제6회 제주물세계포럼

The 6th Jeju Water Forum

" 제주 물, 지역을 넘어 세계로 "

Jeju Water! To the World Beyond Jeju

Jeju Grand Hotel

6-8 October, 2014

주최/주관 제주특별자치도개발공사 Jeju Special Self-Governing Province Development Corp. KIGAM 한국지질자원연구원 Korea Institute of Geoscience and Mineral Resources Coordinating Committee for Geoscience Programmes in East and Southeast Asia

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2014.10.06.

2014.10.07.

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▶만 찬(Dinner) ······ 18:10~20:00

Potential of groundwater resources for bottled water market in East & Southeast Asia

Role of Regional Organization - CCOP

Dr. Adichat Surinkum

Current Position

▶Director, CCOP TS, Bangkok, Thailand **(2013-present)**

Experience

▶Department Spokesman/ Director, Bureau of Environment Geology and Geohazard and Expert Advisor on Geological Resources Management of the Department of Mineral Resources, Thailand **(2008-2012)**

▶Director of Geotechnique Division and Director of Environmental Geology and Geohazard Division, DMR, Thailand **(2003-2008)**

▶Project Coordinator for geothermal energy sources/ Practitioner Level Geologist, Secretary of study visit group on education to develop the mining and automotive of Deputy Ministry of Industry/ Practitioner Level Geologist, and Head of the delegation Seminar in GIS training in Australia **(1979-2003)**

Degrees

▶Doctor of Philosophy (Ph.D), Geology, Chiang Mai University, Thailand **(2002)**

▶Master's Degree. (M. Sc.), Geophysics, University of Western Ontario, Canada **(1989)**

▶Bachelor's Degree. (B. Sc.), Geology, Chiang Mai University, Thailand **(1979)**

Expertise

▶Geologist, for a period of 32 years in geophysics, geothermal, geo-environment and mineral exploration and management.

Summary

Groundwater resources play an important role in the development in East and Southeast Asia. Groundwater resources assessments in the region have been taken by governments of member countries during last 30 years, revealing unsustainable using of groundwater resources and threatens caused by nature and human activities. Hence, issues on how to wisely manage and use of groundwater in the urban have appeared frequently in many agendas and cooperating project activities implemented by CCOP. Examples are the 5 year CCOP-KIGAM Project (2013-2017) “Solution for Groundwater problems in CCOP region”; CCOP-GSJ/AIST-GAI Groundwater Project (2008-2015) with Phase III entitled “Development of Geoinformation Sharing Infrastructure for East and Southeast Asia”; Deltares-CCOP Project proposal “International expert contribution to Capacity Development on Assessment and Mitigation of Land Subsidence in SE Asian Cities”; CCOP Deep Groundwater Project proposal “Management system and technology exchanges on deep groundwater aquifer development in CCOP member countries”.

Recently, it is noticed that new generation is growing up with different values than their predecessors such as purchase water in bottles than being used to the routine of boiling tap water. The bottled water market in East and Southeast Asia is growing. One of the driving factors for this growth is bottled water is often regarded as a status symbol in an increasingly affluent society and numbers of tourist of each country. Both factors have to be supplied by a high quality all mineral bottled water especially in hotels and resorts. This market insight covers the still bottled water segment, which is likely to have revenue growth in 2014. But there are still plenty of opportunities to growth and the market is becoming hugely attractive to global drink companies, for whom East and Southeast Asia region has recently becoming a top priority. By promoting cooperation activities on groundwater in the East and Southeast Asian region, we expect that it will enhance the sustainable use of our valuable groundwater resource and promote the connection between governors, hydrogeologists and drink companies.

KIGAM

JPDC

Jeju special self-governing province development Corporation

The 6th JPDC-KIGAM-CCOP Jeju Water Forum

6-9 October, 2014 in Jeju, Korea

Groundwater resources & Bottled water market in East & Southeast Asia ROLE OF REGIONAL ORGANIZATION - CCOP

Dr. Adichat Surinkum & Dr. Nguyen Thi Minh Ngoc

Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

Email: ccopts@ccop.or.th; Website: www.ccop.or.th

Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

INTRODUCTION

Groundwater resources in East & Southeast Asia

Groundwater resources:

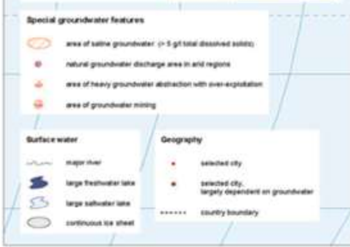
- GW is an important source of freshwater, storing almost 90% of the total non-frozen freshwater available on the Earth
- GW resources play an important role in CCOP regions, which is crucial for human drinking and food security
- Hydrogeological conditions are various from country to country (kaster type is quite developed in Southeast Asia).
- GW resources assessments in Asia countries have been taken during last 30 years.
- GW assessment, monitoring & data management activities are operated regular in China, Japan, Korea &Thailand etc but there are a few in other Asian developing Countries.

