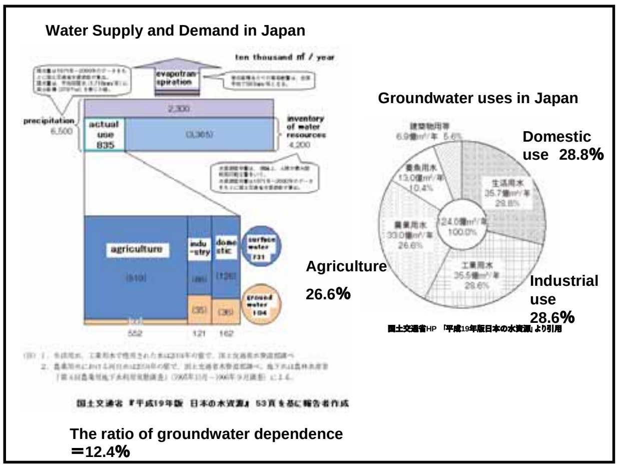


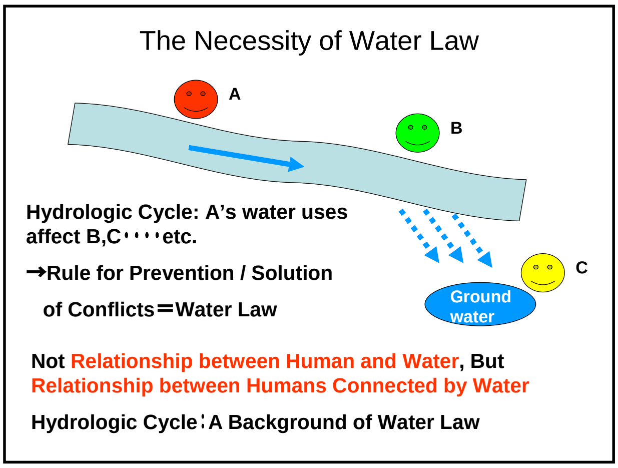
Conclusion

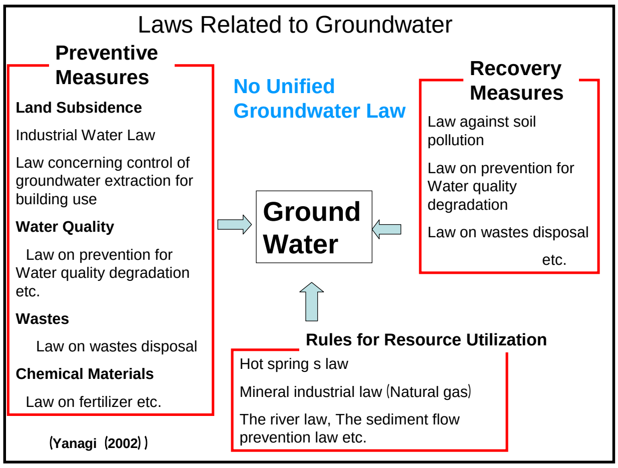
- Long term trend of surface temperature in Asian large cities is analyzed for the purpose of estimating the effect of urban warming.
- Index of estimated urban heat island intensity is suggested as the value which subtracts the grid reconstructed temperature data around the city from observational temperature data in the city.
- This value is lower than the actual temperature difference of urban and suburban observatory, but seems to indicate averaged tendency of urban heat island intensity.
- Indicating this kind of index calculated by unified method is necessary for understanding general situation of urban warming in several cities for long period and compiling it with other environmental data such as subsurface temperature.

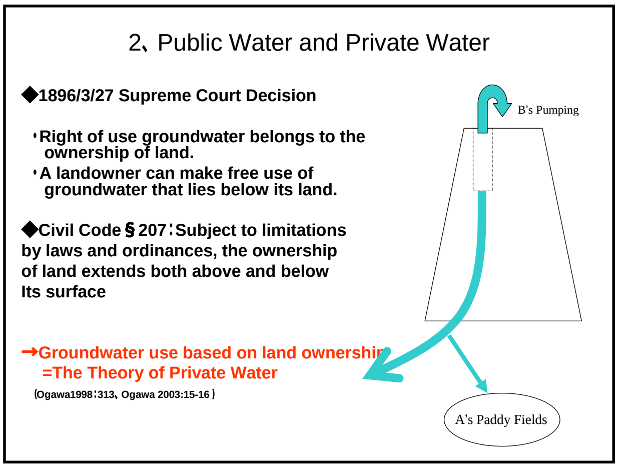

2007/12/7 Workshop on Groundwater Management @Bali, Indonesia
Groundwater Managements from the Viewpoint of Law and Institution – Japanese Experience
Research Institute for Humanity and Nature
Takahiro Endo
Outline
1、Introduction
2、Public Water and Private Water
3、Integrated Management of Surface-Groundwater
4、Regulation on Groundwater
5、Conclusion


1、A General Comparison of Precipitation Levels
世界各国の降水量等


Water Supply and Demand in Japan
Groundwater uses in Japan
Domestic use 28.8%
Agriculture 26.6%
Industrial use 28.6%
The ratio of groundwater dependence =12.4%


The Necessity of Water Law
A
B
C
Ground water
Hydrologic Cycle: A's water uses affect B,C・・・・etc.
→Rule for Prevention / Solution of Conflicts=Water Law
Not Relationship between Human and Water, But Relationship between Humans Connected by Water
Hydrologic Cycle：A Background of Water Law


Laws Related to Groundwater
Preventive Measures
Land Subsidence
Industrial Water Law
Law concerning control of groundwater extraction for building use
Water Quality
Law on prevention for Water quality degradation etc.
Wastes
Law on wastes disposal
Chemical Materials
Law on fertilizer etc.
No Unified Groundwater Law
Ground Water
Recovery Measures
Law against soil pollution
Law on prevention for Water quality degradation
Law on wastes disposal
etc.
Rules for Resource Utilization
Hot spring s law
Mineral industrial law (Natural gas)
The river law, The sediment flow prevention law etc.
(Yanagi (2002))


2、Public Water and Private Water
◆1896/3/27 Supreme Court Decision
・Right of use groundwater belongs to the ownership of land.
・A landowner can make free use of groundwater that lies below its land.
◆Civil Code§207：Subject to limitations by laws and ordinances, the ownership of land extends both above and below Its surface
→Groundwater use based on land ownership =The Theory of Private Water
(Ogawa1998：313, Ogawa 2003:15-16)
B's Pumping
A's Paddy Fields

Public Water VS Private Water

◆The theory of private water: Groundwater = A part of surface land

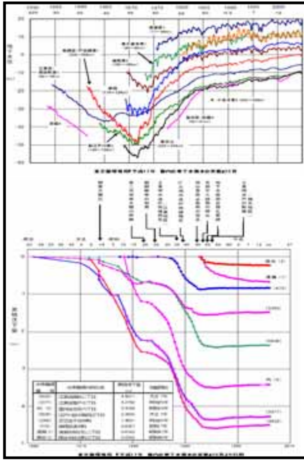
・idea1:Groundwater classification: Soaking water, unmoved water, groundwater stream
Application of the (Old) River Law to groundwater stream
(Takeda 1942:5-18)

・idea2:Groundwater:a "special" part of land in that over-pumping destroys the crust itself (Endo 1976:7)

・idea3:Groundwater may turn into public water through customary practices (Minobe 1940:840)

・idea 4 Judicial Decisions (Limitation by a theory of right abuse)

◆The theory of public water:Groundwater is (should be)regarded as a part of hydrologic cycle.
Public regulation on groundwater uses
(Jurist 1975:61、Sanbongi 1979:163、166-167、Ogawa 2003:21)



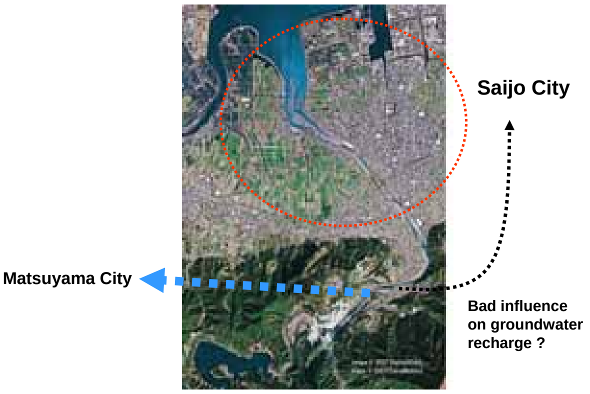
3、Integrated Management of Surface-Groundwater

Overuse / Land subsidence

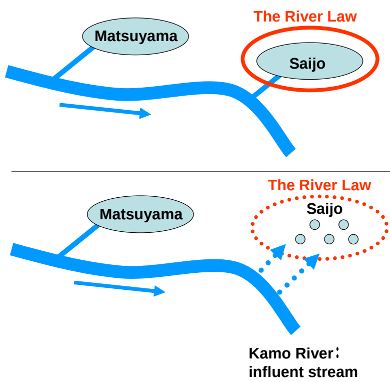
・problem since1930's➔esp.1950〜70's
・Collective Action Problem
➔Justification of government intervention
・ongoing problem➔drought years
・Rise of groundwater level
(今後の地下水利用のあり方に関する懇談会 2007:12-13,34-36)

Solution
・Public regulation on GW uses
➔1956 Industrial Water Law
1962 Law concerning control of gw extraction for building use
・Construction of industrial waterworks
(Matsuda 1975:50、52、座談会1975:27-28、Jurist 1975:55,69, Yanagi 2002:6-7、Takanashi 2003:237)

A Plan of Water Diversion from Kamo-River



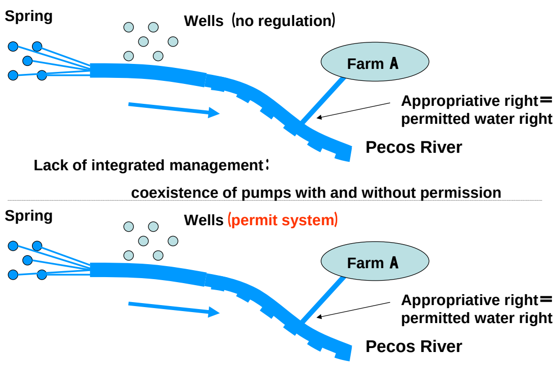
Integrated Management of Surface and Groundwater 2 :The case of Saijo city



・Water diversion from a river (public water)
・concerned river user
・existent water uses are protected against diversion
:Water use conciliation
(The River Law §38〜43)

・Extraction of GW (private water)
・Not regarded as a concerned river user
・Weak protection for existent water uses

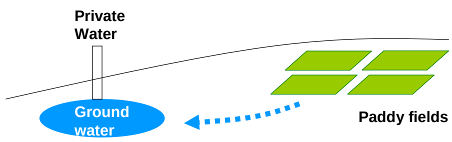
Integrated Management of Surface and Groundwater 3 :The case of New Mexico

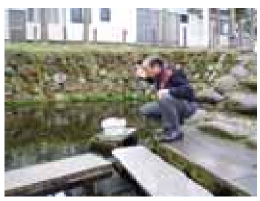


Application of appropriative right system to GW

(Piper and Thomas 1958:21-22, Dunbar 1983:162-172)

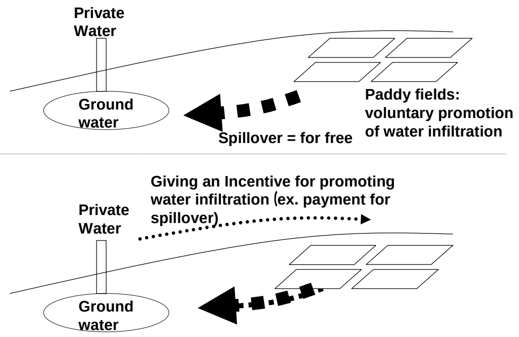
Integrated Management of Surface and Groundwater 4 :The case of Water Banking





Rokugo, Akita Prefecture

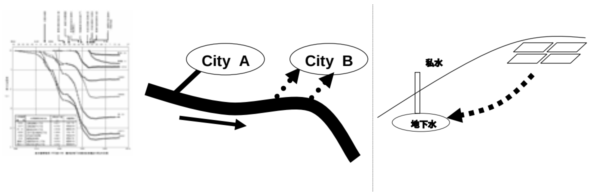
Integrated Management of Surface and Groundwater 4 :The case of Water Banking



Legal status of GW (private water):

disincentive for payment (Fujinawa2003:4)

Integrated Management Surface-Ground water: summary



Different legal status of surface and ground water

- **Desirable / undesirable spillover effects**
- **Lack of mechanism for making people pay for desirable spillovers / compensate undesirable spillovers** (Abe 1981:225)

→Creating such mechanism = a role of Government (Honda2003:30)

- **Public GW (Introduction of permitted GW right system)**
- **Private water with public regulation**
- **GW fee: putting a price on groundwater** (Honda2003:30) (Abe 1981:227~)

4、Regulations on Groundwater uses

4 Plans for regulation on groundwater uses (1974)

	Purpose	Regulation	Collecting Ground water fee	Legal status of Groundwater
Central Council for Env. Pollution (Env. Agency)	Prevention of land subsidence	Designated Area as classified by subsidence Permitted system	○ (Long term goal)	Public water
LDP special committee	Prevention of land subsidence	Designated Area Permitted system		
Study Group of GW management institution (M.of Construction)	Comprehensive management of GW (land subsidence, over-pumping,salt intrusion, pollution)	Permitted system	○	Public water
Resource research group (Agency of Science and Technology)	Comprehensive management of GW	Permitted system		Public water

(Jurist No.582(1975.3.1))

Plans are still plans…….

1、It was hard to establish quantitative estimates on groundwater.

2、Too many drills for government to get exact data on the pumping volume.

3、Too many groundwater users to coordinate their pumping.

4、Recognition that groundwater is private water. (Ogawa 1998:319) (Ogawa 2003:24-25)

5、Bureaucratic sectionalism (Ref:Kanazawa 1960:153)

Prefecture Ordinances

(地下水懇談会2007:22-26)

- **Much of ordinances were made as a part of general rule on environmental protection.**
- **water quality/ artificial recharge salt intrusion/ groundwater extraction and conservation**

City Ordinances

(地下水懇談会2007:22-26)

- City ordinances and regulation→330 examples
- Among them, 181 cases are a part of general ordinances for environmental protection.

Summary

1、Hydrologic cycle→ a background of the necessity of water law

2、No united water law in Japan

3、Lack of Integrated management of surface-ground water (Results of different legal status of surface-ground water)

- Land subsidence (Tokyo, Osaka)
- Weak protection of existent water use in diversion (Saijo city)
- Dry-up of a river (NM: Pecos river)
- Weak incentive for water banking (Kumamoto etc.)
- Integrated management : always right?

4、No national law→ Many prefecture and city ordinances

Use of groundwater age tracers to understand the effect of urbanization in Asian cities

- Progress report of water group -

Jun Shimada

Graduate school of Science and Technology, Kumamoto University, Japan

Contents

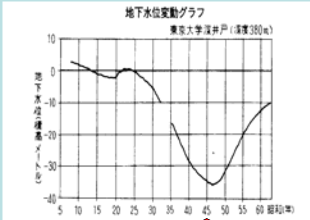
Human impacts on urban subsurface water environments

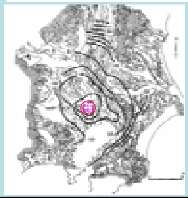
Population growth → global worming (climate change)

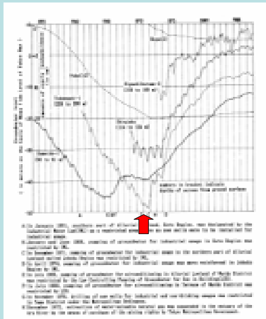
Population concentration toward Urban area (economic activity)

Quantity and quality problems in groundwater caused by urbanization

Groundwater change in Kanto plain (Tokyo)

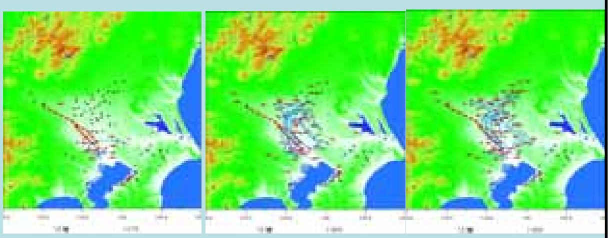






1970

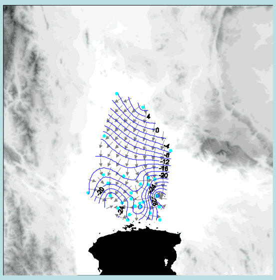
Groundwater potential during last 30years at Kanto Plain, Japan (aquifer **VI**)



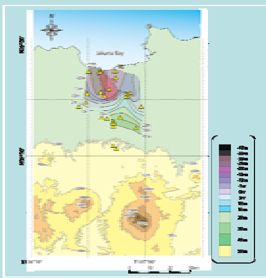
1975 | 1985 | 1995

(Hayashi,et al., 2007)

Groundwater drawdown at Asian city area caused by urbanization



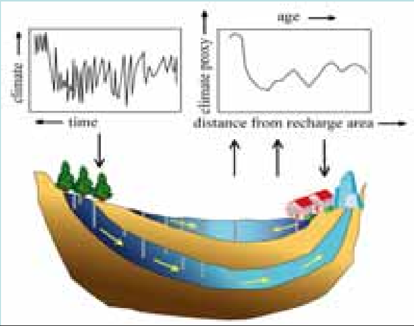
Bangkok NL aquifer 2006



Jakarta 2nd aquifer 2006

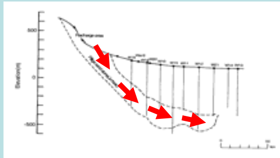
Paleo information
(time record)
from groundwater aquifer
(recharge temperature, etc)

Groundwater flow system information
by environmental isotopes
(residence time, recharge temperature/altitude, etc)

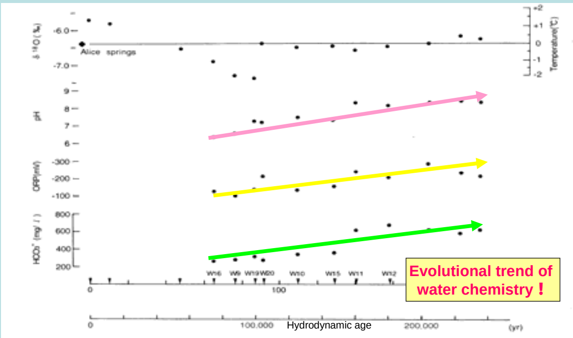


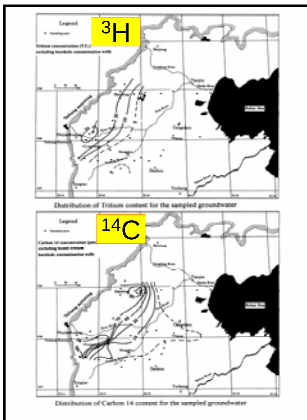
(EOS.No.24,1998)

Great Artesian Basin Australia



Water chemistry along sampling line





The distribution of ^{3}H and ^{14}C content in the NCP groundwater

Evidence of induced groundwater flow by over pumping

Possibility to receive better resolution than natural groundwater flow for short time paleo record

RIHN Bali Symp. 2007.12

study procedure of water group

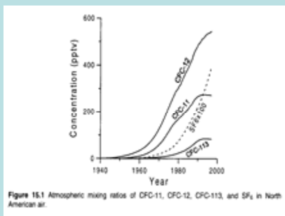
Necessary basic information from study city (Tokyo, Bangkok, Jakarta)
- Aquifer configuration
- Record of groundwater potential distribution during last 50years or more
- Location of observation well and their aquifer parameters
- Related groundwater information

- Understanding the groundwater flow system of the study area
- Evaluation of the effect of over pumping in the city area by using groundwater flow simulation
- Selection of the representative sampling line

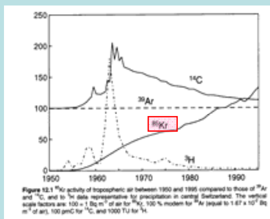
- Evaluation of the time series human impacts from groundwater aquifer in the study city (ex. CFC, NO^3, Pb, D &^{18}O, etc) by using modern age tracer (CFC, ^{85}Kr, ^{3}H etc)
- Comparison of different cities of different development stage

RIHN Bali Symp. 2007.12

CFC and ^{85}Kr for modern groundwater age tracer



Used as refrigeration and air conditioning or spray-gas until 1990

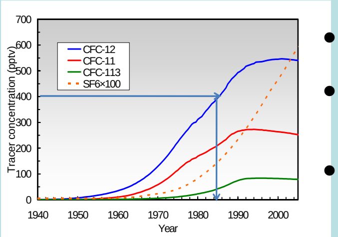


Kr-85: half life 0.7yr
Kr-85 : origin Nuclear power plant, reprocessing plant

RIHN Bali Symp. 2007.12

CFCs (chlorofluorocarbons)

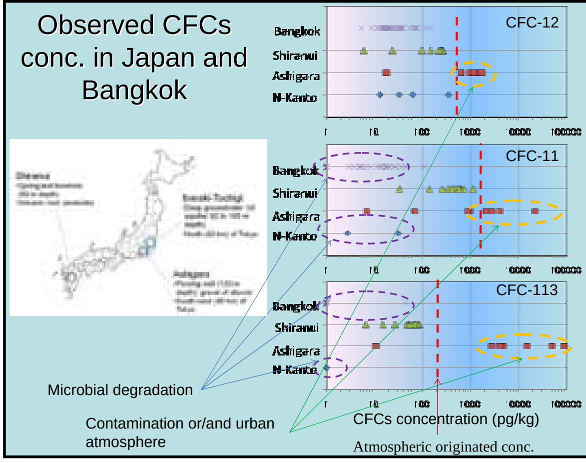
- CFC-11 (CCl_3F, trichlorofluoromethane)
- CFC-12 (CCl_2F_2, dichlorodifluoromethane)
- CFC-113 ($C_2Cl_3F_3$, trichlorotrifluoroethane)



Long trend of CFCs in atmosphere (USGS)

- CFCs is stable in the atmosphere.
- CFCs concentration in the atmosphere is increasing since 1950.
- There has been few CFCs data of groundwater in Asia.

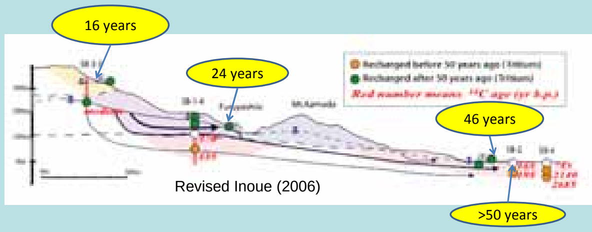
Observed CFCs conc. in Japan and Bangkok



Factors affecting CFCs in GW

Factor	Environment	Process	Effect	Reference
Recharge Temperature	Shallow groundwater	Over-estimate of recharge altitude Under-estimate of recharge altitude ±2℃	Under-estimate Over-estimate 1 year (< 1970) 1-3 years (1970-1990) > 3 years (> 1990)	Busenberg et al (1993)
Excess air	Fissures of rock	Addition of air trapped and dissolved during recharge.	Under-estimate	Wilson and Mcneill (1997)
Recharge altitude	Mountainous region	Water recharged at high altitude dissolves less CFCs because of lower barometric pressure. ±1000m	A few years (< 1987)	Busenberg et al (1993)
Thickness of unsaturated zone	>10m	Air in deep unsaturated zone is older than that of the modern troposphere. 0-10m 30m	Over-estimate < 2 years 8-12 years	Cook and Solomon (1995) Busenberg et al (1993)
Urban atmosphere	Metropolis	CFC mixing ratios in urban and industrialised areas can exceed regional values.	Under-estimate	Szabo et al. (1996) Oster et al. (1996)
Contamination	Industry region	CFCs added to water from local anthropogenic sources	Under-estimate	Thompson and Hayes (1979) Busenberg and Plummer
Microbial degradation	Anaerobic environments	No degradation in aerobic environments CFC-11,113	Over-estimate	Sonier et al. (1994) Deipser and Stegmann (1997)
Absorption	Organic-rich sediment	Sorption of CFCs onto particulate organic carbon and mineral surfaces. CFC-113>>CFC-11,12	Over-estimate	Cook et al. (1995)

Residence time of GW and spring water using CFCs in Shiranui, Kumamoto,Japan



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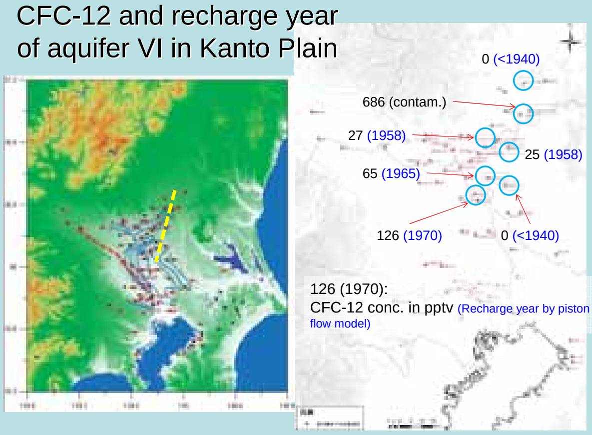
CFC-12 and recharge year of aquifer VI in Kanto Plain



^{85}Kr/Kr

Age tracer for young groundwater

^{85}Kr (half-life: 10.76 years)

origin: nuclear installations

8.6×10^{-5} Bq/L (7×10^{-8} cc STP/g water, equilibrated with modern dry air at 25ºC)

^{85}Kr/Kr $_{(atoms)}$:7.1×10^{-19}

Abundance in groundwater is very low :

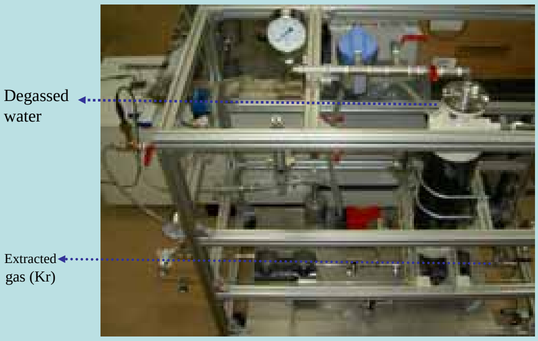
7×10^{-8} cc SPT/g

→ 10,000 L of groundwater will be necessary

Membrane gas extraction system (Prof. Mahara)
Kr gas separation + low level LSC system (Prof. Momoshima)

RIHN Bali Symp. 2007.12

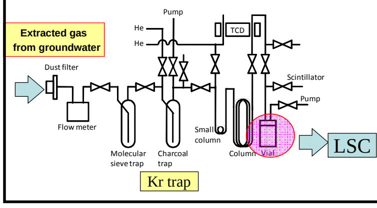
Kr extraction system



- Flow velocity: 24 l/min 99%of dissolved Kr has recovered
- 10 hour continuous water flow can operate 10,000L of water which include necessary amount of Kr gas for LSC counting

(1) Separation and purification of Kr

1. Kr is collected in charcoal column at -196 °C
2. Separation of N_2 and O_2 at -80 °C with He flow
3. Purification of Kr with gas chromatography



(2) Low activity measurement system for Kr-85 (Liquid scintillation counting)

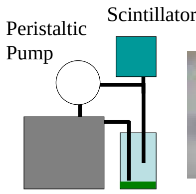
1. Low background counting vial
2. No leakage of Kr

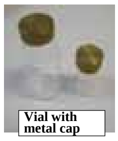
Quart vial Glass vial

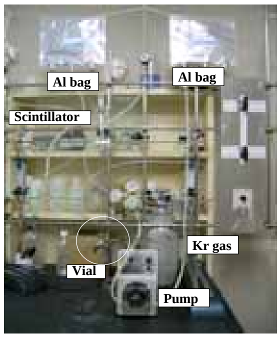
Teflon vial Glass vial

Low background liquid scintillation counter for Kr-85 measurement

3. Preparation of counting sample of Kr-85







(Kr: boiling point −159.2℃

Completed

- On site Kr gas extraction system
- Kr Separation and isolation system
- Low background counting system

Need to complete

- Effective Kr-85 transfer system to the counting vial
- Test sampling of groundwater at Kumamoto and analyze Kr-85 on March 2008

Basic proposed study procedure

Necessary basic information from study city (Tokyo, Bangkok, Jakarta)

- Aquifer configuration
- Record of groundwater potential distribution during last 50years or more
- Location of observation well and their aquifer parameters
- Related groundwater information

on going

- Understanding the groundwater flow system of the study area
- Evaluation of the effect of over pumping in the city area by using groundwater flow simulation
- Selection of the representative sampling line

on going

- Evaluation of the time series human impacts from gro... aquifer in the study city (ex. CFC, NO^3, Pb, D &... modern age tracer (CFC, ^{85}Kr, ^{3}H etc)
- Comparison of different cities of different development stage

Almost finish development and start to field application

Tracing deep groundwater underneath the Bangkok metropolitan area

Tsutomu Yamanaka[1] ,
Jun Shimada[2] & Maki Tsujimura[2]

[1]Univ. of Tsukuba, [2]Kumamoto Univ.

Special thanks to:

Somkid Buapeng & DGR staff members,
Shin'ichi Onodera & Material group,
Makoto Taniguchi & the other RIHN groups
and
Robert Delinom & all of Indonesian hosts

RIHN Workshop: Human Impacts on Urban Subsurface Environments in Asian Megacities. 7-8 Dec. 2007

Background

Population increase and economic growth since 1950's

↓

Drastic increase in water demand for public water supply and industrial use

↓

Excessive groundwater withdrawal

↓

- Piezometirc level decline
  - ⇒ *Groundwater salinization*
- Land subsidence
  - ⇒ *Flood disaster*

Kokusai Kogyo Co., Ltd. (1995)

Background

- ✓ Groundwater Act (1977)
- ✓ Groundwater Use Charges (1985)
- ✓ Groundwater Preservation Charge (2005)
- ✓ Water source change for public water supply

↓

Restoration of piezometric level

Figure 2. Groundwater Pumpage in Bangkok and Surrounding Areas

IGES (2007)

Goal and contents

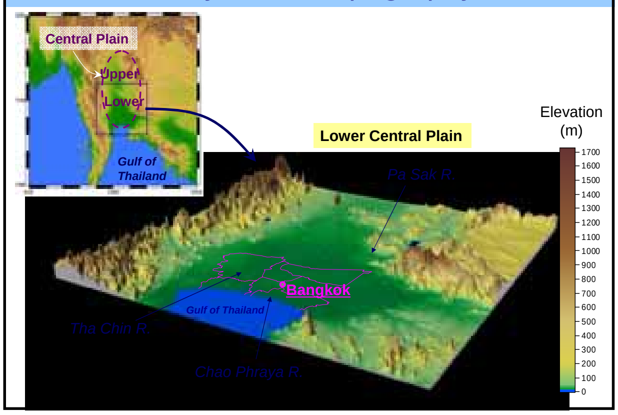
Goal:

➢ To elucidate deep groundwater *recharge-flow systems* and human impacts on them

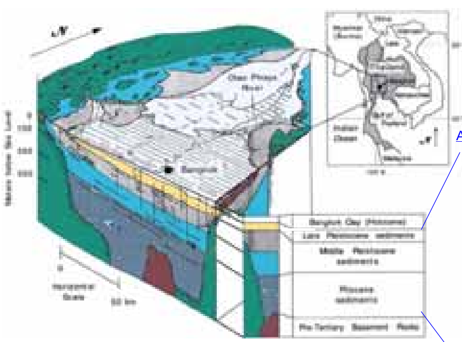
Contents:

- Change in confined groundwater level, quality and flow system during past 30 years
- Origins, flow paths and age of deep groundwater revealed by environmental tracers (D,^{18}O, Cl, CFC)

Study area：Topography



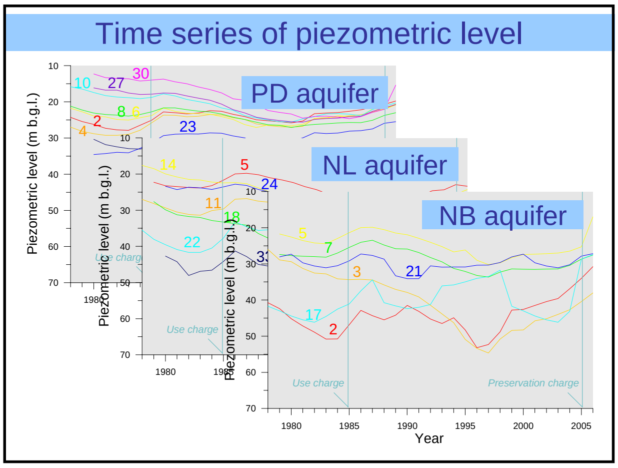
Study area： Hydrogeology

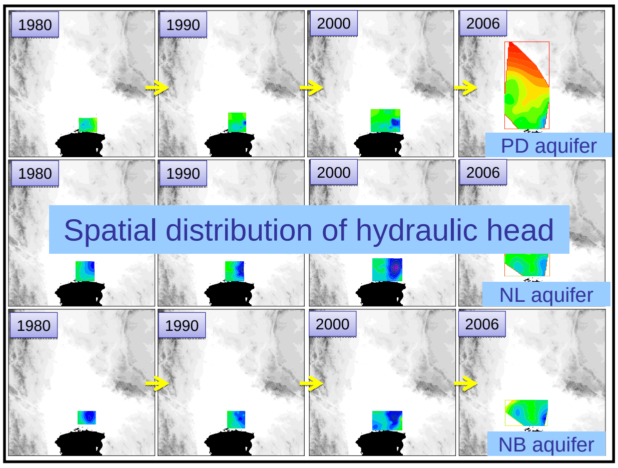


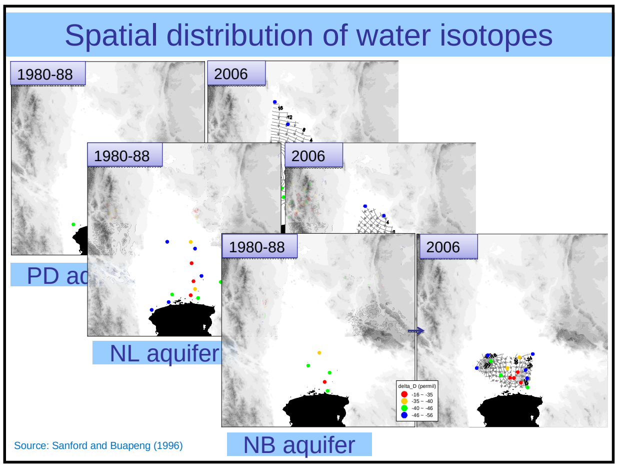
Buapeng (2004)

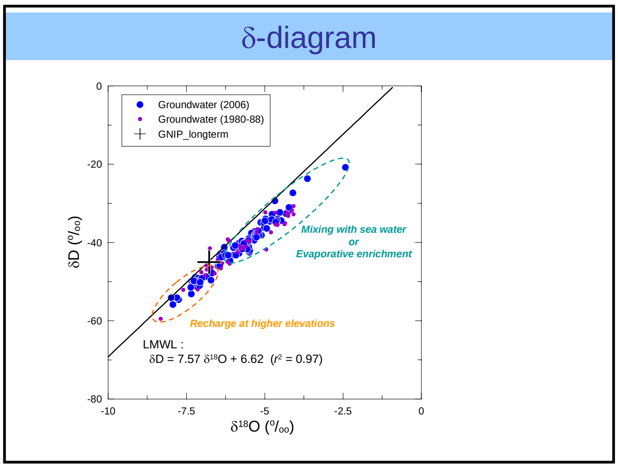
Aquifer classification

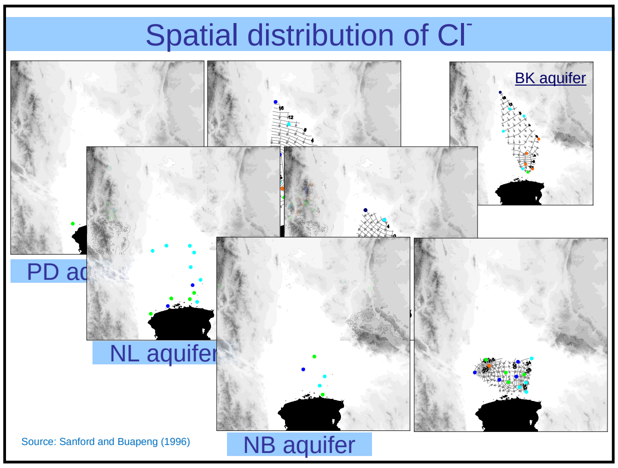
- Bangkok (BK) 50m depth-zone
- Phra Pradaeng (PD) 100m depth-zone
- Nakhon Luang (NL) 150m depth-zone
- Nonthaburi (NB) 200 m depth-zone
- Sam Khok (SK) 300m depth-zone
- Phy Thai (PT) 350m depth-zone
- Thonburi (TB) 450m depth-zone
- Paknam (PN) 550m depth-zone

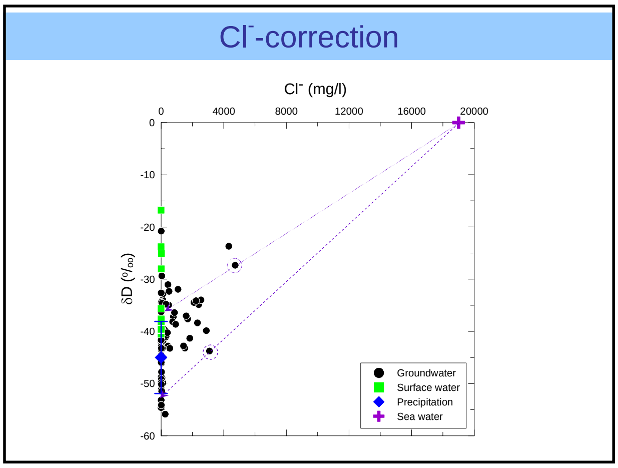

Time series of piezometric level
PD aquifer
NL aquifer
NB aquifer
Piezometric level (m b.g.l.)
Use charge
Preservation charge
Year


1980
1990
2000
2006
PD aquifer
Spatial distribution of hydraulic head
NL aquifer
NB aquifer

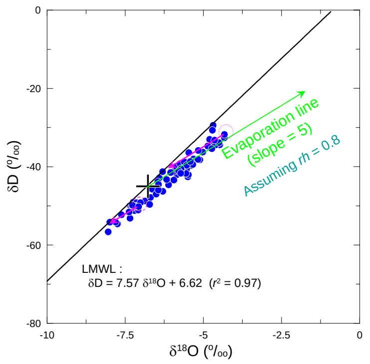

Spatial distribution of water isotopes
1980-88
2006
PD aquifer
NL aquifer
NB aquifer
Source: Sanford and Buapeng (1996)


δ-diagram
Groundwater (2006)
Groundwater (1980-88)
GNIP_longterm
Mixing with sea water
or
Evaporative enrichment
Recharge at higher elevations
LMWL :
δD = 7.57 δ18O + 6.62 (r² = 0.97)
δD (‰)
δ18O (‰)

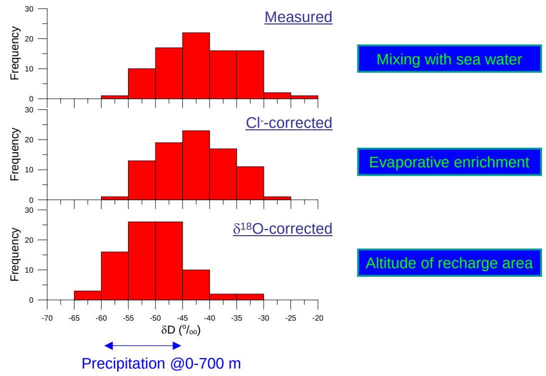

Spatial distribution of Cl-
BK aquifer
PD aquifer
NL aquifer
NB aquifer
Source: Sanford and Buapeng (1996)


Cl--correction
Cl- (mg/l)
δD (‰)
Groundwater
Surface water
Precipitation
Sea water

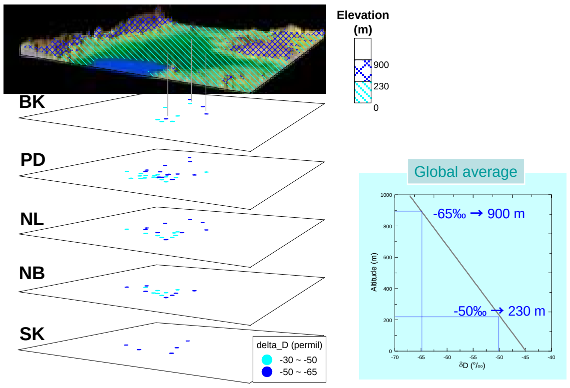
δ^{18}O-correction



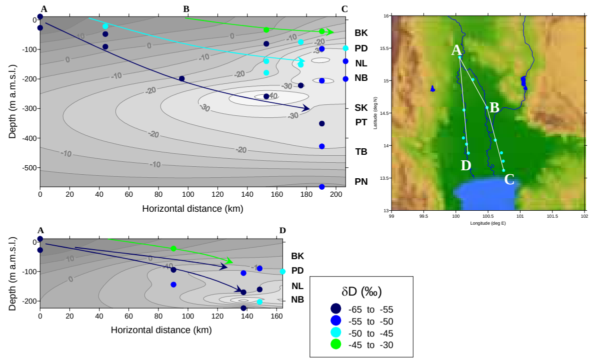
Histogram of δD



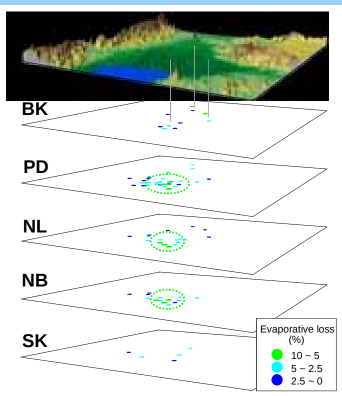
Altitude of recharge area



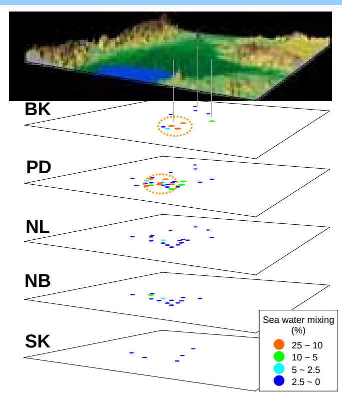
Vertical cross section: N-S



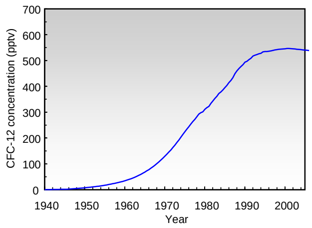
Evaporative loss



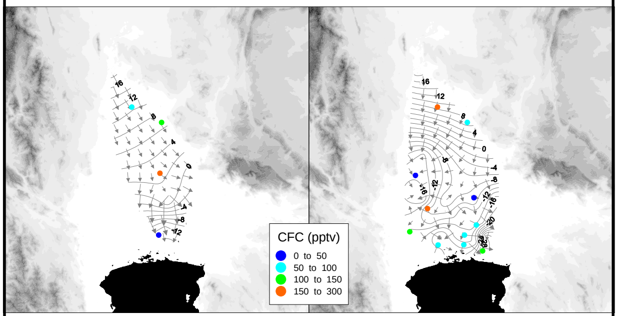
Mixing fraction of sea water



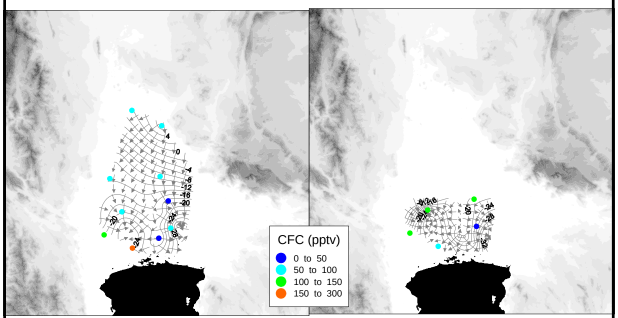
Spatial distribution of CFC & groundwater age



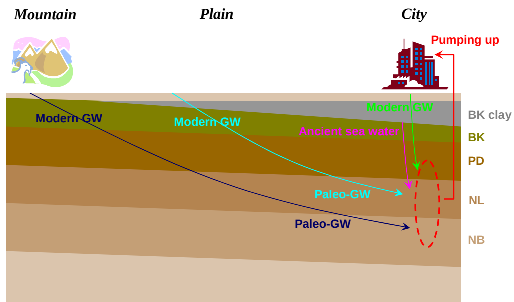
BK aquifer | PD aquifer



NL aquifer | NB aquifer



Mixing due to pumping



Tentative conclusions

1. Fresh groundwater recharged at the plain, terraces, and fans dominates in the whole part of BK, southern part of PD, the central part of NB. At the other area, fresh groundwater recharged at hills and mountains is dominant.
2. Owing to groundwater abstraction, recharge of modern fresh groundwater might be accelerated, and the young water was transported into lower aquifers with ancient sea water stored within and pressed out the Bangkok Clay.

Thank you for your attention!

RIHN workshop
December 8th, 2007
Ramada Bintang Hotel, Bali, Indonesia

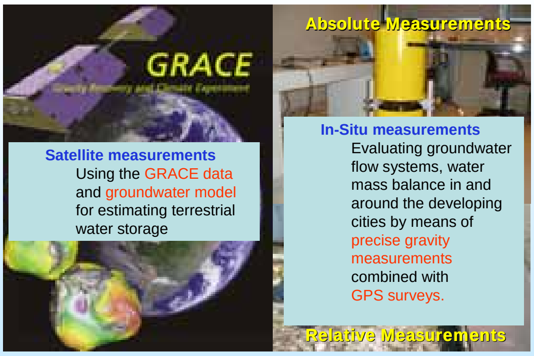
Overview of the gravity group activities and GRACE application for monitoring terrestrial water storage

Yoichi Fukuda

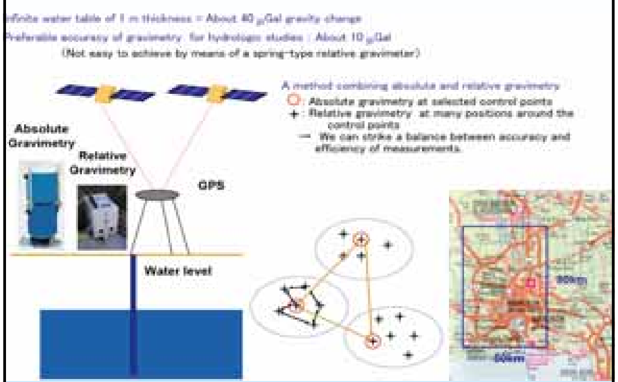
Graduate School of Science, Kyoto University

Monitoring of the Ground Water Variation in Urban Area, by Combining

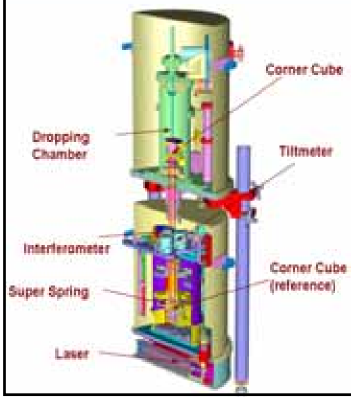
GRACE Data and in-situ Gravity Measurements



Precise Gravimetry on Land



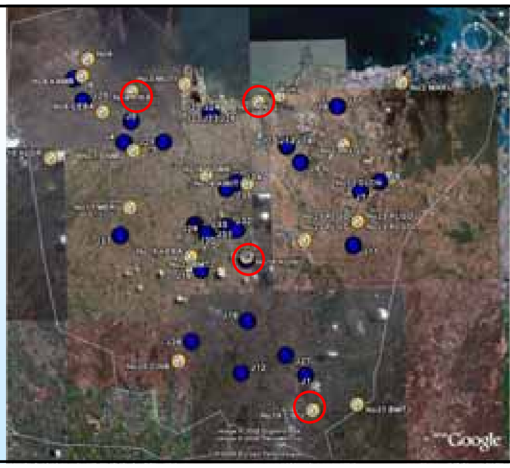
A-10 Absolute Gravimeter



A-10

Survey in Jakarta

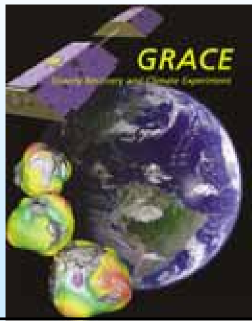
- Point survey (2006)
  - for absolute gravity measurements
  - Select potential 4 points
- Gravity survey collaborated with BAKOSURTANAL
  - for estimating subsurface structure
  - 3 E-W and 3 N-S profiles
- Precise GPS survey collaborated with ITB
  - For estimating subsidence
  - 4 points (KUNI, PIKA, ANCH, CIBU)
  - More than 20 points

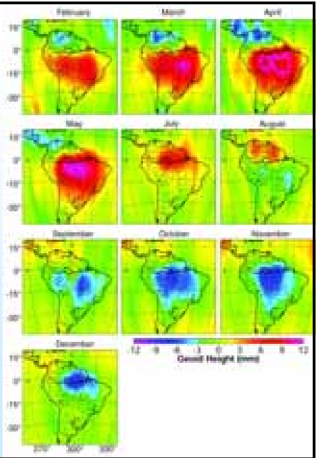


Survey in Bangkok
Mar20-27, 2007

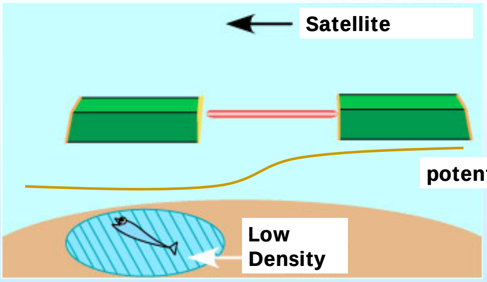
GRACE Measurements of Mass Variability in the Earth System

Tapley et al.,
Science, Vol. 305, July, 2004

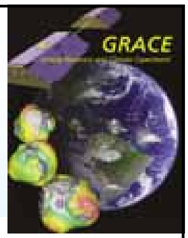




Gravity Measurements by a twin satellite

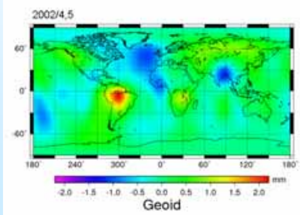


Why GRACE is Important ?



P=E+R+G+⊿S

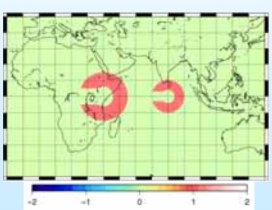
P : Precipitation
E : Evaporation
R : River runoff
G : Groundwater runoff
⊿S : Storage

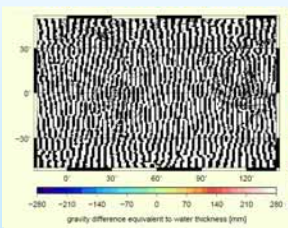


Spatial Filtering

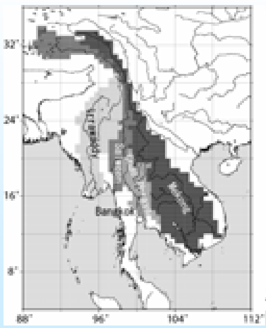
to suppress short wavelength noises

Without filter





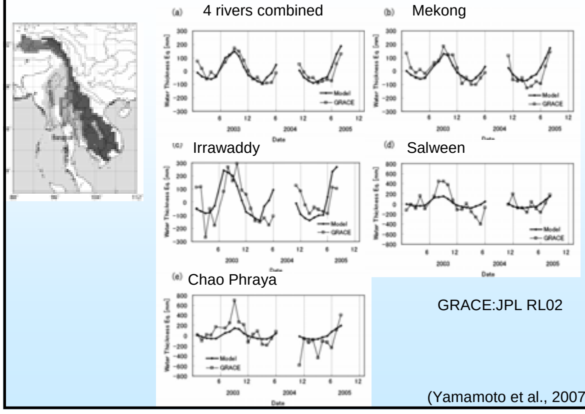
4 River Basins in the Indochina Peninsula



•Catchment Area

River	Drainage Area (km^2)
Salween	330 000
Chao Phraya	178 000
Irrawaddy	425 000
Mekong	814 000
Total	1 750 000

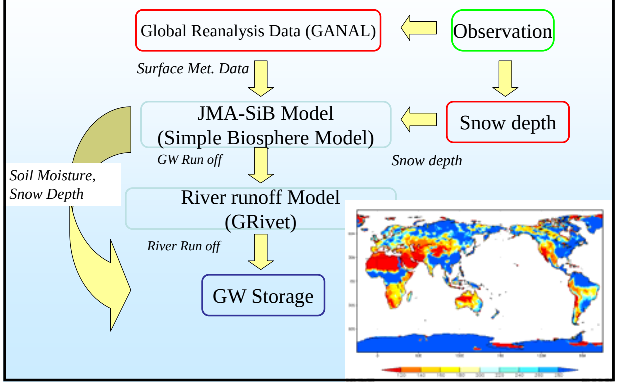
GRACE Data and GW Model



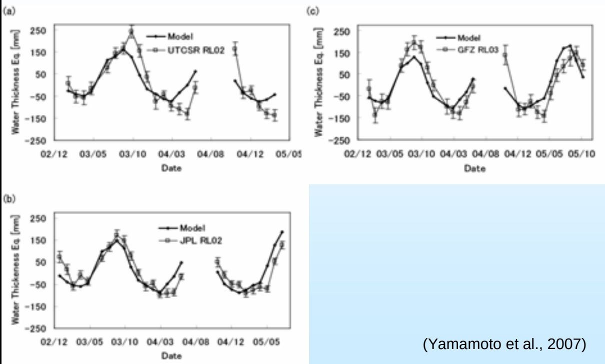
GRACE:JPL RL02

(Yamamoto et al., 2007)

Model Estimation of GW Storage



GRACE data sets and the GW model



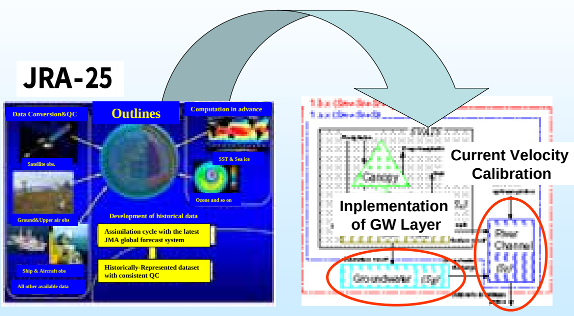
(Yamamoto et al., 2007)

Recent Improvements:

GRACE RL04 Data (Newly Released Data sets):
- Refined algorithm for data processing,
- Improvements in geophysical models for corrections

GW model:
- basic data set: JRA25+JCDAS
- model : GRiveT with GW storage
- river flow : tuned V, constant V(0.4m/s)

Estimation Procedures



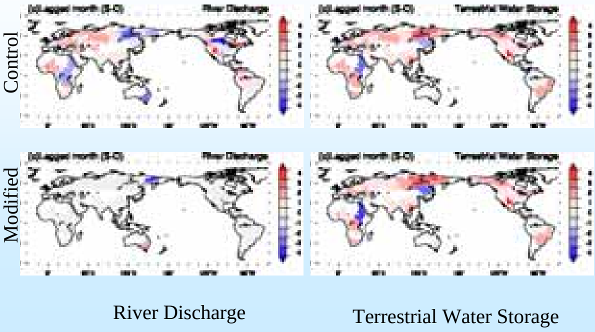
$St = Sm+Ss+Sg+Sr$

Global Annual Water Balances

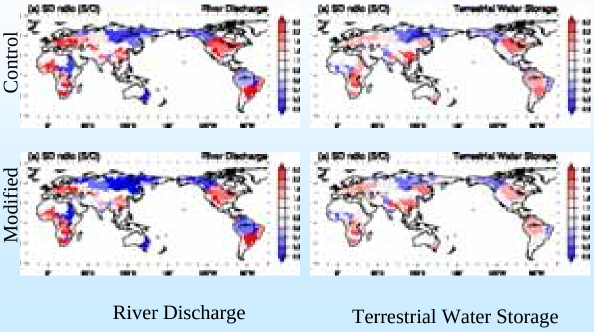
- JRA-25 well reproduces the previous observation-based estimates and has the best closure of the water balance.

		P	E	R	R/P	Pg	Source
Re-Analysis	JRA	731	490	247	0.34	1114	
Re-Analysis	ERA40	779	510	343	0.44	1200	H05
Re-Analysis	ERA15	765	557	309	0.40	988	H05
Re-Analysis	NCEP	772	631	—	—	962	H05
Obs. Esti.	Sellers	720	410	310	0.43	1004	S65
Obs. Esti.	BR75	746	477	269	0.36	973	B75
Obs. Esti.	Korzun	800	485	303	0.38	1130	K70
Obs. Esti.	OM 95	704	467	237	0.34	915	O95
Model Esti.	GSWP2	836	488	348	0.42	—	D07

Phase Reproducibility



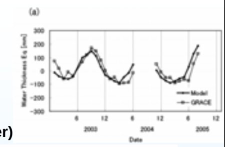
Amplitude Reproducibility



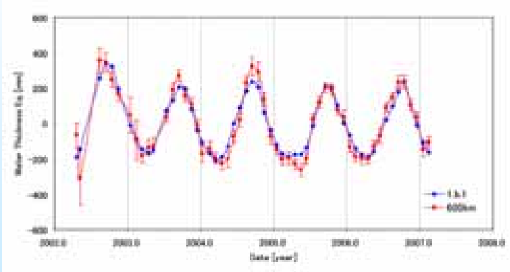
Effects of two modification on reproducibility

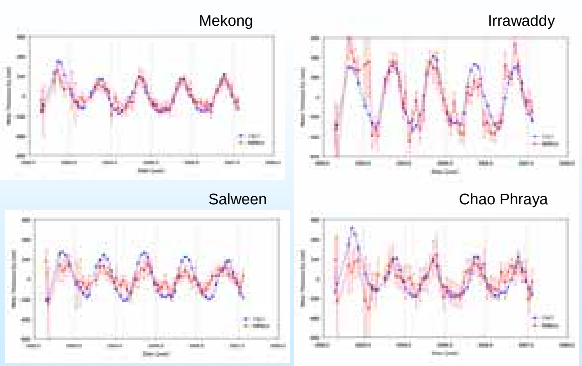
- Phase tuning by current velocity calibration
  - Significant Improvement: river discharge phase
  - Improvement: TWS amplitude
- Implementation of groundwater layer
  - Improvement: TWS amplitude

Comparison between newly released GRACE data and an improved GW model



4 river area (UTCSR RL04, 600km Gaussian Filter)





UTCSR RL04, 600km Gaussian Filter

Summary

- Gravity group aims to detect gravity changes due to terrestrial water mass variations by means of satellite and in-situ techniques.
- GRACE detects water storage variations of 4 river basins in the Indochina Peninsula and shows good agreements with the GW model.
- In-situ measurements with absolute and relative gravimeters and GPS are under preparation.

Gravity and GPS preliminary survey at Jakarta and Bangkok

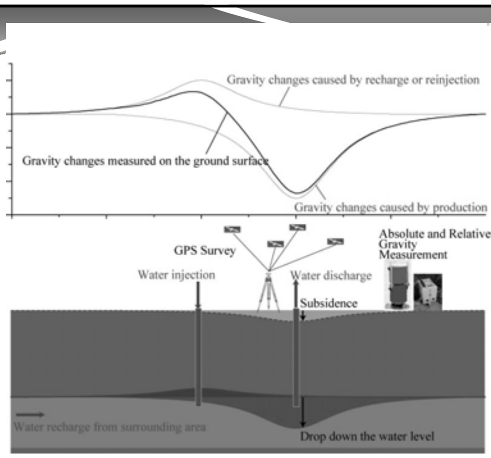
Jun NISHIJIMA
(Faculty of Engineering , Kyushu University)
Yoichi FUKUDA and Satoshi UENO
(Graduate school of Science, Kyoto University)

Background

- It is necessary to monitor the balance of pumping up and recharge to use the ground water for a long term.
- The pumping up of ground water causes mass fluid movement and mass redistributions, which can cause measurable gravity changes and ground deformation at the ground surface
- We are planning to make a repeat gravity and GPS survey at Jakarta and Bangkok to monitor the ground water level changes.

Gravity measurement is used for

- Estimation of the boundary between the low density (Sedimental, Pyroclastic, etc.) and high density (Granitic, Metamorphic, Basaltic, etc.) rocks.
- Observation of gravity changes caused by the natural (Tides, Volcanic eruption, etc.) and the artificial (groundwater level changes, injection of the grout, etc.) underground changes.

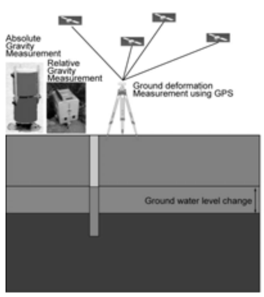


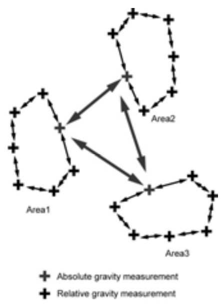
Gravimeter

Absolute Gravimeter
- Mesurement time : 30min
- Reference : Not Necessary
- Required space for the Measurement : 5m x 5m

Relative Gravimeter
- Mesurement time : 2-3min
- Reference : Necessary
- Required space for the Measurement : 1m x 1m

Measure plan

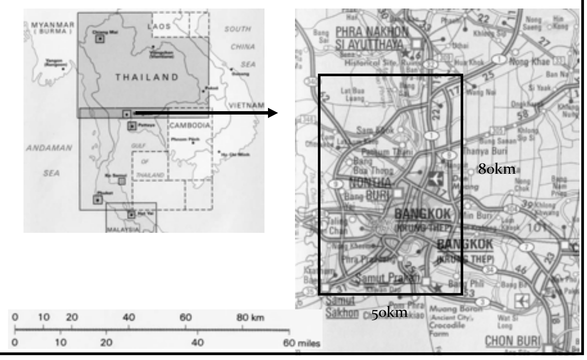




Observed gravity changes include the some gravitational effect

- Height changes 308μgal/m
  →GPS survey at the same time
- Earth tide ±250μgal
  →We can correct using precise model
- Atomospheric pressure changes 4μgal/10hPa
  →We can neglect (Very small)
- Ground water level changes 10～100μgal

Preliminary survey at Bangkok



Preliminary survey at Bangkok

- Construction of the GPS base station at Chulalongkorn University and Preliminary GPS survey at the groundwater wells
- Meeting at Department of Mineral Resources
- Meeting at Department of Groundwater Resources
- Investigation of the well location and condition at the eastern part of Bangkok.

Future plan of gravity and GPS survey at Bangkok

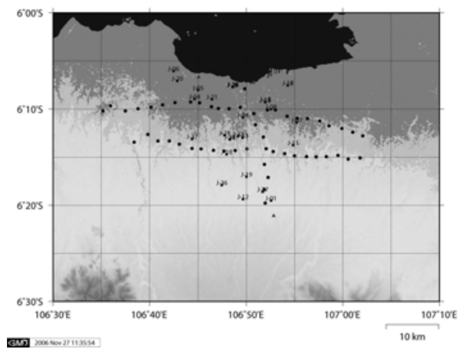
- We will conduct the preliminary gravity and GPS measurement in 2008.
- We will start the repeat gravity (Absolute and Relative) measuremt and GPS survey from 2009.

Preliminary survey at Jakarta

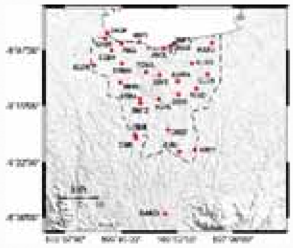
2006-2007 Survey

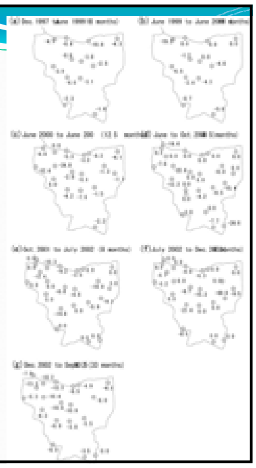
- Select the gravity station (Absolute and Relative)
- Estimation the underground structure using gravity anomaly
- Check the noise level
- Ground subsidence monitoring using GPS (Coducted by ITB)

Gravity monitoring point



Result of Ground subsidence monitoring (Hasanuddin et al., 2007)





Gravity survey

Gravimeter : LaCoste&Romberg Type G (G-956)

Base station : BAKOSURTANAL

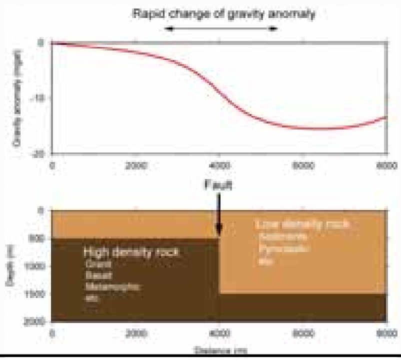
Absolute gravity point (Gravity : 978114860.9±0.3 μ gal)

GPS survey

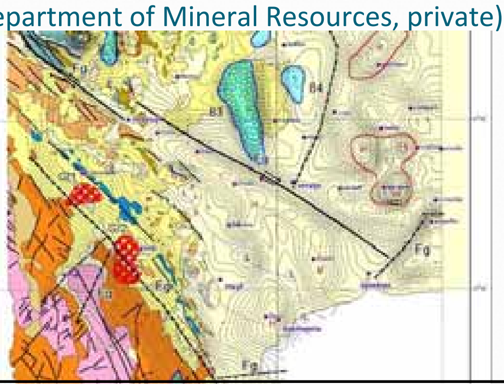
- GPS Receiver : Trimble5400
- Measurement Method : Fast Static(4-15 minute)
- Precision : About 1 cm (Horizontal)
  3-4 cm (Vertical)
  →The effect of Height precision causes less than 0.1mgal

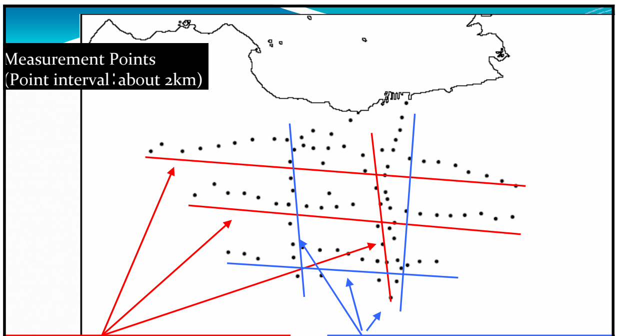
2007	9/4	9/5	9/6	9/7
Heght	34.576m	34.558m	34.587m	34.525m

Gravity survey



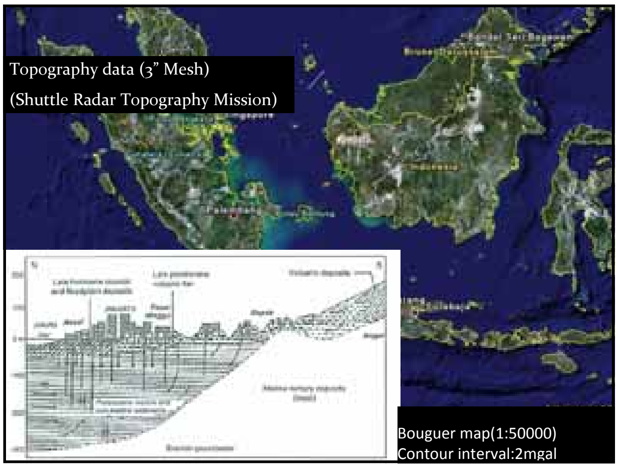
Bouguer anomaly of western Bangkok (Department of Mineral Resources, private)

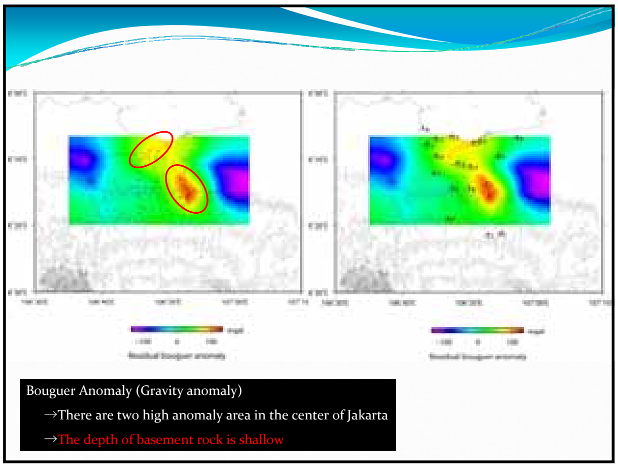


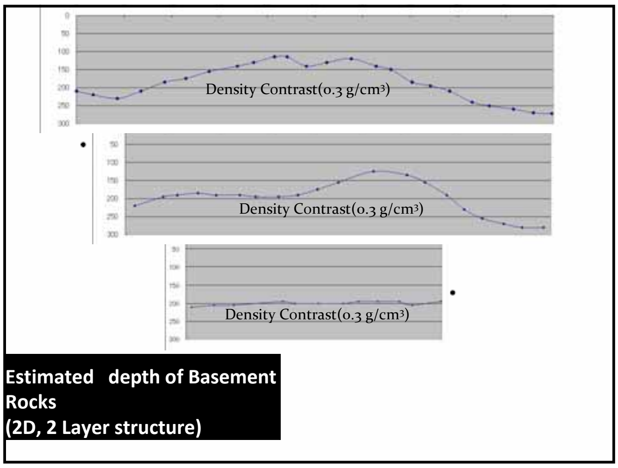


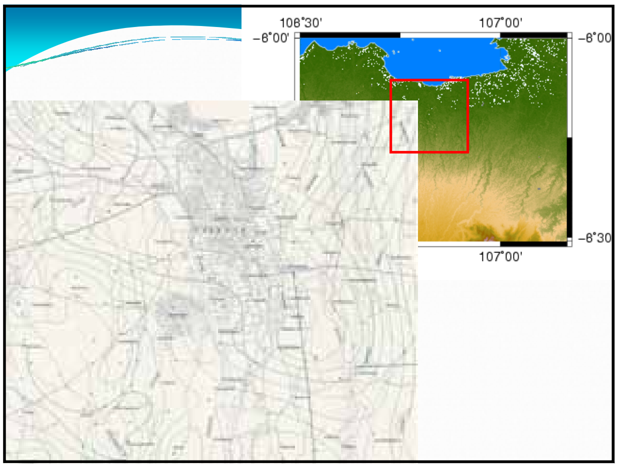
- Measured in 2006
  W-E direction measurement line (24 points, 19 points)
  N-S direction measurement line(8 points)

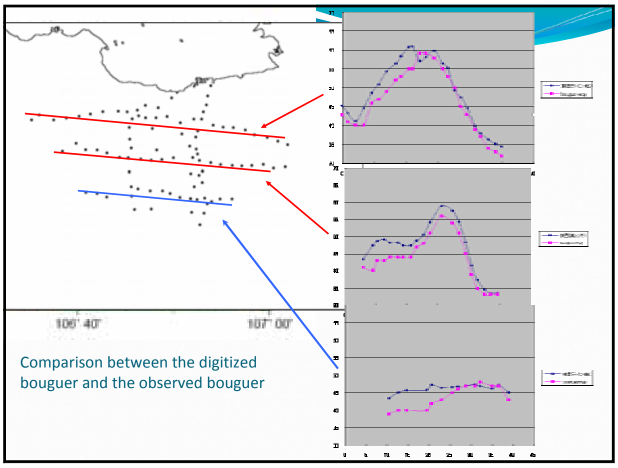
- Measured in 2007
  W-E direction measurement line (14 points)
  N-S direction measurement line (10 points, 12points)











Summary and the Future measure plan

- East – West line
  →The high anomaly was detected in the center of Jakarta. This high anomaly indicates the bulge of basement rocks.
- We will estimate the 3D basement rock structure including the old gravity data.
- We can measure the gravity along the street (The noise is not so big).
- We will start the absolute and relative gravity measurement from 2008.
- Ground subsidence monitoring using GPS will be conducted with ITB.

International Workshop of RIHN in Bali 07-08/12/07

Study on Pollution Discharge Process at Coastal Mega-cities by Material Group

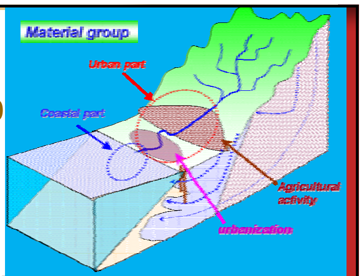
Welcome!

Shin-ichi Onodera* (Grad. School of Integrated Sciences, Hiroshima Univ.)
Tomotoshi Ishitobi, *Yu Umezawa* [Research Institute for Humanity and Nature]
Takahiro Hosono [Akita University], *Mitsuyo Saito* (JSPS fellowship, Hiroshima Univ.)
Makoto Taniguchi (Research Institute for Humanity and Nature: RIHN))

Contents

- General aspects of Material Group for 2 years
- Some results of our group
  - groundwater pollution in urban area :
    - In next presentation By Hosono et al.
  - coastal pollution in coastal area :
    - In this presentation

Activities in Material group for 2 years



- Objective :
  - to confirm accumulation and transport processes of contaminant in coastal mega-city watersheds for more than 3 decades,
  - and to forecast the processes in future.

researched mega-cities in Asia

Research aspects and policies in our group

- Role of Japanese members:
  - Approach to new concept (watershed pollution problem, reconstruction of pollution, etc), and comparison of some cities, intensive research
  - Isotopic and chemical analysis
- Role of International members:
  - Process studies (seasonal variation, SGD, rainwater, etc)
  - Arrangement of intensive research

Japanese Members of our group

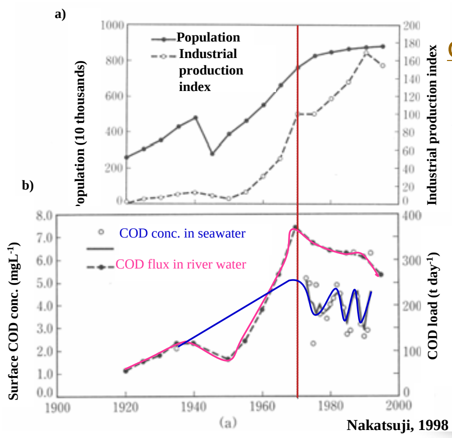
- Core Japanese members:
  - Shin-ichi Onodera, Takanori Nakano, Yu Umezawa, Takahiro Hosono, Tomotoshi Ishitobi, Mitsuyo Saito
- Support Japanese members:
  - Kazuhiko Takeda, Kitagawa
- Osaka members:
  - Mitsuru Hayashi, Tomoyasu Fujii

Corroboration to other group

- Groundwater G. :
  - Water balance, groundwater dating
- Urban G. :
  - Economic and social index, GIS,
- Heat G. :
  - Subsurface thermal data as reaction index

Some results about coastal pollution

A) Current processes as coastal pollution
B) Sediment information on coastal beds
C) Reproduction process of pollution



Osaka:

After 1970
river: ↓
ocean: →
↓
Delayed pollution process!

Objective of Material Group in terms of Land - Ocean Interaction Study

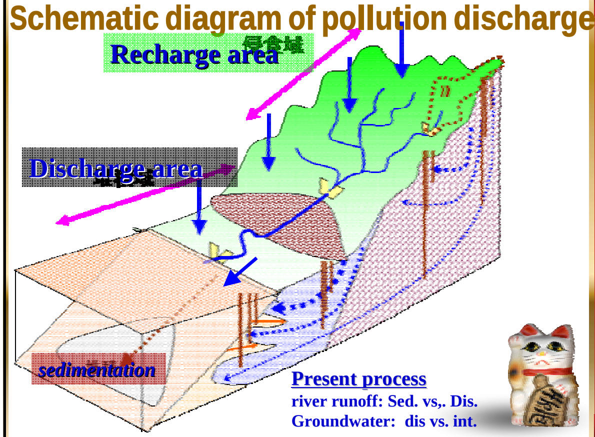
@to evaluate the effect of material load at the mega-cities on ocean environment

A) To confirm the current condition of solute flux on land-ocean interface ; terrestrial groundwater discharge or seawater intrusion

B) To evaluate material accumulation amount in the ocean sediment

C) To clarify the reproduction of accumulated material

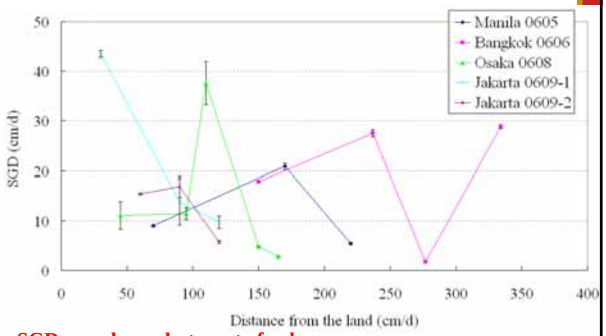
Schematic diagram of pollution discharge



A) Results on a current condition of solute flux

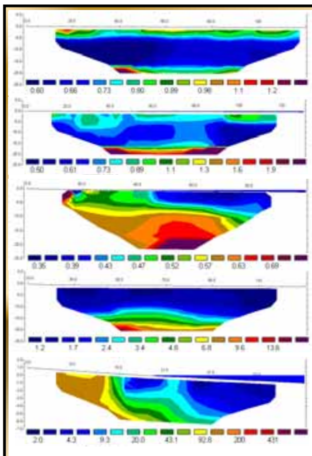
- Observations of seepage meter and resistivity measurements -> Terrestrial submarine groundwater discharge at mega-cities were less. *Ishitobi et al., 2008*
  - Osaka, Bangkok, Manila, Jakarta
  - @total submarine groundwater discharge were large. -> recirculated seawater
- Seawater intrusion: *Onodera et al., in prep.*

Submarine Groundwater Discharge *(Ishitobi, et al.,2008)*



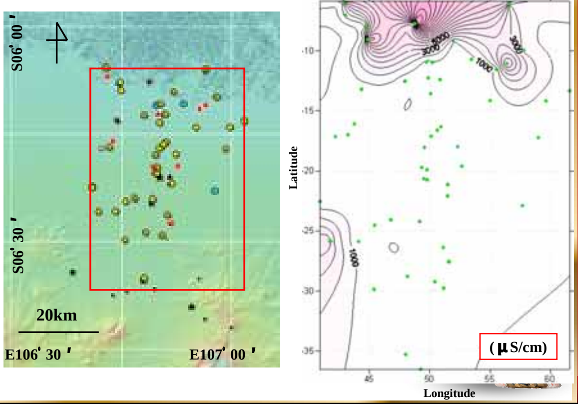
SGD were large, but most of volume were recirculated seawater

Resistivity measurements



	(ohm-m)
Igneous rocks	
Granite	$3\times10^2\sim10^4$
Basalt	$10^3\sim10^5$
Sedimentary rocks	
Glabel	$10\sim10^4$
Mud	$1\sim10^2$
Pore water	
low EC	$2\sim8\times10$
salt water	0.3

Seawater intrusion (2006)



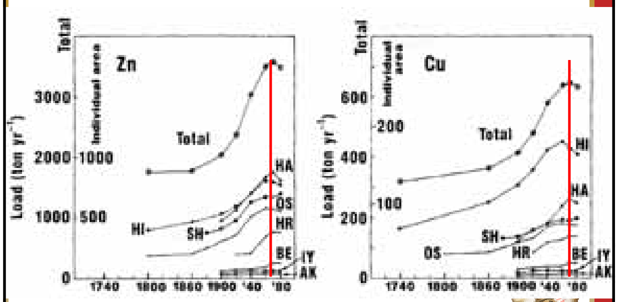
tasks ; current process (A)

- **Seasonal variation in SGD :**
  - Estimation of increasing SGD with groundwater level during a rainy season
  - Ex) Jakarta in February 08
  - Installation of monitoring station of SGD at Manila
- **Scale up of seepage meter method:**
  - tracer method such as Rn, Si
- **Seawater intrusion process :**
  - Resistivity measurement on land area *Ishitobi et al., 2007*
  - New observation system: muti-observation of seepage meter and piezometer, temperature profile method

(B) Results on contaminant accumulations as sea bed sediment

- Collections of sea bed sediments at the each cities
- Chemical profile ->
  - Trace metal profiles *(Hosono et al., in prep.)*
  - Organic property profiles *(Umezawa et al., in prep.)*
  - reconstruction of past pollution, and contaminant accumulations

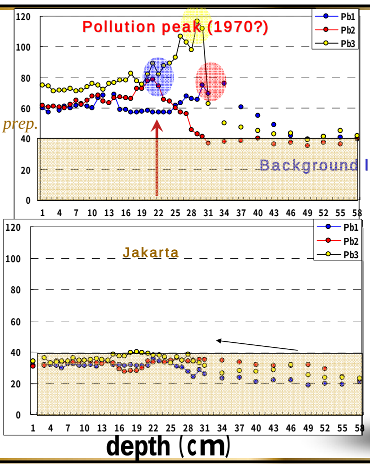
Zn , Cu load in Osaka (Hoshika 1992)



Peak in1970

Pb (ppb)

Hosono et al., in prep.



Zn,Cu,Cd etc.

C & N content at Jakarta &Osaka

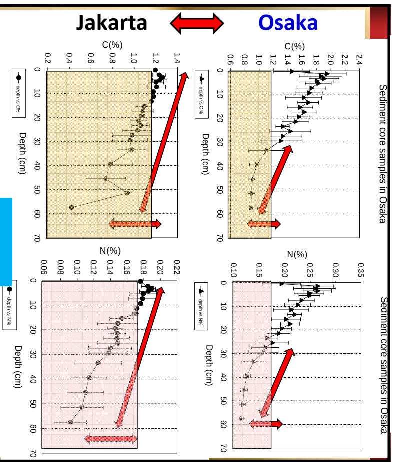
Umezawa et al., in prep.

Carbon (%)

Trend at Jakarta is similar to the trend at Osaka ?!
*Osaka bay : Inland sea
*Jakarta bay : open sea

Nitrogen (%)

N,C isotopic analysis

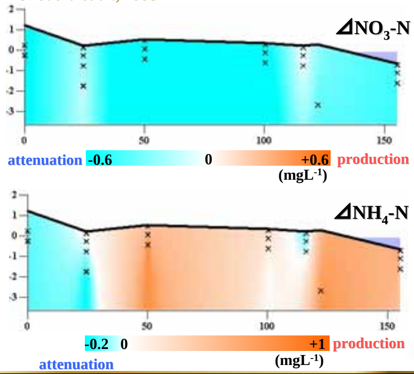


tasks : sediment accumulation (B)

- Dating of sedimentation: by Dr.SU in Taipei
- Quantitative evaluation of pollution accumulation
  - Pollutant content at Osaka was larger than at Jakarta?
    - Economical effect: low GDP etc.
    - Climate effect: high decomposition with high temperature
  - Comparisons at each cities
- Evaluation of contaminant reproduction from sediment→(C)

Nutrient reproduction in tidal slope at Osaka

Onodera et al., 2008



Two component mixing : seawater & terrestrial groundwater

Tasks about reproduction (C)

- Time scale and mass balance
  - When the sediment was supplies and the reproduction started ?
  - How much contaminant was reproduced in all area of the bay ?

summary

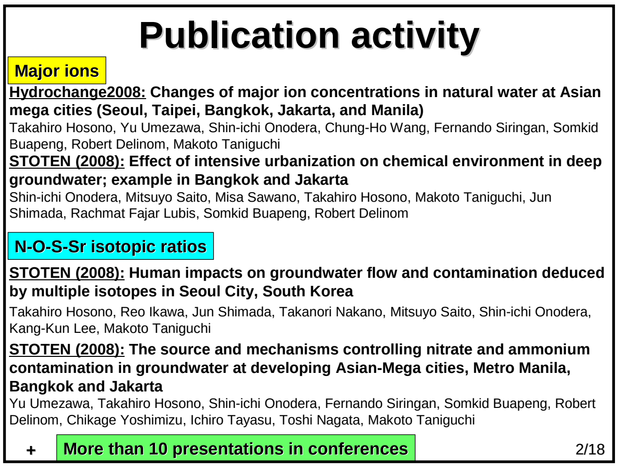
① **Current process :**
- ① No terrestrial groundwater discharge
- ② Seawater intrusion
- ③ Significant seawater recirculation in tidal slope

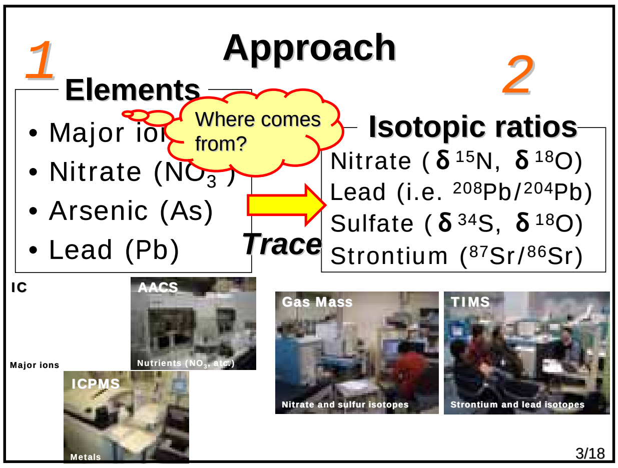
② **Sediment : accumulation & record**
- ① Large contaminant accumulation with the peak in 1970 at Osaka
- ② Surface bed content : Osaka > Jakarta ?

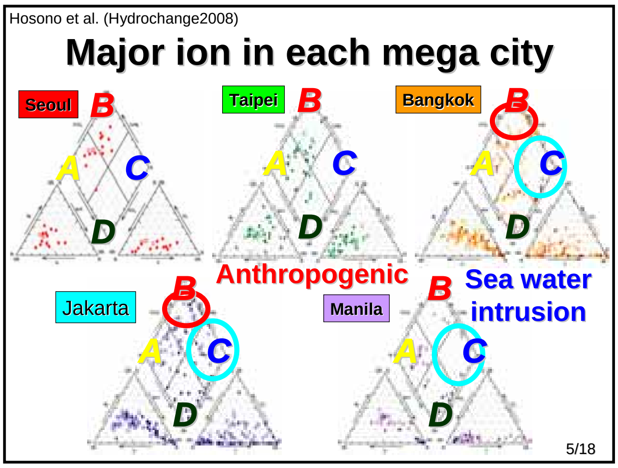
③ **Reproduction :**
- ① Nutrient reproduction in tidal slope

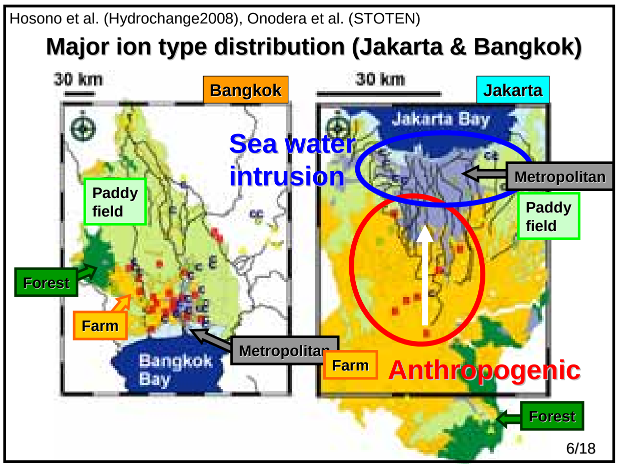
Thank you for your attention!

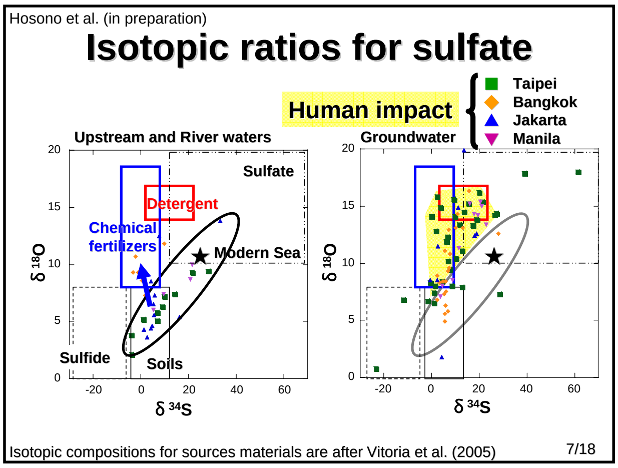

Material Group / Land Team
2007/12/7-8 RIHN International Workshop
at Bali, Indonesia
Result of Material Group study
(terrestrial part)
~ Pollution status and mechanism in each Asian mega city~
Groundwater
River water
Rain water
Waste water
Rocks
Fertilizers
Coastal sediment core
Oil products
Presentation: Takahiro Hosono (Akita Univ., Japan)
1/18

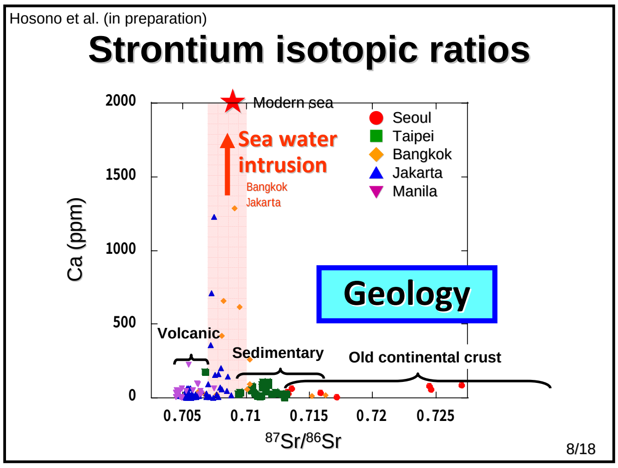

Publication activity
Major ions
Hydrochange2008: Changes of major ion concentrations in natural water at Asian mega cities (Seoul, Taipei, Bangkok, Jakarta, and Manila)
Takahiro Hosono, Yu Umezawa, Shin-ichi Onodera, Chung-Ho Wang, Fernando Siringan, Somkid Buapeng, Robert Delinom, Makoto Taniguchi
STOTEN (2008): Effect of intensive urbanization on chemical environment in deep groundwater; example in Bangkok and Jakarta
Shin-ichi Onodera, Mitsuyo Saito, Misa Sawano, Takahiro Hosono, Makoto Taniguchi, Jun Shimada, Rachmat Fajar Lubis, Somkid Buapeng, Robert Delinom
N-O-S-Sr isotopic ratios
STOTEN (2008): Human impacts on groundwater flow and contamination deduced by multiple isotopes in Seoul City, South Korea
Takahiro Hosono, Reo Ikawa, Jun Shimada, Takanori Nakano, Mitsuyo Saito, Shin-ichi Onodera, Kang-Kun Lee, Makoto Taniguchi
STOTEN (2008): The source and mechanisms controlling nitrate and ammonium contamination in groundwater at developing Asian-Mega cities, Metro Manila, Bangkok and Jakarta
Yu Umezawa, Takahiro Hosono, Shin-ichi Onodera, Fernando Siringan, Somkid Buapeng, Robert Delinom, Chikage Yoshimizu, Ichiro Tayasu, Toshi Nagata, Makoto Taniguchi
+ More than 10 presentations in conferences
2/18

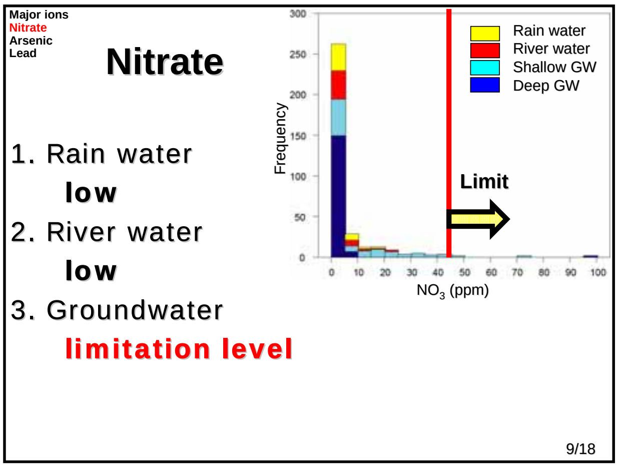

Approach
1
Elements
• Major ion
• Nitrate (NO3-)
• Arsenic (As)
• Lead (Pb)
Where comes from?
Trace
2
Isotopic ratios
Nitrate (δ15N, δ18O)
Lead (i.e. 208Pb/204Pb)
Sulfate (δ34S, δ18O)
Strontium (87Sr/86Sr)
IC
Major ions
AACS
Nutrients (NO3, etc.)
ICPMS
Metals
Gas Mass
Nitrate and sulfur isotopes
TIMS
Strontium and lead isotopes
3/18

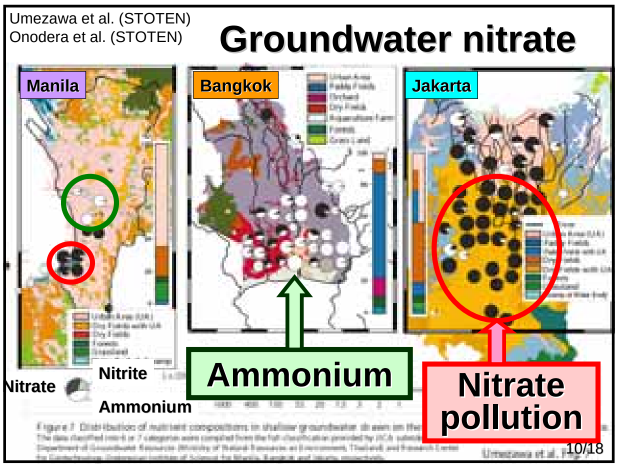

Hosono et al. (Hydrochange2008)
Major ion in each mega city
Seoul
Taipei
Bangkok
Jakarta
Manila
A
B
C
D
Anthropogenic
Sea water intrusion
5/18

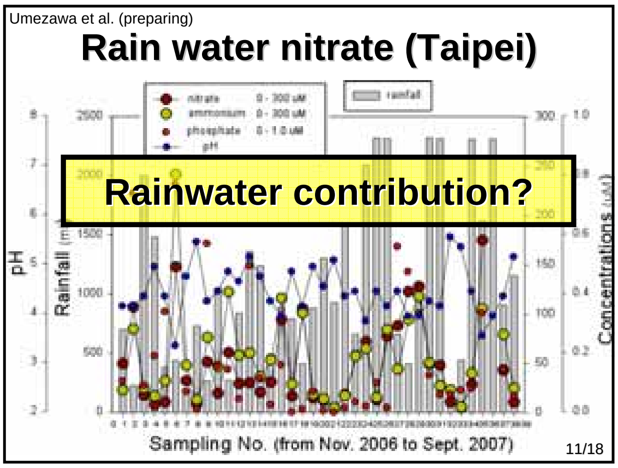

Hosono et al. (Hydrochange2008), Onodera et al. (STOTEN)
Major ion type distribution (Jakarta & Bangkok)
30 km
Bangkok
Jakarta
Sea water intrusion
Jakarta Bay
Metropolitan
Paddy field
Forest
Farm
Bangkok Bay
Anthropogenic
6/18

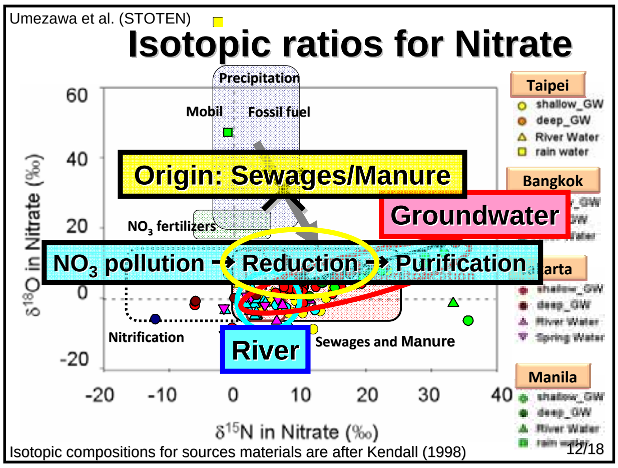

Hosono et al. (in preparation)
Isotopic ratios for sulfate
Human impact
Taipei
Bangkok
Jakarta
Manila
Upstream and River waters
Groundwater
Sulfate
Detergent
Chemical fertilizers
Modern Sea
Sulfide
Soils
δ18O
δ34S
Isotopic compositions for sources materials are after Vitoria et al. (2005)
7/18

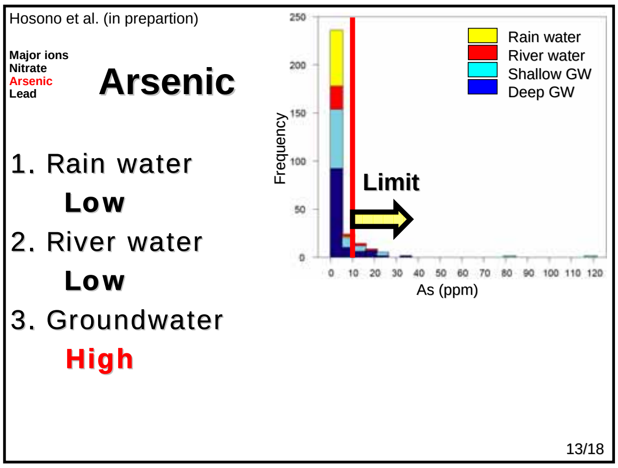

Hosono et al. (in preparation)
Strontium isotopic ratios
Modern sea
Sea water intrusion
Bangkok
Jakarta
Seoul
Taipei
Bangkok
Jakarta
Manila
Geology
Ca (ppm)
2000
1500
1000
500
0
Volcanic
Sedimentary
Old continental crust
0.705
0.71
0.715
0.72
0.725
$^{87}Sr/^{86}Sr$
8/18


Major ions
Nitrate
Arsenic
Lead
Nitrate
1. Rain water
low
2. River water
low
3. Groundwater
limitation level
Frequency
Rain water
River water
Shallow GW
Deep GW
Limit
NO_3 (ppm)
9/18


Umezawa et al. (STOTEN)
Onodera et al. (STOTEN)
Groundwater nitrate
Manila
Bangkok
Jakarta
Nitrite
Nitrate
Ammonium
Ammonium
Nitrate pollution
10/18

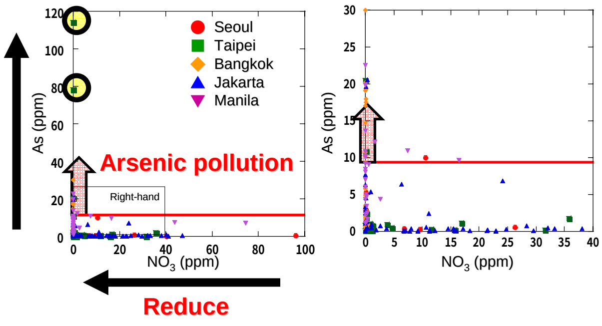

Umezawa et al. (preparing)
Rain water nitrate (Taipei)
Rainwater contribution?
pH
Rainfall
Concentrations
Sampling No. (from Nov. 2006 to Sept. 2007)
11/18


Umezawa et al. (STOTEN)
Isotopic ratios for Nitrate
Precipitation
Mobil
Fossil fuel
Origin: Sewages/Manure
Groundwater
NO_3 fertilizers
NO_3 pollution → Reduction → Purification
Nitrification
River
Sewages and Manure
Taipei
Bangkok
Jakarta
Manila
$\delta^{18}O$ in Nitrate (‰)
$\delta^{15}N$ in Nitrate (‰)
Isotopic compositions for sources materials are after Kendall (1998)
12/18


Hosono et al. (in prepartion)
Major ions
Nitrate
Arsenic
Lead
Arsenic
1. Rain water
Low
2. River water
Low
3. Groundwater
High
Frequency
Rain water
River water
Shallow GW
Deep GW
Limit
As (ppm)
13/18

Hosono et al. (RIHN news letter), Hosono et al. (in preparation)

Groundwater arsenic

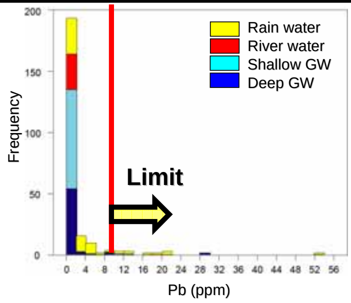


Hosono et al. (in preparation)

Major ions
Nitrate
Arsenic
Lead

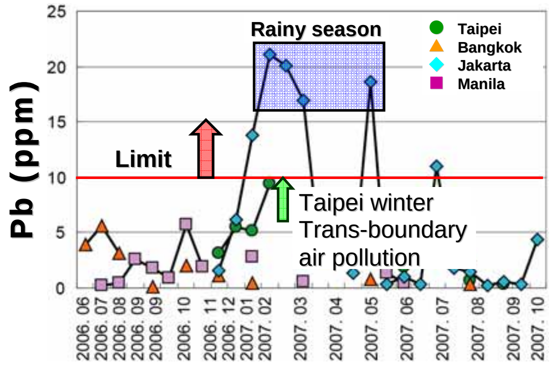
Lead

1. Rain water
   High
2. River water
   Low
3. Groundwater
   Low
4. Sediment core (lead and cadmium)
   ✓**time dependency** *Onodera*
   ✓**different pattern in each city**



Hosono et al. (in preparation)

Rain water lead



Summary: Pollution status comparison

	Rain water			River water			Groundwater			Sediment	
	NO_3^-	As	Pb	NO_3^-	As	Pb	NO_3^-	As	Pb	N, C	Pb
Osaka	in preparation	in preparation	in preparation	in preparation	in preparation	in preparation	in preparation	in preparation	in preparation	Higher	Higher
Seoul	in preparation	in preparation	in preparation	Lower	Lower	Lower	Higher	Medium	Lower	in preparation	in preparation
Taipei	Medium	Lower	Higher	Lower	Lower	Lower	Medium	Higher	Medium	in preparation	in preparation
Bangkok	in preparation	Lower	Lower	Lower	Lower	Lower	Lower	Higher	Lower	in preparation	in preparation
Jakarta	in preparation	Lower	Higher	Lower	Lower	Lower	Higher	Lower	Lower	Lower	Lower
Manila	in preparation	Lower	Lower	Lower	Lower	Lower	Medium	Higher	Lower	Lower	Lower

Compared to environmental standard…

Higher | Medium or Occasionally higher | Lower | in preparation

Future works

1. Additional filed survey
2. Isotopic analysis for potential source materials — **Material G.**
3. Nitrate concentration reconstruction
4. Sedimentation age (with Dr. Su, NTU)
5. Material transportation — **Water G.**
6. Relationship between pollutions and land use — **Urban Geography G.**
7. Relationship between pollutions and economic status — **Social Economy G.**

Thank you!

Evolution of the Subsurface Thermal Environment in Urban Areas

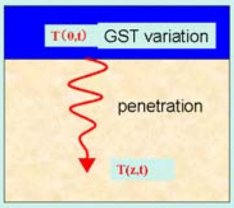
Report of the Heat Group

Makoto Yamano
Earthquake Research Institute, University of Tokyo

2007,12 Bali International WS

Reconstruction of the ground surface temperature (GST) history

Penetration of GST variation into subsurface



$$\frac{\partial T}{\partial t} = \kappa \frac{\partial^2 T}{\partial z^2}$$

κ: thermal diffusivity

Information on the past has been recorded in the subsurface.

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Geothermal method for GST history reconstruction

Features

- Directly determined from temperature data (not through conversion from the proxies)
- Long-term trend (century scale) is obtained.
- Times and areas with no meteorological data

The GST history should contain information on:
Temporal variation of the local climate
Changes in the land use
and so on

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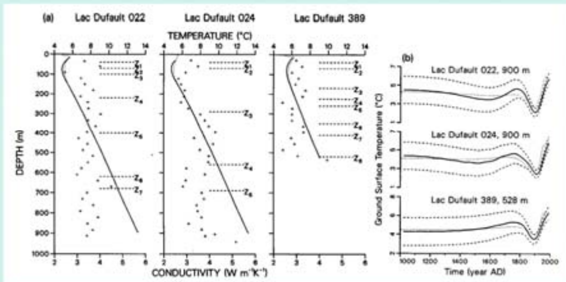
Examples



Wang et al. (1992)

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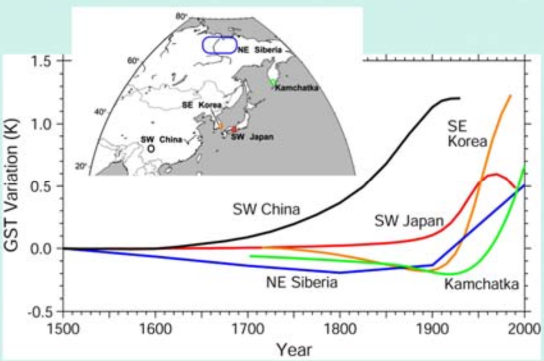
Reconstructed GST histories in East Asia



Climate change, Environment change, Human activity, etc.

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Research Objectives

1. Temperature logging in boreholes
   → Reconstruction of GST history
2. Long-term temperature monitoring at multiple depths
   → Detection of propagation process of GST variation

↓

Investigation of thermal environment evolution at the ground surface

air temperature, land use, groundwater flow, etc.