Problems of Groundwater quality/quantity & geohazards

- Overexploitation → depletion of GW resource
- Pollution & Contamination (As, F, fertilizers, etc.(China, Indonesia, Korea, Thailand, Vietnam, etc.)
- Salt instruction in coastal aquifers (e.g. Japan, Thailand and Viet Nam)
- Geohazards (land subsidence, etc) (In Bangkok, increasingly heavy pump of ground water in during 1955-1982 caused a decline of 45 to 50 meters in the ground-water levels.)

Trans-boundary aquifers

GROUNDWATER RESOURCES IN EAST & SOUTHEAST ASIA

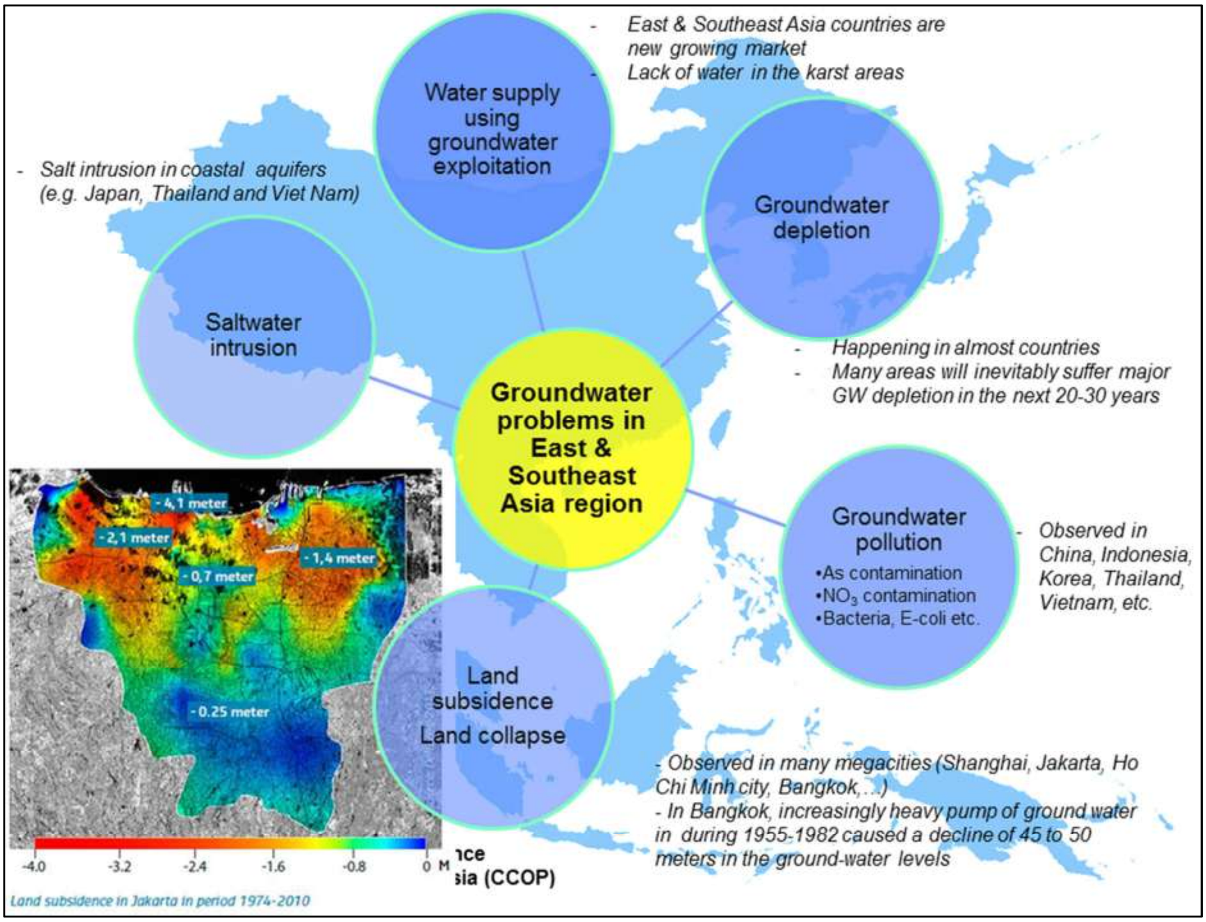


Water availability per person per year of East & Southeast Asian countries

Country	Water Resources						Population	
	1	2	3	4	5	6	7	8
Papua	801.00	–	801.00	–	801.00	166,563	4,809	11
Laos	190.42	37.90	190.42	37.90	333.55	63,184	5,279	23
Cambodia	120.57	17.60	115.97	13.00	476.11	36,333	13,104	74
Malaysia	580.00	64.00	566.00	50.00	580.00	26,105	22,218	68
Brunei	8.50	0.10	8.50	0.10	8.50	25,915	328	62
Myanmar	880.60	156.00	874.60	150.00	1,045.60	21,898	47,749	73
Mongolia	34.80	6.10	32.70	4.00	34.80	13,739	2,533	2
Indonesia	2,838.00	455.00	2,793.00	410.00	2,838.00	13,381	212,092	117
Viet Nam	366.50	48.00	353.50	35.00	891.21	11,406	78,137	240
Thailand	210.00	41.90	198.79	30.69	409.94	6,527	62,806	123
Philippines	479.00	180.00	444.00	145.00	479.00	6,332	75,653	254