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Measurements in target areas

Seoul	Sep. 2005	14 sites
Bangkok	Jul. 2004	27 sites
	Jun. 2006	19 sites (repeated at 5 sites)
Taiwan	Nov. 2005	11 sites
	Jun. 2006	18 sites (repeated at 8 sites)
Jakarta	Sep. 2006	26 sites
	Aug. 2007	9 sites (repeated at 9 sites)

Measurement depth: 100 to 200 m at most sites

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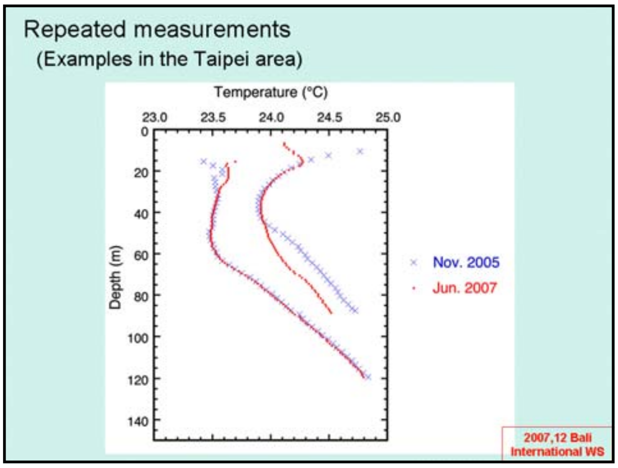
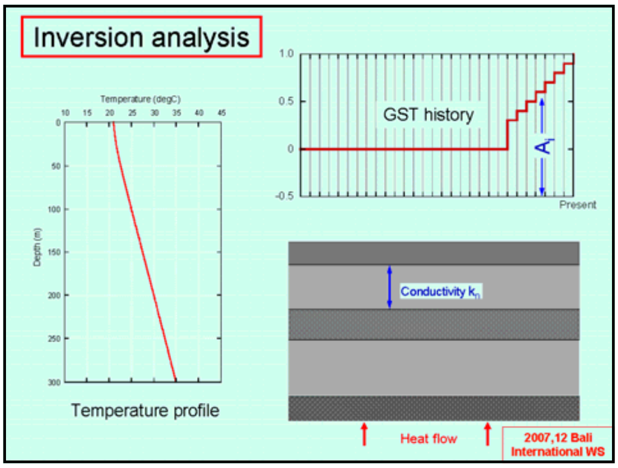
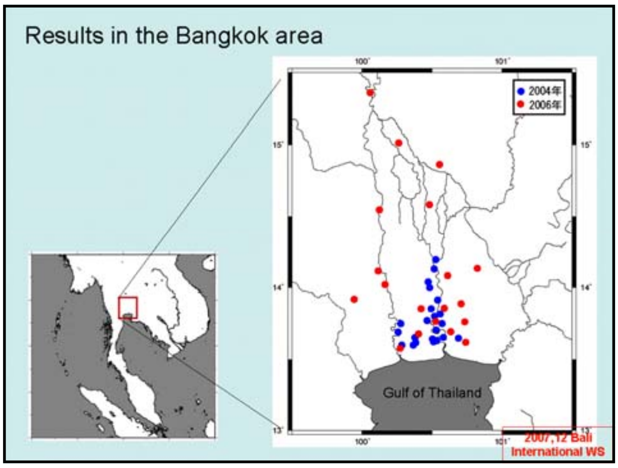
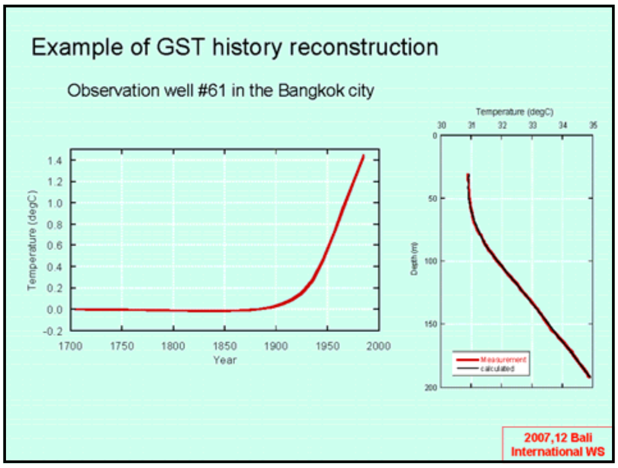
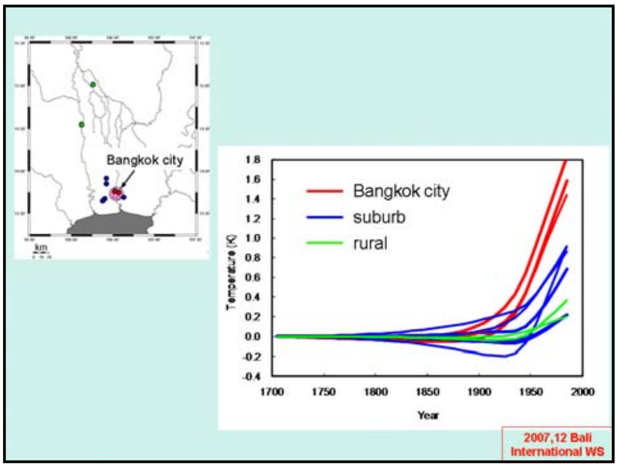


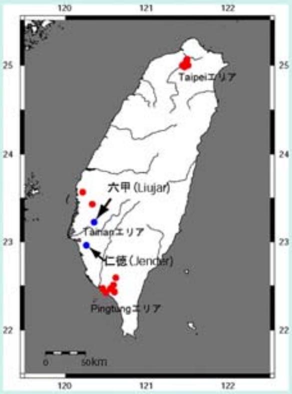


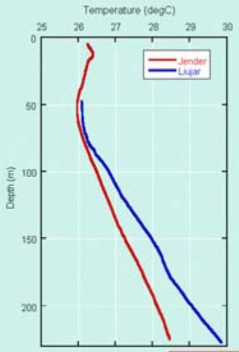






Results in Taiwan





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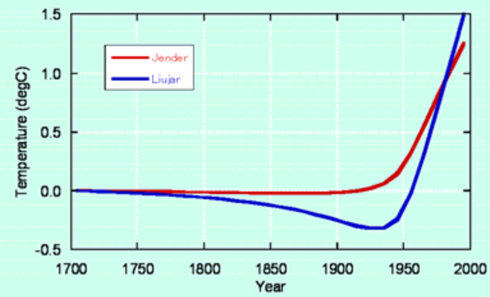

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Long-term temperature monitoring

Penetration of GST variations

- Mechanism of heat transfer
  - Conduction vs. Advection
  - Estimation of thermal diffusivity
- Relationship between GST and SAT

Temporal variations in groundwater flow

- Natural variations
- Effects of human activities

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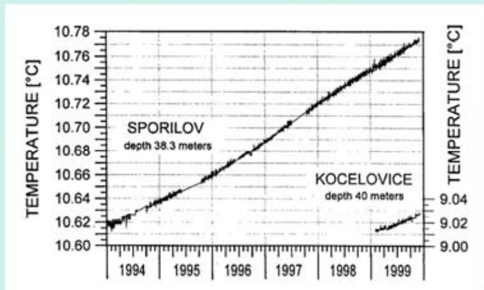
Penetration of long-term GST variation



Czech Republic
(Cermak et al., 2000)

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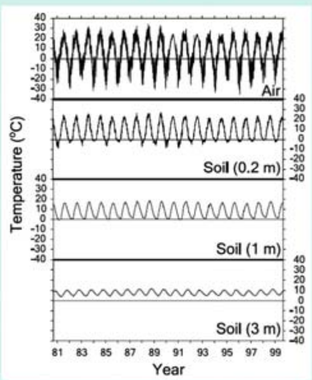
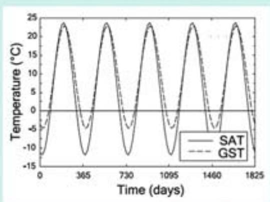
Relationship between GST and SAT

(surface air temperature)





Fargo, North Dakota
(Smerdon et al., 2003)

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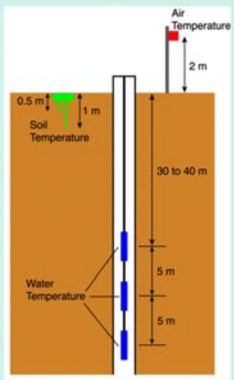
Monitoring of borehole and soil temperatures



Taiwan
Nov. 2005 – Jun. 2007 at 2 sites
Jun. 2007 –

Jakarta
Sep. 2006 – Aug. 2007 at 3 sites
Aug. 2007 –

Bangkok
Jun. 2006 – at 3 sites

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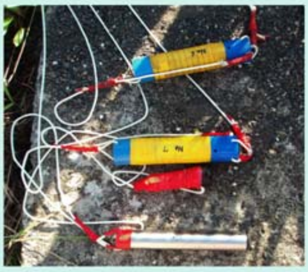
Water temperature recorders
for borehole temperature monitoring



Resolution: 1 mK

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Loggers and sensors
for soil temperature monitoring

Resolution: 0.1 K

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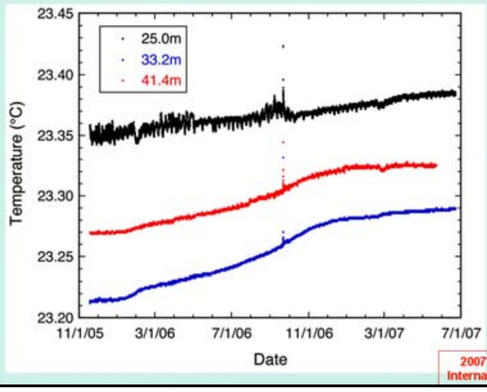
Example of borehole temperature records
(Taipei area)



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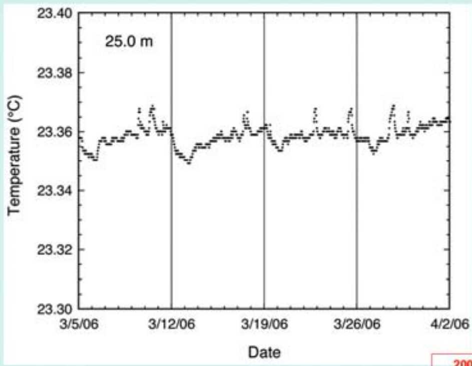
Short-period variations



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Tentative research plan for 2008 (Heat group)

Field surveys

Bangkok (Feb. to Mar.)
Jakarta (Jul. to Aug.)
Taiwan (Nov. to Dec.)

- Temperature profile measurements
  - to be continued by the counter part
- Long-term temperature monitoring
  - data recovery and re-installation of the instruments

(Tokyo and Osaka)

Data analysis

GST history reconstruction from the existing data
- Seoul, Tokyo, and Osaka

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Summary

Borehole temperature profiles
- Repeated measurements have been conducted.
- Existing data will be used for analysis.

Reconstruction of GST history
- Bangkok area
  - Surface warming is larger in the city (heat island effect).
- Effect of groundwater flow needs to be considered.

Long-term monitoring of borehole and soil temperatures
- Peculiar short-period variations were detected.
- Relationship between GST and SAT should be investigated.

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RIHN project 2-4 FR Human Impacts on Urban Subsurface Environments

Reconstruction of the thermal environment evolution in Jakarta

Rachmat Fajar Lubis
Hydrogeology Ph.D Program in Chiba University, Japan

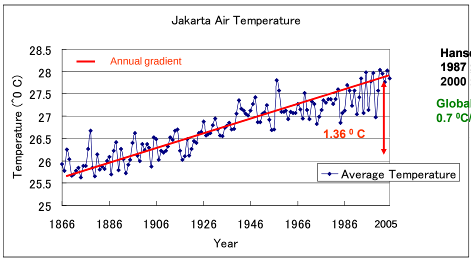
Introduction

Temperatures in boreholes can be an important source of information on recent climatic changes, because the normal upward heat flow from the Earth's crust and interior is perturbed by the downward propagation of heat from the surface.

Ground surface temperature (GST) slowly propagates into subsurface sediments and basement rocks by thermal diffusion in 10^{-6} to 10^{-7} m^2/s. Therefore, the GST variations in the last several hundred years could be recorded as the underground temperature distribution in the upper several hundred meters.

This report intends to reconstruct GST history in Jakarta mega cities, Indonesia. Subsurface temperatures in Jakarta city, where population and density increase rapidly, were analyzed to evaluate the effects. GST history will reconstruct from vertical temperature profiles measured in boreholes.

AIR TEMPERATURE AT JAKARTA



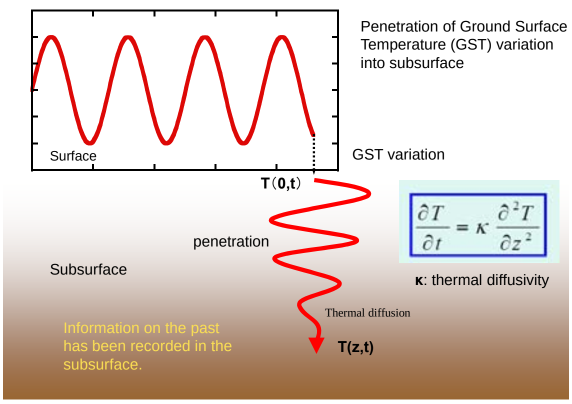
Hansen and Lebendeff, 1987 ; Huang et.all, 2000 :

Global warming : 0.5 – 0.7 ºC/100 year

The rest is effect of heat island

Indonesia Ministry of Environment & NOAA, BMG

Geothermal method of past climate reconstruction

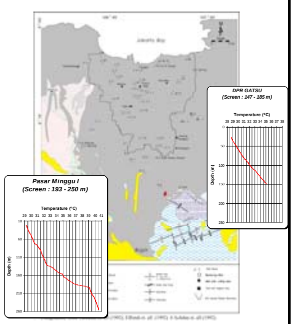


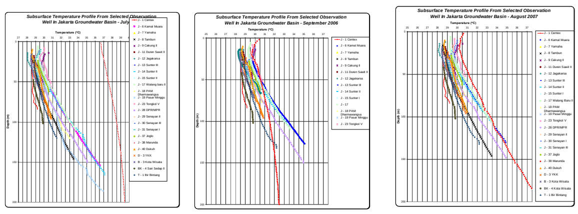
Method
Thermal Measurement Data From Borehole Observation Well

The thermal profiles and water levels in 25 observation wells (40 – 200 m deep) were measured in July, 2004, September 2006 and August 2007.

The thermal-profile measurements were made at 2-m intervals from the water level to the bottom of the hole with a digital thermister thermometer of 0.01 ºC precision.

The boreholes selected are monitoring well, therefore ideal for thermal studies. Due to the time elapsed since their construction, they can be considered to have attained steady-state thermal conditions.





it shows that temperature profiles from July 2004 - August 2007 are nearly identical, indicates that the temperature regime is stable, and curvature is not a transient effect.

Thermal Conductivity Analysis

Thermal conductivity for Jakarta Groundwater Basin

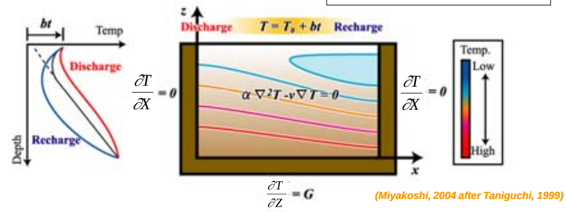
Geology Unit	Depth (meter)	Thermal Conductivity	
		Kcal/m h ^{0}C	Wm^{-1}K^{-1}
Soil	0 – 3	1.3	1.2
Conglomerate	50-60	1.64	1.91
Silt and clay	60-80	1.21	1.41
Sand	80-110	1.70	1.98

Thermal conductivity already measurement use Shoterm QTM DII-76 (Showa Denko Japan, Ltd) in Chiba University. Sample taken from Blok M well and the results are shown

Thermal conductivity values for aquifer system (Conglomerate and Sand) have a very similar range. It shows that the possibilities of curvature effect due to the conductivity are no coherent changes in the temperature-depth curves.

Groundwater Flow and Subsurface Temperature

h, = groundwater hydraulic head
v = groundwater flow felocity
T = subsurface temperature
Ts = constant surface temperature,
G = constant temperature gradient,
x, z are coordinate
t = time

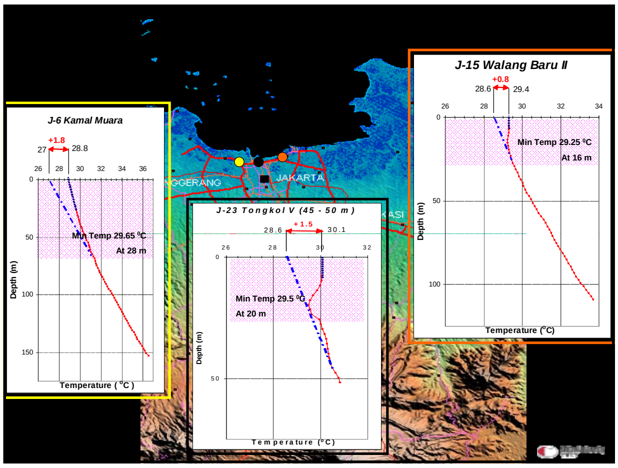


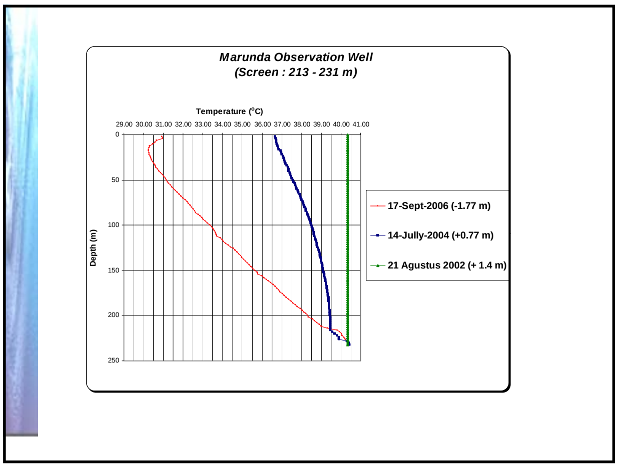
(Miyakoshi, 2004 after Taniguchi, 1999)

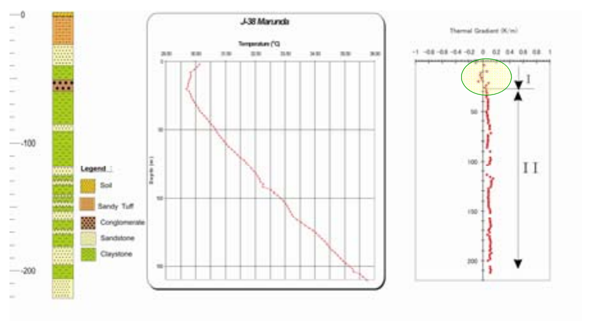
Thermal regime caused by the effects of groundwater flow and surface temperature warming

Subsurface temperature is created by

heat conduction, heat convection and surface warming







Governing to equation and condition

1-D Thermal conduction and convection
(Stallman, 1963; Bredehoeft and Papadopulos, 1965)

$$\frac{\partial T}{\partial t} = \frac{k}{c\rho} \cdot \frac{\partial^2 T}{\partial z^2} - \frac{c_w \rho_w}{c\rho} Vz \frac{\partial T}{\partial z}$$

Upper condition

z = 0 ; t > 0

$$T = T_0 + bt$$

* Surface temperature increase rapidly

Lower condition
*geothermal gradient

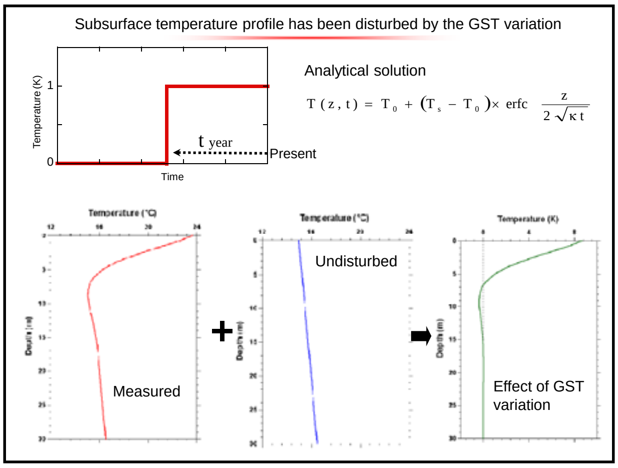
$$a = \frac{\partial T}{\partial z}$$

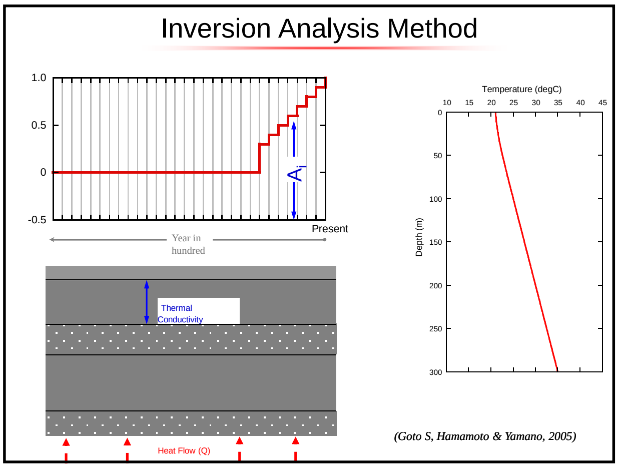
Initial condition

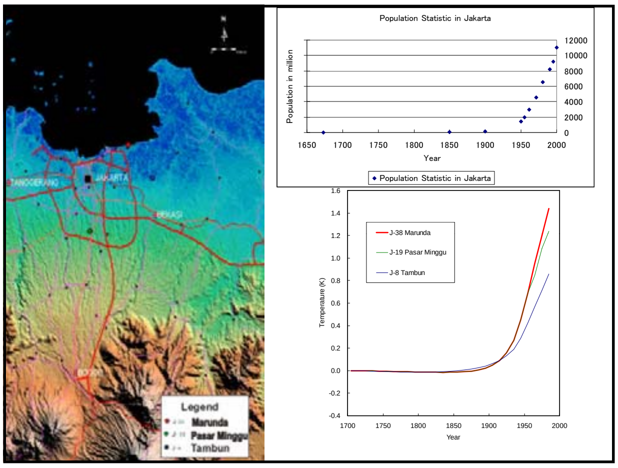
z > 0 ; t=0

$$T = T_0 + az$$

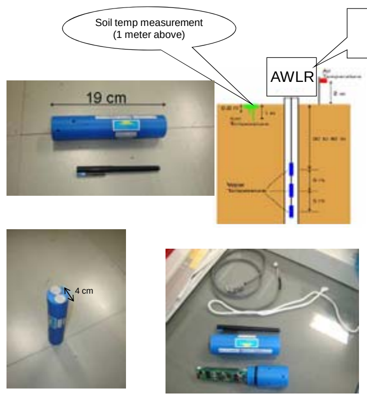
- T : temperature (℃)
- t : time (y)
- k : thermal cond. (J/m・y・℃)
- z : depth (m)
- T_0 : surf. Temp. at t=0 (℃)
- a : thermal gradient (℃/m)
- b : increase rate of surf. temp (℃/y)
- $C_w \rho_w$: heat capacity of fluid (J/m^3・℃)
- $C\rho$: heat capacity of aquifer(J/m^3・℃)
- Vz : vertical groundwater flux (m/y)





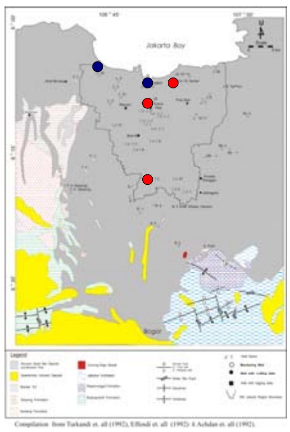


Continuous GST Measurement Research In Jakarta Groundwater Basin



Continuous GST Measurement & Schematic Site Location

- It will put on 35 – 40 -45 m under the surface.
- Together with automatic soil temperature measurement (50 cm & 1 meter under the surface), automatic air temperature measurement (2 meter) and automatic water level measurement (Pressure system)



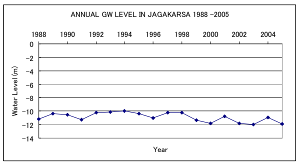
GST Location

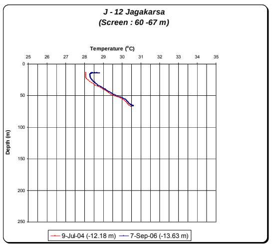
Base on Data Analysis from selected observation well

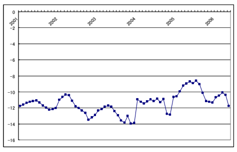
Remarks :

- GST location include automatic water level measurement (pressure system)
- Water level measurement (pressure system) Only

Installed from September 2006

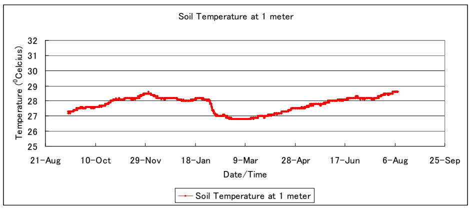




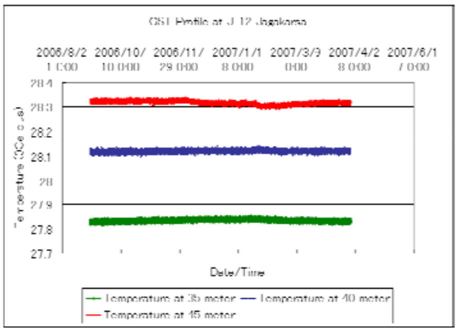


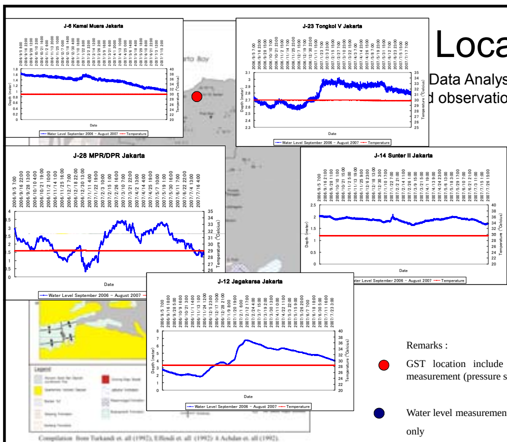
Jagakarsa J-12

Soil Temperature September 2006 – August 2007



Continuous GST Measurement





Location

Data Analysis from
d observation well

Remarks :

GST location include automatic water level measurement (pressure system)

Water level measurement (pressure system) only

The purpose of this research was to Investigation thermal environment evolution at the ground surface cause by air temperature, land use, groundwater flow, etc.

Reconstruction of GST (ground surface temperature) history → Temperature logging in boreholes

Features of the research will be :
- Directly determined from temperature data
- Long-term trend (century scale) is obtained.
- Times and areas with no meteorological data can be covered.

The GST history will contain information on:
- Temporal variation of the local climate
- Changes in the land use

Detection of propagation process of GST variation → Long-term temperature monitoring at multiple depths especially the soil temperature

Conclusion :

- **As a result, T-D profile in selected observation well shows tendency of the subsurface warming near the ground surface.**
- **The difference of extrapolated surface temperature between observed temperature and thermal gradient was estimated to be 1.4 ℃, which agree well with air temperature records during the last 100 years. Observed-temperature-depth apart from thermal gradient may show the time of starting urbanization**
- **Using evidence of ground subsurface temperature (GST) to determine surface warming in Jakarta as a mega cities in Indonesia, estimated about 0.14 K /100 year**
- **Theoretically, when a large amount of heat comes into or out of the ground, the temperature of the rocks and water must change accordingly.**

Discussion :
- **Subsurface temperature increases may mobilize the global stock of soil organic matter which can affected the groundwater quality and change local or regional groundwater flow system.**
- **Continuously research are done to determine this subsurface warming tendency caused by human activity, geological condition or climatologically changes, also the environmental impact**

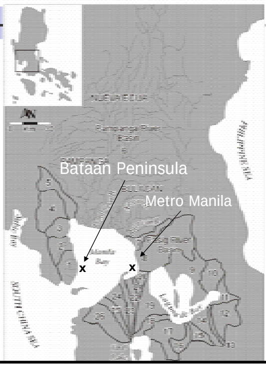
Groundwater Discharge and Nutrient Fluxes off Metro Manila, Philippines Based on ^{222}Rn Measurements

Bill Burnett and Ricky Peterson: FSU
Fernando Siringan: MSI
Yu Umezawa and Makoto Taniguchi: RIHN

Potential Impacts of Submarine Groundwater Discharge (SGD)

- Quantity: changing water levels increases/reduces SGD – saline intrusion, effects on ecology
- Quality: Pathway for dissolved solutes between land and sea; effects on nearshore chemistry, ecology

Manila Bay

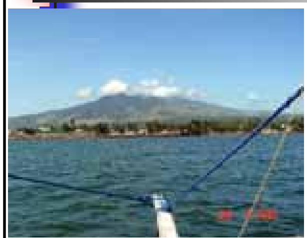


Nutrient inputs via SGD assessed off Bataan in January 2005;

Nutrients inputs via SGD off Metro Manila were measured in May 2006

Study Sites in Manila Bay

Bataan Peninsula **Metro Manila**



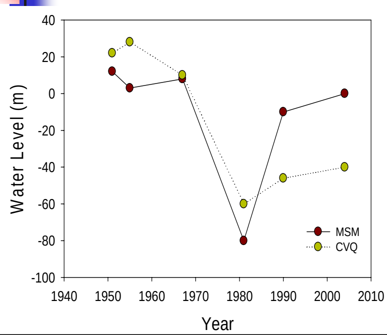
Bataan Peninsula: rural, agricultural; high relief; artesian aquifers present

Metro Manila: heavily urbanized; moderate relief; groundwater pumping has lowered water table

Vessel used for radon surveys...

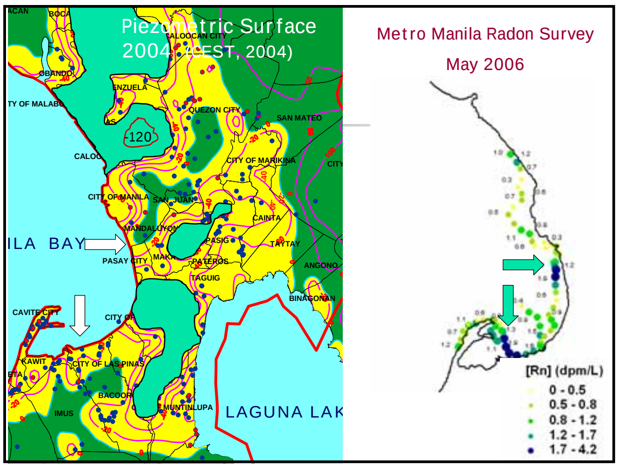
Rn a good tracer of groundwater discharge

Water Levels: Metro Manila

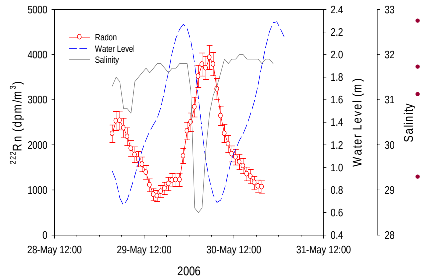


MSM = Manila – San Juan – Mandaluyong

CVG = Caloocan – Valenzuela – Quezon City

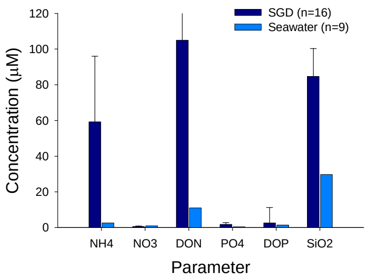


Time-Series Experiment



- Time-series run May 28-30, 2006
- ~300 m off Cavite
- End-member Rn = 288±41 dpm/L (piezometer samples, n=8)
- Flux = 0-12.5 cm/d; av = 2.9 cm/d (av. Seepage meter rate = 5.4 cm/day)

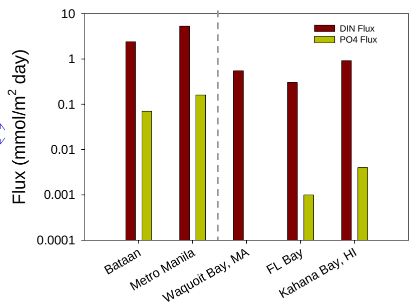
Nutrient Concentrations



Plot shows that much higher concentrations of nutrients are found in seepage waters compared to ambient seawater (Bataan data; Taniguchi et al., in press)

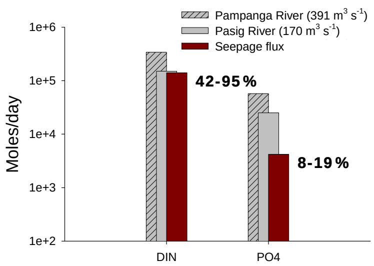
DIN and PO_4 Specific Fluxes

note log scale



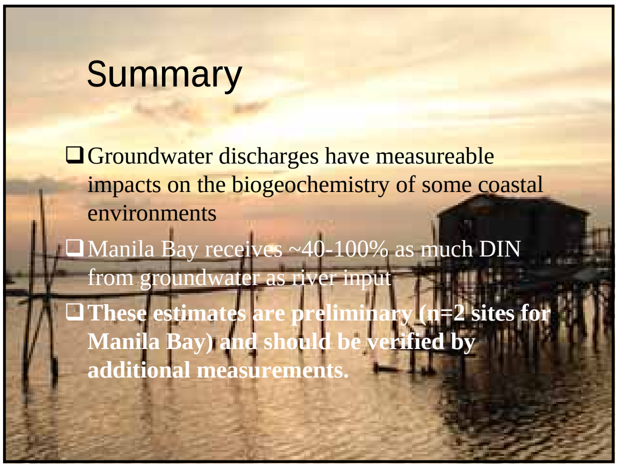
Nutrient Fluxes to Manila Bay Relative to Rivers

note log scale



Assumes shoreline ~25% Metro Manila, ~75% Bataan

Nutrient Flux (moles day^{-1}) = conc. (moles m^{-3}) x seepage (m^3 m^{-2} day^{-1}) x width seepage face (m) x shoreline length (km) x 10^3 m km^{-1} [Manila Bay = 190 km]



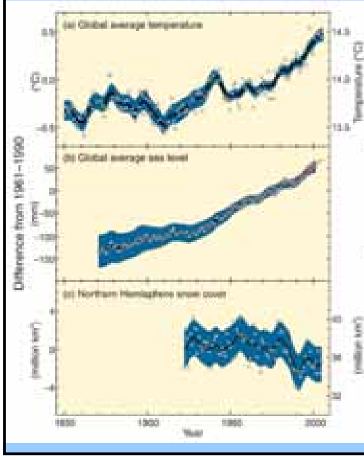
Summary

- Groundwater discharges have measureable impacts on the biogeochemistry of some coastal environments
- Manila Bay receives ~40-100% as much DIN from groundwater as river input
- **These estimates are preliminary (n=2 sites for Manila Bay) and should be verified by additional measurements.**

Warming Effects on Surface and Subsurface Thermal Environment of Taipei, Taiwan

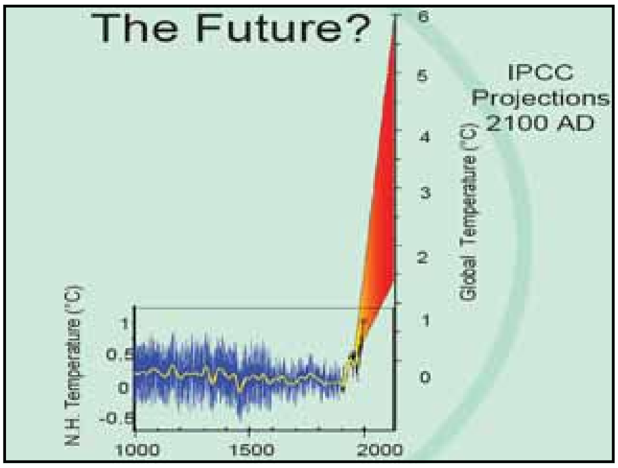
Chung-Ho Wang[1], Wen-Zer Lin[1], Makoto Taniguchi[2], Makoto Yamano[3], Shaopeng Huang[4]

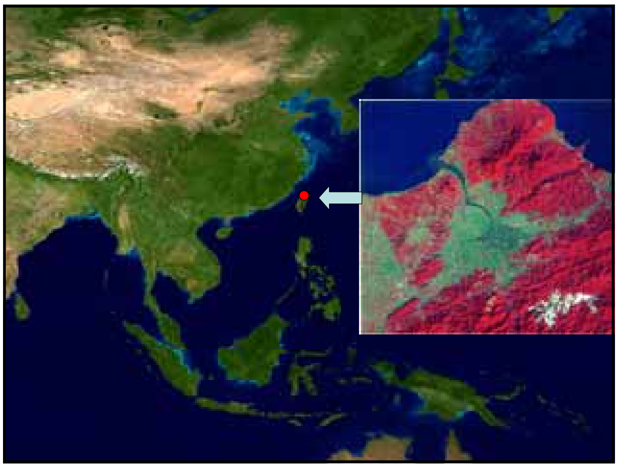
1 Institute of Earth Sciences, Academia Sinica, P.O.B. 1-55, Taipei Nanking, 11529, Taiwan, ROC
2 Research Institute for Humanity and Nature, 457-4 Motoyama, Kamigamo, Kita-ku, Kyoto, 603-8047, Japan
3 Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi Bunkyo-ku, Tokyo, 113-0032, Japan
4 Department of Geological Sciences, University of Michigan, Ann Arbor, Michigan 48109-1005, USA

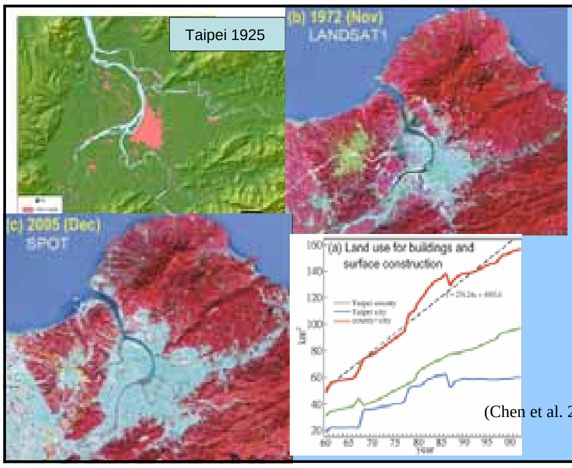


Warming of the climate system is unequivocal

- Increasing global air and ocean temperatures
- Rising global average sea level
- Reductions of snow and ice







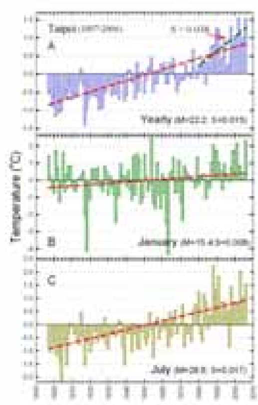
(Chen et al. 2007)

Taipei has a linear rising rate of 0.15°C per decade for the annual records, that is a factor of 2 higher than the world average.

The rising rate after 1980 shows a faster speed (0.38°C/decade) than the linear rate for the past century, suggesting the recent acceleration of climate warming in the Taipei Basin.

Winter (slope = 0.008) shows a relative slow rate than that of summer (slope = 0.017), but also exhibits great fluctuations.

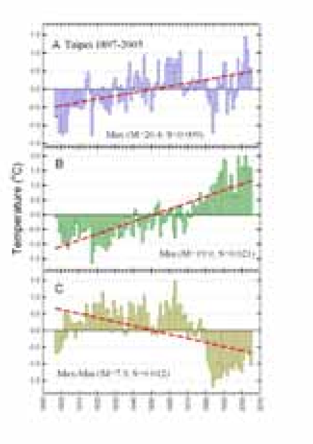
Summer temperatures have been warming more profound that the winter ones.

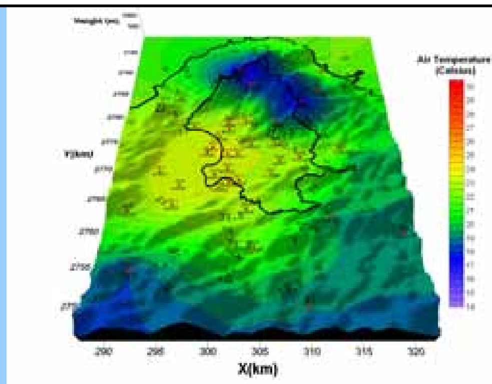


Regarding the diurnal variations, both the mean maximum and minimum temperature records show a rising trends but with different rates.

The mean minimum temperature expresses a fast rising rate (0.21°C/decade) than the mean maximum (0.09°C/decade), indicating that night temperatures have been warming relative fast than that of day temperatures.

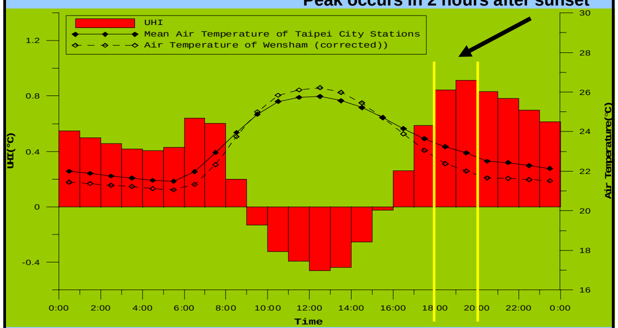
The diurnal difference between maximum and minimum temperatures show a decreasing trend (-0.12°C/decade) and the negative anomalies mainly occurred after 1980



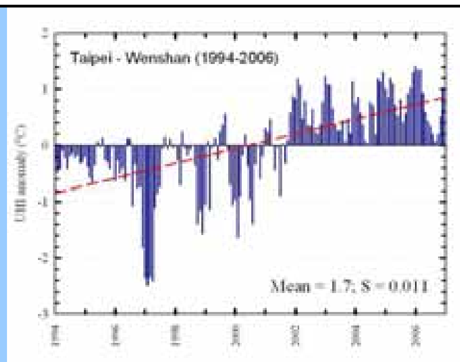


Temperature distribution at 00:00 am from stations inside Taipei basin shows a higher thermal area (old downtown) in the central region and implies where was the beginning of the urban development.

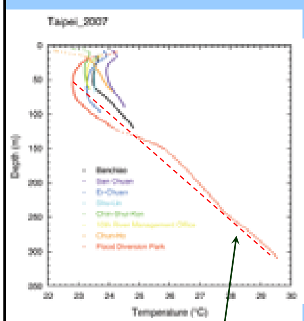
Peak occurs in 2 hours after sunset

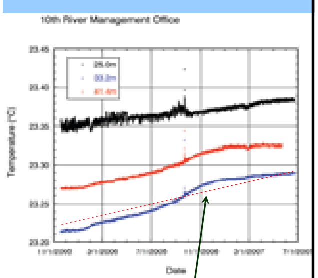


Daily average of UHI intensity in Taipei-Wenshan pair from 1998~2006. Red column shows UHI intensity. Peak of UHI intensity occurring at 2 hour after sunset suggests the earlier reach of temperature climax is due to a very high urban density in Taipei city.



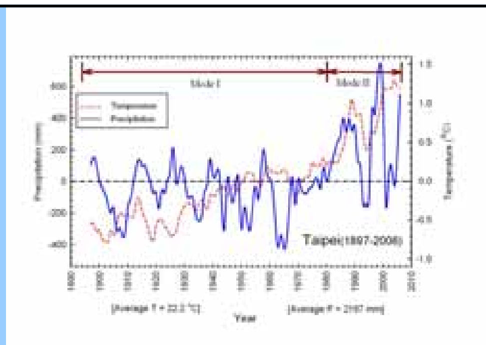
The anomalies and linear trends of monthly mean daily maximum UHI in the pair of Taipei-Wenshan in 1994~2006. This plot indicates an increasing trend with exclusive positive anomalies during the latest four years.





(27ºC/km)

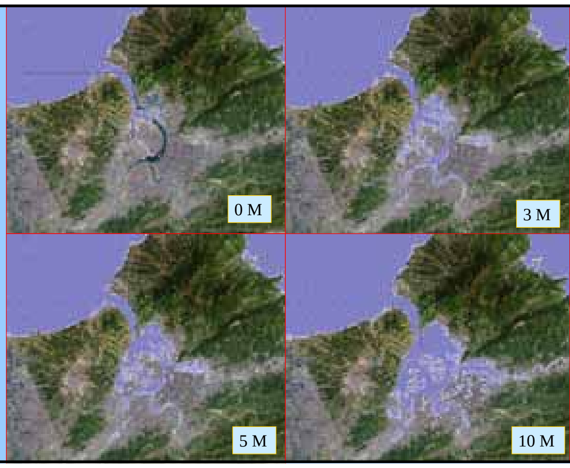
(0.056ºC/year)



Time series of five-year running mean temperature (red dashed line) and precipitation (blue solid line) anomalies of Taipei meteorological station from 1897 to 2006. Two modes can be identified based on the trends: mode-I covers the period from 1897 to 1980; mode-II represents the period after 1980.

Anthropogenic warming would lead to some impacts that are abrupt or irreversible

- Partial loss of ice sheets on ice polar land could imply:
  - metres of sea level rise
  - Major changes in coastlines and inundation of low-lying areas
  - Great effects in river deltas and low-lying islands
- Approximately 20-30% of species assessed so far are likely to be at increased risk of extinction
- Large scale and persistent changes in Meridional Overturning Circulation (MOC) will have impacts on marine ecosystem productively, fisheries, ocean CO_2 uptake and terrestrial vegetation



Conclusion

- A strong warming trend (2 times higher than that of the world average) has been observed in the period from 1897 to 2006 with acceleration after 1980. Certain unfavorable phenomena and trends (such as rapid warming in the city center and at night; hydrological extremity) are very evident and become the major factors in generating the recent environmental problems in Taipei metropolitan area.
- The change in the climate variability and the persistence of high temperatures in the future will certainly have an impact on many aspects, for example, public health (increase in heat-wave mortality), ecosystems, agriculture (particularly during high temperature with drought) and water resources.

Conclusion (cont.)

- A multidisciplinary effort is certainly needed to compile inventory lists regarding important environmental parameters in addition to temperature and hydrological factors (such as air and water pollutions, sunshine hours, etc. both for surface and subsurface environment), and uncover the linkage among these parameters with the development of Taipei metropolitan area through years.
- In addition, an appropriate strategy for the effective management of water resources and living environment in Taipei metropolitan area is urgently needed in perceiving these persistent and gloomy trends in the future.

The Status and Outlook of Land Warming as Part of Global Warming

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Department of Geological Sciences
University of Michigan

Outline

- Relationship between air warming and land warming
- History and current state of the continental heat budget
- 21^{st} century projection of land warming under three scenarios

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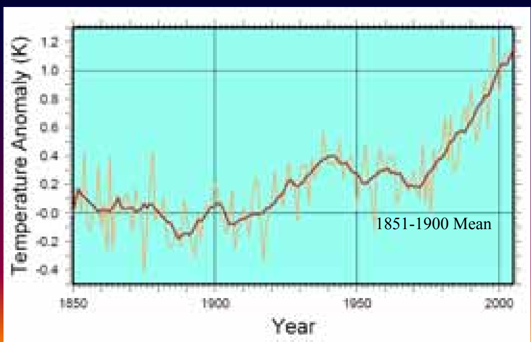
Global Land Surface Temperature



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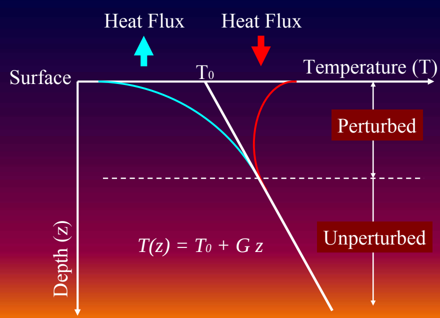
Ground Thermometry



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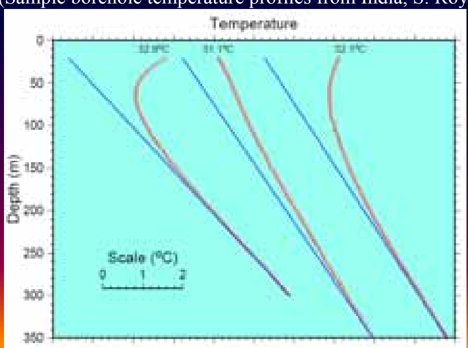
Borehole Temperatures

(Sample borehole temperature profiles from India, S. Roy)



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Temperature & Heat Flux

For a ground surface temperature time series T_i (i=1,2,···,n)

$$q_i = \frac{2\lambda}{\sqrt{\pi \cdot \alpha \cdot \Delta t}} \sum_{j=1}^{i} [T_{j-1} - T_j] \cdot [\sqrt{i-(j-1)} - \sqrt{i-j}]$$

$$\Delta Q = \sum_{i=m}^{n} q_i \cdot A \cdot \Delta t$$

λ – thermal conductivity; α –diffusivity; Δt – time interval
q_i – heat flux; ΔQ – accumulated heat content change

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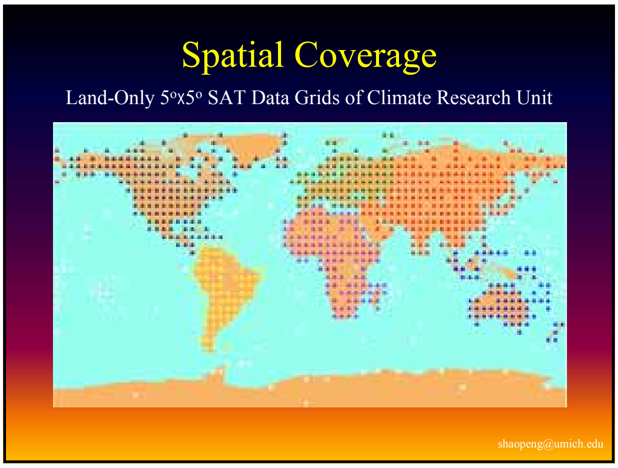
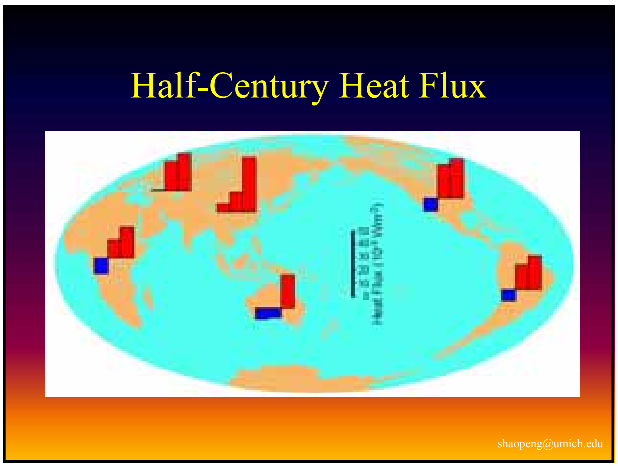

Spatial Coverage
Land-Only 5ºx5º SAT Data Grids of Climate Research Unit
shaopeng@umich.edu


Half-Century Heat Flux
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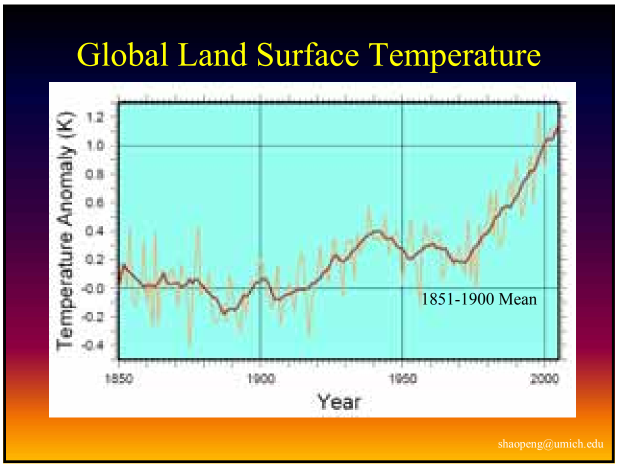
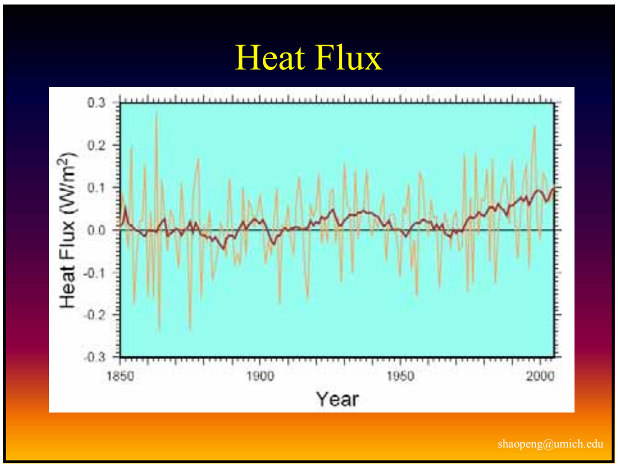
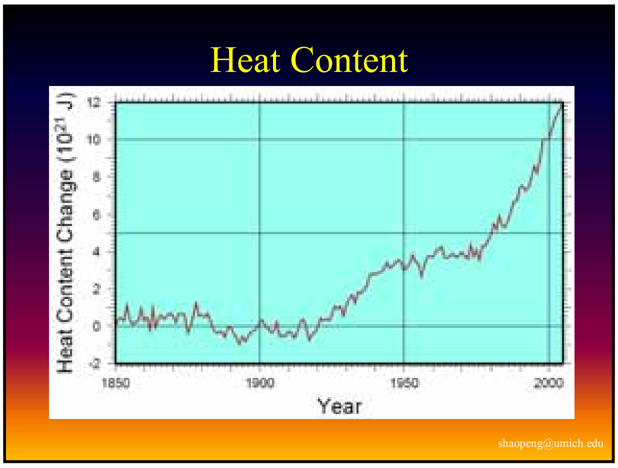
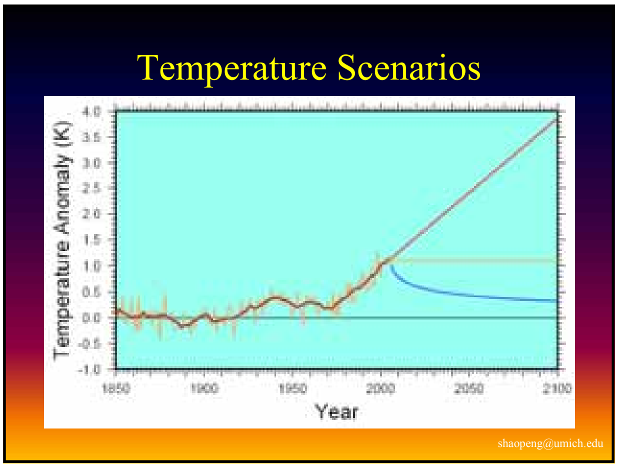
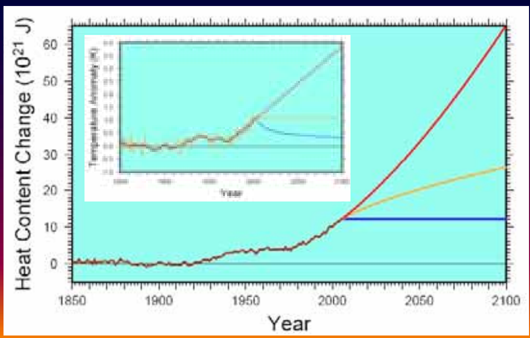

Global Land Surface Temperature
Temperature Anomaly (K)
1851-1900 Mean
Year
shaopeng@umich.edu


Heat Flux
Heat Flux (W/m²)
Year
shaopeng@umich.edu

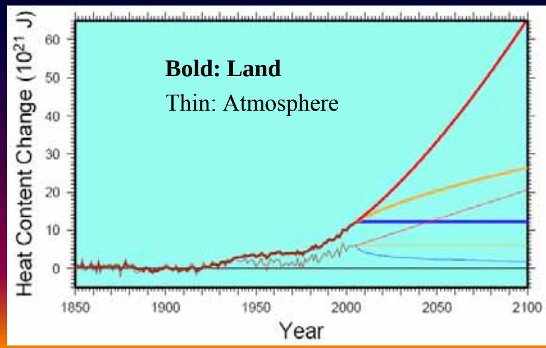

Heat Content
Heat Content Change (10²¹ J)
Year
shaopeng@umich.edu


Temperature Scenarios
Temperature Anomaly (K)
Year
shaopeng@umich.edu

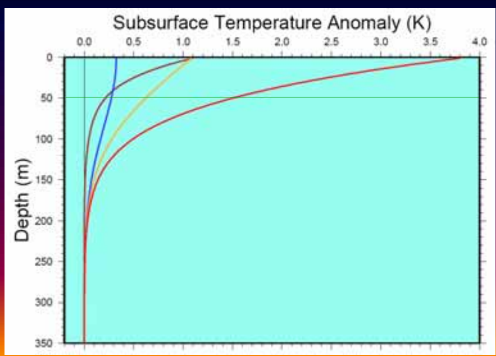
Heat Content Scenarios



Heat Content Scenarios (2)



Subsurface Anomaly



Conclusions

- Changing climate is accompanied by changing energy in the continental landmasses.
- The continental warming is most likely to further intensify in the 21st century.
- The amount of heat absorbed by the lands in recent global warming is much greater than that by the atmosphere.
- Land warming might affect a range of environmental and ecological processes.

Acknowledgements

- I thank Henry Pollack and Paul Shen for their stimulating discussions.
- 5˚×5˚ land-only air temperature anomaly dataset courtesy of the Climate Research Unit of the University of East Anglia.
- Support for this study comes from NOAA Grant NA07OAR4310059 and NSF Grant ATM-0317572.
- This trip to Bali is sponsored by the Research Institute for Humanity and Nature USE project.

Metal Pollution History of Metro Manila from Sediment Cores from Three Water Bodies

[1]Fernando P. Siringan, [2]Kazuhiko Takeda, [2]Shin-ichi Onodera, [3]Makoto Taniguchi, [2]Mitsuyo Saito, [2]Takahiro Hosono, [2]Karen Jago-on, and [3]Yu Umezawa

[1]Marine Science Institute, University of the Philippines
[2]Hiroshima University, Japan
[3]Research Institute for Humanity and Nature, Japan

The Philippine Islands

In 2005
Population – 87.9 M

Metro Manila

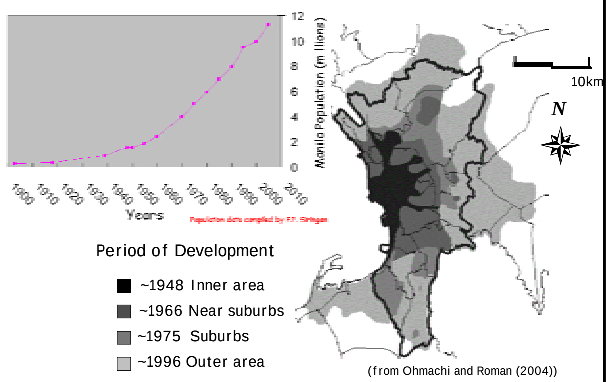
In 2005
Population - 11.3 M

Metro Manila

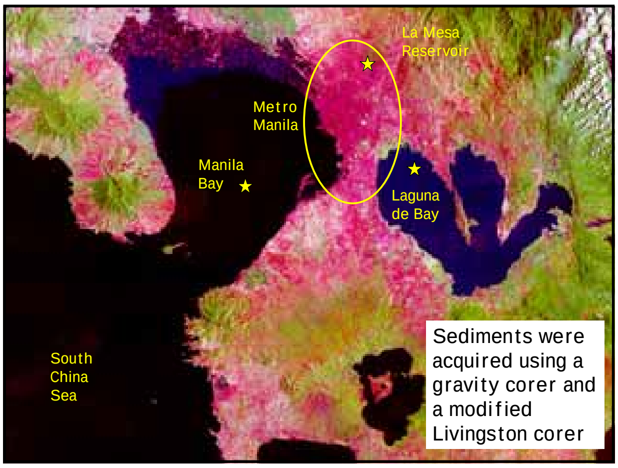
14 cities and 3 municipalities

636 km² or 0.2% of country land but hosts 12.9% of the country population

Urban Growth

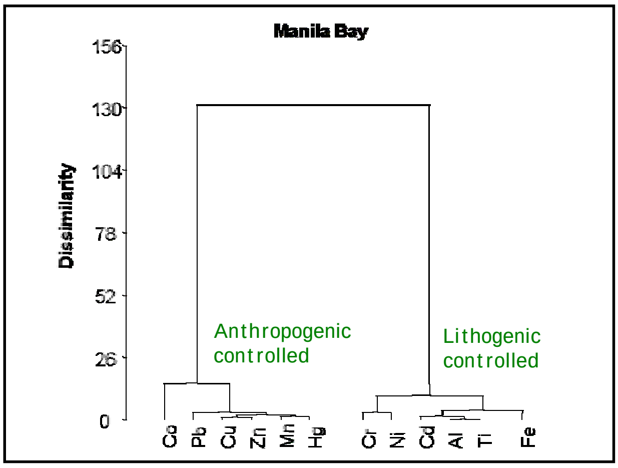


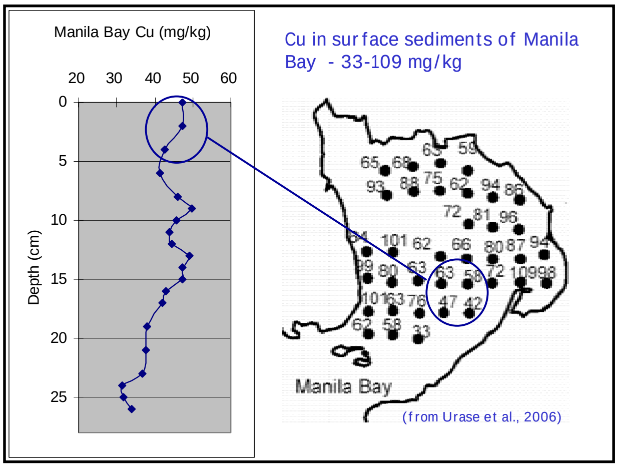
(from Ohmachi and Roman (2004))

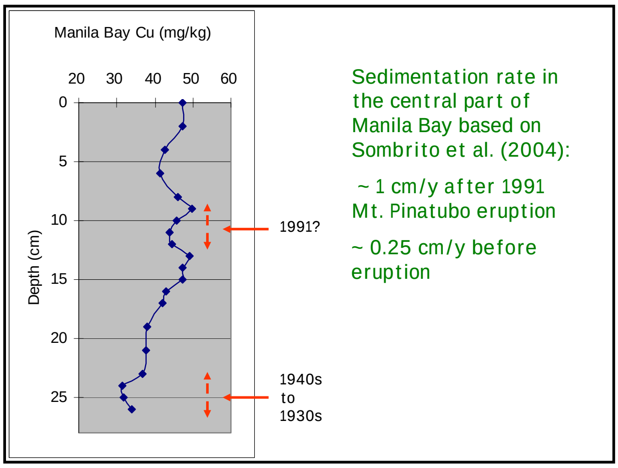


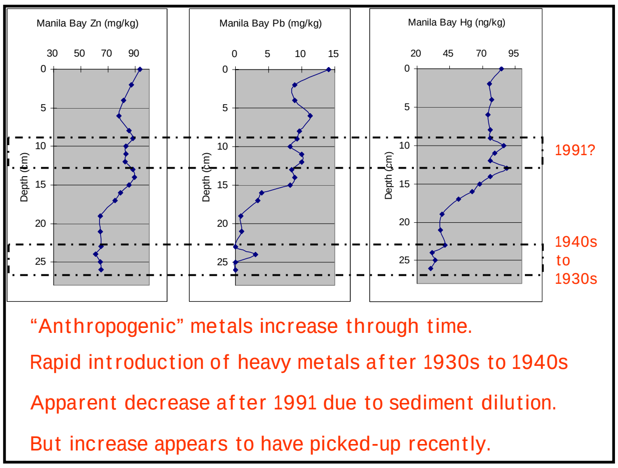
Sediments were acquired using a gravity corer and a modified Livingston corer

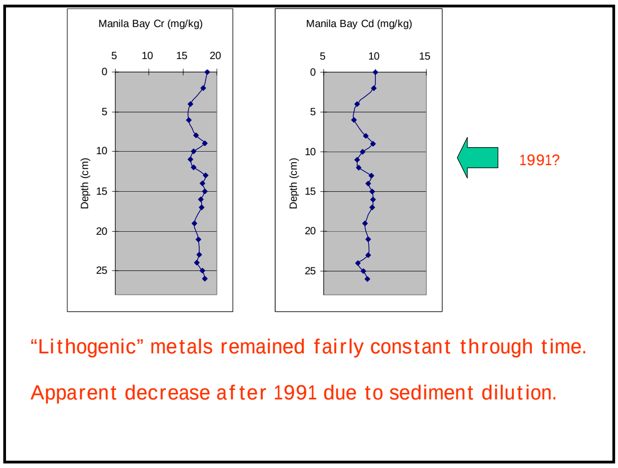
- Subsamples dried at 60 °C until constant weight
- After grinding, ~ 0.2 g digested in 2 ml HNO_3 + 4 ml of HCl in Teflon vessels
- After 1 hour, microwaved at step-wise pressure of 20, 30 and 40 psis at 5 min durations
- Digestant filtered and diluted to 100 ml
- Selected metals measured with Perkin Elmer Optima 3000 ICP-AES.
- 0.2 ml 10% $SnCl_2$, and 0.2 ml 1:1 H_2SO_4 added to a 5 ml aliquot
- Total Hg measured with NIC RA-3 Mercury Analyzer
- 10 ppb Hg standard solution prepared using 10 mg L-Cysteine, 2 ml HNO_3 and 1000 ml H_2O

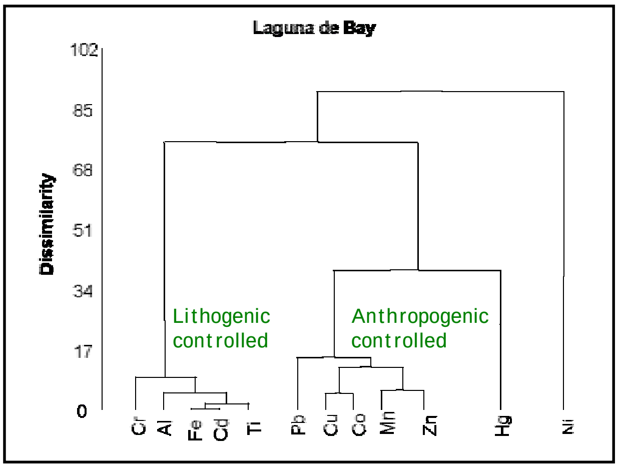

Manila Bay
Dissimilarity
156
130
104
78
52
26
0
Anthropogenic controlled
Lithogenic controlled
Co
Pb
Cu
Zn
Mn
Hg
Cr
Ni
Cd
Al
Ti
Fe

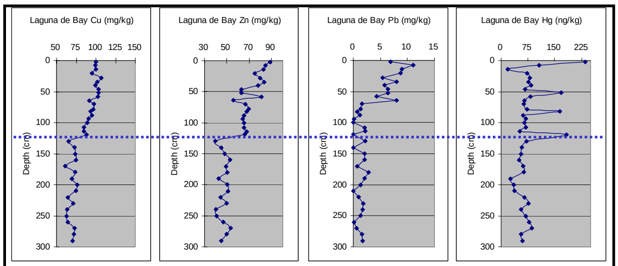

Manila Bay Cu (mg/kg)
20 30 40 50 60
Depth (cm)
0
5
10
15
20
25
Cu in surface sediments of Manila Bay - 33-109 mg/kg
Manila Bay
(from Urase et al., 2006)


Manila Bay Cu (mg/kg)
20 30 40 50 60
Depth (cm)
0
5
10
15
20
25
1991?
1940s to 1930s
Sedimentation rate in the central part of Manila Bay based on Sombrito et al. (2004):
~ 1 cm/y after 1991 Mt. Pinatubo eruption
~ 0.25 cm/y before eruption


Manila Bay Zn (mg/kg)
Manila Bay Pb (mg/kg)
Manila Bay Hg (ng/kg)
Depth (cm)
1991?
1940s to 1930s
"Anthropogenic" metals increase through time.
Rapid introduction of heavy metals after 1930s to 1940s
Apparent decrease after 1991 due to sediment dilution.
But increase appears to have picked-up recently.


Manila Bay Cr (mg/kg)
Manila Bay Cd (mg/kg)
Depth (cm)
1991?
"Lithogenic" metals remained fairly constant through time.
Apparent decrease after 1991 due to sediment dilution.


Laguna de Bay
Dissimilarity
102
85
68
51
34
17
0
Lithogenic controlled
Anthropogenic controlled
Cr
Al
Fe
Cd
Ti
Pb
Cu
Co
Mn
Zn
Hg
Ni

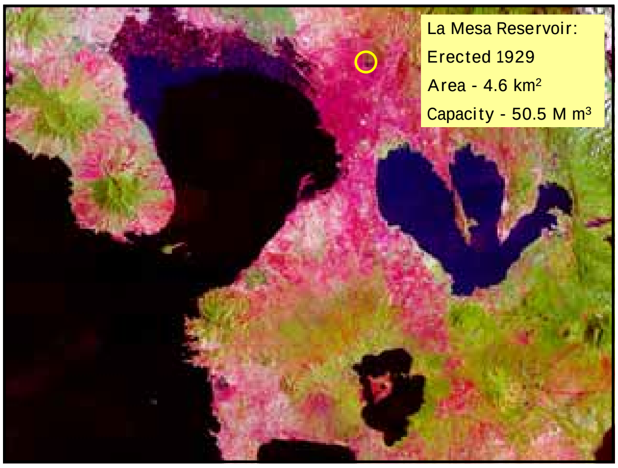


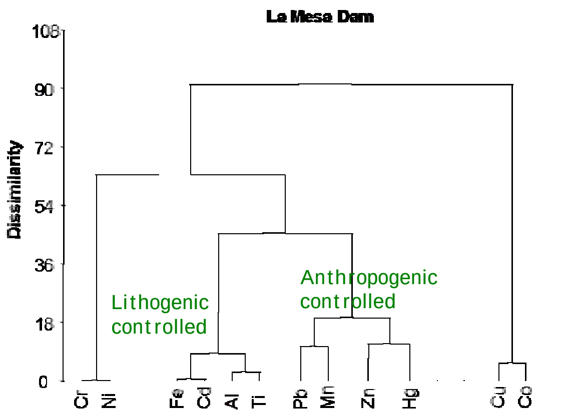
If timing of increase in Cu and Zn is similar to Manila Bay …

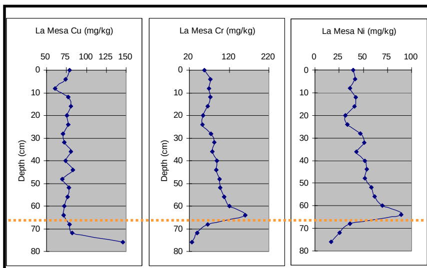
Then, sedimentation rate is within 2 cm/y.

Implies that increase in Pb commenced only in mid-1980s???

Apparent increase in Hg in recent years might be due to opening of Lupang Arenda dumpsite just north of West Bay.

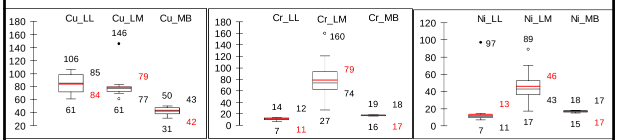




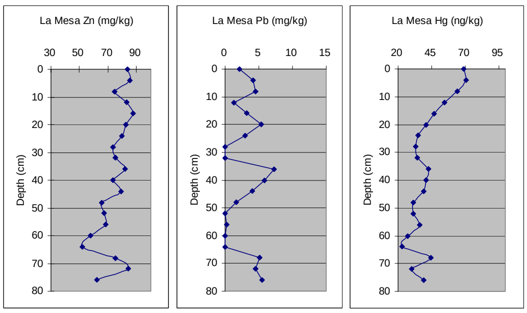


Decreasing Cr and Ni may represent stripping of lateritic top soil

Soil profile of Quaternary volcaniclastics



High Cr and Ni is from ophiolite-dominated watershed



Well-defined increase in Hg in the upper 25 cm is likely due to atmospheric input from Payatas dumpsite which was opened in 1973; predominant wind is from the east

Summary

Accelerated metal pollution after WW II.

Sediment dilution in Manila Bay after the 1991 Mt. Pinatubo eruption is considerable.

La Mesa Reservoir is recipient of Hg, via atmospheric transport from Payatas dumpsite.

Age control is needed to constrain the timing of changes and make better attributions for these changes.

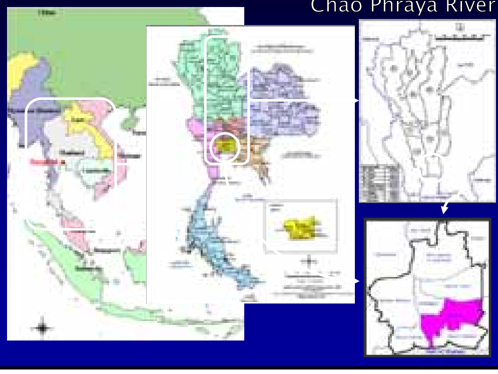
Department of Groundwater Resources
Ministry of Natural Resources and Environment

Groundwater Resources Management in Bangkok Metropolitan Areas

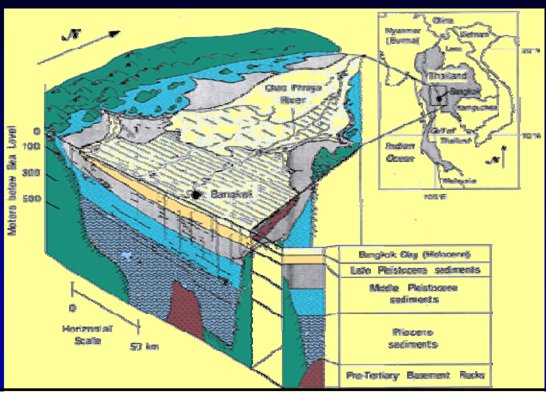
Somkid Buapeng
Director General of Department of Groundwater Resources

Study Area: Bangkok City & 6 Surrounding Provinces

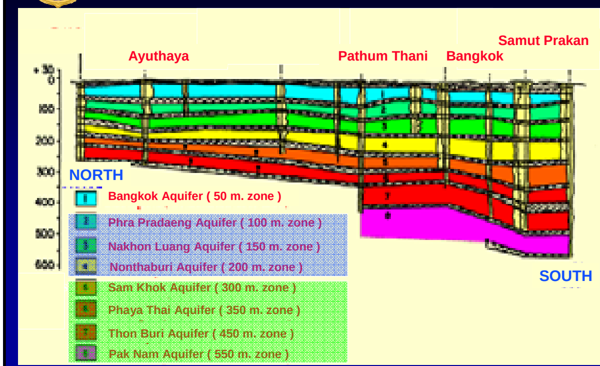
Chao Phraya River Basin



Hydrogeology of Bangkok Metropolitan Area

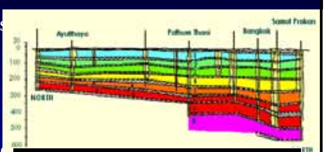


Aquifer System of Bangkok Area



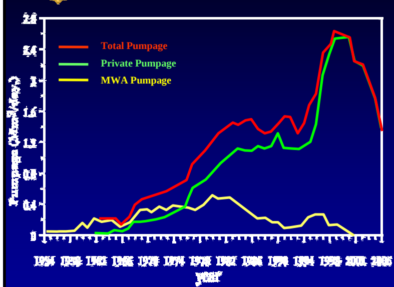
Groundwater System

- Bangkok Aquifer System composed of 8 confined aquifers
- Most of groundwater extraction from 3 aquifers at depths 100-250 m (PD, NL, and NB Aquifers)
- Nonthaburi (NB) Aquifer one of the most productive, yielding up to 200 m^3/hr of excellent quality water
- Deeper aquifers seldom used by domestic wells



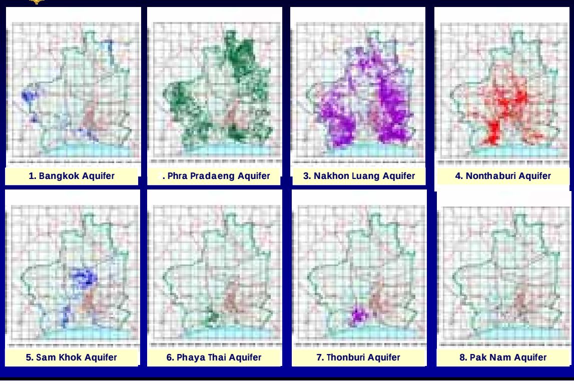
Aquifer	Code	Zone
Bangkok Aquifer	BK	50-m zone
Phra Pradaeng Aquifer	PD	100-m zone
Nakhon Luang Aquifer	NL	150-m zone
Nonthaburi Aquifer	NB	200-m zone
Sam Khok Aquifer	SK	300-m zone
Phaya Thai Aquifer	PT	350-m zone
Thonburi Aquifer	TB	450-m zone
Pak Nam Aquifer	PN	550-m zone

Groundwater Pumpage in Bangkok



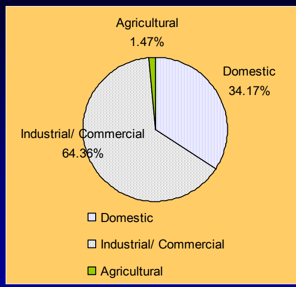
- Mid-1950's: extensive use of groundwater started
- Continuous increase in groundwater use until 1997
- According to DGR, in 2004:
  - Total Groundwater use = 2.2 MCM/d
  - Private Pumpage = 1.8 MCM/d
- Private Users are the largest groundwater consumers

Groundwater Well Distribution in Bangkok Aquifer System



Groundwater Users

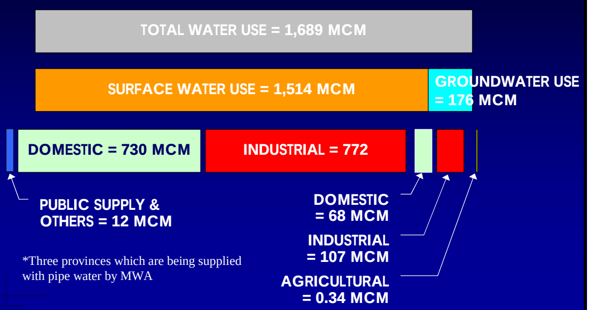
- Agriculture Sector
  - Relatively small amounts
  - Used as supplement water source
- Domestic Water Supply
  - MWA: reduced use but still using
  - PWA: main water source
  - Private users (w/o access to water supply services)
- Industrial Sector
  - Relies heavily on groundwater



Total Registered Groundwater Wells per User Sector (Since 1978)

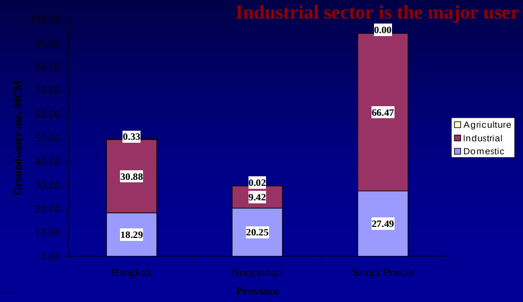
Source: Kasetsart University (for DGR), 2005.

Current Water Use



*Three provinces which are being supplied with pipe water by MWA

GW Use in 3 Provinces, 2003

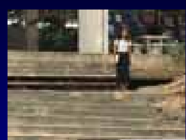


Public Water Supply

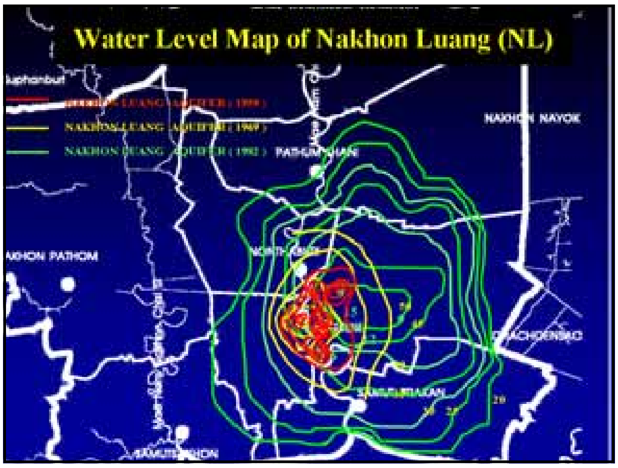
- Metropolitan Waterworks Authority (MWA)
  - For Bangkok, Nonthaburi, and Samut Prakan provinces
- Provincial Waterworks Authority (PWA)
  - For other provinces; Usually in or near town centers
- "Village Piped Water Systems (VPWS)"
  - In rural communities far from town centers
- "Private Piped Water Systems (PPWS)"
  - Subdivisions/ housing developments; Responsibility recently handed over to the government

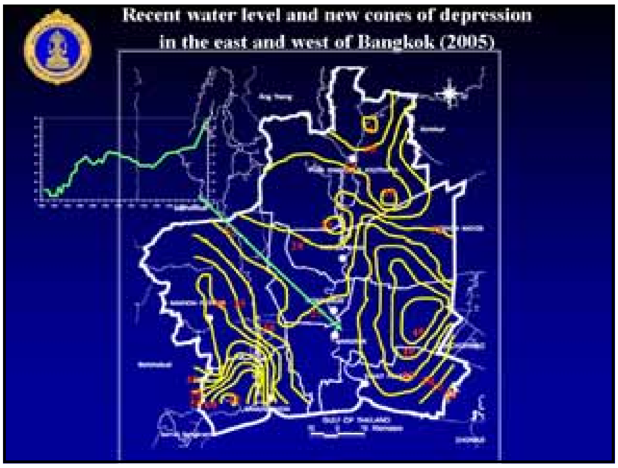
Groundwater-Use Impacts

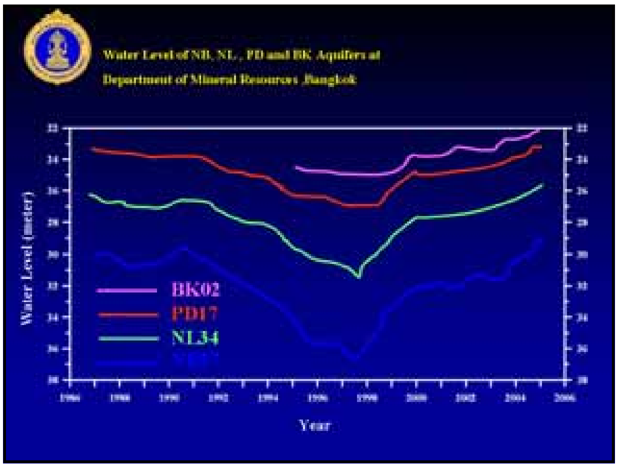
- **Groundwater Depletion**
  - **Water level drawdown**
  - **More difficulty in extracting water**
- **Land Subsidence**
  - **Over-pumping of groundwater**
  - **Loading and settlement of upper clay layer**
  - **Damage to infrastructure**
  - **Flooding**
  - **Disturb/deteriorate drainage systems**
- **Water Quality Deterioration**

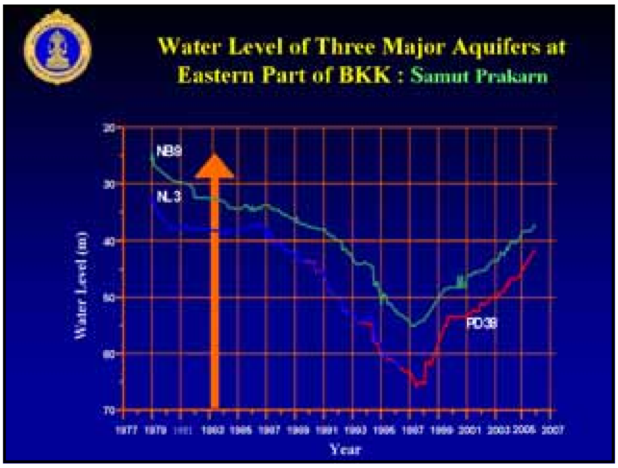


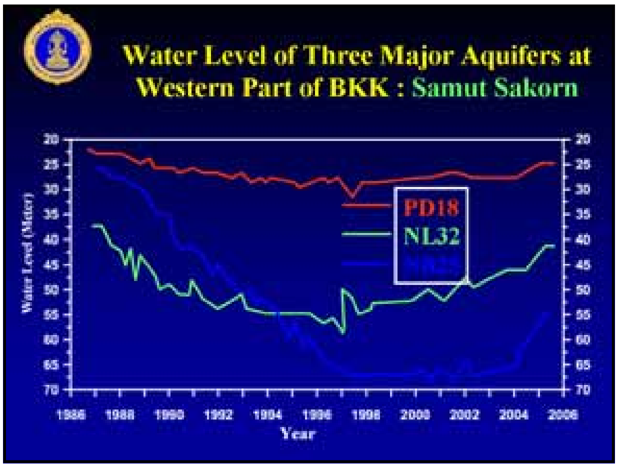
Areas close to the sea (such as here in Phra Pradaeng) can be subject to tidal floods during extreme high tide (spring tide). Source: UNESCAP, 2002


Water Level Map of Nakhon Luang (NL)
NAKHON NAYOK
PATHUM THANI
NAKHON PATHOM
SAMUT PRAKAN

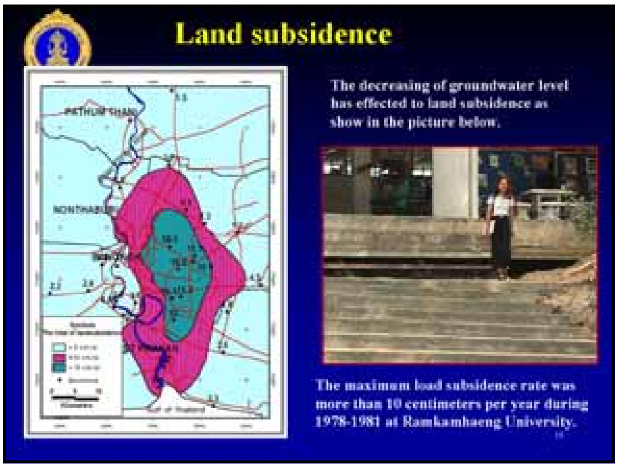

Recent water level and new cones of depression
in the east and west of Bangkok (2005)

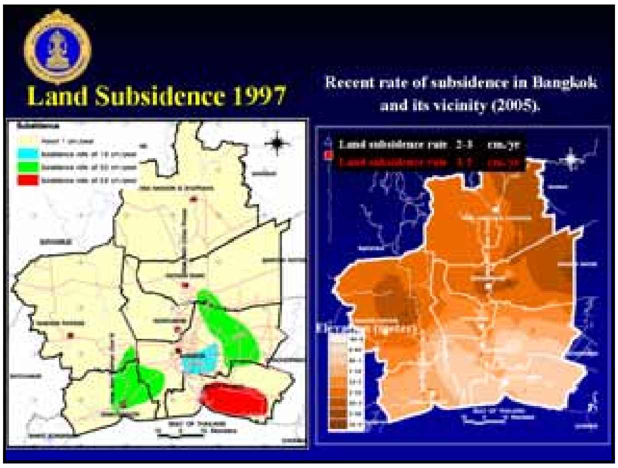

Water Level of NB, NL, PD and BK Aquifers at
Department of Mineral Resources ,Bangkok
Water Level (meter)
BK02
PD17
NL34
Year


Water Level of Three Major Aquifers at
Eastern Part of BKK : Samut Prakarn
NB9
NL3
PD38
Water Level (m)
Year

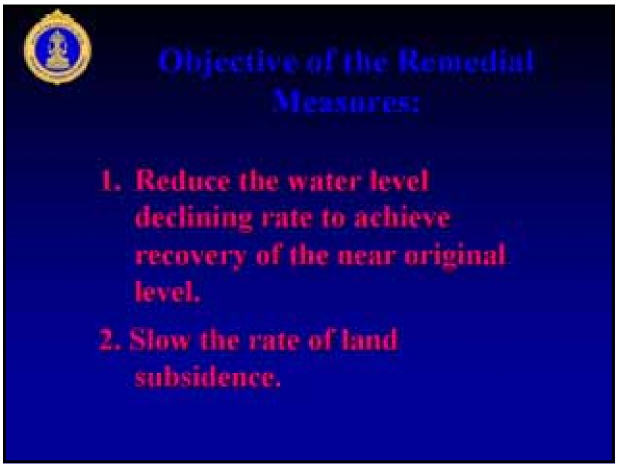

Water Level of Three Major Aquifers at
Western Part of BKK : Samut Sakorn
PD18
NL32
Water Level (Meter)
Year


Land Subsidence in Bangkok
- In 1969, the occurrence of land subsidence in Bangkok and metropolitan area were noticed because of crack buildings and stairs separated from building.
- Well head in some area gradually extruded every year.
- Flooding.

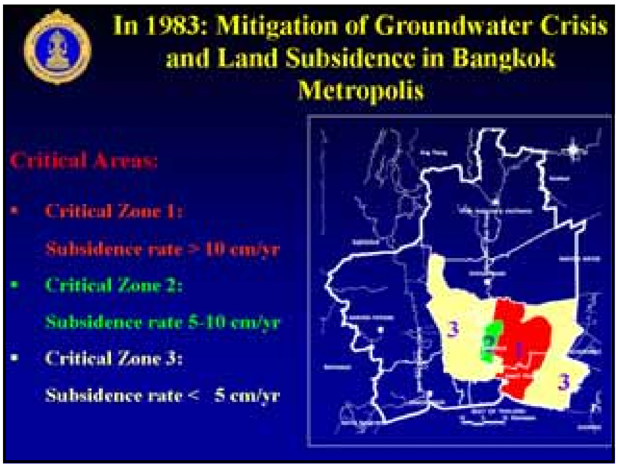

Land subsidence
PATHUM THANI
NONTHABURI
The decreasing of groundwater level has effected to land subsidence as show in the picture below.
The maximum load subsidence rate was more than 10 centimeters per year during 1978-1981 at Ramkamhaeng University.

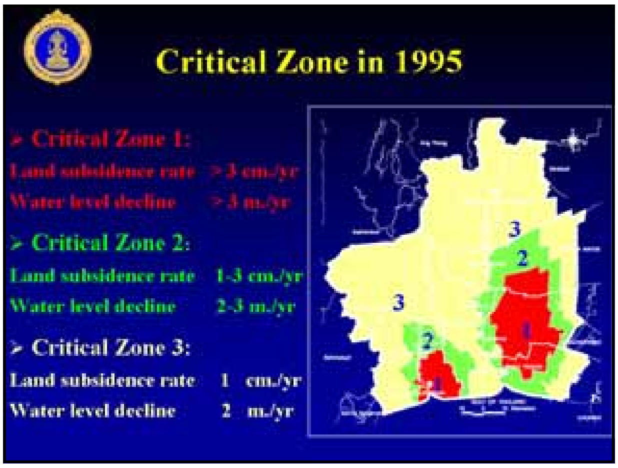

Land Subsidence 1997
Recent rate of subsidence in Bangkok and its vicinity (2005).
Elevation (meter)

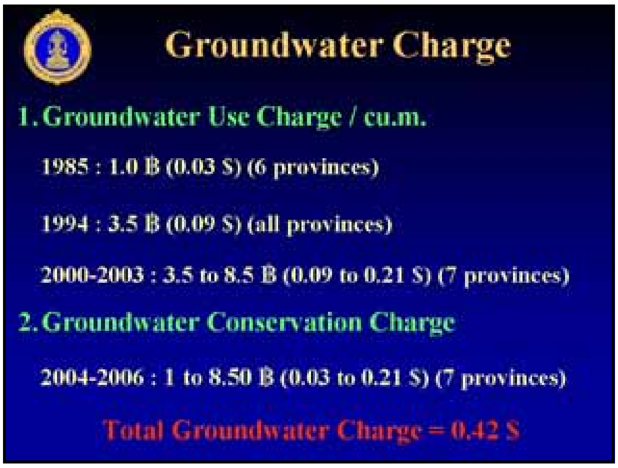

Institutional of Arrangement
Ministry of Natural Resources and Environment
Department of Groundwater Resources
Groundwater Control & Legislation
Groundwater Conservation & Restoration
Groundwater Potential Assessment
Groundwater Exploration & Mapping
Groundwater Drilling
Regional Groundwater Offices
Provincial Groundwater Control Offices

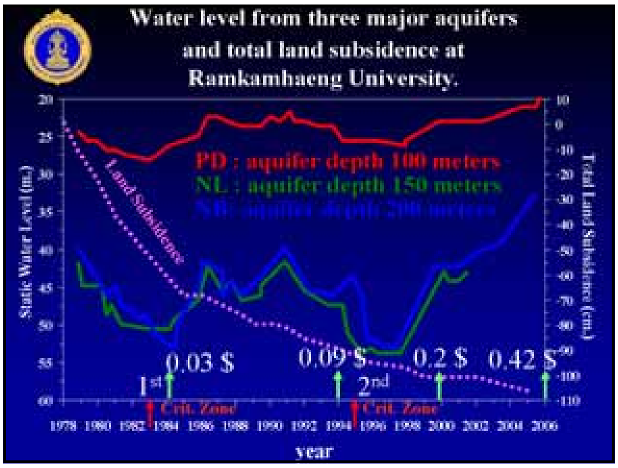

Objective of the Remedial Measures:
1. Reduce the water level declining rate to achieve recovery of the near original level.
2. Slow the rate of land subsidence.

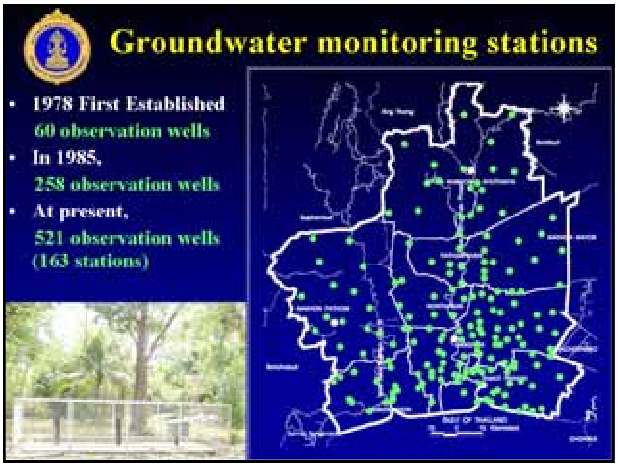

Mitigation of Groundwater Crisis and Land Subsidence
• Groundwater Act of 1977
and Amendments in 1992 & 2003
• Critical zones since 1983
• Groundwater charge since 1985


In 1983: Mitigation of Groundwater Crisis and Land Subsidence in Bangkok Metropolis
Critical Areas:
• Critical Zone 1:
Subsidence rate > 10 cm/yr
• Critical Zone 2:
Subsidence rate 5-10 cm/yr
• Critical Zone 3:
Subsidence rate < 5 cm/yr
3
3


Critical Zone in 1995
➢ Critical Zone 1:
Land subsidence rate > 3 cm./yr
Water level decline > 3 m./yr
➢ Critical Zone 2:
Land subsidence rate 1-3 cm./yr
Water level decline 2-3 m./yr
➢ Critical Zone 3:
Land subsidence rate 1 cm./yr
Water level decline 2 m./yr
3
2
3
2
1
1

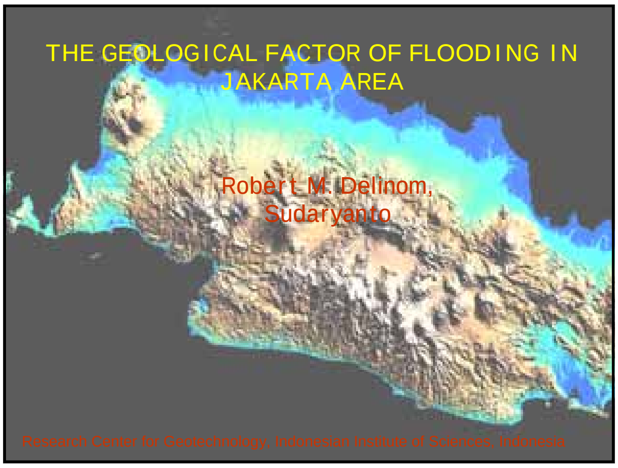

Groundwater Charge
1. Groundwater Use Charge / cu.m.
1985 : 1.0 ฿ (0.03 $) (6 provinces)
1994 : 3.5 ฿ (0.09 $) (all provinces)
2000-2003 : 3.5 to 8.5 ฿ (0.09 to 0.21 $) (7 provinces)
2. Groundwater Conservation Charge
2004-2006 : 1 to 8.50 ฿ (0.03 to 0.21 $) (7 provinces)
Total Groundwater Charge = 0.42 $

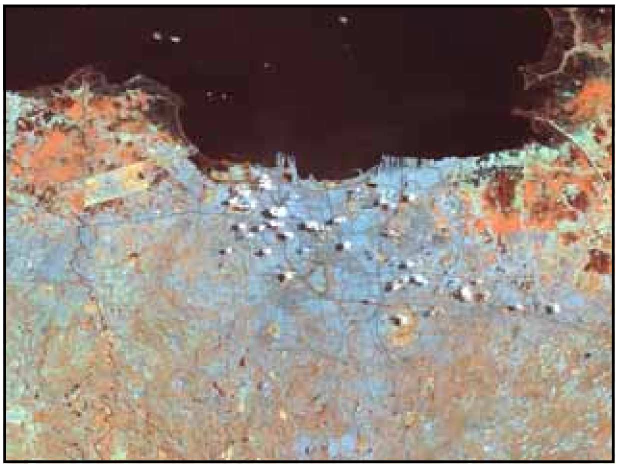

Water level from three major aquifers and total land subsidence at Ramkamhaeng University.
PD : aquifer depth 100 meters
NL : aquifer depth 150 meters
Land Subsidence
Static Water Level (m.)
Total Land Subsidence (cm.)
0.03 $
0.09 $
0.2 $
0.42 $
1st
2nd
Crit. Zone
Crit. Zone
1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
year


Groundwater monitoring stations
• 1978 First Established
60 observation wells
• In 1985,
258 observation wells
• At present,
521 observation wells
(163 stations)


Conclusions
• Declining Rate of land subsidence and water level in recent years due to the successful of implementation of
• Control of groundwater use.
• Economic measure.
• The two new areas of land subsidence are carefully controlled.
• The important tool for groundwater management is groundwater and land subsidence monitoring system.


Thank you
for your attention

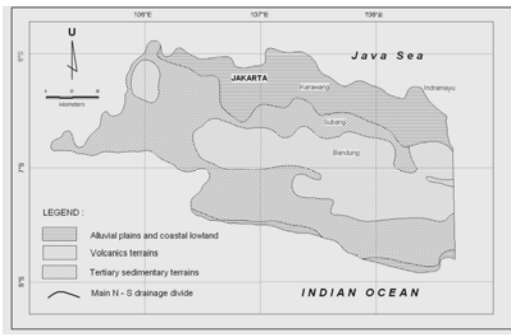


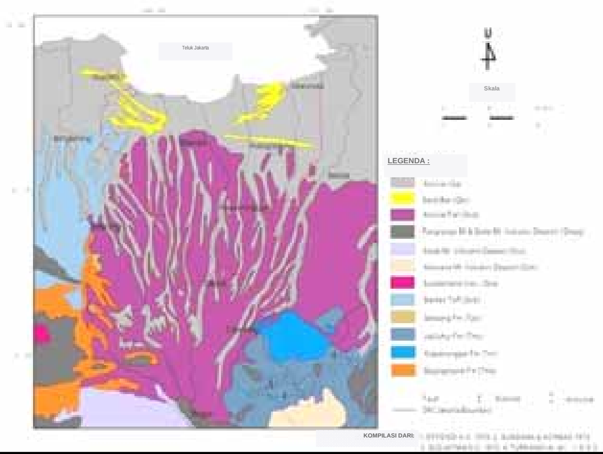


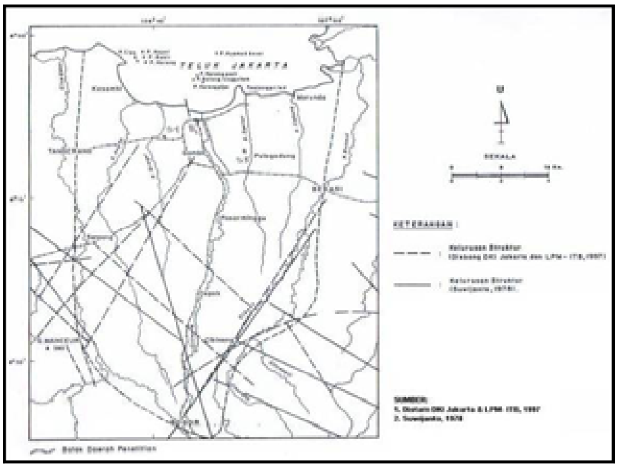
INTRODUCTION

- Around 10 millions inhabitants live in Jakarta Area. (During Office Hour around 12 millions)
- Located in the coastal lowland
- 13 rivers flow inside this area
- Floods in Jakarta were recognize since long time ago (Dutch Occupation Era)
- Enormous Flood occurred on year 1621, 1654, and 1918
- The last two floods Occurred on 1976 and 1996
- General causal factors: excessive rainfall, landused change and uncontrolled city develoment
- The Geological Factor?

Three major geological terranes on West Java
(After Engelen and Kloosterman, 1996)

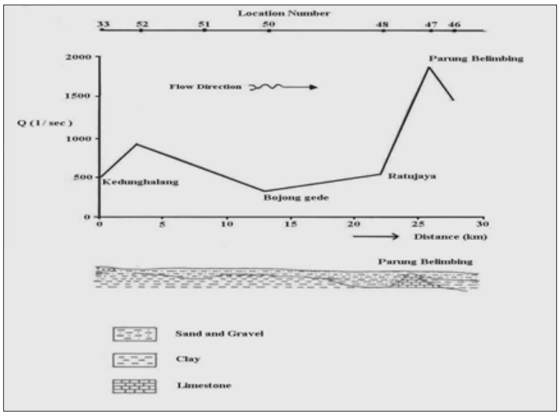


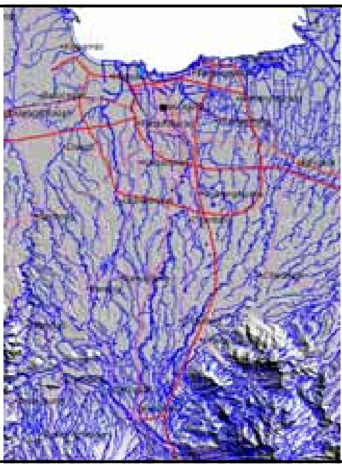


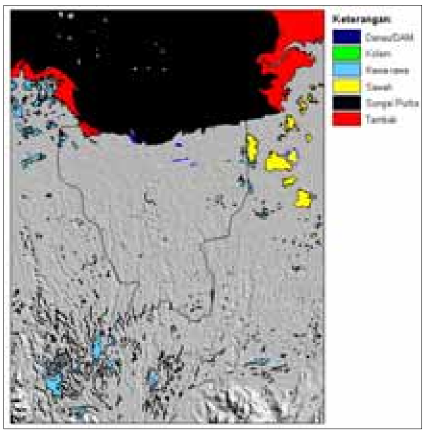


JAKARTA LITHOLOGY CHARACTERISTIC

- Genetically, formed in fluviatile, fluvio-marine, fluvio-volcanic or shallow marine environment
- As an area with volcanic chain in the hinterland area, it is mostly formed by fluviatile and fluvio-volcanic sediment
- Groundwater over production can cause water quality decline
- High porosity
- Some aquifer found as a lens in beach ridge

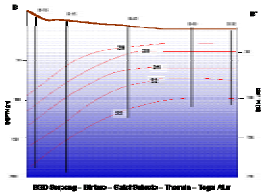


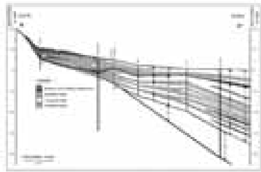




- A detail observation in geological properties
- Borehole temperature measurement
- Objectives :
  - identify the Jakarta Basin recharge Area
  - control of geological condition to the groundwater flow of this basin

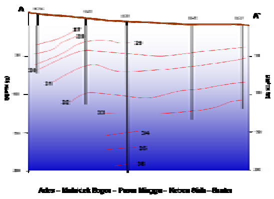
Subsurface temperature distribution in the cross section of B – B'



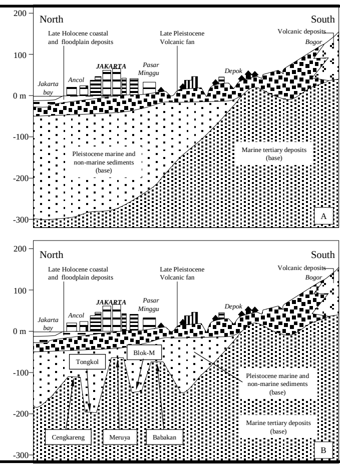


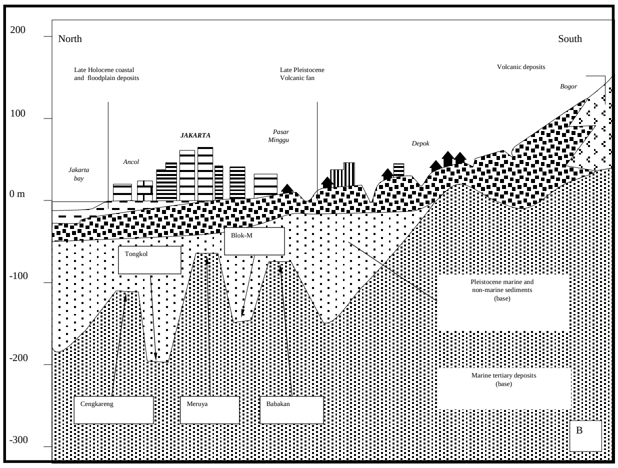
Cross section B-B` showing convective heat flow distribution along the primary groundwater-flow path as well as it`s reflection in the geological cross section

Subsurface temperature distribution in the cross section of A – A'



Cross section showing some local pattern that can be identified as a local recharge. Compare to the geological cross section it`s reflection some Limestone Formation (Depok High) that controlled the groundwater flow. This difference presumably reflects a shallow thermal regime.





CONCLUSION

The geological condition in Jakarta Basin should be considered as one important factor in analyzing the Jakarta Flooding .

A Review on Urban Policies to Balance between Environment and Development of Asian Developing Countries

Backjin Lee*, Minho Suh[1] and Yunsuck Lee[2]

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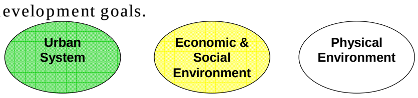
Outline

- Background
  - Characteristics of sustainable urban policy
- Review of urban policies
  - Subject cities: Seoul, Tokyo, Beijing, Singapore, Jakarta
  - Urban management policy
  - Environmental management policy
  - Transportation management policy
- Comparison of urban policies
- Conclusions and discussions

Background

- Sustainable development in urban area is a complex concept which refers to the interaction of three critical environments; an urban system, the physical, the economic and the social environments (Camagni et al, 1998).
- To establish effective policy-decision for sustainable urban policy, it is crucial to develop an integrated approach involving interdisciplinary fields related to economics and urban environment.
- In developing countries, it is important to establish urban policies that incorporate joint environmental and development goals.