Korea, Dem.	67.00	13.00	66.00	12.00	77.14	3,464	22,268	185
Korea,	64.85	13.30	62.25	10.70	69.70	1,491	46,740	473
Japan	430.00	27.00	420.00	17.00	430.00	3,383	127,096	349
China	2,879.40	891.80	2,715.50	727.90	2,896.57	2,259	1,282,437	137

1 Total internal renewable water Resources (km3/year)
2 Groundwater produced internally (km3/year)
3 Surface water produced internally (km3/year)
4 Overlap: Surface and groundwater renewable (km3/year)
5 Water resources: total renewable (km3/year)
6 Water resources: total renewable per capita (m3/capita year)
7 Populations in 2000 (1000 Inh)
8 Population densities in 2000 (inh//km2)

Sources: UNESCO "Water for People Water for Life - Ranking in the world", 2003



TRANS-BOUNDARY AQUIFERS IN EAST & SOUTHEAST ASIA

Research on trans-boundary aquifers is significant for the management of shared groundwater resources of neighboring countries or regions.

Name of Transboundary aquifer system	Countries sharing this aquifer system	Type of aquifer	Extension (km^2)
Ili River plain	China, Kazakhstan	Porous	53.000
Yemosei upstream	Russia, Mongolia	Porous, Fissured/fractured	60.000
Heilongjiang River plain	China, Russia	Porous	82.000
South Burma	Myanmar, Thailand	Fissured/fractured	53.000
Mekong River plain	Thailand, Laos, Cambodia, Vietnam	Porous	220.000
New Guinea Island	Indonesia, Papua New Guinea	Fissured/fractured	870.000