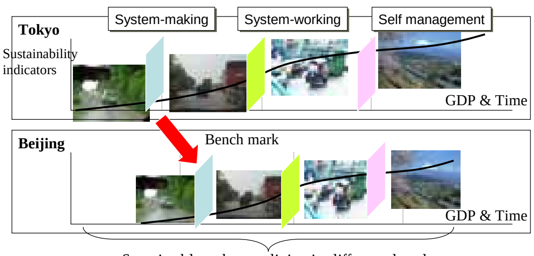
Sustainable urban development(1)

- Multidimensional aspects:
  - Various factors influencing sustainable urban development:
    - -Urban growth factors: land use, urban density, etc.
    - -Environmental factors: air and water pollution, energy consumption, etc.
    - -Transportation factors: car ownership, car usage, etc.
    - -Progress of technology
- Time dimensional aspects:
  - Varying influences at different stages of urban development

Dynamic change and influence each stages

Sustainable urban development(2)

- A gap of developed and developing countries
  - Socio-economic conditions
  - Need to achieve joint development and environmental goals



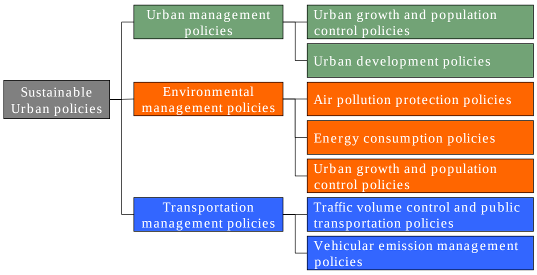
Sustainable urban policies in different levels

Research Purposes

- To review urban policies underlying five Asian countries regarding multidimensional aspects of sustainable urban development
  - Seoul, Tokyo, Beijing, Singapore and Jakarta
- To look at balanced policies to achieve joint environment and development goals in developing countries.:
  - The urban policies of the underlying five Asian countries are compared in time lags

A review framework of urban policies

- To better understand the multidimensional aspects of sustainable urban development in developing countries, the urban polices are divided into three main categories



Seoul (Korea)

	Policy
Urban Management	• In 1964 "*Special Measures for the Restriction of Population Growth*" • In 1971 "*Restricted Development Zone* (RDZ)", otherwise known as green-belt. • In 1972 "*National Land Use Management Law*" • In 1972 "*Industrial Estate Promotion Law*" • In 1977 "*Industry Distribution Law*" • In 1981 "*Seoul National Physical Development Plan*"-"*Crippled Inter-regional Decentralization Policy*" • In 1982 "*Capital Regional Management Law*" • In 1982 "*Seoul Metropolitan Strategic Plan*" - Seoul Oriented and Mono-centric spatial structure, - Saturation and Over-population suburban areas, Environmental sensitive area, - Urban sprawl along major arterial roads, - Urban consumption of agricultural land, - Automobile dependent traffic system and congestion, etc. • In 1984 "*Capital Regional Plan*"-Five zonal system (Relocated promotion zone, Restrict rearranged zone, Development inducement zone, Nature preservation zone, Development reservation zone) • In 1989 "*New town development*" • In 1992 "*Capital Regional Plan*" revised • Currently, urban renewal and redevelopment strategy in Seoul (2002-) focus to recover competitive power of Seoul by balancing with North and South area of the Han river. - "*The New Restoration*" - "Urban Regeneration" - "*Cheong-gae-cheon Restoration*" • In 2002 "*City and Dwelling Environment Maintenance Act*"

Seoul (Korea)

Part	Policy
Environmental Management	• In 1960 "Sewerage Act" • In 1979 "*Emission standard on nitrogen oxide*" • In 1983 "*Emission standard on carbon monoxide, nitrogen dioxide, dust, ozone, e tc.*" • In 1990 "Comprehensive Measures on the Provision of Clean Water" • In 1993 "Special *Measures for Metropolitan Air Quality Improvement*" • In 1993 "Special *Act on Metropolitan Air Quality Improvement*" • In 1999 "*Han River watershed*" • In 2005 "*Water Environment Management Master Plan*" - Fundamental directions of water environment policies for the next 10 years • The "*Energy Policies 2010*": Environment regulations & Consumption of high-quality energy.
Transportation Management	• In 1996 Emission Tax:" *Short-term Congestion Management Program (SCMP)*" - Road congestion pricing policy in restricted zone of CBD on weekdays and Saturday • In 1999 "*Seoul City Air Quality Management Plan (SCAQMP)*" • In 2002 Traffic control system was completed at inner city expressway - Establish an AI and ITS traffic system • Since 2000s BRT (Bus Rapid Transport), BIS/BMS (Bus Information/Management system) and Smart Card system using any public transport in Seoul has operated • In 2006 "*Ultra Low Emission Vehicle*", "*EURO-4*"

Tokyo (Japan)

Part	Policy
Urban Management	• In 1968 "*New City Planning Law*" • From 1970's "*Decentralization Policies.*" • In 1970 "*Building Standard Law*" -Urban promotion and control areas are divided. • In 1980 "*District planning system*" • In 1995 "*Power Decentralization Law*" • In 2000 "*Revised City planning Law*"-To promote the welfare of the people. • In 2001 "*The Tokyo Plan 2000 from 2001 to 2015*" - To revive of the centre core and construct a ring urban axis
Environmental Management	• In 1992 "*Automobile NOx regulation law*" - Tokyo, Nagoya and Osaka areas. • In 1995 "*Energy-Saving Law* " • In 1997 "*Environmental Quality Standards for groundwater*" • In 2001 "*NOx-PM* (particular matters) *law*" • In 2001 "*2005 emission standard*"
Transportation Management	• In 2002 "*Motor Vehicles Exhaust Emission Standard*" • In 2002 "*NOx and PM emission regulation*" - To prohibit diesel vehicles to use unfulfilled fuel • From 2002 "*Automobile green tax and subside for low emission vehicle*" • Local Government has supported subsidy for diesel particulate filter, low-emission vehicles, and natural gas station.

Beijing (China)

Part	Policy
Urban Management	• China has a strong population control as represented by the one-child policy. • Two greenbelts along the ring roads and major highways were proposed in general development plan of Beijing in 1983 and set up in 1993. • the Beijing State Council promulgated the "*Regulations for the Protection of Basic Agricultural Land*" in 1994 and China's government issued the revised "*Land Management Act*" to ensure sustainable socio-economic development in 1998. • China's urban development policies still have obvious features of the planned economy and these include urban-rural migration policy and urban development guidelines, called as "*Chengshi fazhan fangzhen*."
Environmental Management	• The "*Prevention and Control of Atmospheric Pollution*" was enact in 1987 and amended twice, in 1995 and 2000, provide detailed information about two emission standards, which is "*Integrated Emission Standard of Air Pollutants*" for coal-burning, oil-burning and gas-fired boilers. • The "*Integrated Emission Standard of Air Pollutants*" was came into effect in 1997. • The law of "*Prevention and Control of Water Pollution*" came into effect in 1984 and was revised in 1996, which includes the three synchronization systems; preventing water pollutions, pollutant discharge fees (ex. pollution levies) and emission registration.
Transportation Management	• From 1978, one-way traffic has been established in the more congested roads. • The flexible work hour system has been gradually implemented to cut down the volume of journey-to-work during the peak hours since 1984. • Reducing policy of vehicular emission using catalytic converter and regulation or monitoring to condition of construction vehicle since 2000s is also enacted. • In 2006, the regulation of prohibiting operation of light-vehicles in CBD has been implemented since 1998.

Singapore

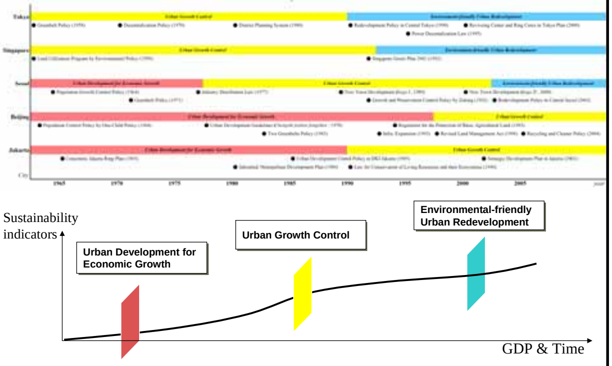
Part	Policy
Urban Management	• Since 1950, "*National Land Utilization Program*" had been drawn up for each facility according to its line of business, the degree of environmental loading, and the possibility of pollution. • In Singapore, the location of the factory is determined by the environmental investigation conducted under the guidance of the "*National Environment Agency (NEA)*" • "*Singapore Green Plan 2002 (1992)*" to raise recycling rates for all wastes to convert power plant fuels to natural gas, to meet water demand by desalination and recycling of wastewater, and to introduce advanced environmental technology.
Environmental Management	• The "*Clean Air Act*" legislated in 1978 and the "*Environmental Pollution Control Act*" in 1999. • In 1983, Singapore established the "*Pollution Control Department (PCD)*", combined organization of the "*Anti-Pollution Unit (APU)*" and the "*Water Pollution Control Section*". • The environmental regulations are the "*Environmental Pollution Control Act,*" enacted in 1999 and the "*Sewerage and Drainage Act,*" revised in 2001. • Factories in the Jurong Island or Tuas district must use clean fuels such as natural gas.
Transportation Management	• In 1975, a road pricing scheme (the ALS, 7:30 a.m. to 10:15 a.m.: morning ALS) was set up. • In 1994, the "whole day ALS (WDALS)" was implemented to include off peak hours (10:15 a.m. to 4:30 p.m.). • In 1990, the vehicle quota scheme (VQS) was introduced as an instrument of final control and check on automobile growth. • In 1990, purchasers of new automobiles, or those intending to keep their present cars for more than 10 yr, must tender or bid for a license or certificate of entitlement (COE) as a control method, which the number of new vehicles on the road is to be fixed. • In 1992, all new cars with catalytic converters, motorcycles and scooters must to comply with the standard for exhaust emission specified in the U.S. Code of Federal Regulations.

Jakarta (Indonesia)

Part	Policy
Urban Management	• A development concept about a concentric ring in the "Jabotabek" area (including Jakarta Metropolitan Area, Jakarta-Bogor-Tangerang-Bekasi) was established in the master plan of Jakarta from 1965 to1985 and three detailed regional plans. • In Jakarta, the "*DKI Jakarta Structure Plan 2005*" was approved through Local Government Regulation in 1984. The Objectives of the DKI Plan are to implement population policies to reduce Jakarta's population growth and are that main urban development is directed towards the east and west; development towards the north-west and north-east is to be limited; and development is to be strictly controlled in the southern area.
Environmental Management	• The "*Environmental Management Act*" enacted in 1982 were drastically revised and the new Act, enacted in 1997, proposed to strengthen environmental regulation handling of environmental disputes, and penalties for environmental pollution. • The "*Environmental Impact Management Agency (BAPEDAL)*" has performed a strategic program for mitigating air pollution, called "*LANGIT BIRU (Blue Sky) Program.*" • The environmental standard for inland water, which separated water types into four classifications from level *A* to *D*, was established as a regulation in 1991 and revised in 1995. • Biomass consumption is around 35% of national energy consumption of Indonesia in 2001. • However, cleaner fuels are unavailable in Indonesia
Transportation Management	• The administration has implemented a "*three-in-one*" policy, a car must carry at least three passengers when passing through the restricted zone in Jakarta from at 7:00 a.m. to 10:00 a.m. and from 4:30 p.m. to 7:30 p.m. since 2001. • There have been feasibility studies of transport systems like underground, mass rapid transport (MRT) and bus systems but none were selected until 2004. • The Indonesia government reached an agreement with the automotive industry on the application of Euro 2 standard and took effect in 2005.

Comparison of urban policies

Urban Management Policies in Five Asian Cities

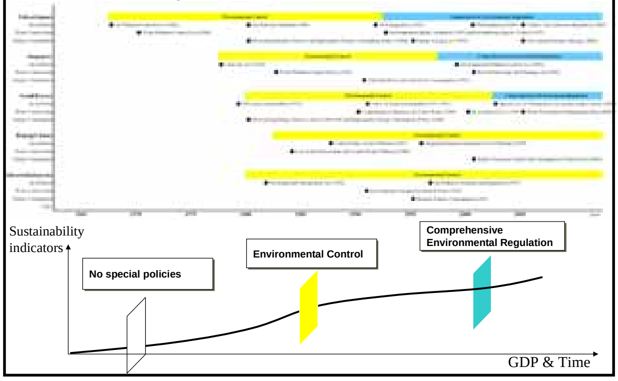


Urban management policies

- The timing introducing sustainable urban management policies are strongly related to economic conditions of each city.
- Tokyo and Singapore start urban growth control policies before 1965. On the other hand, Seoul adopted urban growth control policies from 1977 and Beijing and Jakarta adopted in 1997 and 1990, respectively.
- Japan is one of economically wealth counties in the world, so that it can afford to implement urban management policies for human welfare. Recently, Japan has been facing to the era of decreasing populations, so that redevelopment policy in central Tokyo is applied.
- The economics of Beijing, on the other hand, is growing rapidly in recent. Urban management policies of urban development for economic growth had implemented until 1997 and these are changed to the policies for urban growth control, as its economic condition is improved.

Comparison of urban policies

Environmental Management Policies in Five Asian Cities

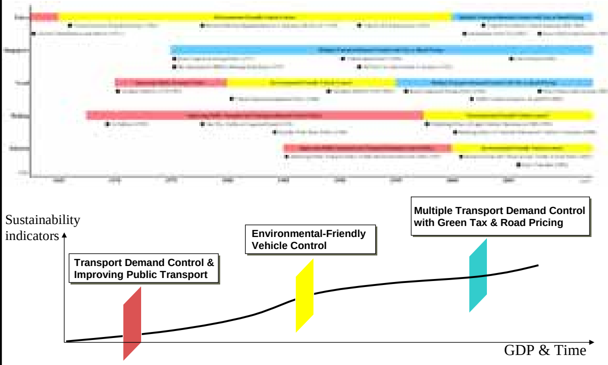


Environmental management policies

- Tokyo started a policy for environmental control in 1968 and a policy for comprehensive environmental regulation implemented after 24years later.
- The gap between the urban environment policies of the environmental control and comprehensive environmental regulations become shorten in Singapore and Seoul.
- Beijing and Jakarta are still on the stage of environmental control.

Comparison of urban policies

Transportation Management Policies in Five Asian Cities



Transportation management policies

- Tokyo have implemented the transportation policies for environmental-friendly vehicle control during 1966 to 2000, even it started the transportation policies quite earlier than other cities.
- On the other hand, Seoul implemented policies for multiple transport-demand control earlier than Tokyo; even the timing of introducing environmental-friendly vehicle control policies was later.
- In Singapore, they introduced transportation management policies effectively for multiple transport-demand control. From the first stage introducing transportation management policies, the policies have been effectively introduced for multiple transport-demand control, such as Road Congestion Pricing and Bus Operation in morning peak hours in 1975.

Conclusions and discussion(1)

- Incorporating multidimensional aspects of urban environments is an important issue in terms of introducing and implementing sustainable urban policies in developing countries. However, few researches have focused on the multidimensional aspects.
- The paper is focusing on the multidimensional aspects in terms of the sustainable urban policies of urban management, environmental management and transportation.

Conclusions and discussion(2)

- The results of the paper can be summarized as follows.
  - ✓ For sustainable urban management, the timing introducing the policies is strongly related to economic situations of each city.
  - ✓ For the environmental management policies, The time gap between the urban environment policies of the environmental control and comprehensive environmental regulations become shorten in Singapore and Seoul. Beijing and Jakarta are still on the stage of environmental control.
  - ✓ For transportation management policies, Seoul implemented policies for multiple transport-demand control earlier than Tokyo; even the introducing timing of the policy for environmental-friendly vehicle control was later. In Singapore, they introduced transportation management policies effectively for multiple transport-demand control.

Conclusions and discussion(3)

- As for future research issues, the above conclusions should be further examined based on environmental and economic indicators in longitude way. In addition, the balanced polices can be induced by comparing the sustainable urban polices with those indicators (e.g., for air, groundwater, etc.)

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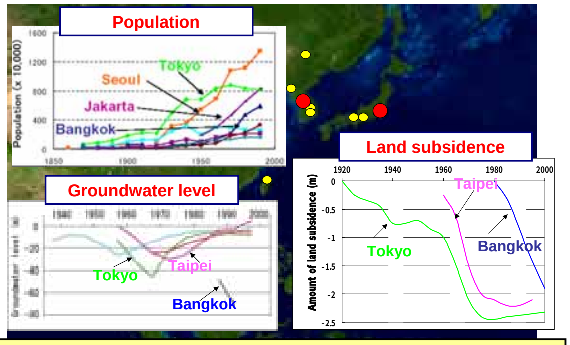
Overview of the RIHN project 2-4 "Human Impacts on Urban Subsurface Environments"

M. Taniguchi and RIHN 2-4FR members
Research Institute for Humanity and Nature (RIHN), Japan

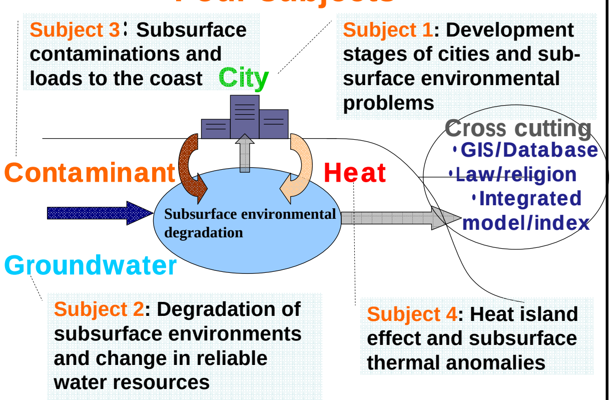


Subsurface environmental problems such as land subsidence, groundwater pollution, and subsurface thermal anomalies, occurred one after another in Asian major cities with a time lag depending on the development stage of each city.

RIHN project 2-4 (2006-2010)

Incubation Study (2003)
↓ (Internal evaluation)
Feasibility Study (2004)
↓ (External evaluation)
Pre-Research (2005)
↓ (1st Int Symp, Kyoto
↓ Oct, 2005)
Full-Research (2006-2010)
↓ (2nd Int Symp, Bali
↓ Dec, 2007)
Intermediate Evaluation
(Feb.2008)

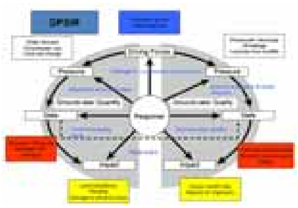
Four subjects

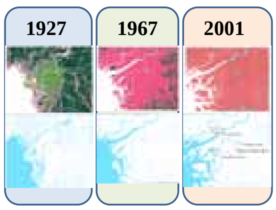


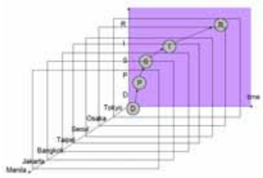
RIHN project core members

and more…..

Urban Group (social economy + urban geography)

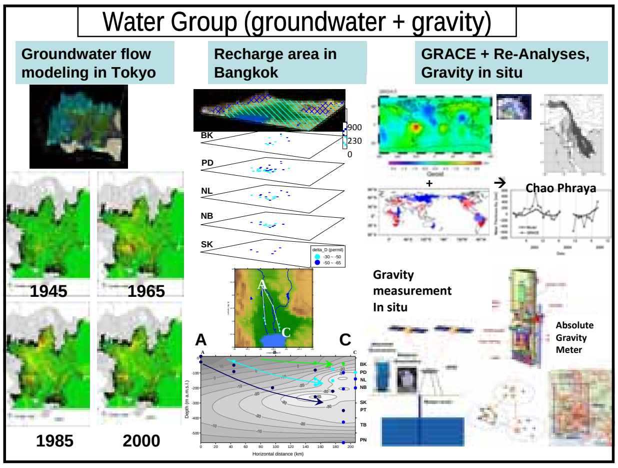


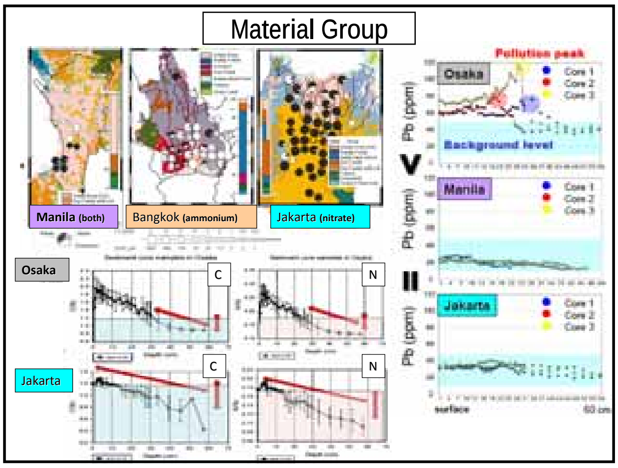


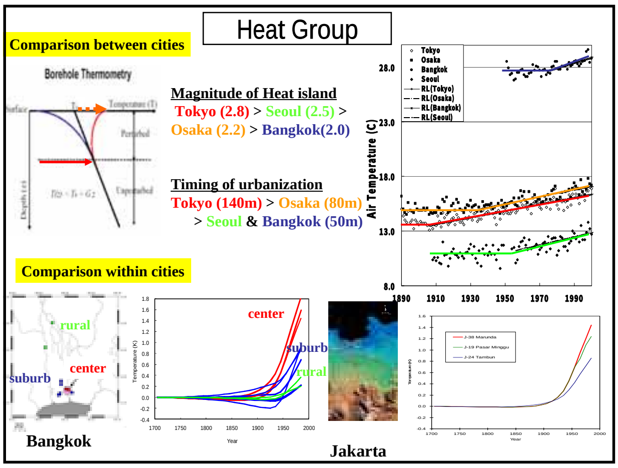


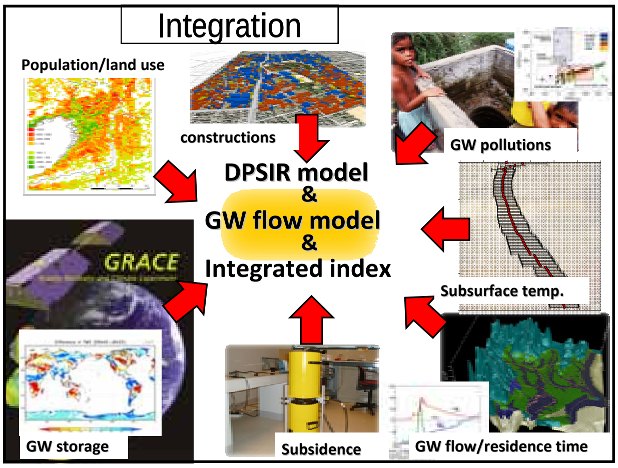
GIS (land use) in Osaka

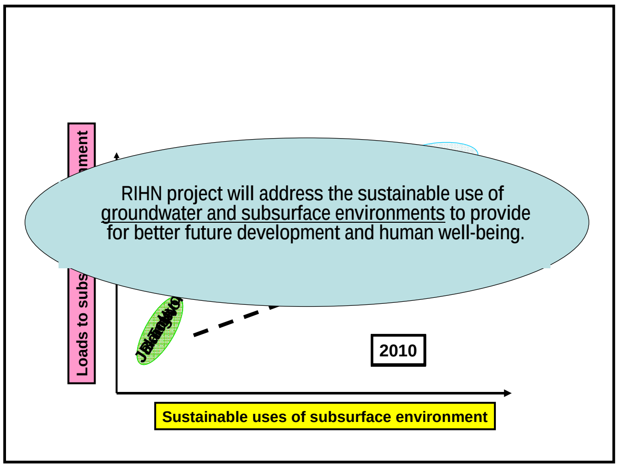
1920's impermeable : permeable = 68 : 88
1960's impermeable : permeable = 158 : 30
2000's impermeable : permeable = 183 : 17





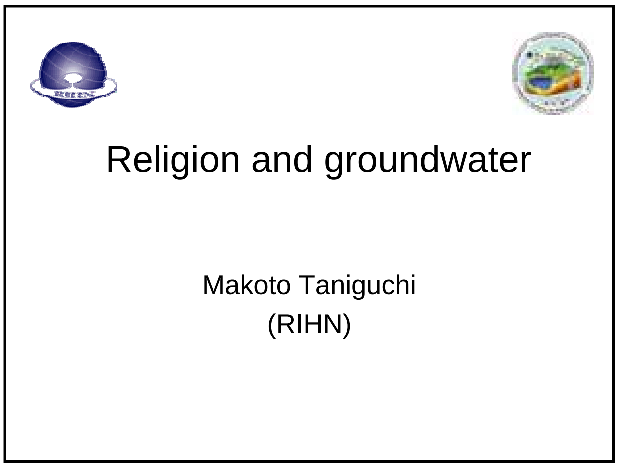


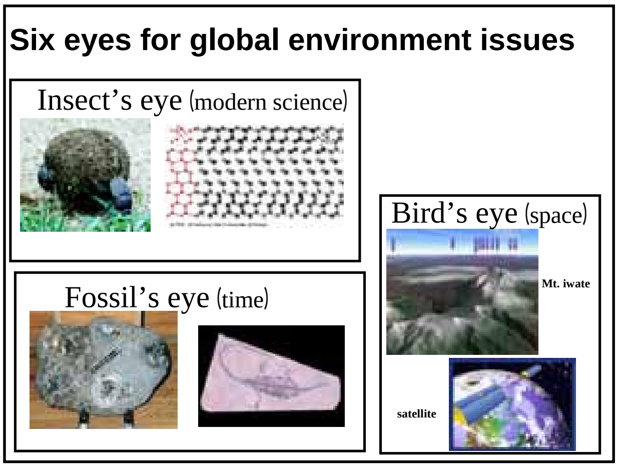


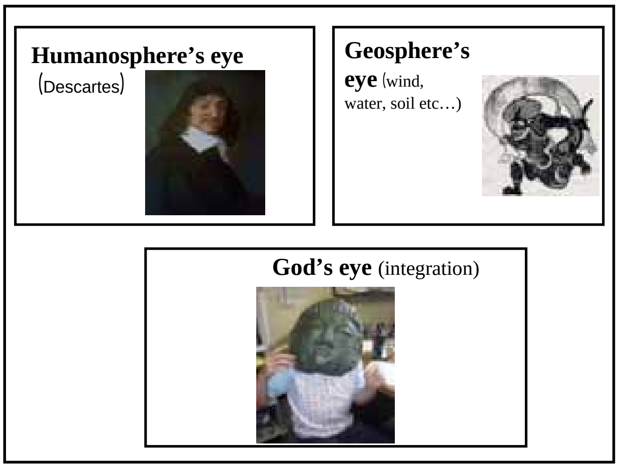


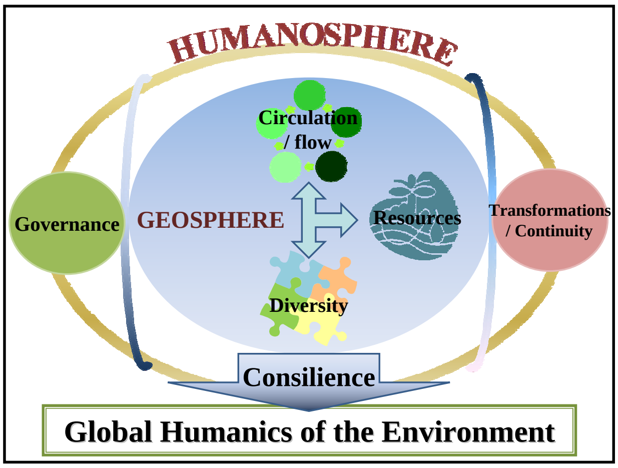
Summary

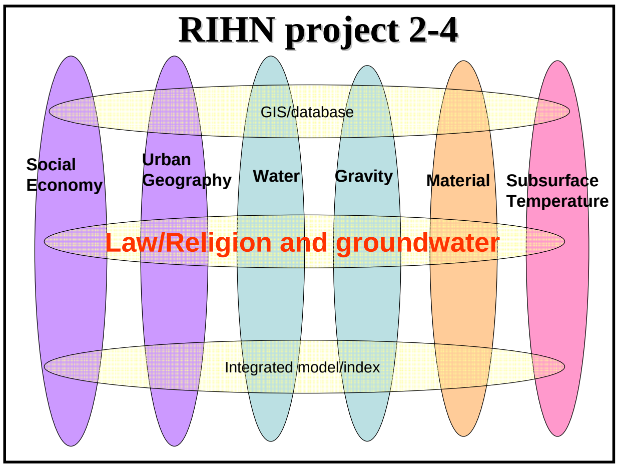
- RIHN Project 2-4 "Human impacts on urban subsurface environment" (2006-2010) has started to evaluate the changes in subsurface environments in Asia under the pressures of human activities and climate changes.
- Target areas are Tokyo, Osaka, Bangkok, Jakarta, Manila, Seoul, and Taipei. Four subjects; (1) urban, (2) water, (3) material, and (4) heat, with cross cutting issues are chosen.
- We will evaluate the relationship between the development stage of the cities and subsurface environmental problems.
- We will assess the sustainable use of groundwater and subsurface environments to provide for better future development and human well-being.

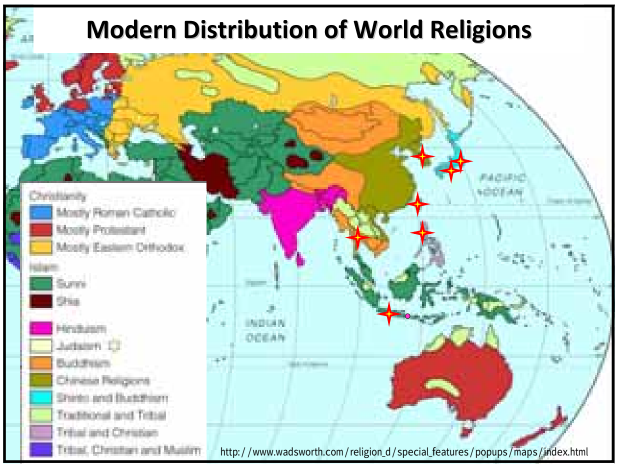

Religion and groundwater
Makoto Taniguchi
(RIHN)


Six eyes for global environment issues
Insect's eye (modern science)
Bird's eye (space)
Mt. iwate
satellite
Fossil's eye (time)


Humanosphere's eye
(Descartes)
Geosphere's eye (wind, water, soil etc…)
God's eye (integration)

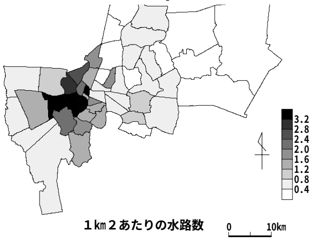

HUMANOSPHERE
Circulation / flow
Governance
GEOSPHERE
Resources
Transformations / Continuity
Diversity
Consilience
Global Humanics of the Environment

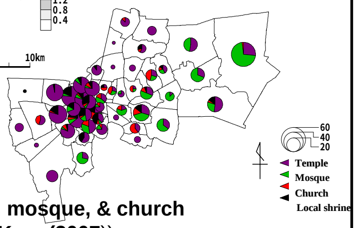

RIHN project 2-4
GIS/database
Social Economy
Urban Geography
Water
Gravity
Material
Subsurface Temperature
Law/Religion and groundwater
Integrated model/index


Modern Distribution of World Religions
PACIFIC OCEAN
INDIAN OCEAN
Christianity
Mostly Roman Catholic
Mostly Protestant
Mostly Eastern Orthodox
Islam
Sunni
Shia
Hinduism
Judaism
Buddhism
Chinese Religions
Shinto and Buddhism
Traditional and Tribal
Tribal and Christian
Tribal, Christian and Muslim
http://www.wadsworth.com/religion_d/special_features/popups/maps/index.html

Number of Canal per km² (Kano, 2007)

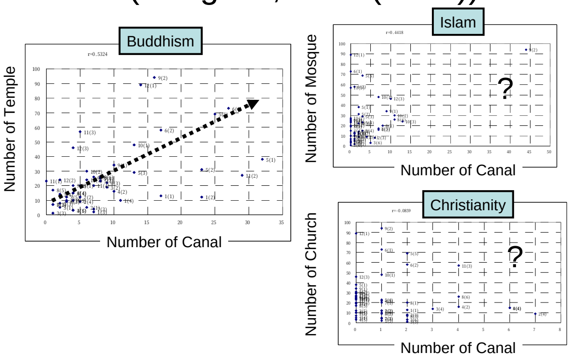
Bangkok



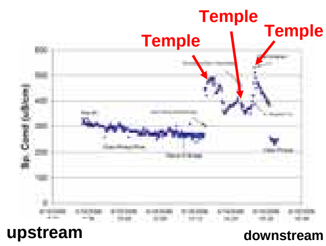


Number of temple, mosque, & church (Bangkok, Kano(2007))

Number of Canal vs Religions (Bangkok, Kano(2007))

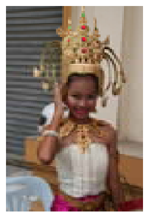


RIHN 2-4: Bangkok (Klong and temple)

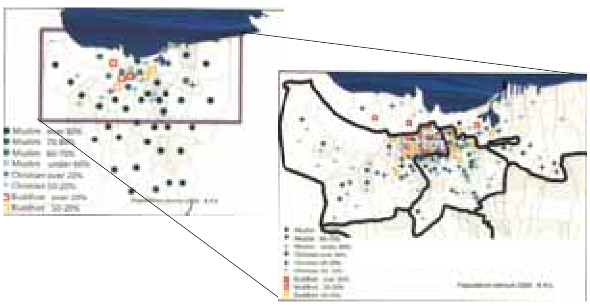


Bangkok (hypnoses)

- **Electric conductivity (EC) of the canal water was higher at the front of temples.**
- **Groundwater (with high EC) may discharge near the temples.**
- **The people who live in Bangkok respect "Buddhism and temples", therefore they build the temples at relatively stable land (such as silty/sandy soil with high permeability), therefore groundwater discharge may occur**



Jakarta (Kimura,T. & Fukami N., 2007)



RIHN 2-4: Water uses at Mosque (Jakarta)

← Groundwater level decreases depending on the religious activities at Mosque

- Can we detect the changes in number of prayers from the GWL records ?
- Is there any difference of the relationships between GW use in Indonesia (wet) and Islam countries in arid areas (dry) ?

Water in Islam Perspective and its Practices in Indonesia.

Water is not sacred matter, eventhough water is very important to fulfill conditions prior to daily worship.

- Robert Delinom
- Abdurrahman Asssegaf
- Rachmat Fajar Lubis
- Muhammad Djuansah
- Sudaryanto
- Arief Rahmat
- Hendra Bhakti

Spring Conservation

- Hindu **Era :** Temple near **the spring and other important** water **resources (ex: Tampak Siring Bali)**
- **Budhism**
- Christian
- **Islam**
- **Dutch** Era : **Graveyard** in near the **spring**

Mention of water In the Holy Qur'an: Conception

- The origin of life,
- Need of every living creature,
- Hydrologic cycle,
- Means for transportation,
- Agriculture etc.,
- even paradise is illustrated as a garden with (rivers) water flows in the center. There is about 30 (at least) verses in the Holy Qur,an related with water, shows how important we should take attempts to water.

Mention in hadith (paroles of the prophet s.a.w.): Perceptions

- Social function:

(1) *The requests of somebody else which should not be refused are water, fire (flame) and salt.*

(2) *A give alms (sidqah) which result a continues merit is to dig a public well.* These two hadits are indicating that water have a very important social function.

- The orders to natural conservation: *Plant a tree if you can, even if you know that you will die tomorrow.* It is also signaled that it is important to do something for the next generation.

Mention in Fiqh (rules of daily life) Books

- fiqh books always begin by Chapter of cleanse where paragraph on water is usually put at the first section.
- The purity conditions of water for the purpose of abulition and bathing are explained based on their physical appearance (colour, smell), minimal volume, and movement status (flowing or stagnant).
- Wudhu (abulition) and ritual bathing are required before performing daily five-times obligatory prays (shalat). One abulition and ritual bathing could be done for several times of shalat as long as the condition is not revoked,

Water in daily worship

- Wudhu (abulition) and ritual bathing are required before performing daily five-times obligatory prays (shalat). One abulition and ritual bathing could be done for several times of shalat as long as the condition is not revoked,
- The purity condition of water for abulition is less strict than that required for drinkwater. Seawater could be use for wudhu. In case of water scarcity, it is permissible to prioritize water for drink or other important use (ex.: cooking) than for abulition. Whereas abulition could be remplaced by tayamum (ritual cleaning by earth or dust). It is also forth sugested to economise water for abulition. Prophet s.a.w. show by an example that he s.a.w. used to perform wudhu by one *mud* (1 – 2 l) of water and took a ritual bath by a *sha* (3 – 5 l) of water.

Water Worship Requirement

- The requirements on water for ritual purposes in islam is not much, and it could be included to the domestic need.
- The domestic water consumption of a muslim is as much as the other people of any religion.
- Much more water is needed are for any other purposes such as for Industry, agriculture, sanitations, environmental flushes etc.
- Mosque construction almost always equiped by clean water (sanitation) facilities that is provided for community, such as toilet and abulition place. It is also similar to any other public bathroom and toilets for the other communities.

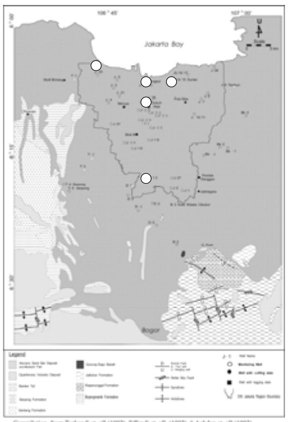
No	Location	Fridays Praying	
		Before	After
1	Darmawangsa	30 Meter	30 Meter
2	Pasar Rebo	17- 20 Meter	30 Meter
3	Cengkareng	10 Meter	12 Meter
4	Sunter	7-12 Meter	7 – 12 Meter


Cengkareng


Darmawangsa


Pasarebo


Sunter



Compilation from Turkandi et. all (1992), Effendi et. all (1992) & Achdan et. all (1992).

GST Location

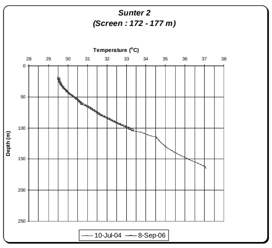
Base on Data Analysis from selected observation well

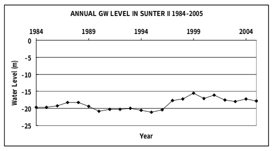
Remarks :

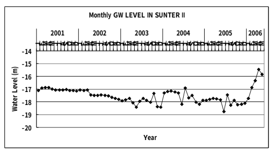
○ GST location include automatic water level measurement (pressure system)

○ Water level measurement (pressure system) only

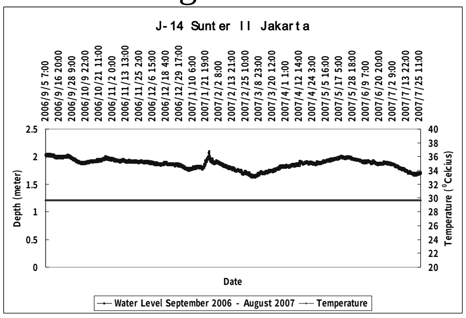
J-14 Sunter II



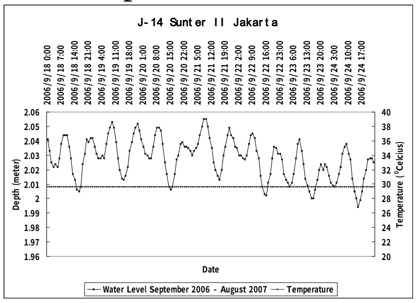




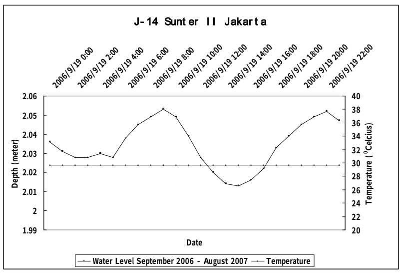
Water Level September 2006 – August 2007



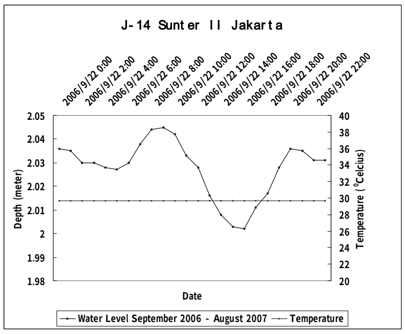
Water Level Weekly September 2006



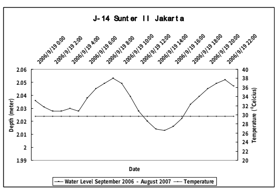
Water Level Daily Tuesday 19 September 2006



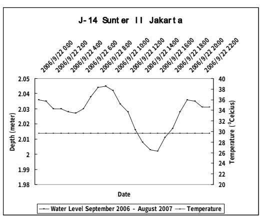
Water Level Daily in Muslim Special Day (Friday)



Comparation



Tuesday



Friday

Conclusion

- Moslem behavior to water and water resources is not different from any other people.
- Consumption pattern is influenced by cultural background and levels of education and income rather than by religion.
- It is admitted that behavior of some Muslim community to water and water resources is still not as proper as it should be.
- Religion approach could be performed in improving community awareness in point of view of water resources conservation and consumption behavior.

GROUNDWATER MANAGEMENT IN INDONESIA

Workshop on Current Problem In Groundwater Management
And Related Water Resources Issues

7-8 December 2007
Bali, Indonesia

DIRECTORATE OF GEOTHERMAL ENTERPRISE SUPERVISION AND GROUNDWATER MANAGEMENT
MINISTRY OF ENERGI AND MINERAL RESOURCES

2007

Groundwater Management in Indonesia

According to : Law No. 7/2004 of Water Resources

Groundwater management :

is an effort of planning, implementation, monitoring, and evaluation of :

1. conservation activity
2. utilization activity
3. natural hazard control

Conservation Activity

Conservation :

is an effort to :

1. preserve groundwater
2. maintain groundwater availability
3. manage groundwater quality
4. control groundwater pollution

Utilization Activity

Utilization :

is implemented trough the activity of:

1. establishment of the utilization zone
2. groundwater supply
3. groundwater usage
4. development
5. entrepreneurship

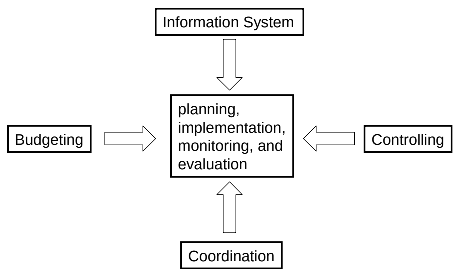
Natural Hazard Control

Natural Hazard Control

is an effort of :

1. prevention
2. mitigation
3. recovery

Groundwater Management



Groundwater Information System

Groundwater Information System

is a network of groundwater information found and managed in difference institutions

groundwater information network should be accessible for the public

Content of Groundwater Information System

Groundwater Information System

contains information of :

1. hydrogeology
2. regulations
3. wells
4. groundwater technology
5. groundwater environment
6. social and economy
7. culture related to groundwater

Indonesian Groundwater Basin

No	Location	Groundwater Basin				
		Total	Inside District	Intra Districts	Intra Provinces	Intra Countries
1	Sumatera	65	28	22	15	
2	Jawa-Madura	80	19	53	8	
3	Bali	8	5	3		
4	NTB	9	3	6		
5	NTT	38	28	10		
6	Kalimantan	22	8	10	2	2
7	Sulawesi	91	55	31	5	
8	Maluku	68	68			
9	Papua	40	30	4	4	2
	Total	421	244	139	34	4

Example of Groundwater Basin Map of Bali

Groundwater Potention in Indonesia

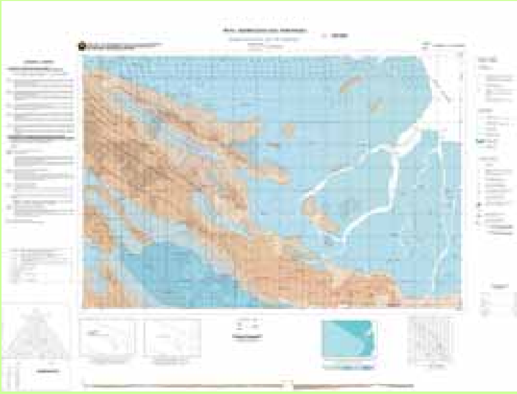
NO	LOCATION	GROUNDWATER BASIN			
		TOTAL	AREA [Km^2]	GROUNDWATER POTENTION (milion cubic meter/year)	
				unconfined (Q1)	confined (Q2)
1	P. Sumatera	65	270.756	121.701	6.548
2	P. Jawa & P. Madura	80	80.937	38.551	2.046
3	P. Kalimantan	21	181.362	67.963	1.102
4	P. Sulawesi	91	37.778	19.694	550
5	P. Bali	8	4.381	1.577	21
6	Prov. NTB	9	9.475	1.908	107
7	Prov. NTT	39	31.929	8.229	200
8	Kep. Maluku	68	25.830	11.943	1.231
9	P. Papua	40	262.870	222.524	9.098
TOTAL		421	905.318	494.390	20.903

Hydrogeological Map

Hydrogeological Map of Indonesia, scale 1 : 250.000 (published)

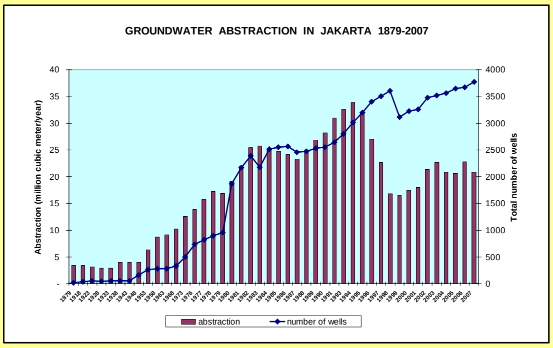
Java	: 11 sheets
Sumatera	: 8 sheets
Kalimantan	: 2 sheets
Sulawesi	: 13 sheets
Bali	: 1 sheet
NTB	: 1 sheet
NTT	: 9 sheets
Maluku	: 5 sheets
North Maluku	: 3 sheets
Papua	: 2 sheets

Example of Hydrogeological Map of Palembang



Wells

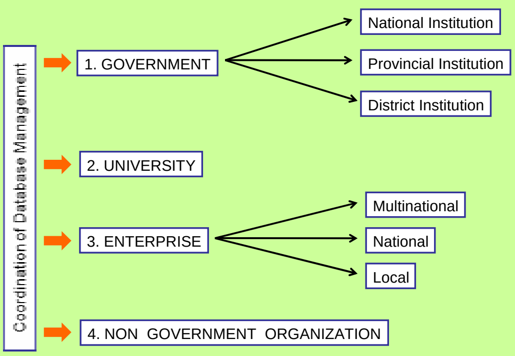
No	PROVINCE	Number of Monitoring Wells	Number of Production Wells	Groundwater Abstraction (million cubic meter/year)	Groundwater Tax (billion Rp)
1	West Java	42	6477	150	47
2	Banten	7	-	31	9
3	Central Java	18	4000	39	-
4	East Java	-	-	421	16
5	Bali	4	-	67	-
6	Nusa Tenggara Timur		-	19	0.37
7	Lampung	4	653	14	0.18
8	Gorontalo	-	-	-	0.02
9	DKI Jakarta	61	3674	22	58



Data of wells in West Java Province, 2006

NO	DISTRICT	Number of Tax Obligator	Number of Wells	Volume of Abstraction (m3)	Groundwater Tax (Rp)
1	Kab. Bogor	492	731	28,439,519	3,524,324,857
2	Kota Bogor	102	118	762,542	278,296,897
3	Kota Depok	124	234	2,600,936	1,107,046,930
4	Kab. Sukabumi	77	135	7,011,331	15,358,138,010
5	Kota Sukabumi	72	91	1,314,616	98,131,566
6	Kab. Cianjur	155	217	1,630,010	341,089,669
7	Kab. Purwakarta	74	110	1,338,762	560,757,294
8	Kab. Karawang	179	261	2,361,251	969,234,346
9	Kab. Bekasi	251	490	5,959,493	2,966,972,507
10	Kota Bekasi	231	411	4,655,424	1,907,964,330
11	Kab. Subang	169	169	3,407,977	3,562,216,155
12	Kab. Bandung	448	870	16,067,524	5,861,430,826
13	Kota Bandung	607	903	17,786,249	3,492,103,504
14	Kab. Sumedang	87	179	7,166,321	2,276,753,299
15	Kab. Garut	160	191	3,596,560	326,597,124
16	Kab. Tasikmalaya	26	27	35,052	8,049,592
17	Kab. Ciamis	168	184	193,806	40,878,604
18	Kota Tasikmalaya	123	153	268,971	57,832,049
19	Kota Cimahi	164	419	7,271,155	3,144,932,736
20	Kota Banjar	27	28	47,045	10,557,141
21	Kab. Cirebon	200	322	3,944,696	304,387,766
22	Kota Cirebon	60	82	158,435	37,480,614
23	Kab. Indramayu	35	38	333,592	31,102,802
24	Kab. Kuningan	60	77	33,180,342	1,137,061,141
	Total	4118	6477	150,145,261	47,493,245,262

EXISTING DATABASE



Development of Groundwater Database

1. Most of raw data stored in District Level, the summary of data should be collected by Province
2. The summary of data from all Provinces should be collected by Central Government
3. Information about occurrence of data managed by different institution should be provided by special institution (Indonesian Hydrological Society ?)
4. Mechanism of data transfer
5. Coordination in constructing database

International Symposium and Workshop on Groundwater Problems in Developing Countries, Bali, 3-8 December, 2007

METHODOLOGICAL AND MODELING ISSUES OF GROUNDWATER HYDROLOGY IN INDONESIA

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OUTLINE OF PRESENTATION

- Introduction
- Groundwater Problems in Indonesia
- Groundwater potentials in Indonesia
- Groundwater Issues in Indonesia
- Methodological and Modeling issues
- Research Needs in Groundwater Hydrology
- Closing Remarks

INTRODUCTION

- As archipelagic country, hydrogeology of Indonesia is characterized by volcanic island types; major groundwater basins are spread extensively
- over exploitations of g/w are occurring in many urbanized areas w/- negative impacts (contaminations, sea water intrusion), however large scale extractions for agriculture uses are limited due to limited potentials at site of needs and very high operational costs.
- understanding of nature of the hydrology of the groundwater systems is limited that needs capacity buildings in wide aspects; g/w is institutionally separated from surface water resources management

Problems in Groundwater Studies

- Exploratory/field observational problems to provide empirical facts, data and other necessary information
- Scientific problems to better understand the description of the hydrologic phenomena
- Engineering/technical problems to achieve some utility or purposes
- Planning and management problems to achieve resources sustainability

Groundwater Problems in Indonesia

- Increasing use of groundwater:
  - municipality, domestic and industry
  - agriculture
- Lack of necessary guidelines:
  - proportional/prioritization of water allocations
  - licensing of groundwater uses
  - sustainable g/w management
- Inventory of groundwater basins
  - major groundwater basins and their potentials
  - major water springs and deep wells

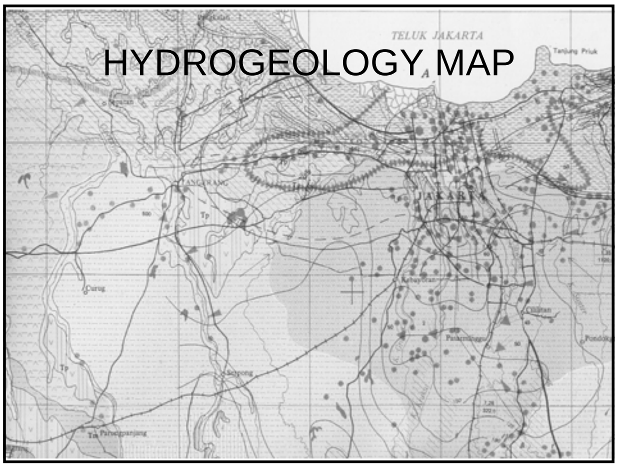
Groundwater potentials in Indonesia

	Major Island	G/W Basins	Basin Size [km^2]	Q/A [10^6 $m^3/yr/km^2$]
	Sumatra	65	17-69776	0,1~0,9
	Java & Madura	80	31-6186	0,05~0,9
	Kalimantan	22	115-95980	0,2~0,5
	Bali & Nusa Tenggara	55	27-10970	0,1~0,6
	Sulawesi	91	4-2270	0,3~0,7
	Maluku	68	31-2069	0,~03~1,4
	Papua	40	110-131609	0,5~1,3

Table: Water springs and Deep wells at Banten, DKI Jakarta and West Jawa Provinces

No	SWS	G/W basins	Districts/ City	Water springs		Deep wells	
				Total	Q (l/s)	Total	Q (l/s)
1	Ciujung-Ciliman	Serang-Tangerang	Serang				8.25
		Labuan	Pandeglang	**127**	2,527.90	**58**	167.70
		Malingping	Lebak	**123**	606.70	**55**	225.80
			Tangerang	**2**	100.00	**380**	551.00
2	Ciliwung-Cisadane	Jakarta	Jakarta			**3224**	569.50
		Bogor	Bogor	**109**	3,274.80	**177**	954.50
3	Citarum	Bandung-Soreang	Bandung	**146**	2,643.50	**2237**	1,855.00
		Cianjur	Cianjur	**175**	1,330.30	**42**	294.90
4	Cimandiri-Cikuningan	Sukabumi	Sukabumi	**125**	3,349.30	**35**	138.60
		Cibuni	Cianjur	**175**	1,330.30	**42**	294.90
5	Cimanuk-Cisanggarung	Sumber-Cirebon	Cirebon			**141**	253.70
		Majalengka	Majalengka	**60**	2,276.70	**74**	148.40
		Sumedang	Sumedang	**158**	3,508.60	**34**	214.70
		Kuningan	Kuningan	**162**	2,802.60	**12**	59.30
		Garut	Garut	**104**	2,624.20	**53**	407.20
6	Citandui-Ciwulan	Ciamis	Ciamis	**167**	2,666.90	**24**	263.20

HYDROGEOLOGY MAP



Groundwater Issues in Indonesia

Type of Activities	Issues
Groundwater investigation: ➢Hydrogeological survey ➢Remote sensing studies & Thematic mapping ➢Database development: DSS	Characterization and Inventory of natural resources: identification of potential g/w basins
Groundwater development and management: ➢Water supply (DMI) ➢Agricultural uses: irrigation ➢Conjunctive use and transfer alternatives	Water use and allocations: ➢Safe yields ➢Efficiency ➢System sensitivity
Monitoring of g/w levels and quality/contaminations, land subsidence	Environmental, Institutional and Capacity Building
G/W recharge and rainwater harvesting	Aug. carrying capacity
G/W modeling and related studies	Capacity building

Methodological and Modeling issues

- Systems identification of groundwater basins and their production capacities based on field observations
- sustainable development and management of groundwater resources
- adoption of ecosystems approach and effects of environmental factors, climate changes
- land subsidence from g/w overdraft
- sea water intrusion in coastal aquifers
- distributed hydrologic modeling of groundwater basins for planning, development and management of water quality and production purposes

J B Joseph Fourier: "Nature is indifferent towards the difficulties it causes to a mathematician"

- Hydrologic Models: descriptive vs conceptual; physical vs mathematical
- the main objective of hydrologic modeling is to explain or to represent the hydrologic phenomenon, to predict or to forecast its future course of action, and to stimulate thoughts by polarizing thinking and posing sharp questions
- prediction: judgment without reference to specific time
- forecasting: judgment with respect to real-time

Environmental Enhancement

- Many variables in environmental systems are in-tangible, while variables in hydrologic systems are tangible
- as hydrologic systems analysis/models would help in design and decision processes in the planning and development of water resources, the result should enhance the environmental betterment and improve management programs

Research Needs in Groundwater Hydrology

- identification/characterization of groundwater basins; submarine groundwater discharge; develop spatial system information of groundwater basins
- monitoring of groundwater development, management, and water quality management/ contamination/pollution control
- ecological/environmental changes, land subsidence, sea water intrusion
- institutional/legal set up
- develop hydrologic modeling and systems approaches of groundwater basins

Closing Remarks

- Solutions to many groundwater problems in Indonesia still need to be found and present valid methodological and modeling issue
- proper understanding of groundwater resources in Indonesia needs to be improved for rational and proportional water uses
- institutional and capacity building set up in groundwater management in Indonesia need to be 'improved'

THANK YOU

TERIMA KASIH

Groundwater Modeling in Indonesia

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Institut Teknologi Bandung
Email: lambok@gc.itb.ac.id

- **Groundwater Model**
  - Physical
  - Analog
  - Mathematical
    - Deterministic
      - Analytical
      - Numerical
    - Statistical

- **Modeling**: simplification of natural system.
- **Numerical simulation**: operating numerical model.

Partial Differential Equation

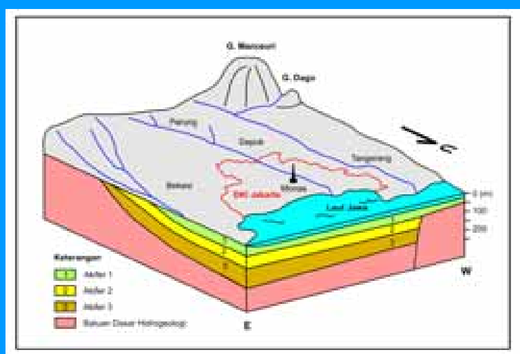
$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{S}{T}\frac{\partial h}{\partial t} \pm \frac{R}{T}$$

S = storativity
T = transmissivity) (m^2/sec)
t = time (sec)
h = hydraulic head (m)
R = discharge (m/sec)

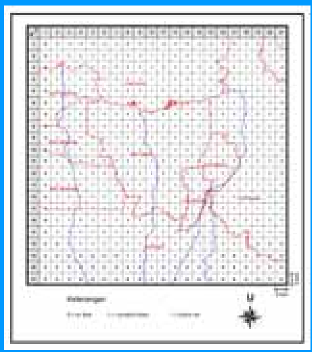
Approximation : becomes sets of linear (matrix) equation

Jakarta

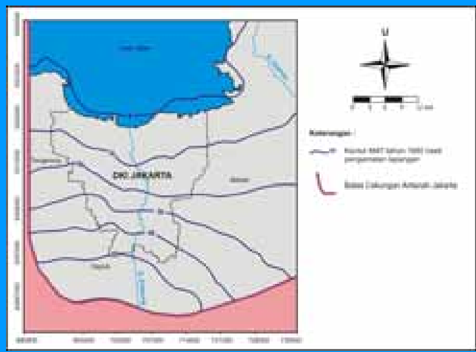
Hydrogeological System



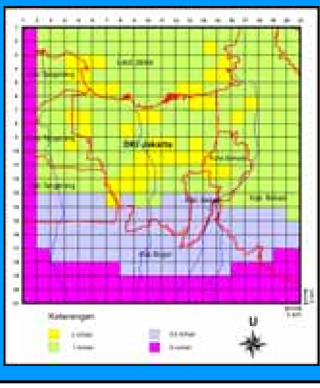
Grid System



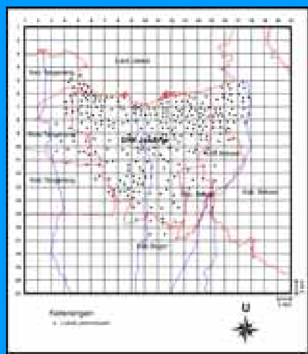
Initial Condition



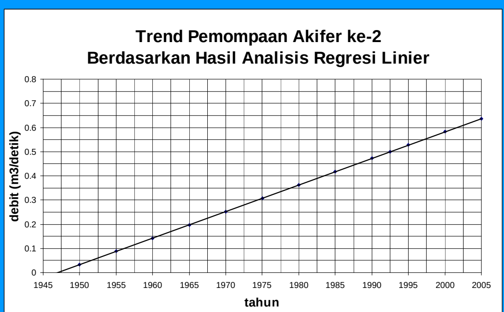
Hydraulic Conductivity



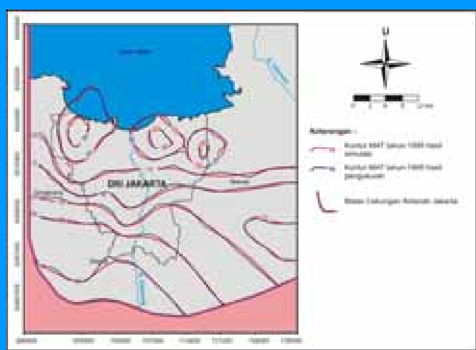
Pumping Location



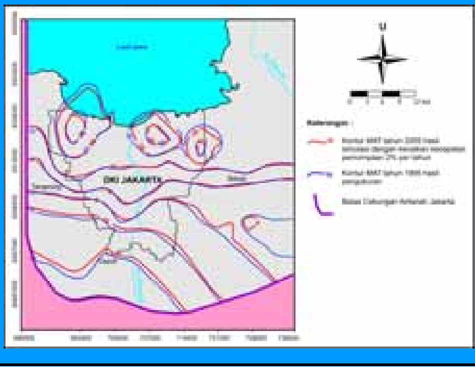
Pumping Rate



Verification

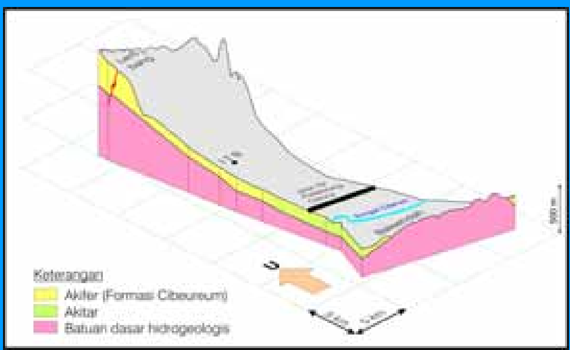


Groundwater Level Prediction in 2005

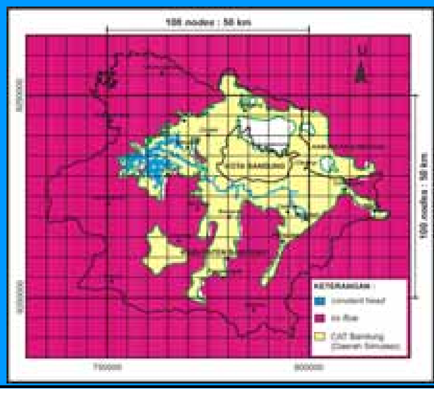


Bandung

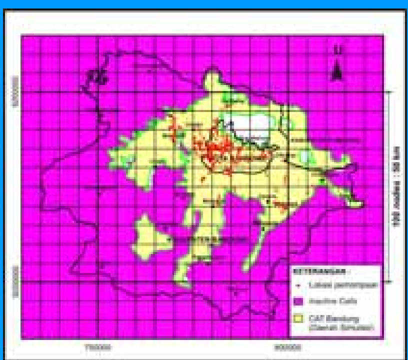
Hydrogeological System



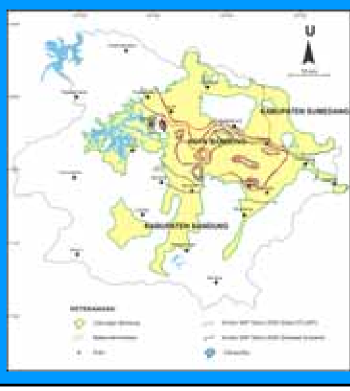
Grid System



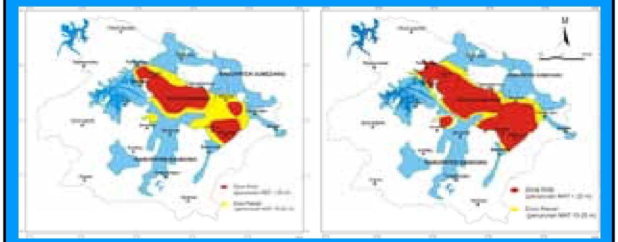
Pumping Location



Verification



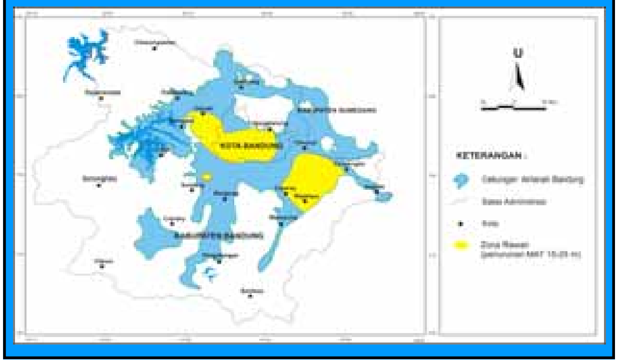
Groundwater Level in 2003 and 2013



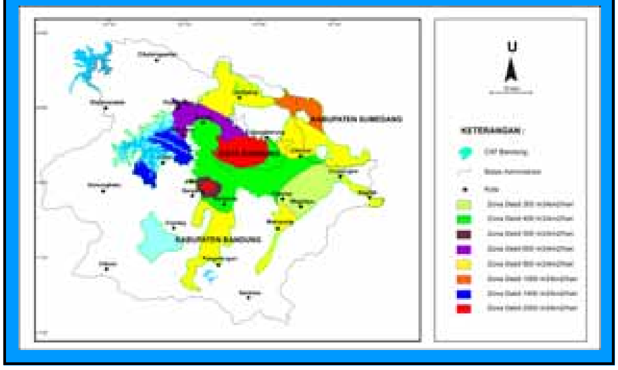
2003

2013
(groundwater use increases)

Target of Simulation



Zone of Groundwater Extraction in Bandung in 2013



Conclusion

- Simulation result:
  - Jakarta: recorded withdrawal = 5% of actual withdrawal
  - Bandung: recorded withdrawal = 33% of actual withdrawal
- For better resolution we need smaller grid system → bigger computer memory
- Main requirement: valid input
  → model update

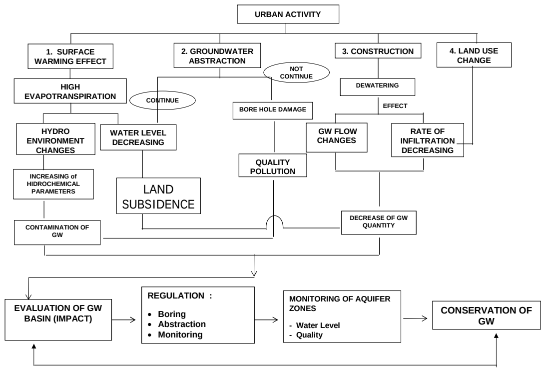
THANK YOU

GROUNDWATER CHANGES AND LAND SUBSIDENCE

HASANUDDIN Z. ABIDIN
ABDURRAHMAN ASSEGAFF

Workshop on Current Problem in Groundwater Management
And Related Water Resources Issues, Kuta, Bali, 3-8 December 2007

GROUNDWATER CHANGES (GW)



Land Subsidence

Types of Subsidence :

- subsidence due to groundwater extraction,
- subsidence induced by the load of constructions (i.e. settlement of high compressibility soil),
- subsidence caused by natural consolidation of alluvium soil, and
- geotectonic subsidence.

➢ In Indonesia, land subsidence of urban coastal areas are usually caused by excessive groundwater extraction.

➢ The already observed subsidence areas :
  → Jakarta, Semarang and Bandung

➢ The expected subsidence areas
  → Denpasar, Surabaya and Medan

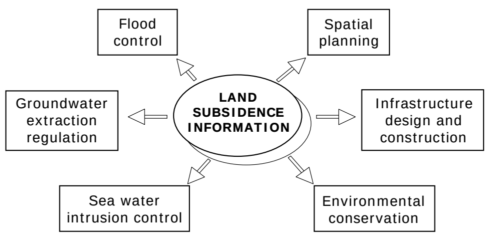
Hasanuddin Z. Abidin, 2006

LAND SUBSIDENCE CAUSES MANY PROBLEMS INCLUDING [USGS, 2007]:

(1) changes in elevation and slope of streams, canals, and drains;
(2) damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, and levees;
(3) damage to private and public buildings; and
(4) failure of well casings from forces generated by compaction of fine-grained materials in aquifer systems.
(5) In some coastal areas, subsidence has resulted in tides moving into low-lying areas that were previously above high-tide levels.

http://geochange.er.usgs.gov/sw/changes/anthropogenic/subside/

IMPORTANCE OF LAND SUBSIDENCE INFORMATION



Hasanuddin Z. Abidin, 2003

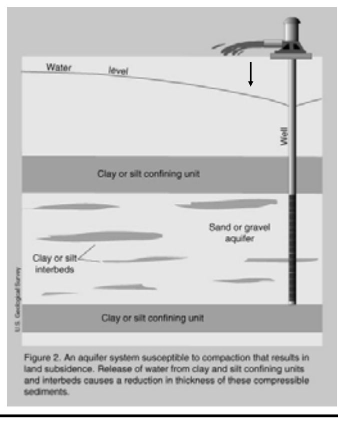


Figure 2. An aquifer system susceptible to compaction that results in land subsidence. Release of water from clay and silt confining units and interbeds causes a reduction in thickness of these compressible sediments.

Groundwater Change and Land Subsidence

Groundwater Change and Land Subsidence

Land subsidence equation
(Lambe and Whitman, 1969)

$$\delta(x,y,t) = \int_0^B \frac{a_v \Delta p}{1+e_0} dz$$

δ = land subsidence
B = aquitard thickness
av = coefficient of compressibility
Δp = pore pressure/hydraulic head drawdown
$e0$ = initial void ratio

Ramdhan & Hutasoit (2007)

Land Subsidence in Indonesian Cities

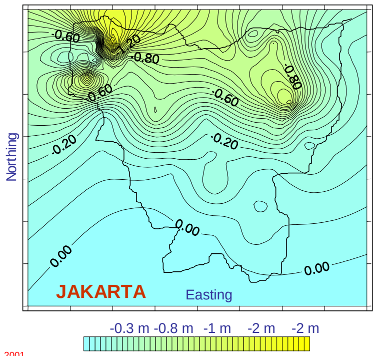
Observed land subsidence :
- Jakarta
- Bandung
- Semarang

Expected land subsidence :
- Surabaya
- Denpasar
- Cilegon
- Medan

observed decrease in groundwater level

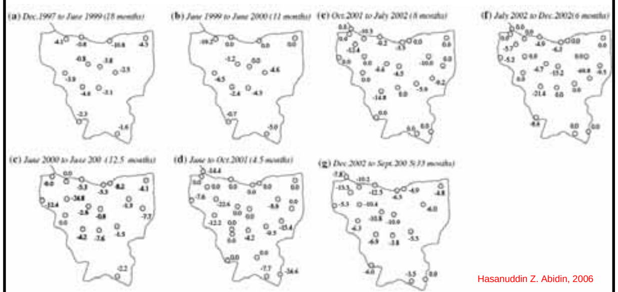
Hasanuddin Z. Abidin, 2006

Land Subsidence from Leveling, 1982 - 1997



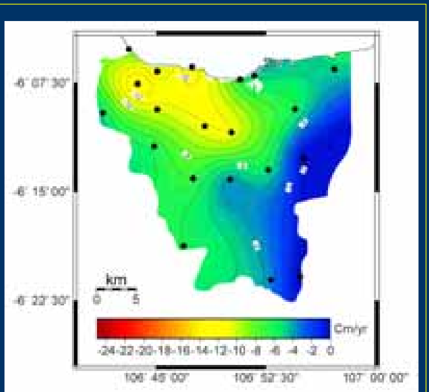
Hasanuddin Z. Abidin, 2001

Land Subsidence from GPS, 1997 - 2005



Hasanuddin Z. Abidin, 2006

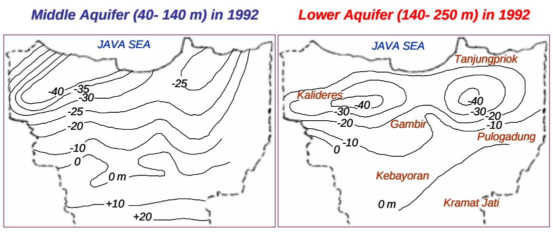
GPS-derived Subsidence in Jakarta

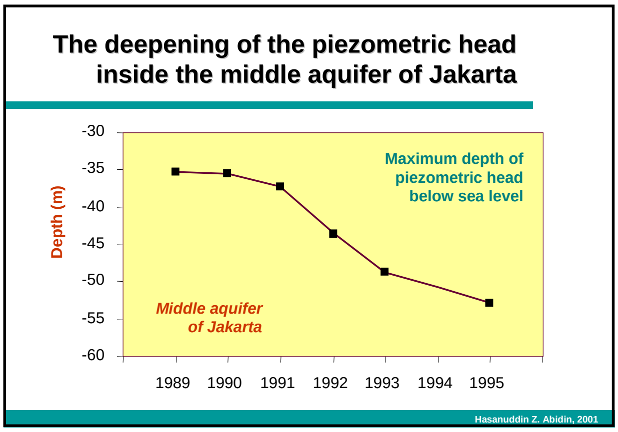


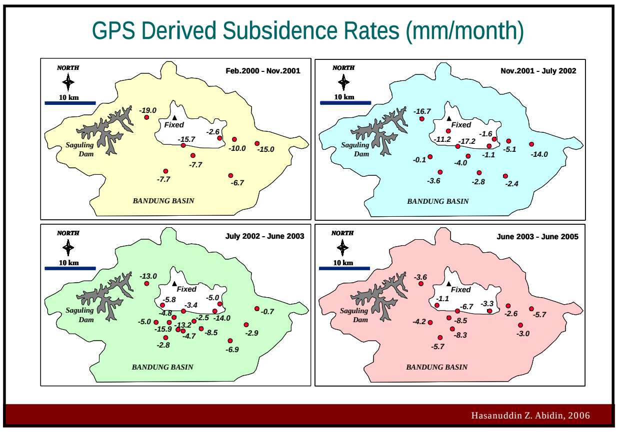
Dec 2002 to Sept 2005

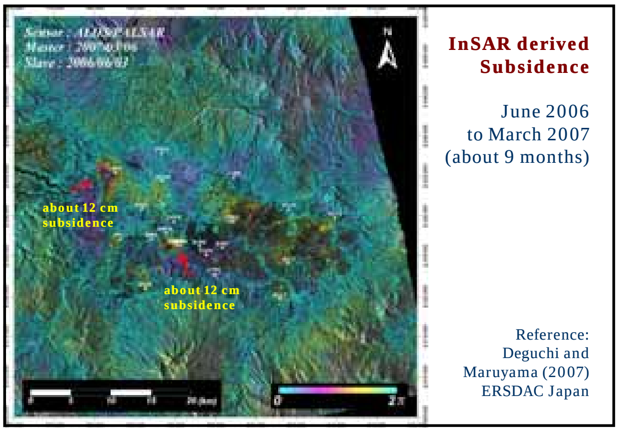
Hasanuddin Z. Abidin, 20006

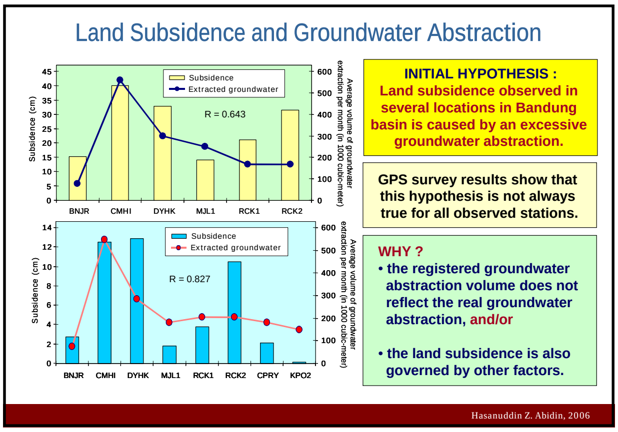
Piezometric water level contours (in metres) inside Middle and Lower Aquifers of Jakarta in 1992

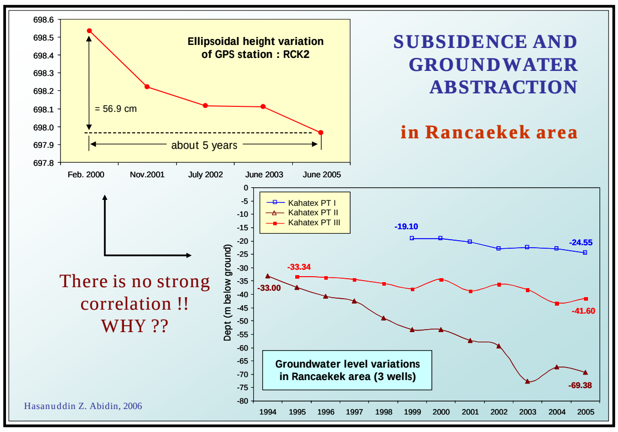


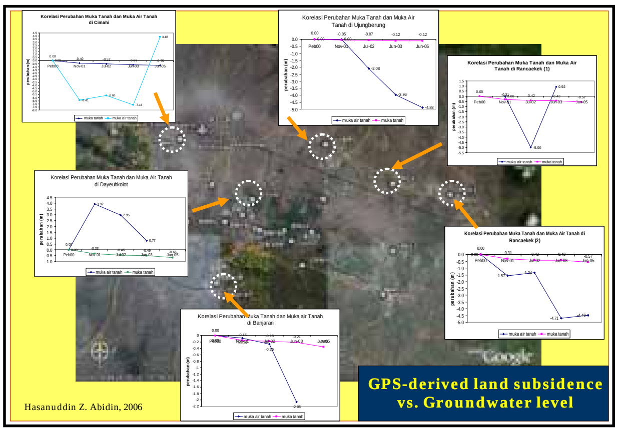

The deepening of the piezometric head inside the middle aquifer of Jakarta
Maximum depth of piezometric head below sea level
Middle aquifer of Jakarta
Depth (m)
-30
-35
-40
-45
-50
-55
-60
1989
1990
1991
1992
1993
1994
1995
Hasanuddin Z. Abidin, 2001

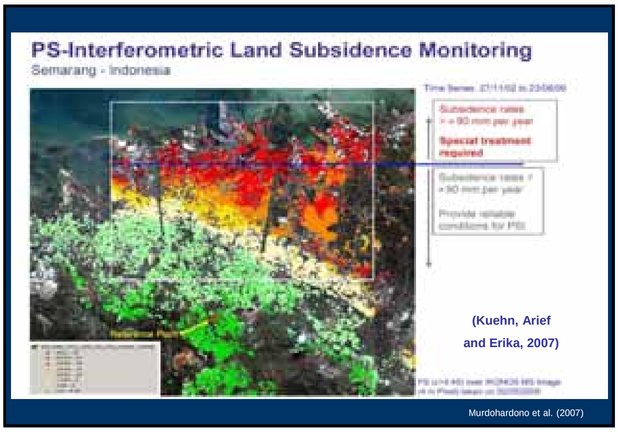

GPS Derived Subsidence Rates (mm/month)
Feb.2000 - Nov.2001
Nov.2001 - July 2002
July 2002 - June 2003
June 2003 - June 2005
NORTH
10 km
Saguling Dam
Fixed
BANDUNG BASIN
Hasanuddin Z. Abidin, 2006

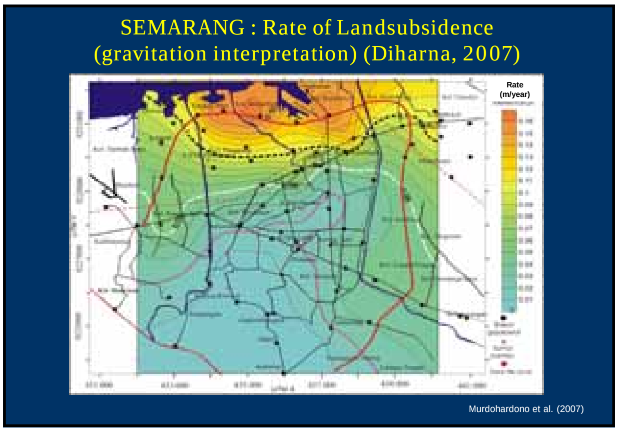

InSAR derived Subsidence
June 2006 to March 2007 (about 9 months)
about 12 cm subsidence
about 12 cm subsidence
Reference: Deguchi and Maruyama (2007) ERSDAC Japan

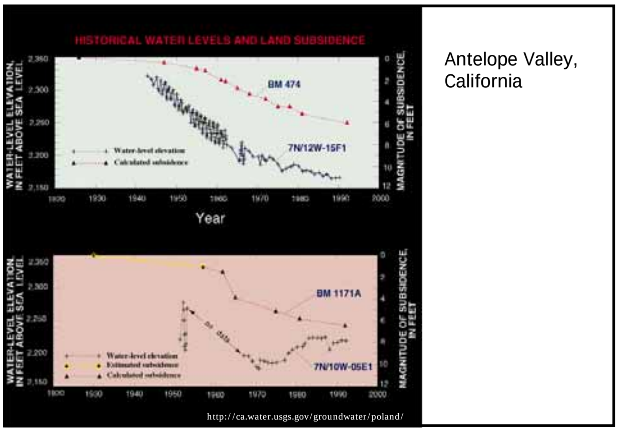

Land Subsidence and Groundwater Abstraction
Subsidence
Extracted groundwater
R = 0.643
R = 0.827
Subsidence (cm)
Average volume of groundwater extraction per month (in 1000 cubic-meter)
BNJR
CMHI
DYHK
MJL1
RCK1
RCK2
CPRY
KPO2
INITIAL HYPOTHESIS :
Land subsidence observed in several locations in Bandung basin is caused by an excessive groundwater abstraction.
GPS survey results show that this hypothesis is not always true for all observed stations.
WHY ?
• the registered groundwater abstraction volume does not reflect the real groundwater abstraction, and/or
• the land subsidence is also governed by other factors.
Hasanuddin Z. Abidin, 2006

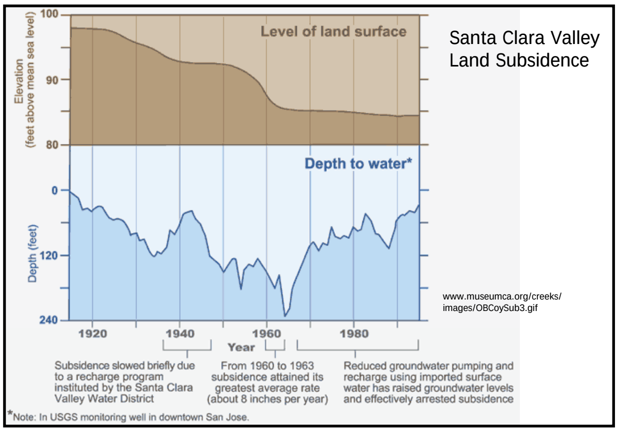

Ellipsoidal height variation of GPS station : RCK2
= 56.9 cm
about 5 years
Feb. 2000
Nov.2001
July 2002
June 2003
June 2005
SUBSIDENCE AND GROUNDWATER ABSTRACTION
in Rancaekek area
There is no strong correlation !!
WHY ??
Kahatex PT I
Kahatex PT II
Kahatex PT III
Dept (m below ground)
Groundwater level variations in Rancaekek area (3 wells)
-19.10
-24.55
-33.34
-33.00
-41.60
-69.38
Hasanuddin Z. Abidin, 2006


GPS-derived land subsidence vs. Groundwater level
Hasanuddin Z. Abidin, 2006









Issues to be Discussed

- “Real” water pumping rate (registered + unregistered) ?
- (Intensification, public education) of recharging wells ?
- (Groundwater level) monitoring wells ?
- (Subsidence) monitoring benchmarks ?
- Subsidence monitoring technique (Leveling, GPS, InSAR) ?
- Regulation and Government Commitment ?

Future plans (tentative schedule) of the "RIHN project 2-4" from 2008 to 2010

Makoto Taniguchi
RIHN

Human Impacts on Urban Subsurface Environment (http://www.chikyu.ac.jp/USE/)

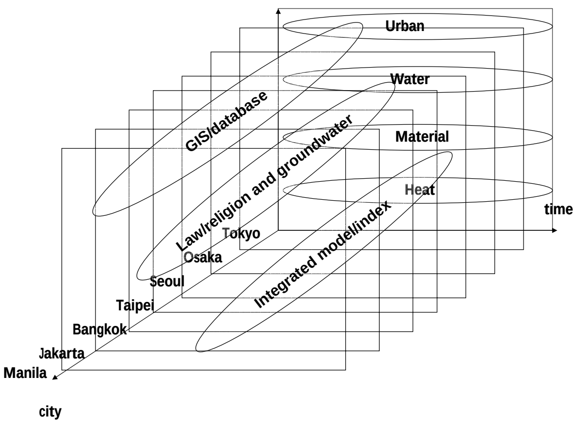
Incubation Study (2003)
↓ (Internal evaluation)
Feasibility Study (2004)
↓ (External evaluation)
Pre-Research (2005)
↓ (1st International Symposium, Kyoto, Oct. 2005)
Full-Research (2006-2010)
↓ **(2nd International Symposium, Bali, Dec. 2007)**
Intermediate Evaluation (Feb.2008)
↓ (3rd International Symposium, ?, Oct. 2009)
Final Evaluation (Feb.2010)
↓
End of the project (Mar. 2011)

1st International Symposium at Kyoto (Oct. 2005)

2nd International Symposium/ Workshop

- **Bali, Indonesia (Dec. 4-8, 2007)**

Nov.4-5: International Symposium on Groundwater Resources
Nov.7-8: RIHN workshop
→ Proceeding (Deadline Jan. 15)
→ interim evaluation (Feb2007)



Publications

- Special Issue : **STOTEN** (*Elsevier)*
  "Sciences of the Total Environment"
  Human impacts on urban subsurface environment
  (Guest editors: M. Taniguchi, WC Burnett, G. Ness)
- Schedule
  - Aug. 30, 2007: submission
  - Nov. 30, 2007: review
  - Jan. 30, 2008: revision
  - Apr. 2008: final files→ Elsevier
  - Aug./Oct. 2008 : publication

Potential papers
1 Overview Paper
15 Original Papers

Communication tools

- HP: **http://www.chikyu.ac.jp/USE/**
  Please check member's page (MP)
  (You need password)
- Newsletters Vol. 1-4: Please contribute your article !!
- Field Reports : HP (MP)
- Lists of Database/GIS/publications/map etc.: HP(ML)
- Mailing List

Opportunities to present your results on RIHN project 2-4

International conference (1)

RIHN/IAHS/GWSP
(Oct. 1-3, 2008, Kyoto)
- Deadline of full paper: Mar. 1, 2008

International conference (2)

IAH2008 in Toyama
Oct 30-Nov.4, 2008

Deadline of abstract: Feb. 30, 2008
Deadline of full paper: June 30, 2008

International conference (3)

DGR Thailand (Somkid)
Bangkok
Jan 2009

Opportunities to present your results on RIHN project 2-4

International conference (4)

IAHS/IAH joint conference
Hyderabad, India
Sep. 7-12, 2009

Sessions:
(1) Sustainability of groundwater in highly stressed aquifers (Taniguchi et al)
(2) GW- SW interaction (Shimada et al), and more……..

International conference (5)

3rd International symposium on RIHN 2-4 project
Oct/Nov, 2009

Other possibilities for publications

- **Urban G**: (Kaneko, Yoshikoshi, Ness, Lee, et al.)
- **Water G**: (Shimada, Fukuda, Buapeng, et al.)
- **Material G**: (Onodera, Burnett, Siringan, et al.)
- **Heat G**: (Yamano, Huang, Wang, Delinom, et al.)
- **Cross cutting G** (GIS etc)
- **Overall** : (Taniguchi et al.), SI, books, database, etc.

We will decide before 3rd International symposium on RIHN 2-4 (Oct 2009).

Introduction of the Database of RIHN project

Member page of the project's homepage

&

FTP server

0. Kind of tools for sharing of this project's information

1.Member page of the project's homepage

2.FTP server

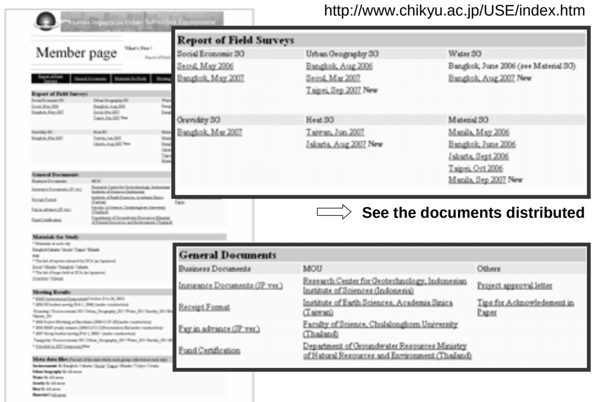
3.FTP server for GIS

1. Member page of the project's homepage

http://www.chikyu.ac.jp/USE/index.htm

1. Member page of the project's homepage

http://www.chikyu.ac.jp/USE/index.htm



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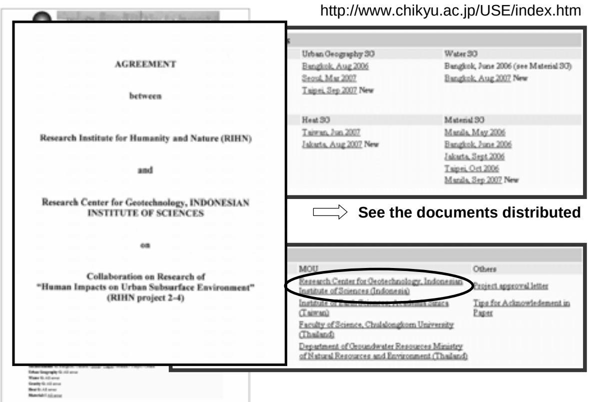

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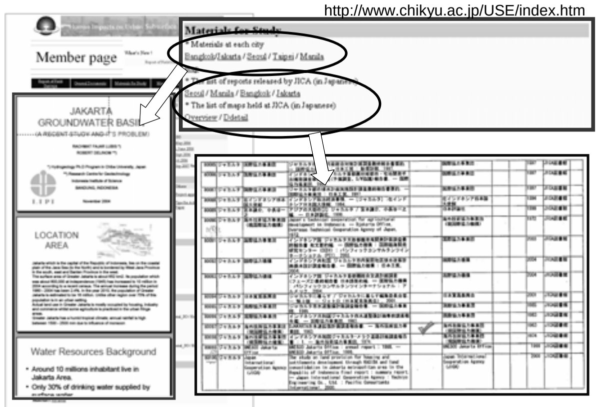

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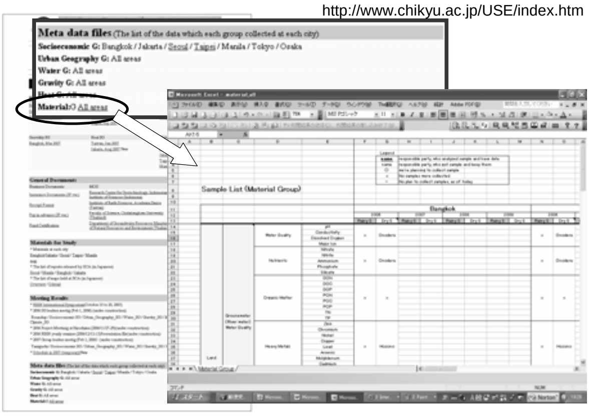


1. Member page of the project's homepage

http://www.chikyu.ac.jp/USE/index.htm

Documents coming out in the future

<u>Paper concerning this project</u>

1. Paper list
2. Paper files (in pdf)

0. Kind of tools for sharing of this project's information

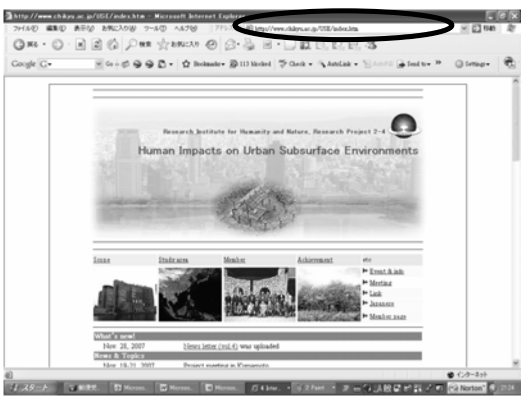
1.Member page of the project's homepage

2.FTP server

3.FTP server for GIS

2. FTP server

ftp://ftp.chikyu.ac.jp/



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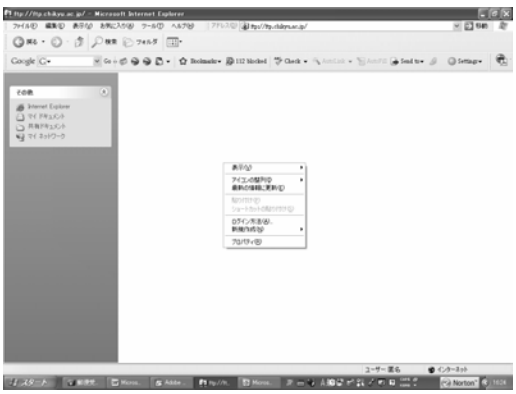

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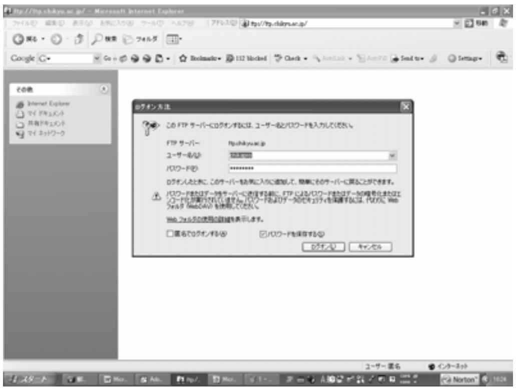

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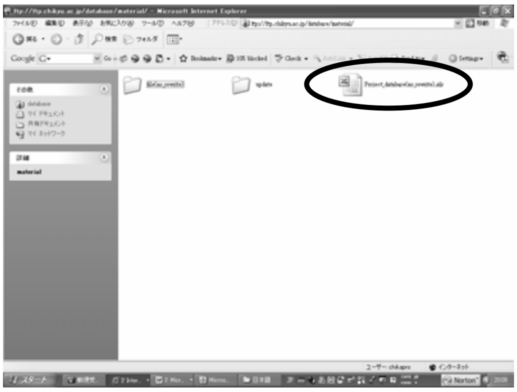
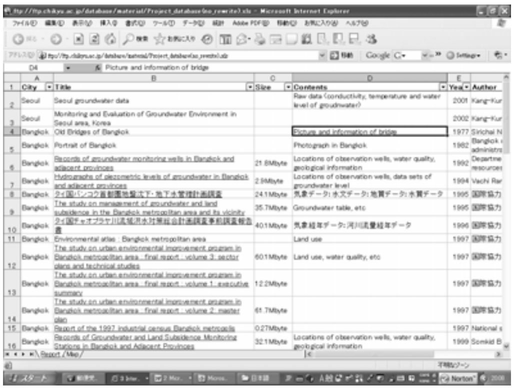


2. FTP server



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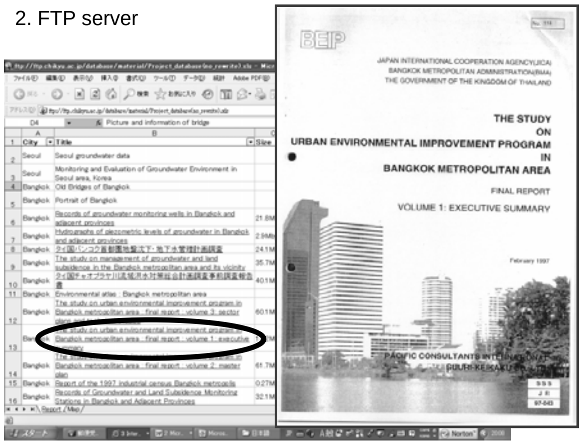

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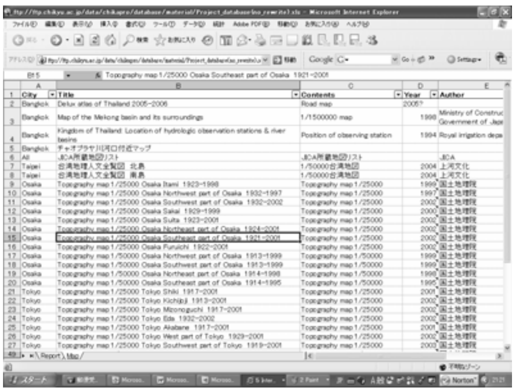


What kind of information do you need?

The Role of GIS Working Group

---- The progress in 2007 and future plan ----

Yu Umezawa
(RIHN, GIS-Working Group)

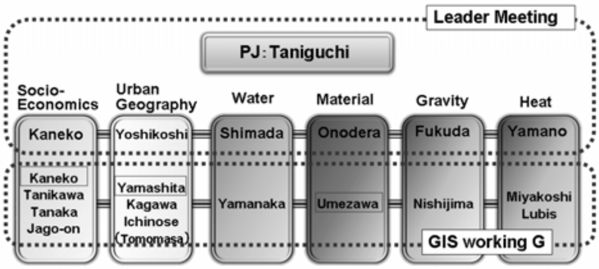
@Bali, Dec. 8 2007

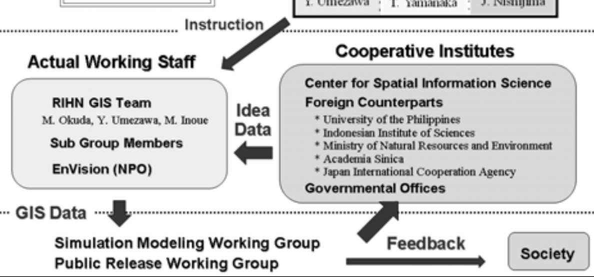
Benefit of using GIS

- Popular format to store a huge sum of data with location information, which were collected at the fields and from statistical book
- Easily understandable format to share the results among group members
- One of potential options in which we will release the final results of our project (Universal format for Explanations!)

Benefit of forming GIS−WG

- Enabling effective explanation of the specific data
- Facilitating communication among the sub-groups





Current progress and future plan

- (～FY2006)
  - Set up the server
  - Confirmation of technical matter
- (～FY2007)
  - Data gathering and Converting into GIS format (Initially from Osaka & Bangkok)
  - Starting making land use map with 500 m mesh data (3 period for Tokyo & Osaka, and 1period for the other cities)
- (～FY2010)
  - Accomplishment of the land use map
  - Cooperation with simulation model working group
  - Public release of the results using ArcIMS

Decision on technical matter

- Application software ------ ArcGIS
- File format---- shp or mif/mid for vector data
  GeoTIFF or jpg, tiff for raster data
  csv for the location data
- Language ---- English
- Coordinate System ---- WGS1984
  - UTM Zone 47: Bangkok
  - UTM Zone 48: Jakarta
  - UTM Zone 51: Taipei, Manila
  - UTM Zone 52: Seoul
  - UTM Zone 53: Osaka, Tokyo
- Metadata-file format----
- FTP Server (2TB) for GIS use only
  ftp://ftp.chikyu.ac.jp

Classification for Land use map

Permeability (Water Group) vs. N and P Loadings / Redox Conditions (Material Group)

- 1. ***Forest*** (Conifer・Broadleaf wood・Bamboo)
- 2. ***Grassland*** (Park・Golf Course)
- 3. ***Paddy Fields***
- 4. ***Fields*** (Dry fields, Meadow, Orchard)
- 5. ***Industrial Area***
- 6. ***Residence Area***
- 7. ***Water body, Wetland***
- 8. ***Others*** (Vacant land)

Prior topics to create GIS map

A: Basic Maps (@ 7 cities, 3 or 5 periods)

① Land Use
② Population
③ Water System
(④ Water & Sewer pipes)

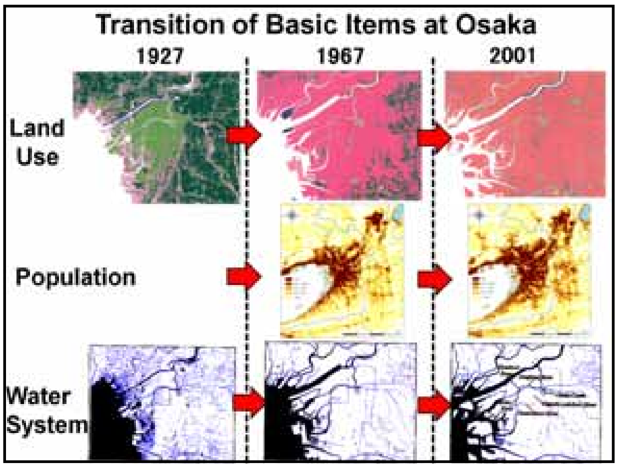
➡ Decide the definition of the city boundary

B: Important Topics

① Water Level
② Land Subsidence
③ Water Quality
④ Temperature (surface & subsurface)

C: Temporary Unchanged Item

① Geology
② Topography



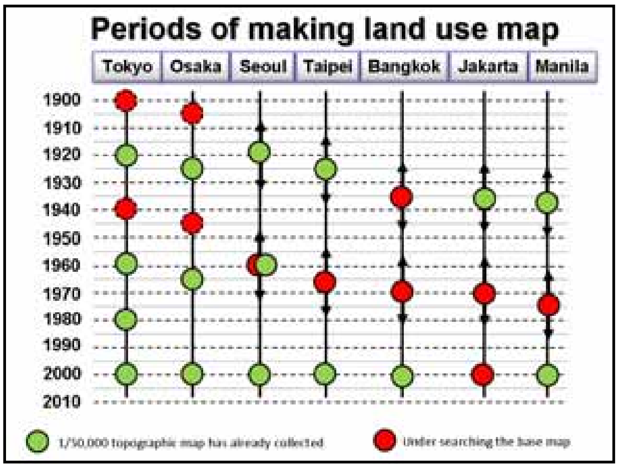
Land Use map (mesh)

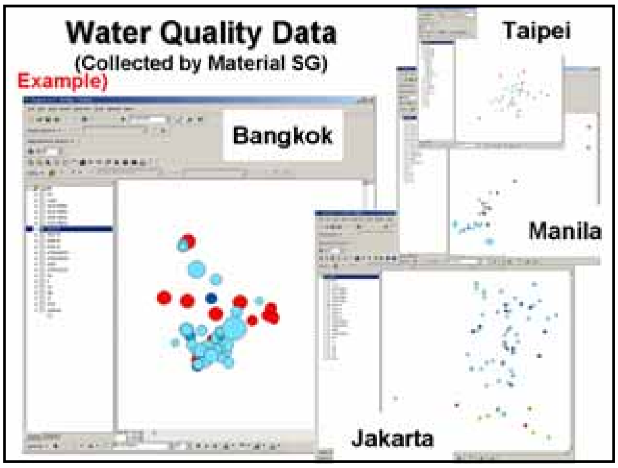
--- Specification ---

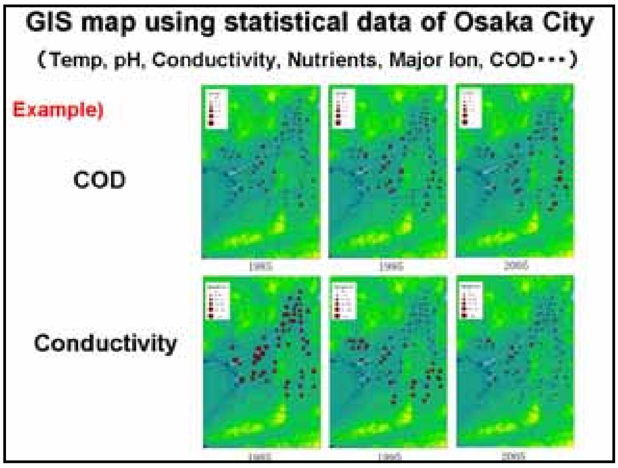
1. Base map is 1/50,000 Topographic map
2. 500 m mesh size
3. 8 classification
4. Schedule: ~ Dec. 25 2007: 3 periods at Osaka & Tokyo
   ~ Feb. 2008: 1 period at the other cities
   ~ Dec. 2008: 3 periods at all cities

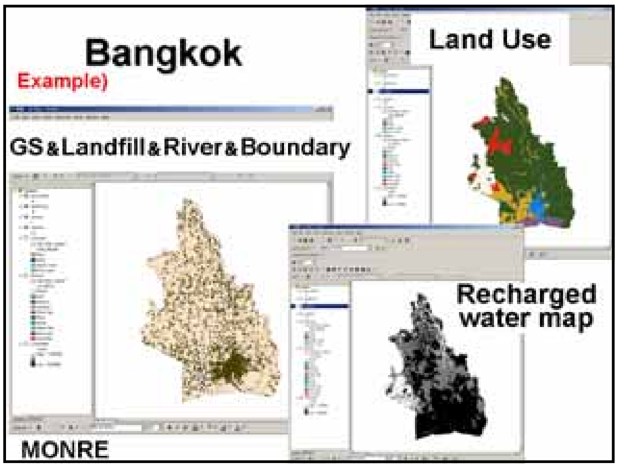
⬇ same criteria

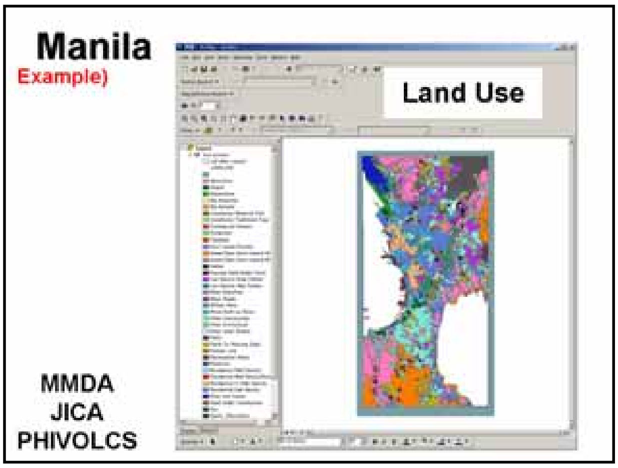
First standard map of Asian Areas!