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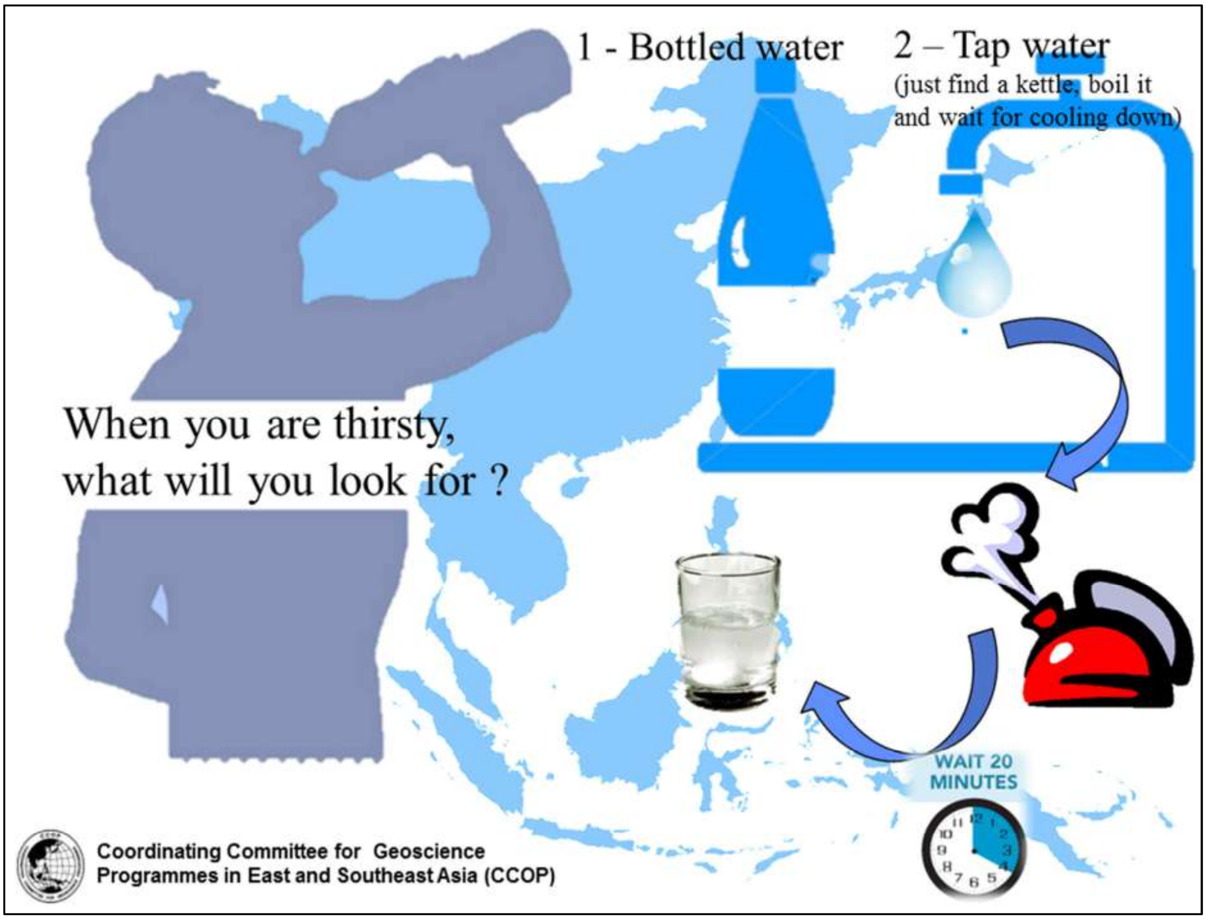
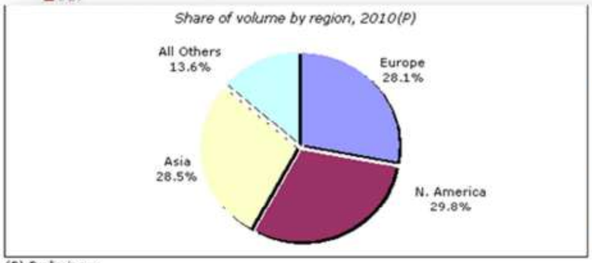
Source: Han Zaisheng & Wang Hao (CGS), 2013



Bottled water market in East & Southeast Asia



(P) Preliminary
Source: Beverage Marketing Corporation

ASIAN BOTTLED WATER MARKET
CHANGE IN CONSUMPTION BY COUNTRY
2003 – 2007(P)

Countries	2002/03	2003/04	2004/05	2005/06	2006/07(P)	5 yr CAGR
China* (r)	17.9%	26.1%	14.9%	13.9%	15.0%	17.5%
Indonesia	13.0%	6.0%	3.4%	7.3%	11.4%	8.2%
Thailand	2.0%	0.6%	0.5%	8.3%	7.5%	3.7%
India	45.6%	32.7%	23.8%	4.9%	6.5%	21.7%
Korea, Republic of	20.0%	20.0%	17.2%	11.5%	11.4%	16.0%
Japan	9.3%	11.1%	12.8%	28.3%	8.3%	13.7%
Philippines	5.5%	3.8%	4.4%	10.0%	8.8%	6.4%
Pakistan	5.9%	9.8%	11.2%	13.8%	9.5%	10.0%
China, Hong Kong SAR	10.0%	10.0%	10.1%	11.9%	8.4%	10.1%
Malaysia	8.5%	12.0%	11.3%	4.6%	9.5%	9.1%
Viet Nam	9.1%	3.6%	4.2%	15.9%	8.6%	8.2%
Singapore	8.0%	7.8%	7.8%	11.5%	9.8%	9.0%
Brunei Darussalam	9.0%	9.0%	9.0%	4.2%	2.1%	6.6%
Subtotal	**13.6%**	**14.4%**	**10.2%**	**11.3%**	**11.5%**	**12.2%**
All Others	9.2%	5.7%	6.3%	5.9%	4.5%	6.3%
GLOBAL TOTAL	**10.1%**	**7.5%**	**7.2%**	**7.1%**	**6.1%**	**7.6%**

(P) Preliminary
(r) Revised
** Includes Taiwan.*
Source: Beverage Marketing Corporation

Status:

The bottled water sales in Asian region have nearly doubled in the past five years.