Rule for using GIS data in paper & presentation

Jakarta	Let to know Dr. Delinom(LIPI) about citation of the data. Put the name "Indonesian Institute of Sciences" in acknowledgement
Manila	For the GIS data 「Metro Manila2」 Source: Metro Manila Development Authority (MMDA) and Greater Paris Regional Planning and Development Institute (IAURIF). Updating the Land Use Map of Metropolitan Manila Final Technical Report. MMDA, Metro Manila, Philippines 1997. For the GIS data 「Earthquake Impact」 Source: Japan International Cooperation Agency (JICA), Metro Manila Development Authority (MMDA) and Philippine Institute of Volcanology and Seismology (PHIVOLCS). Earthquake Impact Reduction Study for Metropolitan Manila, Republic of the Philippines. 2004
Bangkok	Let to know Dr. Adisai Charuratna (MONRE) about citation of the data. Put the name "MONRE" in acknowledgement. Send the report and paper to MONRE.

Benefit of exhibiting the results on web site

(together with submission to scientific journals)

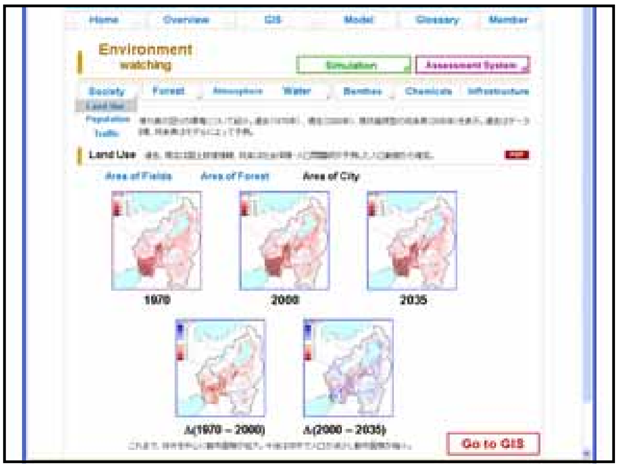
- Higher accessibility for any people (students, researchers, government officials) can effectively propagate the results of our project, and resulting in

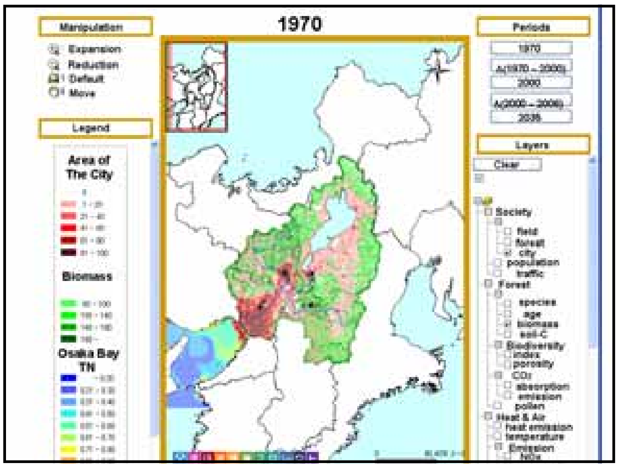
① Enhancing the attentions of ordinary people for the sustainable use of subsurface environments

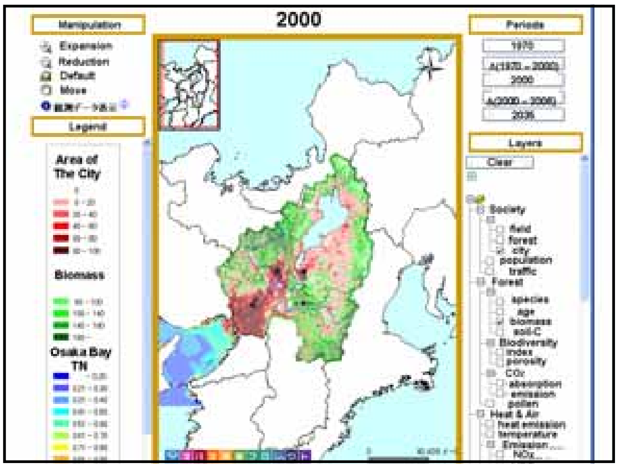
② Facilitating the secondary use of our data (peer reviewed data) by the other researchers, who may conduct further studies related to our project

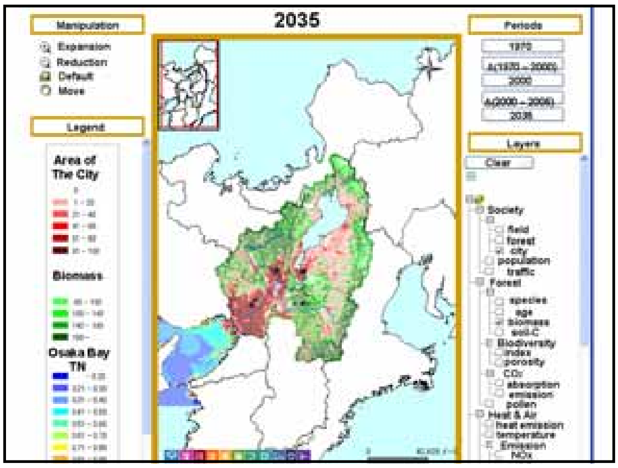
③ Raising the name of RIHN project, and collaborating institutes

④ Raising the evaluation of project by counting the number of access to web site, as of the year, when 2 years passed from the end of the project.









Current Issues

1. How to completely get enough data?
2. How deep we should create web-base system?
3. How to collaborate with "Simulation Model Team"?
4. Efficient and inexpensive staff
5. Complete meta data file simultaneously with GIS
6. ・・・・・
7. ・・・・・

Thank you so much for your kind cooperation!

A review for the studies on Seoul

Backjin Lee

Transportation Research Division, Korea Research Institute for Human Settlements (KRIHS), 1591-6 Gwanyang-dong, Dongan-gu, Anyang-si, Gyeonggi-do, 431-712, Korea

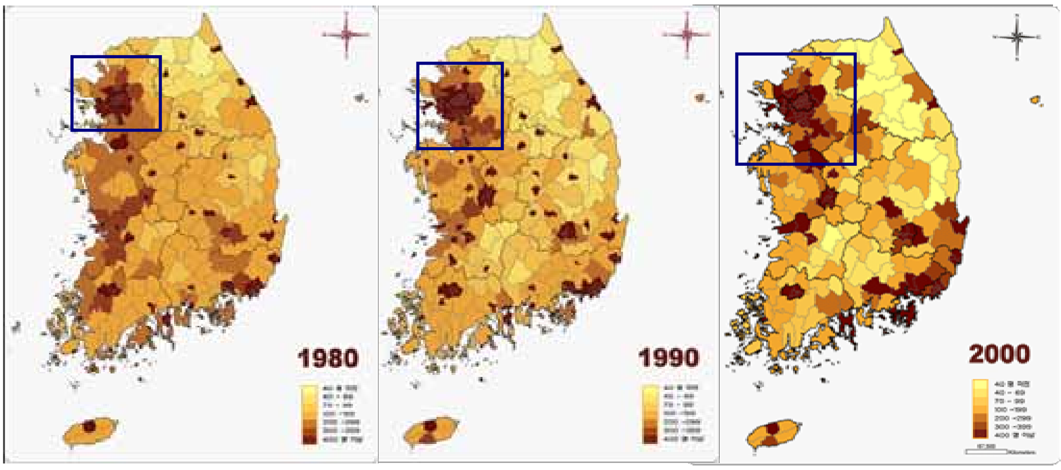
International Symposium and Workshop on Current Problem in Groundwater Management and Related Water Resources Issues was held in Bali from December 3 to 8, 2007. The aims of the review are to overview and give some comments for the papers focusing on Seoul, presented in the Symposium and Workshop.

The author would like to start by briefly introducing Seoul, the capital city of Korea. Seoul had been experienced rapid urban growth. Since 1960, the size of the Korean urban population has increased by 15.8 million, more than the increase in the total national population over the same period. The speed of urbanization of Seoul accelerated during 1966-70 directly after the implementation of the country's first Five Year Economic Development Plan (1962-66). Rapid urbanization itself, however, does not imply a spatial problem; the major urban problems of Seoul have caused by heavy population concentration, leading to a skewed pattern of urban development.

<Table 1>

Group	Title	Author
Urban geography Group	The Effect of Climate Change on Urban Subsurface Temperature	T. Ichinose
Socio-economic Group	Applying DPSIR-C Framework on Urban Subsurface Environmental Issues in Asia Cities	Kaneko et al.
	Urban Development and Groundwater Use in Asian Cities	Karen et al.
	A Review on Urban Policies to Balance between Environment and Development of Asian Developing Countries	Backjin et al.
Material Group	Human Impact on the Environment at Asian Mega-cities, Evaluated by the Groundwater and Marine Sediment Samples	Hosono et al.
Heat Group	Long-term temperature monitoring in boreholes for studies of the ground surface thermal environment and groundwater flow	Yamano et al.

During the workshop, there were six papers focusing on Seoul in their analysis. The papers are shown in Table 1. The methodologies and some results of the papers were relevant to effectively represent the relationships between the urbanization and environment in Seoul. For instance, Ichinose clarified the impact of city's urbanization to subsurface temperature by using the serial data of temperature and populations of Seoul from 1950 to 2000. The paper by Hosono from material group used the field work data which were collected from several representative wells and the Han River in Seoul. They showed the impacts of human activity to groundwater quality of Seoul city.



<Figure 1>

Two papers by Kaneko and Karen, respectively, from socio-economic group used various data including nature condition, demographic, economy and infrastructure of Seoul. The paper by Backjin et al. focused on the urban and environmental policies. They reviewed urban policies of five Asia cities for urban management, environmental management and transportation.

Two points are raised to enhance the significance of the research about Seoul city and future research direction. The first one is related to the change of socio-economic conditions and urbanization patterns of Seoul city. After peaking at 10.97 millions in 1992, the pace of population growth began to slow down. The drop represents the suburbanization in1994 related to the development of new residential towns outside Seoul. However, people in the new residential towns still commute to the centre of Seoul. The suburbanization may have some impacts to the environment of Seoul in the respects of water and air pollutions.

Due to the data requirement of some researches the second concern is the availability of long-term data especially environment-related data before 1990. For instance, groundwater reservation act was legislated in 1994 and the quality test of groundwater started from 1998. The data condition of water and air pollutions also similar.

As a result, more efforts are necessary to collect a long-term data of Seoul and more cooperative works between the RIHN project members and Korean researchers would be required.

RIHN Workshop at Bali, Indonesia

Human Impacts on Urban Subsurface Environments in Asian Megacities

Comments by Chung-Ho Wang on the studies in Taipei area

(December, 2007)

General

Group members had visited the Taipei for their respective study objectives in the past two years (November, 2005; September and October, 2006; June and October, 2007). They have carried out many good measurements and data collection for the project in Taipei area (for example, presentations of Toshiaki Ichinose, Shinji Kaneko, Takahiro Hosono; Makoto Yamano, and others).

The physical and social aspects of the impacts caused by nature and anthropogenic factors both in the global and local scales have been evaluated and documented in their studies; these records are invaluable in our future work. Some further interactions among group members and host scientists are encouraged in order to generate more insightful results and publish in international journals.

Data and Methodology

A standard method should be adopted by all participants of this research for similar topics (for example, UHI parameter, borehole temperatures, groundwater hydrology etc.)

Basic data collection is the main part of this research, fully interaction among group members are desired and do not hesitate to ask help and assistances to the host respective countries. We are very pleased to collect relevant data for all members to use. In this respect, the data archive center is very vital and should be well maintained for all members to access freely in this project.

A metropolitan view on the studied cities is important in our project. In this aspect, Taipei site comprises of Taipei city and part of Taipei County. Many data only cover the Taipei city but not the Taipei County, thus we should bear in mind the difference due to municipal boundaries. The Taipei partner will do the best effort to compile relevant data both for Taipei city and Taipei County for our studies.

Inter-comparisons among seven mega-cities are possible and desirable in the further phase of our project. Parts of the endeavor have been already done by our group members and preliminary results do show some promising and encouraging comparisons. We should pursue along this line in the following years.

Field work can be costly and time consuming. It is suggested that Japan colleagues can leave some spares of sampling tools and vessels in the Institute of Earth Sciences, when the right chance comes, Taipei partner can do the sampling work for most studied items and send the samples to Japan colleagues for a further analyses. I think this is an efficient and economic way for our project.

Workshop and Symposium

A regularly workshop is essential for the promotion of data integration and calibration in this project; we should regularly hold small workshops to enhance the interactions among our group members.

Institute of Earth Sciences is very welcome all project members to come to Taipei for the proposed symposium in the fall of 2009. In addition to that, we also welcome small scale workshops or meetings held in Institute of Earth Sciences at any time if desired. We have conference rooms (two, 100-person and 60-person capacity), as well as discussion rooms (three, <30 persons) with no charge. The accommodation fee is also relatively low at our guest house.

Missing part

Global warming and sea-level rising will be unavoidable threats to the world and pose increasing threats to our environments, including our studied areas. We need to include these impacts and mitigation strategy in our research.

Overview and Comments on the Studies in Metro Manila of RIHN Project 2-4 "Human Impacts on Urban Subsurface Environments"

Fernando Siringan
(Marine Science Institute University of the Philippines; ando_nigs@yahoo.com)

Two groups within RIHN Project 2-4 have conducted fieldworks in Metro Manila - the Material and the Socio-Economic. The Material Group has thus far conducted two fieldworks – in May 2006 and September 2007. The May 2006 fieldwork, which was at the end of the dry season, involved sampling of surface and groundwater in various sites of the city. Measurements of SGD using automated seepage meters, stationary RAD 7 and resistivity were performed in the southern fringe of Metro Manila. RAD 7 survey along the coast of Metro Manila and river landward of the SGD survey site was also conducted. Sediment cores were acquired in Manila Bay.

In September 2007, an automated seepage meter and piezometers for long-term, continuous monitoring were installed inside the Manila Yacht Club in Malate, Manila. This site, based on 2004 piezometric maps and the 2006 RAD 7 measurements, is a potential site of high SGD. Together with personnel from Manila Water Inc., one of the two water concessionaires in Metro Manila, vertical temperature profiling and deployment of TD loggers for continuous monitoring were attempted in several wells across the metropolis. Deployment was not possible because of an incompatibility between the diameters of the TD loggers and monitoring pipes.

Other activities performed by the Material Group is the reconstruction of the pollution history from sediment cores acquired in three water bodies receiving effluents from Metro Manila. A TD logger was also deployed in June 2006 in a well in Makati for long-term monitoring. Rain, river and piezometer water sampling is also conducted at a regular interval or when possible

The Socio-Economic Group went to Manila in December 2006. Several government and non-government offices were visited to acquire secondary data ranging from land use plans to demographics Though data is scattered, with the help of personal contacts, a considerable collection was gathered. These have been made available to all the groups of the projects.

Results of the processing and analysis of samples and data acquired in 2006 were presented by both Material and Socio-Economic Groups in the Bali Workshop last December 2007. The results were very informative. Some are pleasantly surprising such as the lower nitrate content of groundwater than what was expected. Some though are alarming like the occurrence of high concentrations of As in the coastal area of Metro Manila. It is hoped that these results can be relayed to Filipino end users at the soonest. A seminar dove-tailed with fieldwork in 2008 can accomplish not only the passing of information but also the drumming up of support from other locals for the conduct of future work and more importantly, it may lead to action to address the deterioration of Metro Manila's subsurface environment.

Future fieldworks should consider the highly seasonal precipitation in Metro Manila although the continuous monitoring at the Manila Yacht Club may already partly address this. Also. the 2006 fieldwork site is in a relatively young part of the metropolis and is mostly residential. Measurement in an older and more industrial or commercial portion of the city, such as north of Pasig River, may provide interesting variation. For proper interpretation of data, some attention may also have to be given to the nature of Metro Manila's groundwater system, which is still poorly understood.

Overview and Comment
for the Research Studies in Bangkok Metropolitan Areas

Somkid Buapeng
Department of Groundwater Recourses, Bangkok

The progress report of RIHN Project 2-4 “Human impacts on subsurface environments” shows the results of the surveys and studies in Bangkok areas. There are 6 groups of studies namely Water Group, Material Group, Heat Group, Gravity Group, Socioeconomic Group and Urban Geography Group. The study aims to investigate groundwater flow, pollutant contamination, material transports, temperature profile in sediments, land subsidence and statistics data.

The results of survey and studies are in well progress and in good results. Each team conducted their good field surveys and interpretation except some topics need to be interpreted in more details. In Bangkok Metropolitan areas subsurface environments have impacts from human activities such as over pumping of groundwater, construction of underground train and land used. Land subsidence was occurred and can be observed in many areas of heavy pumping of groundwater for more than 20 years. The results from the research project will be useful for future development and management of groundwater resources in Bangkok City.

The results from Urban Group on the religion and groundwater management in Bangkok, it is not clear from the study witch has been found that conductivity of canal water was high in front of the temple. It is also concluded that, there is relationship between conductivity and the location of the temple. The fresh of water in dug well was also found in the area of temple near the canal and from the radon study indicated that the source of water is from groundwater. The general comment on this study: the detail study is needed to confirm because the shallow groundwater in Bangkok are generally is brackish to salty water due to marine deposits in the ancient time. The relationship between the temple and canal have been found in everywhere in Thailand. This is due to in the ancient time the villagers have to utilize water from the canal

For Urban Group, groundwater resources management in Bangkok have been conducted since 1977. Groundwater Act B.E. 2520 was implemented in 1978 and Groundwater Development Fund was established in 2003 to collect groundwater conservation fee in the critical areas. Groundwater Management in Bangkok is also used the technical information such as safe yield and water level decline. So more detail information on groundwater development and management in Bangkok are recommended for the research in order to have a better results in comparing the management of groundwater between each cities.

For Water Group and Material Group, most of the results of study are good and useful for groundwater management in the future. Only the term “Saltwater intrusion” used in the study should be careful considered due to complex conditions of saltwater in Bangkok Aquifers system. The term of saltwater encroachment may be appropriate to use for saltwater movement in mainland. The groundwater quality and the study of seawater level rising due to global warming related to land subsidence are also recommended for future study. Contamination sources in Bangkok especially As, NH_3 /NH_4 and NO_3 are needed to study more details in concentration, original (source) and distribution of the contaminants.

General comments for future work of the project :

1) Coordination and planning for the study should be informed and consult with the counterpart in advance, both for field survey and data collection
2) Meeting and discussion between technical group from RIHN and counter part should be conducted after/during the filed survey.
3) Close collaboration between RIHN and counterpart is necessary for successful of the project.
4) Public relations of the project should be carried out to publish the result of the project and to be used for sustainable groundwater management.

RIHN Workshop on
Human Impacts on Urban Subsurface Environments in Asian Megacities

Bali, 7 – 8 December 2007

Overview and comments for the studies in Jakarta

By

Robert M. Delinom
LIPI, Indonesia

A study in Jakarta was carried out on the period of 4 – 14 September 2006 and was lead by Prof. Dr. Makoto Taniguchi. The team consists of Heat, Water and Material Groups; and 12 scientists and 2 students were involved. The scientists were Prof. Makoto Taniguchi (RIHN), Prof. Jun Shimada (Kumamoto University, Prof. Yoichi Fukuda (Kyoto University), Dr. Jun Nishijima (Kyushu University), Dr. Shin-ichi Ondera (Hiroshima University), Dr. Akinobu Miyakoshi (AIST), Dr. Yu Umezawa (RIHN), Dr. Tomotoshi Ishitobi (RIHN), Dr. Takahiro Hosono (Akita University), and Dr. Fajar Lubis (Chiba University). Two students were Miss Misa Sawano (Hiroshima University) and Mr. Satoshi Ueno (Kyoto University). Some Indonesia scientists and technicians who joined this study were Dr. Robert M. Delinom (LIPI), Ir. Arief Rahmat (LIPI), Drs. Dadan Suherman (LIPI), Dudy Priadi (LIPI), Dr. Parluhutan Manurung (Bakosurtanal), Prof. Abdurrahman Assegaf (Trisakti University). Two students of Trisakti University (Rendy and Fauzal) were also involved.

Heat Group (Miyakoshi and Fajar Lubis) visited 26 sites monitoring wells which were located inside Greater Jakarta Area. 3 (three) locations (Jagakarsa, Dukuh Atas, and Sunter) were chosen for installing Continuous Ground Surface Temperature (GST) Measurement and 2 (two) locations (Jln. Tongkol and Kamal Muara) were chosen for automatic water level measurement (pressure system) only. The GST was installed at 35 – 40 – 45 m under earth surface. It was installed simultaneously with automatic soil temperature measurement (at 50 cm and 1 m under earth surface), automatic air temperature measurement (2 meter above earth surface), and automatic water level measurement (pressure system). On the period of 6 – 14 August, 2007, Fajar collected some recordings of those equipments and made groundwater temperature measurement at 9 sites of 26 sites that visited on previous measurement. The results are presented on this RIHN Workshop.

Water and material groups visited and sampled some water from springs, rivers, dug wells, and monitoring wells. Those samples were taken for radio-isotope and chemical analysis in Japan. Sub-marine Groundwater Discharge (SGD) was measured at Carnaval Beach in the northern part of Jakarta. Some gas samples were taken for further analysis in Japan. The results of those above analysis are also presented on this RIHN Workshop.

All result analysis showed a good representation of sub-surface condition of Jakarta Area. The Heat Group made a re-construction of the thermal environment evolution in Jakarta Area, nicely. The information about Jakarta basin geometry was one of the good result in supporting the sub-surface condition role in Jakarta flooding analysis. The water and material groups had already came to preliminary result of pollution status and its mechanism in Jakarta. The sea water intrusion along coastal area was identified using the data analysis that carried out after field work in Jakarta. It will be completed by using new age tracer (CFCs) that is planned to be executed this year. SGD technique enriched Indonesian scientist knowledge about groundwater flow in Jakarta area. As a whole, this study gave good information about the sub-surface present condition in Jakarta and must be taken into calculation in doing Jakarta development planning in the future. The aim of this study is just about to reach the goal but some addition analysis of new samples and available secondary data must be added in the near future. The socio-economic analysis about this topic is a necessity as human activities in a certain area is always connected with socio-economic condition of that area. It is planned to be executed soon in order to complete the available secondary data.

It is hoped that this study can give some contributions in solving sub-surface and flooding problems in Jakarta, especially in sub-surface condition management in order to decrease the speed of its descent.

Comments by W.C. Burnett on Presentations and Progress of RIHN Project 2-4 "Human Impacts on Urban Subsurface Environments"

INTRODUCTION

These comments are based on a review of hand-out materials and presentations made at the International Conference in Bali, Indonesia during Dec. 7-8, 2007. My comments will emphasize the research of the "Materials" and "Water" groups as my own background is oriented in that direction. A few comments are also directed at other components.

My overall impression is that the project has achieved a measure of success that is somewhat remarkable in the short time since its inception only about two years ago. The various groups have already launched several field expeditions, collected extensive data sets, and have written papers that are in an advanced stage of publication. For example, a special issue of the journal "Science of the Total Environment" (STOTEN) has been approved and 16 papers have been submitted, most of them already reviewed. It is very likely that the completed publication project will go to the printers during 2008.

I will divide my comments into a few topic-oriented sections and conclude with a few additional comments.

GROUNDWATER TRACING/AGE DATING

The development and use of natural (e.g., CFCs) and artificial (e.g., ^{85}Kr, SF_6) groundwater tracers by the Water Group is an extremely valuable approach. The development of ^{85}Kr (a radioactive noble gas released to the atmosphere by nuclear reprocessing facilities) is extremely challenging but may open many avenues of research in the future. I encourage the group to continue this pursuit recognizing that it will benefit the scientific community beyond this project.

While this type of research clearly advances our understanding of the subterranean environment, the field and analytical studies are very time and labor intensive. It may thus be unrealistic to pursue groundwater tracing investigations in all seven of the target megacities. It would be better to have data sets complete enough for proper interpretation from just a few cities rather than incomplete data from several sites.

SEDIMENT CORE STUDIES

These studies aim to provide a history of contamination over the past 100 years or so. While this is a worthwhile goal and can provide valuable information, the connection to the subsurface environment is not obvious. In some cases additional information, such as the example shown for Osaka Bay, may provide this link. Serious thought on how this link could be made for any particular study site should be given before selecting additional sites for this purpose.

I will also add here a few technical points: (1) thus far, no rigorous geochronological control (e.g., ^{210}Pb, ^{137}Cs) has been provided for the studied cores – this is a critical shortcoming; (2) the metals work presented was apparently done on acid extracts to leach off surface-bound contaminants – this is a controversial approach and thought should be given to documenting what these extracts actually measure; and (3) the isotope (e.g., Sr, Pb isotopes) tracing to indicate the source(s) of contaminants is very useful and should be continued.

SGD/NUTRIENT LOADING STUDIES

The objective of these studies is to document how subterranean waters discharge nutrients and other dissolved species to surface waters and influence the chemistry and contamination of the surface environment. As such, these studies have a direct link to the subterranean environment and should be a key area of research. After all, if we contaminate groundwater but those waters remain isolated forever, there would be no effect at the surface.

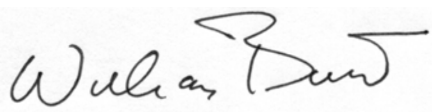
Thus far, these studies have been going well but with some surprises. For example, the groundwater exchange along the coast of the Upper Gulf of Thailand appears to be dominated by recirculated seawater and thus recirculated nutrients. The groundwater discharges in Manila Bay did show some a fresh component but again consisted largely of recirculated seawater. While recirculated nutrients are still of ecological interest, it is likely that there are more direct linkages to the groundwater environment. Thus far, the one area that seems to indicate direct groundwater discharge is from some ephemeral surficial aquifers that discharge into the canals (“klongs”) of Bangkok. These discharges show a strong signal but preliminary data indicates they are restricted to the wet season. Additional klong surveys and more intensive work in selected canals, including piezometers and seepage meter studies, should be pursued. New areas should be investigated at some sites.

These SGD studies, in a manner similar to the groundwater tracer studies, are very time and labor intensive. Thus, it is recommended that the number of targeted cities be restricted to a few, perhaps three, that can be successfully investigated in the remaining years of the project. Based on the information gathered thus far, a reasonable choice may be Manila, Bangkok, and Osaka. We already have some good background information on these sites, good working collaborations, and they represent a range in their urban developmental stages.

FINAL COMMENTS

As mentioned earlier, this reviewer is impressed by the high level of accomplishment realized by this project in a short time. The work performed to date will serve as a good foundation to build to a successful conclusion. I’ll conclude with a few points for consideration by the project members.

1. The urban geography and socio-economics groups have amassed a considerable amount of data and they are searching for more. While it is always preferable to have complete data sets, it is not too early to formulate hypotheses and make tentative interpretations. Why are these cities expanding so rapidly? Why are people drawn to the cities (e.g., Manila) even when there are no jobs?
2. It seems clear that it will not be possible to derive the same level of research in all seven target cities. This would be an appropriate time to make the decisions on where certain lines of research should be concentrated.
3. A useful exercise for all project members would be to reflect on what they have already accomplished and formulate research hypotheses (or revised hypotheses) that can be tested in the 2nd half of the megacities project.



William C. Burnett
Dec. 10, 2007

Comments on the ongoing RIHN Research Project 2-4 "Human Impacts on Urban Subsurface Environments"

Shaopeng Huang
(University of Michigan, Ann Arbor, MI 48109-1005; shaopeng@umich.edu)

Firstly I would like to congratulate the USE team for the hard work and good work done. A great portion of field work has been carried out over all seven target cities, and a huge amount of data has been acquired. Many interesting results were presented at the International Symposium and Workshop on Current Problem in Groundwater Management and Related Water Resources Issues 3-8 December 2007, Bali Indonesia. The followings are some comments and suggestions based on what I learned from this international symposium and workshop.

- Interdisciplinary data integration and interpretation

I am particularly impressed to see several new, cross-cutting projects/topics discussed at this meeting. Human beings modify urban subsurface environmental system mainly through changing land surface energy budget, water utilization, and pollution. But human activities are governed by laws and religious/moral believes. Moreover, human impacts are superimposed on natural changes. The USE project team is divided into social economic group, urban geography group, water group, gravity group, material group, and heat group. Each group has its specific tasks and could generate insights into specific aspect of urban environmental changes. However, a good understanding of the anthropogenic effects on subsurface environment could be achieved by collective efforts of related groups through integrative analysis of interdisciplinary data sets. I see the new projects/topics such as GIS data system, laws and water resource, religion and water quality as great start points for integrative analysis to bring many seemingly separated phenomena into a coherent understanding of the human impacts on urban environments.

- Baseline data should be the focus of next stage data acquisition effort

With a tight budget and the relatively abundant urban data acquired, I think it is time to better focus our next stage data acquisition effort on filling critical data gaps. From my own experience in trying to detect urbanization effects in Osaka surface and subsurface thermal environment, I found a shortage of rural data for separating natural and urbanization effects. Urbanization effects are superimposed on natural variability. To reliably isolate an urban anomaly, we will need to have a good understanding of the background. In other words, to isolate urbanization signal, we need to determine the normal baseline. Unfortunately, there is very few rural data available. Although the natural baseline can be inferred from global database or model, acquiring baseline data from the rural areas immediately adjacent to the target cities is the most reliable approach for the task. At this stage, filling the data gaps in rural and suburban areas will be of a much greater significance than acquiring additional urban data.

- Database development should be given a high priority

At this stage of the project with a huge amount of data acquired, I would like to suggest that database development be given a high priority. I would further suggest that the data sets acquired by individual groups should be made accessible to all project members via internet. The database should be constructed not only as the data repository, but also as an important platform for exchanging ideas among the researchers across working groups. Each individual group has its own special focus on certain environmental processes. However, subsurface environmental system encompasses interactions among various processes. Therefore, many environmental changes are correlated rather than isolated. Project members should be encouraged to use data acquired by different groups for cross verification of their working hypotheses. Important insights would be missed if researchers are limited to their own data sets. I think that the productivity and the overall quality of the final products of this project could be substantially affected by the functionalities of the project database.

- Data quality control

We all draw our conclusion based on data. Data is the starting point of our research. We ought to keep in mind that not all data are of the same quality and of the same value to the problem we want to address. Taking borehole temperature data as an example, temperature is a fundamental parameter associated with almost all physical, chemical, and biological processes. On the one hand, temperature measurements carry rich information about many processes. On the other hand, they are subject to various perturbations. Signal and noise are relative, depending on the purpose of a research. In principle, every measurement bears both regional and site-specific information. An important aspect of data quality control is to document the geographical settings of the data sites and the circumstances under which the measurements were made. This kind of information will become valuable in later stages of data interpretation and modeling. They will help data users to avoid misinterpretation of noise as signal. We want to make sure that we will be using appropriate data to address a related issue.

- Standardization of data processing

Keep in mind that most geophysical data inversions (including geothermal and gravitational interpretations) are parameter dependent. Their solutions are not unique. There are many assumptions and parameters in a numerical model. By changing some of the assumptions and/or parameters, one can usually fit the same set of observation data equally well with different solutions. It is essential for the modelers to follow certain standards and rules in numerical simulations to make sure that the results will be compared at a common reference level.

- Concrete/practical case studies to promote the publicity of the project

I think one way of promoting the publicity and extending the social impacts of the USE project is to develop come concrete and practical case studies that could attract attentions from news media and the general public. One perspective study of such potential would be the effect of subsurface warming on the early onset of cheery blossom in the urban areas in Japan, as mentioned by Taniguchi-san in his overview presentation. The report "Long-term trends of phenological events in Japan" released by Japan Meteorological Agency shows that nation-wide cherry blossom blooming date has advanced by 4.2 days over the past 50 years, with a 6.1-day shift for six selected big cities versus a 2.8-day shift for eleven selected smaller cities. Urban heat island effect is obvious in the contrast between big and small cities. However, JMA has been having difficulties in correctly predicting festival dates for cherry-blossom based on air temperature data. Incorporation of subsurface temperature could potentially improve the predictability because the biological rhythm of a cherry tree could be affected by both air and soil temperatures. Given the cultural and social-economic significance of cherry blossom festival in Japan, such a study could serve as a vehicle to foster the publicity of the project and the awareness of subsurface environmental effects.

- Possible spatial extension of the USE research?

Most existing environmental projects are focused on changes above the ground surface. The on-going RIHN research project 2-4 is the first multidisciplinary project to study anthropogenic effects on urban subsurface environments on an international scale. Nevertheless, the target of this project is restricted to seven cities in eastern Asia. I think it would be another great contribution to the international community for RIHN and the USE project leader Taniguchi-san to develop a follow-up project to extend the spatial coverage of this type of research. In particular, as the largest and fastest developing country China is undergoing an unprecedented urbanization process and facing enormous environmental pressure. The impacts of Chinese environmental issues are not restricted to China, but also affect its adjacent countries including Japan. I think such a follow-up project with a focus in China would be of great significances yet highly cost effective, given the knowledge base built by the USE project team and the instruments acquired during the project period. Additionally, such a project would be in lines with the RIHN Initiative for Chinese Environmental Issues.

Note of Discussion
December 8, 2007

I. Future Plans

Research and fieldwork plans of each group for 2008 were presented. Important schedules for the project were also discussed as follows:

Deadline for submission of articles for the workshop proceedings
January 15, 2008
Project Interim Evaluation
February 2008
Urban Seminar (Seoul)
June 2008
3rd International Symposium on RIHN 2-4 Project
October/ November 2009, Taipei

II. Overview and Comments for the studies in Manila, Seoul, Taipei, Bangkok and Jakarta

Fernando Siringan, Backjin Lee, Chung-Ho Wang, Somkid Buapeng and Robert Delinom

III. General Comments: William C. Burnett and Shaopeng Huang

Summary of the Discussion

Each foreign counterpart gave comments on different aspects of the project including research results, project scope, research methodology and instruments, fieldwork implementation and information sharing, among others. Prof. Burnett and Dr. Huang, on the other hand, initially presented their general comments on the project and later divided the task to give specific comments to the Water and Material Groups (Burnett), and Heat and Gravity Groups (Huang).

To sum up the discussion, we tried to organize the issues into the following topics:

1. Results of data gathering during the previous years

From the reports presented, we can see that the project is progressing and project members have gathered data in just a short time. Seeing the research results from different cities, it is positive that we can make inter comparisons among the 7 case study areas in the future phase of the project. However, if possible it would be better to apply standard model or methodologies in data gathering in all areas. It is necessary to have in-depth discussions about the research results and more detailed interpretation of the data to ensure its validity and reliability, especially with our foreign counterparts and research collaborators. In this manner, we can also solicit suggestions to improve our research methodologies.

In using and interpreting the data, we have to be careful and need to keep in mind that not all data are of the same value and they can be subjected to various perturbations.

Ensuring the validity and reliability of data is very important, especially if we intend to report our results in public or write it in journals. If the results are seen as not consistent with the data gathered by local agencies, or perceived by stakeholders as not consistent with the local conditions, these might be interpreted in a different manner. In worst circumstances, it might encourage negative reactions from stakeholders and the implications may not be favorable on our part. It is suggested to repeat measurements and check again the source of the data.

We also have to be clear in describing situations such as “saline intrusion”, “salt water intrusion”, “sea water intrusion”, “land subsidence, sea level rise, or flooding, or in applying concepts such as integrated groundwater management or urban development (population increase, depopulation).

2. Project Scope

Based on previous fieldwork experiences, some data gathering methods are very labor-intensive, time-consuming and need a lot of resources. In this kind of situation, it would be necessary to be selective of study sites. For example in SGD and nutrient loading studies, it would be better to limit the studies to Osaka, Manila and Bangkok.

On the other hand, if we describe urban development, we need to clearly define the scope of the areas that we intend to include in the study, either on a city-level, county-level, metropolitan level, or even to include the peri-urban areas or rural areas. Different scope or area coverage would reflect different natural and socio-economic conditions. For meteorological data, for example, if we want to isolate urban effect, we also need to see the rural data.

3. Research Methodologies

Below are some specific comments/ suggestions on methodologies:

Groundwater tracing/ dating

- Development of tracers (CFCs, Kr-85) is very valuable and the use of multiple tracers allows for unique solutions (age, fraction)

Sediment/ Core studies

- Need geochronological control (Pb 210, Cs-137)
- Normalize metals to terrestrial component (e.g. Al) to remove the effects of dilution, etc.
- Isotope tracing

SGD/ Nutrient loading studies

- Evaluation of nutrient and other contaminant fluxes via SGD

4. Fieldwork Implementation

Fieldwork Plan

There is a need to formulate and to give a detailed plan about the field survey to our foreign counterparts so that they will be able to make necessary arrangements for sites or areas to be visited and to prepare the local staff who will be able to assist in the field.

The fieldwork plan should contain the following:

- **Objectives of the field survey (sampling, visits to local offices/ interviews, etc.)**
- **Kind of data/ information needed**
- **Resources needed during fieldwork (human resources, equipments, etc.)**
- **Intended places to visit**
- **Period/ Schedule of activities**

After making the plan, it would be better to discuss with our foreign collaborators the feasibility of the fieldwork and to solicit ideas if there are adjustments to be made in the plan. We should also try to organize the fieldwork in a way that the local staff will be able to learn from the experience and from the methodologies that we apply.

Availability of and Access to Information and Data

Different groups have different data needs and not all data are available or easily accessible in the areas. In some occasions, we need special connections and arrangements to acquire the data that we need.

Sampling Location and Period

As the project deals with the impact of urban development, there is a need to gather as much information based on different land use types and built up areas (i.e. residential, commercial, industrial), or different water sources, if applicable. (i.e. deep wells, shallow wells, rivers, etc).

The desired sampling location should be informed in advance because in some areas, access is limited or restricted and special arrangements or permissions should be acquired beforehand.

The target urban areas have prominent wet and dry seasons. To achieve more relevant research results, there is a need to take measurements during both dry and wet seasons. In Manila, for example, the data were taken during the dry season so now it is better to take measurements during the wet season.

If repetitive measurements are needed, the local researchers can help in sampling.

Groups in Fieldwork

Taipei: It is better to come to Taipei in separate groups
Manila, Bangkok and Seoul: It is fine if all groups come together during one fieldwork period.

(Seoul: There is a need to check if the government will allow field survey in some areas).

5. Sharing of information a) among members; b) to the public

As we have already gathered considerable amount of data, at this time we need to consider how we are going to share the results to our research counterparts, related researchers or to the government agencies where we took some of our information. Suggestions include conducting workshops, seminars or write shops (smaller groups) during the field survey period.

Regular workshop is also essential for data integration and validation. For the evaluation of the project or publicity of the project, we need to consider practical case studies that can be easily understood by the public (*i.e the effect of temperature on the blooming of cherry blossom*).

Human impacts on urban subsurface environment

Makoto Taniguchi , Research Institute for Humanity and Nature

RIHN project 2-4 "Human impacts on urban subsurface environment" started at 2003 as IS, followed by FS (2004), and PR (2005). The full research (FR) of the project had started at 2006, and the project will have an external evaluation at the end of 2007 financial year. This project tries to evaluate the relationship between the development stage of the city and various subsurface environmental problems which were ignored for long time because of invisibility of the problems and difficulty of the evaluations. The project has four subjects; urban, water, heat, and material, then two different methods are used for each subject. Therefore eight sub-groups work for the project in the basins including Tokyo, Osaka, Bangkok, Jakarta, Manila, Seoul, and Taipei. Research groups with about 50 project members have done many field works, and domestic and international meeting (1st at Oct. 2005, and 2nd at Dec, 2007 which is authorized as one of side events of COP13). The interim results of the project will be published in the special issue of STOTEN (Science of Total Environment, Elsevier). The new methods for evaluating the changes in groundwater storage by Satellite GRACE, and residence time by Kr and CFC, have been developed in this project. Cross cutting theme, such as groundwater and religion, the law and change in reliable water resources between groundwater and surface water, the development of integrated indicators based on GIS for understanding the relationship between human activities and subsurface environment, and combining subsurface environmental problems into socio-economic model, have been considered as additional insights for the project. The results of submarine groundwater discharge and dissolved material transports into the ocean by uses of stable isotopes (C, N, O, Sr) revealed the origin of the groundwater in each city. The paper in *Vadose Zone Journal* (Soil Sci. Soc. Amer.) which evaluated the magnitude and timing of the urbanization from subsurface temperature was introduced in open scientific news "Scitizen". The RIHN project 2-4 also works with UNESCO-GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Changes). The results of the project were shown in some newspapers (Yomiuri and Mainichi), radio show (Kyoto Broadcasting System), and open lectures.

Research Achievements of the socio economic research group for the last one year

Shinji Kaneko
Graduate School for International Development and Cooperation, Hiroshima University

The Socio economic research group aims at providing overall causal relations between urban development processes and subsurface environmental changes from longer term perspectives while compiling and synthesizing the research achievements of the project. Therefore, it encompasses three major dimensions for the direction of the research achievements, namely, (1) increase in number of cities to be compared which finally covers seven selected Asian cities; (2) extension of period to review which finally covers the last 100 years; (3) examination of three issues of groundwater quantity and quality and subsurface thermal environment and their interactive relations.

For the last one year, major research achievements are summarized into the following four items: (1) with a comprehensive review of the existing studies, the overall causal relations are summarized in reference to the DPSIR framework; (2) with the survey in Bangkok, rich datasets and relevant information are obtained; (3) longer term statistical database for the selected seven cities in Asia on demographic and water use are developed, and (4) methodological progress in individual researches including comparative study on the changes in nitrogen balance of city with substance flow model, estimation of stock and thermal capacity of underground structures of cities, and social capacity of city to cope with subsurface environmental issues and so on.

In sum, tentative results and achievements show that the continued efforts of the research activities currently conducted will lead us to the expected outcomes in the initial research plan and proposal.

Urbanization in Asian cities and its implications on water supply and demand

Shinji Kaneko and Karen Ann B. Jago-on
[1]**Graduate School for International Cooperation and Development, Hiroshima University**

The rapid urban growth in Asia during the last 50 years has affected the environment's capacity to provide adequate water resources for the growing population. Water supply has also been affected by the demand created by increasing economic activities in the cities.

In the more developed cities such as Osaka, Seoul, Taipei and Tokyo, the water demand of the population has been supported by increasing government efforts and investments to achieve a hundred percent coverage of piped water supply. However, until this time in other urban areas like Metro Manila, access of population to clean and sufficient water supply still remains a crucial problem. Demand from industries and other sectors are also affected by the unstable water supply from local waterworks system.

In this presentation, we will try to analyze how the urbanization process in Asia during the last five decades has affected the demand for water of households, industries and other sectors in urban areas, by comparing the experiences of Bangkok, Manila, Osaka, Seoul, Taipei and Tokyo. This will include analysis on the changes in demand and supply structure of both surface water and groundwater among the study areas. Taking into consideration the extent of data availability among the study areas, we will also try to review the different factors that have facilitated or hindered government initiatives to provide adequate water supply for the growing population as well as the increasing economic activities in the cities. Insights from the experiences of these cities will help us plan for long-term water demand in Asian cities.

History of Sewage Works in Bangkok, Thailand

Tsuyoshi IMAI, Professor, Graduate School of Science and Engineering, Yamaguchi University

The city of Bangkok has been the capital of Thailand for more than 220 years. For centuries, canals or klongs as called by Thais, have been serves as sources of portable water as well as transportation means and leisure activities. Bangkok is located on lower flat plain of the Chao Phraya River extended to the Gulf of Thailand. The water which is used by more than two million households as well as industries are discharged to 6,000 km public drains via 2,284 km canals network eventually to the river with or without properly treated. Thus, Bangkok urbanizes, water pollution becomes one of the most severe problems which need to be solved. The large scale properties such as office buildings, hotels, condominium etc. are required to have wastewater treatment plants to be conformed to the effluent standards set by the National Environment Board. Normal households are required to have septic tank to accept toilet wastes. Following the cabinet resolution which approved the Bangkok Metropolitan Administration (BMA) investment plan, seven wastewater treatment projects have been completed and are under operation both by BMA staff and private sectors. Future treatment scheme is going to be implemented using the experience grained from the previous success.

Urbanization process in Asian cities and its implications on water supply and demand

Karen Ann B. Jago-on and Shinji Kaneko
Graduate School for International Cooperation and Development, Hiroshima University

The rapid urban growth in Asia during the last 50 years has affected the environment's capacity to provide adequate water resources for the growing population. Water supply has also been affected by the demand of increasing economic activities in the cities.

In the more developed cities such as Osaka, Seoul, Taipei and Tokyo, the water demand of the population has been supported by increasing government efforts and investments to achieve a hundred percent coverage of piped water supply. However, until this time in urban areas like Jakarta and Metro Manila, access to clean and sufficient water supply still remains a crucial problem. The ratio of the population supplied with water is still very low and even among the population covered, piped water is not supplied the whole day.

In this presentation, we will try to analyze how the speed and scale of urbanization process affected the supply and consumption of water resources, by comparing the experiences of Bangkok, Jakarta, Osaka, Seoul, Taipei and Tokyo. Taking into consideration the extent of data availability among the study areas, we will also try to review the different factors that have facilitated or hindered government initiatives to provide adequate water supply for the growing population. Insights from the experiences of these cities will help us plan for long-term water demand in Asian cities.

Life Cycle Impact Assessment of Urban Heat Island in Tokyo

GENCHI Yutaka
National Institute of Advanced Industrial Science and Technology

The urban heat island phenomenon is believed to be a serious social issue in Japan. Researchers have studied the direct mitigation effect on UHI of countermeasures to UHI. We consider other effects of countermeasures to UHI, such as the contribution of UHI countermeasures to the mitigation of global warming through the reduction of life cycle energy consumption. UHI countermeasures are expected to reduce energy consumption for cooling in summer. However, some UHI countermeasures could result in an increase in energy consumption for heating in winter. If the energy consumption for heating exceeds the energy consumption for cooling for a particular kind of UHI countermeasure, large scale introduction of that countermeasure might actually result in an increase in the energy consumption for the year-round heating and cooling of buildings. In this case, the UHI countermeasures could exacerbate the environmental problem of global warming. Decision makers must take into account such potential conflicts between different environmental issues when considering the adoption of UHI countermeasures.

In this study, we aim to quantitatively estimate several kinds of environmental impacts caused by UHI in Tokyo and integrate these impacts by using a life cycle impact assessment method, LCIA. LCIA is widely used to understand the environmental impacts of products and services. An integrating technique called LIME (Life-cycle Impact assessment Method based on Endpoint modeling, Itsubo 2004) was used to estimate the impacts of UHI. We quantified four kind of environmental impacts such as energy consumption, thermal stress, hyperthermia and sleep disorder in Tokyo metropolitan area, and concluded that the environmental impact on energy consumption and sleep disorder were significant.

Research Institute for Humanity and Nature, Research Project 2-4

Human Impacts on Urban Subsurface Environments

Activity Report by Katsuya Tanaka, Hiroshima University

1. Introduction

My primary research activities related to "Human Impacts on Urban Subsurface Environments" in the year of 2007 is to apply econometric and SWAT model to estimate the impacts of land use change on water quality. Before applying this approach to Tokyo and Manila, I conducted study in the US Midwest to test the validity of the model. I obtained simulation results quite reasonably and presented at the Soil and Water Conservation Society West North Central Regional Conference (Dubuque, Iowa, October 17-18, 2007). The following is the essence of the study.

2. Environmental Consequences of Increased Biofuel Production in U.S. Midwest

This paper investigates environmental consequences of biofuel crop production, primarily focusing on corn, in the Upper Mississippi River Basin (UMRB). This objective is achieved by applying an integrated modeling system to nitrate-N (NO3-N) runoff from the UMRB. An integrated modeling system developed in this study consists of an economic model and physically-based hydrologic balance simulation model.

The economic model predicts corn acreage at different output price levels in 353 counties in the UMRB. This model is estimated using a series of agricultural and economic data and spatially-explicit locally-weighted regression model (geographically weighted regression; GWR). Using this approach, the model can be fitted at each county, allowing corn acreage response to vary spatially among counties in the UMRB. Based on predicted corn acreage from the economic model, the Soil and Water Assessment Tool (SWAT) is then used to simulate the level of NO3-N runoff from the UMRB.

As a result, our integrated modeling system provides basin-scale simulation of pollutant runoff, while incorporating county-specific corn acreage response to corn price increase.

Our results show that higher corn price resulting from enhanced biofuel production increases considerably NO3-N runoff from the UMRB. For example, 25 percent increase in corn price will increase the level of NO3-N runoff by nearly 10 percent due to corn acreage expansion. Because corn price is forecasted to continue to trend upward, policymakers need to consider relevant actions to meet or maintain water quality goals and sustainable agriculture in the region.

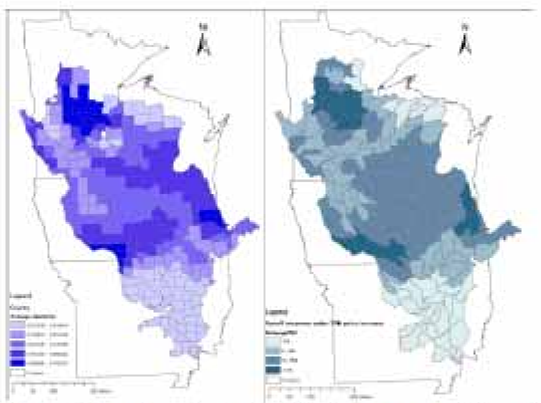


Figure 1. The estimated price elasticities of corn acreage (left) and predicted NO_3-N runoff due to 50% corn price increase (right)

ESTIMATION OF UNDERGROUND MATERIAL STOCK OF MEGA CITIES

Hiroki Tanikawa, Wakayama Univ. and Shinji Kaneko, Hiroshima Univ.

Huge material is required in the city region for maintaining and developing Urban infrastructure (i.e. the stock of buildings and road networks). These materials are stocked not only above-ground but under-ground. The material stocked on the ground is easy to recognize, but underground stock is hard to quantified. Furthermore, underground stock relates to some urban problems, such as intentional withdrawal of underground wastes, efficient use as recycling resource, urban heat island. This paper attempts to estimate above/under-ground material stock related to urban infrastructures of 11 Government Ordinance Designated City. The results indicated that overall average of above ground material stock related to building and roadway is 78 tons per capita, underground material stock is 45 tons per capita in the year of 2004.

Development of the DPSIR+C Framework for Evaluating the Impacts of Human Activities on the Use of Water Resource

Junyi ZHANG, Graduate School for International Development and Cooperation, Hiroshima University

To comprehensively evaluate the impacts of human activities on the use of water resource, it is proposed to introduce the concept of social capacity (C), which is indispensable to better management of water resource usage, into the widely applied DPSIR (Driving force – Pressure – State – Impact – Response) framework proposed by OECD in the context of environmental management. The social capacity refers to the total capacity wherein the whole society—composed of three social actors: government, firms, and civil society—tackles water use problems to achieve sustainable states through the learning process about DPSIR, taking into consideration inter-actor interactions and future uncertainty. According to this framework, human activities (i.e., driving forces: D) exert pressure (P) on the use of water resource and, as a consequence, the state (S) of the water resource (e.g., quality of water) changes. This leads to impacts (I) on human health that may elicit a societal response (R), e.g., policy-making, which directly feeds back to the driving forces (D), or on the state (S), or impacts (I), through adaptation or curative action. And, the capacity (C) is the basis of having good responses (R) to the D-P-S-I elements and there is a two-way relationship between capacity (C) and responses (R). Such improved framework could be not only used to comprehensively evaluate the impacts of human activities, but also useful to capacity building for better management of water resource usage.

History of Industrial Waste Water Treatment by Sewerage System in Osaka City

Ryo Fujikura, Hosei University

In Osaka City, almost all factories are connected to sewerage system and discharge waste water into the sewer. Only 85 factories were designated by the Water Pollution Control Law and discharge waste water into the public waters in 2005.

River water quality was improved by the establishment of the sewage treatment facilities. In 1967, 45% of factories and houses were already connecter sewer. However, there were only two sewage treatment facilities which adopted activated sludge method. Upgrading 12 facilities was completed in 1972, and the water of the city rivers has been rapidly improved afterwards.

When waste water does not meet sewerage water quality standards, the factory must treat it by waste water treatment facility before discharging it into the sewer system. Highly polluted waste water was frequently discharged without treatment until the end of 1960s. In 1972, Osaka Municipal Government started periodical monitoring, and violation was revealed in collaboration with the Osaka Police Office. As a result, factories which installed waste water treatment facilities increased from 47.5% of the whole in 1972 up to 95.4% in 1978.

Administration costs for the monitoring and guidance is high. There are over 3,000 factories subject to the inspection in the city, and approximately 8,600 inspections are being conducted every year. One factory is inspected 2.9 times a year in average. One municipal officer inspects two factories every working day throughout the year.

Total volume of the waste water discharged from factories in Osaka decreased 40.2% during ten years between 1974 and 1983. While the number of the factories decreased only 5.1% during the same period, the decrease of the waste water can be attributed to the waste dater reduction of each factory. Factors caused the reduction are considered to be as follows: introduction of gradual increase of sewerage fee in 1972, and introduction of water quality fee in 1973, which is charged according to BOD, COD, or SS concentration of waste water, as well as economic recession due to the oil crisis of 1973. This demonstrates the effectiveness of the economic instruments.

Analysis on Material Flow Pertinent to Food Consumption in Urban Area : Comparison between Tokyo and Taipei

Toru Matsumoto and Yonghai Xue, The University of Kitakyushu

This study first analyzed the development of waste and waste water treatment and disposal system in Tokyo and Taipei. Based on statistic data, Material Flow Analysis (MFA) and Substance Flow Analysis (SFA) were used for quantifying Nitrogen flow from food supply to emission to air, water and soil. First per capita per day protein supply from Food supply and utilization yearbook of Japan and Taiwan were used for calculation of per capita per day Nitrogen supply. Then MFA was used for calculating material flow of kitchen waste and human waste in waste and waste water treatment and disposal system. Next, emission from waste and waste water treatment and disposal system to air, water and soil was determined by statistic data and literature review. Finally, use the Nitrogen concentration in each material in the system, the Nitrogen flow was calculated. The result shows that the input of Nitrogen in Tokyo and Taipei gradually increased, and most Nitrogen were emitted as human waste into surface water. But with increase of incineration of waste and treatment of waste water, more and more Nitrogen were converted into gas, emitting into air. Waste compost and Kitchen waste as feeding stuff also help Taipei to recycle Nitrogen instead of emitting to surface water.

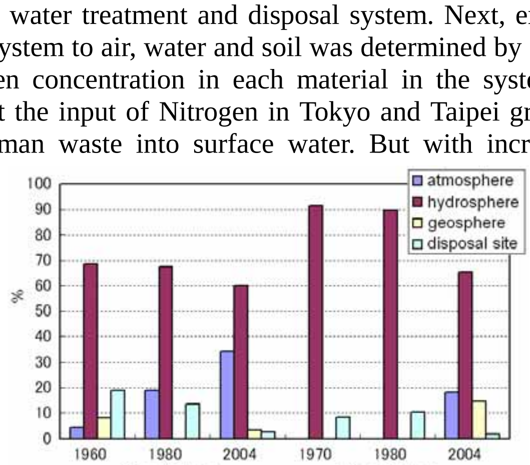


Fig. Change of nitrogen outflow of Tokyo and Taipei

The result of research (urban geography group)

Akihisa Yoshikoshi, Ritsumeikan University

Urban geography group separated from the social economy group, this year. And three specialists of urban climate were added from the heat group, and it became the following members.

Itsu Adachi (Japan International Cooperation Agency), Toshiaki Ichinose (National Institute for Environmental Studies), Manabu Inoue (Ritsumeikan University), Takahiro Endo (Research Institute for Humanity and Nature), Yuichi Kagawa (University of Shiga Prefecture), Kumi Kataoka (University of Tsukuba), Masahiro Kato (Ritsumeikan University), Kazuya Suzuki (Japan International Cooperation Agency), Tomomasa Taniguchi (Rissho University), Taiko Todokoro (Ritsumeikan University Graduate School), Yingjiu Bai (Tohoku University of Community Service and Science), Akio Yamashita (Rakuno Gakuen University), Akihisa Yoshikoshi (Ritsumeikan University)

Urban geography group got the following results. We showed them by itemized statement.

- ＊ Research on development of the cities, urban geography, climatic environment and hydrological environment
- ＊ Collection of literature and database creation about the above
- ＊ Collection of maps and database creation
- ＊ Digitization of the collected maps (GIS)
- ＊ Field survey
- ＊ Present in the societies

Holding of symposium and seminar (Japanese Association of Hydrological Sciences2004, Bangkok Seminar2007, Association of Japanese Geographers2008)

The result of research

Akihisa Yoshikoshi, Ritsumeikan University

The author has collected the literature about the urban geography, development of the city, hydrological environment of city region of the object cities as a member of a urban geography group. Moreover, the authors have advanced collection of the topographical maps, the old maps, the aerial photographs, and the satellite imageries. The urban geography group has performed database creation and digitization of these data.

Based on those data, although it is rough, we have researched city development and change of hydrological environment in Tokyo, Osaka and Bangkok. We are doing the following assumption.

The concentration of population and industry to the city caused urbanization. Urbanization decreased the water area and had changed the former site into the road or the residential section. Use of groundwater was only a small-scale thing in the homes before urbanization. Use of groundwater became a big-scale thing in the factories after urbanization. As a result, the fall of the groundwater level and land subsidence were caused. Thus, urbanization changed not only surface hydrological environment but also subsurface hydrological environment. This change took place in order of Tokyo・Osaka, Seoul・Taipei, Bangkok, Jakarta・Manila.

Based on the above outlines, with some members of the urban geography group, the paper ("Hydro-environmental changes and their influence on the subsurface environment in the context of urban development") for “Science of the total environment” was written and it contributed in 2007.The authors showed clearly that there was no disagreement in the above-mentioned outline and the result of the comparative research of three cities (Tokyo, Osaka and Bangkok).

Surface Climate Change Accompanied by Urbanization

ICHINOSE, Toshiaki

National Institute for Environmental Studies

The author proved mutual relations by collecting information on the changes in surface climatic factors, comparing to a vertical profile of subsurface temperature obtained from the subjected cities in Asia, information on the transition in land use and strength of human activity which enable to explain the changes in inter-annual surface climatic factors. He aimed to clarify the influence of urbanization in regard to the vertical profile of subsurface temperature. Especially he compiled and showed data of warming for more than 100 years in the subjected cities and pointed out probability of anthropogenic jump of data forced by relocation of the observatories through interviews to meteorological observatories in Bangkok and Seoul. He mapped hours exceeding 30 deg C in every year and month based on data of AMeDAS (Automated Meteorological Data Acquisition System) of whole Japan since 1976 when this system started. He, therefore, clarified synoptic pattern in hot summer was more significant for inter-annual warming than urbanization and mentioned that policy on countermeasure for urban heat island had to be re-established. He mainly collected observation data up to the past 150 years, so now he started numerical simulation on both of historical sub-surface temperature (vertical profile) and surface climatic factors with meso-scale climate model in the subjected cities. Groups of urban geography and socio-economics prepared databases from collected data and they enabled him to input them to a climate model.

My work is as follows in 2007

Manabu INOUE, Ritsumeikan University

1. Digitalization of maps.

The map list was updated by adding maps collected in 2007. All of the maps were scanned and stored in digital formats. The digitalized maps were maintained on the server so that all of the project members can easily get access to them.

2. Georeferencing the scanned map images.

According to the information of lat/long coordinates on maps, the scanned map images for six cities were georeferenced.

The result of research

Takahiro Endo, Research Institute for Humanity and Nature

The main activity in this fiscal year was to make a survey on domestic literature which dealt with groundwater problems with the keywords such as “city”, “law” and “management”. Broadly saying, most of those literature were found to be classified into four groups; 1) groundwater law, 2) land subsidence, 3) groundwater quality problem, 4) water leakage. Among those, least attention has been paid to water leakage.

According to statistics made by Tokyo Metropolitan government and Osaka City government Bureau of Waterworks, the rate of water leakage has been below 10% in the last ten years. This rate is far smaller compared to the ones in other large cities in Asia. In Tokyo, the yearly volume of water leakage once amounted to be the same volume in its main dam. In other words, this fact implies that prevention of water leakage can be a substitute for making a new dam. So to speak, the prevention of water leakage is another policy against water shortage and other large cities in Asia which are facing growing demand can learn from the experiences of Tokyo and Osaka.

Although some researches have been made about technical aspects of prevention of water leakage, few have been done about the institutional aspects. Studies on groundwater law and the institutional aspects of water leakage prevention policy will be the two main topics for the next year.

Consideration about the setting range of the large city sphere for the investigation objects

Yuichi KAGAWA , The University of Shiga Prefecture

The city before the modernization was a scale of an extremely small range among a castle wall and the castle towns. In the investigation for the object cities, after modernization in approximately 150 years before, a range of the city area began to enlarge it by increase of the population and the urban infrastructure. Cities enlarged toward each direction although there was limitation of the topography such as the river and hill part. It is important to decide a setting range so that aging compares these as from a topographical map to GIS data or statistics document.

Our group set the range where four pieces fitted into by 1/50,000 topographical map of published by GSI as an object of detailed analysis. This becomes the range of about a radius of 10km from each core city department. It may seem to be small when we think about a metropolis, but a radius of less than 10km show the greatest a population of scale in a national census within Osaka in 2000 and become greatest at a radius of 10km - 20km in Tokyo. Even if it watches annual comparison by the national census in the Tokyo metropolis, it is 1960 that population within a radius of 10km is outrun to population of a radius of 10km - 20km except direct after W.W. Ⅱ.

The range of the city seems to be delivered to a radius of 10km in Bangkok, Seoul, Taipei where a city geography group made a field work. If we chases a city from the historic growth process, at first I think about consistency of the space analysis such as an administration territory or GIS data used for statistics data and let us enlarge it from the range of a radius of 10km, and is it realistic to leave around 50km?

Estimation of Heat Island Intensity at Asian Large Cities for 100 Years

Kumi KATAOKA, University of Tsukuba

Heat Island Intensity (HII), which is defined the temperature difference between city and urban, largely depends on the observatories which are used for calculating the temperature difference. Therefore, the way for selecting observatories has been discussed for long time. In this project, HII in several Asian cities for approximately 100 years is analyzed. For comparing long term HII in several cities, the differences of the number of observatories and period of data exists become problems.

In this study, HII is estimated using not only observational data in each country but also reconstructed global 0.5-degree grid data for 1901-2002, CRU TS 2.1, which made from observational data. Temperature of representative observatory in each city is decided as temperature of city observatory. Average temperatures of four grids in the CRU TS 2.1 around city observatory are defined as temperature of suburb observatories. HII is calculated as difference between temperature of city observatory and average temperature of four suburb grids. Using this estimated HII, it could be possible to discuss HII for the period that the data exists at the representative observatory in each city.

Comparing this estimated HII and HII that is actual temperature difference between city observatory and specific suburb observatory in Tokyo and Bangkok, both has been increasing but estimated HII shows smaller value. This is considered to be the effect that the data was smoothed when grid data was compiled. Putting some weight by city size and distance of one-degree longitude for deciding temperature in suburb is necessary for more precise HII estimation.

A Study of the Formation Process of Industrial Area in Osaka City: Focusing on the Land subsidence and its Management

Masahiro KATO, Ritsumeikan University

The aim of this study is to propound some models for the relationship between location of industry and degree of land subsidence in Mega cities, but here I limit the discussion to the transformation of land use and the configuration of urban environment in Osaka.

The history of this city has been intertwined with stages of pre-modernism, modernism, especially industrial capitalism, and postmodernism. Each stage has provided the urban form with various built environment for social life at large. In modern Era, Osaka had developed through the formation of industrial areas, and

In this study, I am going to understand locality of subsidence in the light of the formation of industrial area through location and accumulation of many factories, the production activities, and the regional transformation caused by these activities.

Changes in distribution of well in Tokyo and Seoul

Tomomasa TANIGUCHI, Faculty of Geo-Environmental Science, Rissho University

It is important to clarify the change of groundwater use for the better understanding of the groundwater environment in city. In order to use groundwater wells are used, but these changes were not disclosed. In this study, I made shown distributions of wells in Tokyo and Seoul at past and present. Distribution of well in past understood from the historical data and maps, and the current distribution is well understood from the data and field survey. To reconstruct historical groundwater environments in Tokyo and Seoul, I used the following maps; (1) Tokyo 1/ 5, 000 published at 1887 (2) Seoul 1 / 10, 000 surveyed at 1915

As a result, many wells had existed in residential areas at central Tokyo at late 19th century. Currently, many wells remain for a religion well, well in temples and disaster prevention well. Well in Seoul have been in residence area in the past. However many wells on the map shown are practically disappeared except the remaining historic material well.

Analysis on the relationship between urban heat islands and urban development in Taipei

Yingjiu BAI, Tohoku University of Community Service and Science

The purpose of this study is to clarify the relationship between urban heat island and urban development in Taipei by satellite images and the statistical data.

Taipei city with 2.616 million populations (2006) has advanced at an unprecedented pace in urban expansion over the past few decades. This has caused the annual mean temperature has increased. The rise in annual mean temperature in Taipei is over 1.5℃/100 years since 1896. Furthermore, during 1996-2006, the monthly mean temperature in both the maximum temperature and the minimum temperature in July (the warmest month) has risen over 0.5℃.

Currently, studies indicate that the three big causes of urban warming are an increase in heat emissions from human activity, a reduction of green spaces and water surface area, and heat retention in surfaces such as concrete and asphalt. It means that temperature rises in city due to the "urban heat island effect."

Urbanization and the Change of Water Use in Osaka City

- Spatio-Temporal Analysis with Data Maps -

Akio Yamashita, Rakuno Gakuen University

This study tried to analyze the spatio-temporal characteristics of urbanization and the change of water use in Osaka city about for 100 years (espacially for resent 50 years). The following datasets were used in this analysis: polygon data of land use and line data of rivers and canals which were made from old topographic maps; the changes of population and the number of establishments by ward; residential and industrial water demands by ward; the change of water supply area for industrial uses. As a result, land use and population greatly changed until the 1960s, while they didn't change significantly after 1970. Groundwater was mainly used for industrial uses until the 1950s. The source of industrial water was switched to surface water of the Yodo River with the construction of industrial water works. In conclusion, by the middle of 20th century, permeable land use was progressively converted into the impermeable one with the extension of urban area, and water source was switched from groundwater to surface water with the occurrence of land subsidence problem. These facts indicate that the range of water flow associated with human activities came to converge in the space of surface without underground space.

The targets of Water Group

Jun　Shimada, Kumamoto University

The targets of Water Group are;

1. to compile the groundwater potential trend for target cities
2. to extract the anthropogenic trend information stored in aquifer from each cities
3. to develop the young groundwater tracer (CFCs and K-85 method)
4. to understand the difference of development stage among studied cities

In 2006, CFCs method has established and tried at Kanto aquifer. However the result shows not clear because of biological degradation in the confined aquifer. In 2007, groundwater sampling for CFCs analysis is planed at Bangkok and Jakarta area.

Kr-85 method has developed separately for on-site rare gas extraction system and LSC measurement for Kr-85. Both system has been completed within FY2007, and hope to try application of on-site Kr sampling and its LSC measurement. As for collection of groundwater potential data, Tokyo has almost completed, Bangkok is on going and Jakarta has not yet started.

On the relationships between aerosols and clouds over East Asia

Kazuaki Kawamoto, Faculty of Environmental Studies, Nagasaki University

Aerosols in the atmosphere can alter cloud properties, thus have some effects on surface and subsurface environments via sunshine and precipitation. For this reason, an analysis was done using satellite data, numerical models and emission inventories focusing on East Asia in order to study how gaseous emission from anthropogenic activities, aerosols and cloud were correlated.

Vertically integrated anthropogenic aerosol mass concentration M_a calculated from numerical models and low-level water cloud properties (optical depth τ, effective particle radius r_e, and columnar droplet number N_c) obtained from satellite data were correlated over East Asia to elucidate human-induced effects on low-cloud properties. Aerosol and cloud properties were obtained from numerical simulations and satellite observations, respectively. Monthly averages of geographical matches between collocated M_a and cloud properties for three seasons showed that as M_a increased, τ and N_c increased and r_e decreased, which is consistent with the Twomey effect. Their changing rates became less steep when M_a was large. However, the importance of a dynamical effect was also suggested. A comparison of different cloud top heights revealed that values of τ and r_e of middle and lower clouds followed those of the total water cloud cases and reflected vertical characteristics.

Establishment of CFCs analytical system and application to age dating of young groundwater and spring

Maki Tsujimura, University of Tsukuba

Residence time of groundwater is essentially important factor to elucidate the hydrological processes in a certain region. The radio isotope of ^3H has been used for dating of groundwater and surface water since 1960's, though the ^3H is ineffective recently in Japan, because the ^3H concentration of precipitation has been approximately under 5 T.U. during recent 10 years (Yabusaki et al., 2003). Chlorofluorocarbons (CFCs) has been broadly used for dating of young groundwater instead of ^3H since 1990's, because (1) the atmospheric mixing ratios of these compounds are known and/or have been reconstructed over the past 50 years, (2) the Henry's law solubilities in water are known, and (3) concentrations in air and young water are relatively high and can be measured (Plummers et al., 1998). In Japan, however, the CFC's has been used mainly by oceanographic scientific community, whereas there are completely no data on CFC's concentration of terrestrial water of groundwater, soil water and surface water. An establishment of analytical and calibration scheme is highly required also in Japan.

We constructed a new simple analytical line of CFCs concentration of groundwater based on Bullister and Weiss (1988). It is easy to handle and not crucial to proceed the purification of gas, and loss could be minimized during the process. The CFCs were applied to age dating of groundwater and spring water in Shiranui region, Northern-Kanto region, Ashigara plain, Japan and Bangkok region, Thailand. An effect of urban air and CFCs contamination was observed in Ashigara region, and biodegradation might cause a very low concentration of CFC-11 and 113 of groundwater in North-Kanto region. The residence time of spring and groundwater in headwater, mid-stream region and costal region weres estimated to be 16 years, 24 years and 46 years, respectively. These results agreed well with those evaluated by groundwater potential measurement and stable isotope observation. CFCs should become an effective tool for dating the young groundwater less than 50 years in Japan. The samples taken in Bangkok are now analyzed for CFCs.

Temporal change of groundwater environment and estimation of hydrogeological structure in the Tokyo area

Tomochika Tokunaga , Univ. Tokyo, Takeshi Hayashi , Akita Univ.,
Masaatsu Aichi, Univ. Tokyo

Groundwater extraction in Tokyo increased as economical activities grew up and it caused groundwater-related problems such as land subsidence. The regulation for groundwater usage was applied in the central area of Tokyo for the countermeasures and it resulted in the increase of groundwater usage in the surrounding area. As a result, hydraulic potential in the central area of Tokyo recovered. However, subsurface infrastructures have been damaged due to high hydraulic potential, which has been a newly emerged problems for the Tokyo area.

The confined aquifers are considered to spread out widely in the Kanto Plain and form regional groundwater flow system. Thus, it is important to reveal the aquifer structures to better understand the groundwater flow system and its temporal change.

Here, three dimensional aquifer structures in the Kanto Plain were studied from existing reports on geological structures and well completion reports. The results are used for analyzing hydraulic equipotential maps for each aquifer and for constructing a hydrogeological model in groundwater flow simulation in this project.

Temporal and spatial change of hydraulic potential in the Kanto Plain, Japan

Takeshi Hayashi , Akita Univ., Tomochika Tokunaga, Univ. Tokyo,
Masaatsu Aichi, Univ. Tokyo

Groundwater extraction in Tokyo increased as economical activities grew up. After the regulation of groundwater extraction started, groundwater extraction in central area of Tokyo decreased while that in surrounding area increased.

In this study, in order to reveal the impact of temporal and spatial change of groundwater extraction, changes of the equipotential maps for each aquifer were analyzed based on observed groundwater level.

From the comparison among these equipotential maps at different years, the area which hydraulic potential was lowest moved from the central area of Tokyo to the northern part of the Kanto Plain as the area of heavy groundwater extraction moved.

The equipotential maps are also used for the calibration of the groundwater flow simulation in this project.

Extraction of the dissolved Kr from groundwater by using hollow-fiber membranes for the ^{85}Kr groundwater dating

Yasunori MAHARA, Kyoto University Research Reactor Institute

The ^{85}Kr dating technique is useful for estimation of the residence time of shallow groundwater. Since the activity of ^{85}Kr is very low (1×10^{-4} Bq/L) in the present shallow groundwater, we have to collect 0.5~1.0 ccSTP of Kr from an approximate 10,000 L groundwater sample. We have assembled the hollow-fiber membranes, which is made of poly-4-methyl-1-pentene, into the proto-type degassing system. We conducted the following two tests to investigate the degassing performance of the system. One is the performance test of Kr extraction from the flowing water dissolving Kr at a pressure of 2 atmospheres. Another is an endurance test of a continuous degassing for dissolve oxygen.

We checked the Kr extraction performance by comparing the dissolved Kr concentration in water at an inlet of the degassing system with that at an outlet of it. Simultaneously, we measured concentrations of the dissolved oxygen and chloride ion in water at the inlet and the outlet. After degassing, concentrations of Kr and oxygen at the outlet were reduced to 1 % of that at the inlet in a few minutes. But, the dissolved chloride ion concentration did not change at the inlet and the outlet after degassing. Although the dissolve chloride ion was not at all extracted from water, all dissolved gases were degassed at a high efficiency. We had continuously extracted the dissolved oxygen at the 99.8 % degassing efficiency from 2000L water inletting into the system during 6 hours. Consequently, results of performance tests suggest that more than 99 % of dissolved gases was continuously collected from groundwater by using the assembled prototype degassing system.

Measurement system for Kr-85

Prof. Noriyuki Momoshima, Radioisotope Center, Kyushu University

The purpose of this research is to establish a dating method of groundwater using Kr-85. In this part of the research we develop the method for isolation of Kr and radioactivity measurement of Kr-85 which is recovered from groundwater. Kr-85 is rare gas with half-life of 10.7 y and emits beta ray of maximum energy of 0.687 MeV, therefore, gas chromatography and liquid scintillation counting (LSC) with low background liquid counter were applied.

We develop the analytical method similar to that for Kr-85 in air because the major dissolving gas in groundwater would be air. Until now we have established the recovery method of Kr from a large volume of air, separation of N_2 and O_2 from Kr and complete isolation of Kr by gas chromatography. The fundamental points for low background measurement of Kr-85 have examined. The material of a counting vial for Kr-85 was examined and we determine to use synthesized quart and then a background count in LSC comparable to Teflon was obtained, very low background is quite important for low level measurement such as Kr-85 in groundwater. The Teflon is not suitable for Kr-85 measurement by LSC due to leakage of Kr from the wall. No leakage of Kr-85 from synthesized quart vial was confirmed. Presently we are developing a method for Kr transfer to organic solution based scintillator in the synthesized quart vial.

The result of research

Tsutomu YAMANAKA, University of Tsukuba

To reveal the confined groundwater flow system in and around Bangkok Metropolitan Area (BMA) and its recharge mechanisms under human impacts, field surveys were carried out in June 2006 and August 2007. Hydraulic head and isotopic compositions of groundwater were measured using totally 120 boreholes within eight confined aquifers down to a depth of 600 m. Hydrometric measurements clarified horizontal flow system in each aquifer and showed that groundwater pumping disturbs the flow lines at three areas: (1) western part of BMA, (2) eastern part of BMA, and (3) suburban area on the northwest of BMA. In the last area water level depression was found only for PD aquifer (second upper one), while in the other two areas the depressions were more remarkable in deeper aquifers (i.e., NL and NB). These results correspond to regionality in groundwater withdrawals. Isotopic data suggest that vertical flow between aquifers is non-negligible especially in BMA and saline waters remaining in upper aquiclude(s) move downward and mix with flesh groundwater, although in the three areas mentioned above the main body of groundwater appears to be supplied by horizontal flow rather than vertical flow. Thus, there is a possibility that the groundwater pumping at the areas enhances recharge of the deep groundwater. Based on both hydraulic head and isotopic data, a principal recharge zone is estimated to be a hilly region to the northeast of BMA. On the other hand, such an enhancement of groundwater recharge cannot be induced at the central part of BMA under the present conditions of spatial pattern of hydraulic head. A part of these findings was presented at JGU (Japan Geoscience Union) meeting 2007 and 4th annual meeting of AOGS (Asia Oceania Geosciences Society).

Estimation of the spatio-temporal change of the groundwater recharge based on the numerical simulation in the Kanto Plain, Japan

Masaatsu Aichi, Univ. Tokyo, Tomochika Tokunaga, Univ. Tokyo,
Takeshi Hayashi, Akita Univ.

Groundwater extraction in Tokyo increased as economical activities grew up. Since the regulation of groundwater extraction started in the central area of Tokyo, the usage of groundwater has increased in the surroundings.

In order to reveal the impact of temporal and spatial change of groundwater extraction on groundwater flow and recharge, spatial distribution and temporal change of groundwater extraction were reconstructed and a groundwater simulation for the Kanto Plain was carried out.

In this simulation, the movement of the area with low hydraulic potential was well reproduced. From the result of our simulation, recharge area moved from the Musahino Upland to the Omiya Upland in accordance with the movement of the area of heavy groundwater extraction. In the northern part of the Kanto Plain, the result of the simulation indicated that main recharge area was uplands in the Tochigi Prefecture.

Age-Dating of Groundwater Using Chlorofluorocarbons (CFCs) as a Tracer

Kiyohiro OHTA , Graduate School of Environmental Sciences, University of Tsukuba

Estimation of residence time of the groundwater is basically important to understand the groundwater flow system. In overseas, CFCs has been used for dating of young groundwater instead of tritium (^3H). In Japan, there have been few studies on CFCs concentration of groundwater in the field of Hydrology. Therefore, an establishment of analytical and calibration system of CFCs in groundwater was necessary in Japan.

In order to use chlorofluorocarbons (CFCs) as an age-dating tool and tracer in shallow groundwater, an analytical line of CFCs concentration of groundwater was constructed. Furthermore, calibration curves for CFC-11, CFC-12, and CFC-113 with high correlation coefficient (more than $R^2 = 0.995$) were determined using this analytical system.

We analyzed the groundwater in the Kanto plains (at 7 locations, Tochigi and Ibaraki Pref.) using the analytical system. The samples were collected in March 2007 using the Benet Pump. The CFCs concentrations and dissolved ions were determined on all water samples.

As a result, CFC-12 and CFC-11 were detected from the samples of 5 and 2 sites, but CFC-113 was not detected from any samples. It is suggested there is a possibility of the disassembly of CFCs under restoration condition, or a possibility of the residence time of groundwater is long.

Groundwater flow system and its change in Jakarta, Indonesia

Makoto Kagabu, Graduate school of Science and Technology、Kumamoto Univ.

For many years, in Jakarta, the groundwater decline and the subsidence of ground is remarkable because of an excessive pumping of groundwater under urbanization pressure.

RIHN water group made investigation from 6th to 21st in September, 2006. We could make groundwater potential map based on that investigation. But we didn't know the past groundwater changes in Jakarta. So we have asked Mr. Fajar at Chiba University to collect the groundwater monitoring record at Jakarta area. The data we got from Mr. Fajar contains annual groundwater level changes from 1982 (the oldest) to 2005 at 32 observation wells. Overall trend of groundwater level changes are declining tendency year by year, but some observation wells show rising pattern. We will prepare groundwater potential distribution and their change based on this data.

Tritium concentration of groundwater in Jakarta which was collected in September, 2006 were under analysis. I will report the details at the meeting with stable oxygen and hydrogen data.

I intend to go and stay in Indonesia from February to March, 2008 under the framework of Kumamoto University's PhD students training fund.

Summary of the Gravity Group Activities

Yoichi Fukuda, Graduate School of Science, Kyoto University, Kyoto, 606-8502

The gravity group is mainly conducting the following two research subjects; 1) Estimation of terrestrial water storage (TWS) variations by combining the GRACE satellite gravity data and TWS variations obtained from a Soil-Vegetation-Atmosphere Transfer Scheme (SVATS) model implemented in a global climate model, 2) in-situ measurements that combines absolute and relative gravity measurements as well as GPS measurements for detecting groundwater level changes and associated land subsidence in Bangkok, Thailand, and Jakarta, Indonesia. Regarding the first subject, we estimated regional scale water mass variations in the Indochina Peninsula from the GRACE data, and then, compared the variations with SVATS models with different river flow/ground water flow assumptions. The result shows the importance of groundwater flow and river velocity in estimating the total terrestrial storage. Regarding the second subject, we conducted preliminary surveys in Bangkok and Jakarta last year for selecting gravity points, estimating urban noise levels for gravity measurements, GPS test measurements and so on. We also conducted gravity surveys in Jakarta for estimating the subsurface density structures. In addition to the same surveys in Jakarta this year, as a joint research with ITB (Institut Teknologi Bandung), we conducted precise GPS surveys for detecting the subsidence associated with the groundwater pumping in the area. We will introduce a portable absolute gravimeter in this year and will employ it for the next year surveys after several test measurements in Japan.

Introduction of the A-10 Field Absolute Gravimeter

Yoichi Fukuda, Graduate School of Science, Kyoto University, Kyoto, 606-8502

One of the research subjects of the gravity group is the in-situ measurements of the absolute, and the relative gravity measurements as well as the GPS surveys combined for detecting the groundwater changes in Bangkok and Jakarta. In this research, employment of the portable absolute gravimeter is essentially important. Therefore we purchase the A-10 portable absolute gravimeter of Micro-G LaCoste Inc. in this finance year. Micro-G LaCoste Inc. is the only one company of commercial absolute gravimeters and the most popular absolute gravimeter FG-5, which is a high precision absolute gravimeter with a 2-microGal-precision for laboratory use, is the main product of the company. A-10 is a modified version of the FG-5 for outdoor field surveys. It is much smaller than FG-5 and can be operated with 12VDC power. As the trade-off, the precision of A-10 is 10 microGal. This is mainly due to the precision of the laser frequency stability, and there is still room to be improved. We plan the following schedule as the introduction of A-10; delivery and initial training in middle December, 2007; filed test survey in Japan from January to March, 2008. After these initial test phases, we plane to employ A-10 for the surveys in Jakarta and Bangkok in 2008. Although using A-10 absolute gravimeter is still challenging, especially for groundwater monitoring, there is no doubt that the absolute gravity measurements are much superior to the relative measurements. We therefore expect the fruitful results of the surveys with the A-10 gravimeter.

Improvement in reproducibility of the simulated terrestrial water storage for GRACE estimation

Tosiyuki Nakaegawa, Meteorological Research Institute, Tsukuba, 305-0052

This study upgrade a Global River flow model , (GRiveT) to represent more realistic groundwater and river flow processes and examine the effects of these modifications on the reproducibility of the observations. This modification includes the assignment of spatially distributed current speeds, and the implementation of groundwater scheme and propose current speed calibration method to make no river discharge phase differences (RPD) between the observation and the simulation. We perform a set of 9-year integrations of the modified version of GRiveT with Re-analysis data to examine the reproducibility of the modified version of GRiveT, and compare experiment results with the observations. The proposed calibration method provides reasonable calibrated speeds that make no RPD for most of the 70 rivers. The calibration significantly improves the river discharge correlation coefficient and phase difference, but slightly does TWS correlation coefficient and phase difference. However it scarcely improves both river discharge and TWS amplitudes. The implementation improves both river discharge and TWS correlation coefficients and phase differences for experiments without calibration, but the calibration can compensate for the drawbacks due to no implementation of the groundwater scheme.

Preliminary gravity and GPS survey at Jakarta and Bangkok

Jun Nishijima, Faculty of Engineering, Kyushu University
Yoichi Fukuda and Satoshi Ueno, Graduate School of Science, Kyoto University

We carried out the preliminary gravity and GPS survey at Jakarta and Bangkok.

Jakarta

We conducted the about 2km interval gravity survey to make clear the underground structure. The ground deformation survey using GPS has been started by Institute of Technology Bandung (ITB). Many benchmarks are established by ITB, and we went to some benchmark to check the benchmark size and noise level. We selected the four benchmarks in order to measure the gravity using the A10 absolute gravimeter in 2006.

Bangkok

In Bangkok, We had a meeting with Dr. Adichat (Director of Geotechnics division, Department of Mineral Resources). And we checked the Scintrex and LaCoste gravimeter. We also constructed the GPS base station on the top of the building of Chulalongkorn University.

Estimation of subsurface density structure in Jakarta by gravity survey

S. Ueno, Y. Fukuda, Graduate School of Science, Kyoto University
J. Nishijima, Graduate School of Engineering, University of Kyushu

To estimate the subsurface density structure in Jakarta, we conducted gravity surveys combined with fast static GPS survey by means of a Lacoste & Ronberg gravimeter and a GPS receiver. The surveys were conducted from September 9th to 12th, 2006 and from September 4th to 7th in 2007. In 2006, we set up two east-west survey lines with about 50 km in length, and one south-north line with about 25km in length, respectively. The survey lines in 2007 were two 25km-south-north lines and one 30km-west-east line. The average interval of the gravity points is about 2km and total number of the gravity points reaches about 100 in the are of about 50km*25km. As the reference station of the gravity survey, we used the absolute gravity point in BAKOSURTANAL (The National Coordinate Agency for Surveys and Mapping) of which gravity value is 978114860.9±0.3μgal. For the drift correction, the gravity measurements were conducted so as to occupy the same gravity point for the first and the last measurements in the same day. For the reference of the fast static GPS survey, we used the IGS station in BAKOSURTANAL. The Bouguer anomaly map obtained shows a high anomaly in the center of Jakarta, which perhaps suggests a bulge of the geological basement.

Monitoring of terrestrial water storage the variations using GRACE data

Takashi Hasegawa, Geodesy Labo. Department of Geophysics, Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University

This study monitored terrestrial water storage variations using satellite gravity data. Previously, Yamamoto et al., (2007) employed GRACE satellite gravity data to recover the mass variations of four major river basins of the Indochina Peninsula, and compared the detected mass variations with a Soil-Vegetation-Atmosphere Transfer Scheme (SVATS) model including a river flow. This study re-evaluated mass variations in the same area as Yamamoto et al., (2007) using recently released most upgraded GRACE data (RL04). Estimated mass variations were compared with the four types modified SVATS models, model version 1 was obtained using globally uniform river velocity without considering groundwater storage, model version 2 was obtained using calibrated river velocity without considering groundwater storage, model version 3 was obtained using globally uniform river velocity considering groundwater storage, model version 4 was obtained using calibrated river velocity considering groundwater storage. Model ver. 3 attained the best fit to the GRACE data, and the model ver. 4 yielded almost the same values. This implies that the groundwater plays an important role in estimating the variation of total terrestrial storage. It also indicates that tuning river velocity needs further investigations in combination with the GRACE data. The GRACE estimations exhibit basically good agreement with the hydrological model estimations, although the GRACE estimations in Salween and Chao Phraya basins are noisier than the others. This is a huge improvement in RL04 data sets compared to the previous versions.

Research Aspects of Material Group in Second Year

Shin-ichi Onodera, Hiroshima University

To confirm the variation of contaminant load at mega-cities in Asia, we conducted the field researches at each city, review of research papers in regarding to the pollution in Osaka and development of method for confirmation of material transport in coastal area. The results are summarized as follows: 1) huge accumulation amount of trace metal, dissolved nitrogen, and chloride in groundwater, 2) various N origin and denitriphication by using N isotope distribution in groundwater, 3) less terrestrial submarine groundwater discharge but huge material flux by total SGD.

In addition, we would like to conduct 1) analysis of S, Sr and Pb isotope of groundwater and rainwater, 2) sedimentation rate and trace metal transport, using the Pb isotope and chemical component of sediment in next year. We are also going to develop the new research method, 1) dissolved N2/Ar, 2) Rn analysis, 3) collaboration of seepage meter, piezometer and tracer method.

Material transport with various groundwater flow systems at coastal mega-city in Asia

Shin-ichi Onodera, Hiroshima University, members in Material Group

To confirm the variation of contaminant load at mega-cities in Asia, we conducted the field researches at each city, review of research papers and development of the method for confirmation of material transport in coastal area. The results are summarized less terrestrial submarine groundwater discharge, and huge material flux by total SGD. But our research season was still only dry season in main fields, Bangkok and Jakarta. We will consider the flash discharge of solution by SGD during a wet season, in next February in Jakarta and next April in Bangkok. In addition, we have some future works in terms of coastal sediment, one is the Pb isotopic and chemical analysis of sediment in each city for reconstruction of variations in sedimentation rate and material load with urbanization, and second is reconstruction of variation in solute load with recirculated SGD.

We are also going to develop the new research method and apply those to the next research in Jakarta. 1) First one is analysis system of dissolved N2/Ar in groundwater for reconstruction of dinitrification in groundwater and nitrate content during the groundwater recharge. 2) Second one is Rn analysis system for the quantification of SGD and seawater intrusion. 3) Third one is a collaboration system of seepage meter, piezometer and tracer method for quantification of input of seawater into sea bed as a source of recirculated SGD and seawater intrusion.

Submarine groundwater discharge in the coastal zone of the Asian cities

Tomotoshi Ishitobi, Makoto Taniguchi, Yu Umezawa, RIHN,
Shin-ichi Onodera, Hiroshima University

Submarine groundwater discharge (SGD) is the end process of the groundwater flow system in the coastal zone, and much water and material transport to the sea from the land occurs by SGD. Though quantitative measurements of SGD had been not done well because it is difficult to measure, some field researches have been done in recent days by catch the attention for SGD.

Some field researches have been done to estimate the amount of groundwater discharge from the land and clarify the discharge process of SGD in Osaka area (Nishinomiya city, Hyogo), Seoul area (In-chon), Taipei, Manila, Bangkok and Jakarta. As a results, in Manila and Jakarta where decreasing of groundwater level occur, it is guessed that fresh groundwater discharge does not occur in the coastal area by the field research (reported in Japan Geoscience Union Meeting 2007, Chiba). On the other hand, a quantity of fresh groundwater was seen under the inter-tidal zone at the beach in Osaka bay, and amount of groundwater discharge from whole the beach was guessed using the result of field measurement (reported in IUGG 2007, Perujia, Italy).

Long-term measurement of SGD rates has been started by seepage meter and piezometer in the Manila bay from September, 2007. Long-term measurement of SGD is worthful because it has been done only a few studies in the world.

This presentation is based on these study results.

Human impacts on the subsurface environments and adjacent coastal areas in Asian-Mega cities, estimated by stable isotopes ratio of light elements

Yu Umezawa, Research Institute for Humanity and Nature

Increase of nitrate pollution in groundwater and nutrient loading into the adjacent coastal areas have been intensively reported at developed cities. In addition to the population and land use, background characteristics (e.g., geology, topography, climate, governmental policy and social morality) may be also important factors to control the extent of these human impacts on the systems.

Our surveys of Metro Manila, Bangkok, and Jakarta demonstrated that excessive NO_3^- and NH_4^+ contamination of the aquifers was not monitored, suggesting low risk of drinking groundwater to human health, at present. Nitrate $\delta^{18}O/\delta^{15}N$ in groundwater suggested that an anoxic subsurface system associated with the natural geological setting and artificial pavement coverage served to buffer waste water-derived NO_3^- contamination via active denitrification (Umezawa et al. submitted to STOTEN). Then low nutrient contamination in groundwater and lowered groundwater levels due to over-pumping suggest a decrease of the fresh groundwater and associated nutrient flux into the sea (Umezawa et al. 2007, IAHS publ.).

Currently, I'm trying to reconstruct the history of the trophic state in the coastal areas combining statistic data set, C, N and P contents and $\delta^{15}N$ and $\delta^{13}C$ values in organic matter, which was extracted from the sediment core samples collected at each coastal area. Furthermore, captured data have been assembled with GIS system, and they will be demonstrated to many people on our official web-site in future.

Comparison of groundwater pollution status among Asian mega cities

Takahiro Hosono
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In the last meeting at Hiroshima, our group reported the result of extensive field survey and planning for the future research on groundwater and coastal pollution study. On the other hand, in this year we focused our research activities on material analysis along the schedule, except a small scale of groundwater research at Taipei city at October, 2007. In the first part of this presentation, I will introduce how the analysis proceeded compared to the last year. In the main part of this presentation, the status and cause of groundwater pollution will be shown by using four pollution factors; pH, acids (NO_3 and SO_4), minerals (Ca and Sr), and metals (Pb, Mn, and As), which data are available until now. Considering these data, groundwater pollution status among Asian mega cities (Seoul, Taipei, Bangkok, Jakarta, and Manila) will be categorized each other. In last part of the presentation I will state several suggestions on the future work including how we can make effective research connection among different groups.

Water Pollution and its accumulation in subsurface zone in Bangkok

Mitsuyo Saito, Graduate student, Hiroshima University, and research members in Bangkok

Most of groundwater potentials in some aquifers at same sites indicated downward groundwater flow with the hydraulic gradient of 0.01 to 0.1 in the urban area, except for the northern suburban area. As a topographic gradient is extremely low (0.0001 to 0.001) in the urban area, it is obvious that the downward flow is dominant rather than the lateral flow. However, Sanford and Buapeng (1996) indicated the upward deep groundwater flow with long residence time, using ^{14}C analysis and numerical simulation. These differences mean the radical change of groundwater flow with intensive pumping for last 15 years. The ^{18}O of deep groundwater on the northern suburban area was low, compared with shallow groundwater and surface water. On the other hand, that was high on the urban area. These results suggest that downward gradient caused surface water intrusion into deep groundwater. In addition, Mn concentration in deep groundwater was extremely high under the urban area. This suggests also the contaminant intrusion and storage in deep groundwater. These results imply that we have to recognize the possibility of contaminant transport with deep groundwater discharge after recovery of its potential in the future.

Report on the activities of the Heat Group

Makoto Yamano, Earthquake Research Institute, University of Tokyo

The heat group aims at revealing subsurface thermal anomalies in urban areas caused by human activities. For this purpose, we have been conducting measurements of vertical temperature profiles in boreholes, which will be used for reconstruction of the ground surface temperature (GST) history for the last several hundred years. We have also started long-term monitoring of the temperature in boreholes and soil temperature for studies of downward propagation of the GST variation and coupling between the GST and the air temperature.

In 2005 through 2007, we carried out field surveys in five areas, Seoul, Taiwan (including Taipei), Bangkok, Jakarta, and Osaka. Temperature profile measurements were made in 93 boreholes in total. Most of them are observation wells for groundwater level monitoring and the depths are generally 100 to 200 m, though the maximum depth reaches 400 m. Many of the obtained profiles have negative (or nearly zero) temperature gradients in the upper part of the holes, indicating recent increase in the GST due to the global warming and/or the "heat island" effect. We attempted reconstruction of GST histories from selected temperature profiles in the Bangkok, and Jakarta areas. Preliminary results obtained for the Bangkok area show that surface warming occurred in the last century and the amount of warming is greater in the city than in the northern rural area.

Long-term temperature monitoring has been conducted at eight stations in the Taiwan, Bangkok, and Jakarta areas. At each station, water temperature recorders were installed at three depths in the borehole. Soil temperature is being measured with sensors buried 0.5 and 1.0 m below the ground surface just beside the borehole. In Taiwan and Jakarta, we could recover temperature records for the first 1 to 1.5 years.

Long-term monitoring of borehole and soil temperatures

Makoto Yamano, Hideki Hamamoto, Earthquake Research Institute, University of Tokyo,
and Akinobu Miyakoshi, Geological Survey of Japan, AIST

Long-term records of subsurface temperatures at multiple depths should demonstrate how the ground surface temperature (GST) variation is propagated downward through formations. Time series data will provide information on the mechanism of heat transfer (conduction or advection) and the thermal diffusivity. Long-term measurements of soil temperatures near the ground surface are also useful for investigation of the relationship between the GST and the surface air temperature.

We have carried out long-term temperature monitoring in a borehole located on the coast of Lake Biwa, Japan. Temperatures at 30 and 40 m below the ground surface were measured for 4 years and 2 years, respectively, with a resolution of 1 mK. The obtained records indicate steady increases at both depths with a higher rate at 30 m. Probable causes of these temperature variations are: 1) construction of a building in 1996, which covered the top of the borehole, 2) fill-up of artificial sediment (6.7 m thick) on the original ground surface. For obtaining more information, we recently installed a temperature sensor cable in the borehole and started monitoring temperatures at 10 depths.

In the target areas of the project, we have been monitoring borehole temperature and soil temperature at selected stations in the Taiwan, Bangkok, and Jakarta areas. During the surveys in Taiwan and Jakarta in 2007, we could recover borehole and soil temperature data for 1 to 1.5 years. At one station in Taipei, short-period variations containing one-day and one-week components were detected, which should be attributed to influence of human activities. In Jakarta, the soil temperature records show a steep temperature decrease corresponding to a major flood in February, 2007.

Effect on subsurface thermal environment accompanying with operation of ground coupled heat pump system

Sachio Ehara, Faculty of Engineering, Kyushu University

The urban thermal environment has been getting worse and worse with the increasing human activities. One of the main causes is the rapid popularization of the conventional heating and cooling system in houses and buildings. Therefore we developed a new heating and cooling system for a house with Ground Coupled Heat Pump(GCHP). Downhole Coaxial Heat Exchanger (DCHE) was introduced to exchange heat between the system and the shallow ground. GCHP system saves electric power and oil consumption and also does not discharge waste heat to the air. The system was carefully designed using geophysical methods, and heat transfer simulation technique. After the system installation, the operation parameters were turned so that the system could achieve high performance. The system demonstrated quite high performance (COP=5.0). The high system COP showed that the system could contribute for 30% energy saving and reduction of CO_2 emission.

However, the little is known about their impact on the subsurface thermal environment originated from the operation of the GPHP system. We observed the subsurface temperature changes in the vicinity of the heat exchanging well. Mass and heat transfer simulation by the three-dimensional finite element method was performed using observed data. These simulation results showed that GCHP system operation showed slight impact to the subsurface temperature field. The temperature rise due to the GCHP operation did not exceed 1 ℃ at a distance of five meters from the heat exchanging well. The effect was practically small enough to be neglected. These results proved the GCHP system gives low impact on the subsurface thermal environment.

Reconstruction of ground-surface temperature history from underground temperature data: Development of the inversion code and its application

Shusaku Goto, Geological Survey of Japan, AIST

Temporal variation of ground surface temperature (GST) propagates down to underground and is recorded as thermal disturbance relative to the background thermal structure in the region. If the transport of heat is heat conduction only under the ground, the background thermal structure is determined from thermal conductivity of the earth material and heat flow transported from the deep, in the region. Because the downward transport of GST is very slow, underground temperature to a depth of 1000 m has potential to record GST history of several hundred years. In this study, as a part of the research project "Human Impacts on Urban Subsurface Environment", a FORTRAN code to reconstruct GST history from borehole temperature profile was developed, with an assumption that heat transport under the ground is subject to heat conduction only. This code is able to reconstruct GST history from borehole temperature profile measured in a multi-layer underground structure with an assumption that each layer has a uniform thermal conductivity. Thermal conductivity of each layer and heat flow transported from the deep is also inverted. The test of this code is performed using borehole temperature data obtained in northern Awaji Island where the underground structure is known, and provided reasonable results of the reconstruction of GST. At present, Heat Group is analyzing the borehole temperature profiles that were measured in Bangkok (Thailand), Jakarta (Indonesia), Taipei and the vicinity of Tainan (Taiwan), and Seoul (Korea).

Subsurface thermal environment and groundwater flow around Tokyo Bay

Yasuo SAKURA, Vuthy Monyrath, Chiba University

Around Tokyo Bay, subsurface thermal environment formation is an important process that is basically controlled by the groundwater flow and heat transport, and human activity. In order to understand the characteristics of the distribution of the subsurface temperature and thermal environment around Tokyo Bay, subsurface temperature was measured using observation wells around the bay in a vertical profile. A cross section which cuts across the bay from east to west and vertical distribution of subsurface temperature at the depth of 50m and 100m below the sea level on both sides of the bay were made using the borehole temperature data. Preliminary 2D simulations of the groundwater flow and subsurface temperature distribution were also done to confirm the field observation. The results show that the subsurface temperature in the western side, Tokyo area is higher than in eastern side, Chiba. This fact suggests that groundwater discharges into Tokyo Bay. The difference distance from the recharge area to Tokyo Bay results in the variability of topographical driving force. Furthermore, the intensity of recharge may be also different. Human activities such as urbanization and groundwater pumping also affect the subsurface temperature and groundwater flow in the study area. Anyway, three dimensional numerical simulation including almost of such factor is assuming to explain the observation data. In Aug. 2007, we have restarted for measuring borehole temperature profiles in the Ishikari Lowland, Hokkaido for the first time in 7 years to make clear the change of subsurface temperature.

Estimation of the past ground surface temperature change from borehole temperature data in the Bangkok area

Hideki Hamamoto, Univ. Tokyo, Shin Kamioka, Kyushu Univ., Vuthy Monyrath, Chiba Univ., Makoto Yamano, Univ. Tokyo, and Shusaku Goto, AIST

The effect of temperature change at the ground surface propagates into the underground and disturbs the underground temperature structure that is determined by the thermal conductivity distribution and heat flow from the deep. Analyzing the disturbances in the underground temperature structure, we can reconstruct the past ground surface temperature (GST) change, which is closely related to the past climate change.

A field survey in the Bangkok area was conducted in June, 2006 and temperature profile measurements were made in 20 wells for groundwater monitoring. The temperature profile at one site was quite different from that measured in 2004, probably due to temporal variation of groundwater flow. It shows that repeated measurements are useful for checking the stability of temperature profiles.

We attempted to reconstruct the GST history during the last several hundred years using the temperature data obtained in this survey together with the temperature profiles measured in 2004. All of the reconstructed GST histories show surface warming in the last century. The amount of the temperature increase ranges from 0.2 to 1.5 K and is larger in the Bangkok city than in the northern rural area. This difference may result from the heat island effect related to human activities.

Evaluation of change in subsurface thermal environment due to effects of human activity in the Tokyo metropolitan area.

MIYAKOSHI Akinobu, AIST

Information on three-dimensional subsurface temperature distribution and its change were examined by measuring of temperature-depth profiles at observation wells in 2001-2002 and 2005-2006, to evaluate the subsurface thermal environment in and around the Tokyo Area. Regional variation was observed as follows: low temperatures were found in the Musashino and Shimousa Uplands, and high temperatures were observed in the central part of the Tokyo Lowland. Low temperatures are considered to result from groundwater recharge, and the high temperature area corresponds to an area where the lower boundary of groundwater flow is relatively shallow. These regional variations suggest the effects of groundwater flow in the Tokyo area. On the other hand, subsurface warming at the shallow part affected by ground surface warming is recognized in almost all of this area. The subsurface warming represents a minimum in temperature-depth profiles. In the Musashino Upland, depths of minimums are deeper than the lowlands, and temperature above minimum depths is warmer in the eastern urban area than the western suburban area. A comparison of 2001 to 2002 data and 2005 to 2006 data shows the subsurface warming above the minimums of about 0.06 °C/year in the urban area and 0.02 °C/year the suburban area. This fact suggests the existence of the heat island phenomena in the subsurface environment. Subsurface environment shows the various changes in the depth, location and amplitude due to the effects of human activity.

The result of research

Shin KAMIOKA, Kyusyu University

1．Summary

I participated in the measurement of 2006 in Bangkok as a member of heat-group. The data of 2006 was analyzed by Mr. Hamamoto. And I analyzed the data of 2004 in Bangkok on this June.

2．Result Report

The measurement points (2004) are 27 spots and 31 wells (Fig.1). But only 6 spots and 6 wells are useable because of the subsurface water flow (Fig.2).

Fig.3 is the final result which is recognized the result of 2004 and 2006.

We can say the time of the temperature rising is earlier and the extent is high as we approach the cities.

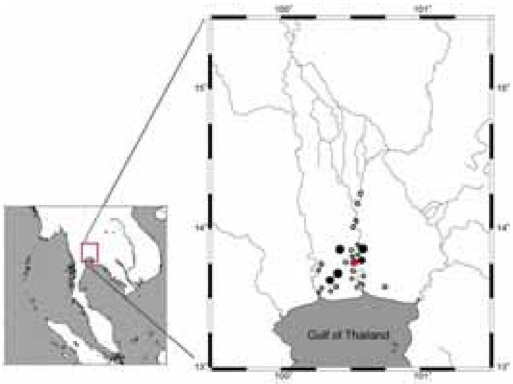

Fig.1：Observation points of 2004 in Bangkok

(●:#61 is located in urban area,● is observation points)

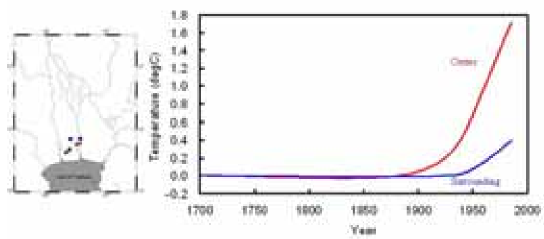

Fig.2：Analysis points and the result of 2006 observation

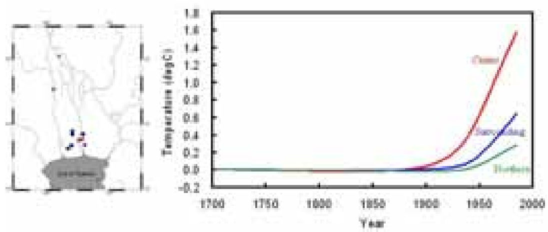

Fig.3：Analysis points and the result, including the result of 2004 and 2006 observation (red:urban area,blue:surrouding area,green:the suburbs)

Status report of reconstruction the thermal environment evolution in Jakarta from underground temperature profiles

Rachmat Fajar Lubis[1], Yasuo Sakura[2], Makoto Yamano[3], Robert Delinom[4], Akinobu Miyakoshi[5], Makoto Taniguchi[6].

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Heat island effect is one of major problematic effects in developed cities, and it is important to understand this effect to subsurface environments. We made field surveys in September 2006 and August 2007 to reconstruct ground surface temperature (GST) history in Jakarta mega cities, Indonesia. GST history will be reconstructed from vertical temperature profiles measured in groundwater observation wells. In the 2007 survey, temperature profile measurements were conducted in 12 boreholes. The result shows that the temperature profiles were very stable in some holes. The fact that the profiles measured in July 2004, September 2006 and August 2007 are nearly identical indicates that the temperature regime is stable, and curvature is not a transient effect. Temperature recorders were installed in September 2006 for monitoring of borehole and soil temperatures, water level and air temperature at 3 stations. Some of the monitoring records were successfully recovered during the 2007 survey.


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Starting from the left back row : Hosono, Kobori, Fukuda, Ishitobi, Umezawa, Nishijima, Ichinose, Endo, Onodera, Yamanaka, Kaneko, Jago-on, Lubis

Front row : Burnett, Lee, Delinom, Buapeng, Taniguchi, Huang, Yoshikoshi, Wang, Siringan, Shimada, Yamano

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