- Growth has been spectacular in a number of countries, most notably in Japan, with bottled water becoming the norm for homes and on-the-move hydration.
- China represents the largest market in terms of volume consumed with Indonesia representing the second largest market (thanks to excessively large populations).
- In terms of per capita consumption, the highest is South Korea & Indonesia (thanks to strong economies). For Indonesia & South Korea, there has been significant growth in the bottled water market in large parts due to the growing middle class.
- The leading companies across the Asia regions are Aqua Group, Wahaha & Robust.

Forecast:

East & Southeast Asia is expected to remain the most "promising" market for growth.

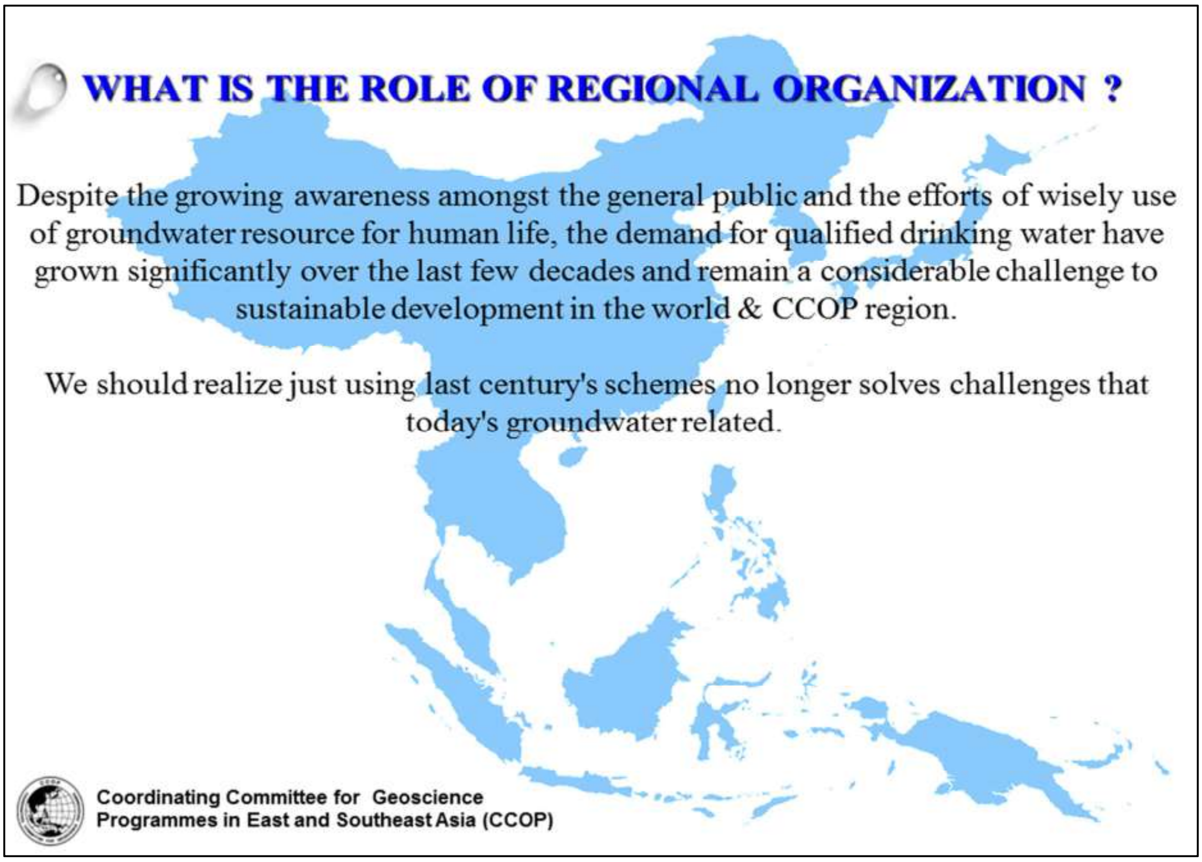
- Countries such as China, Korea, Thailand, Indonesia and Japan are expected to be the chief contributors to this growth.
- There is great potential for sustained growth in countries such as Vietnam, which have large populations and the supply sage drinking water is of paramount concern.
- China will continue to be the dominant consumer within this region with the largest population and with increased prosperity in some of its cities

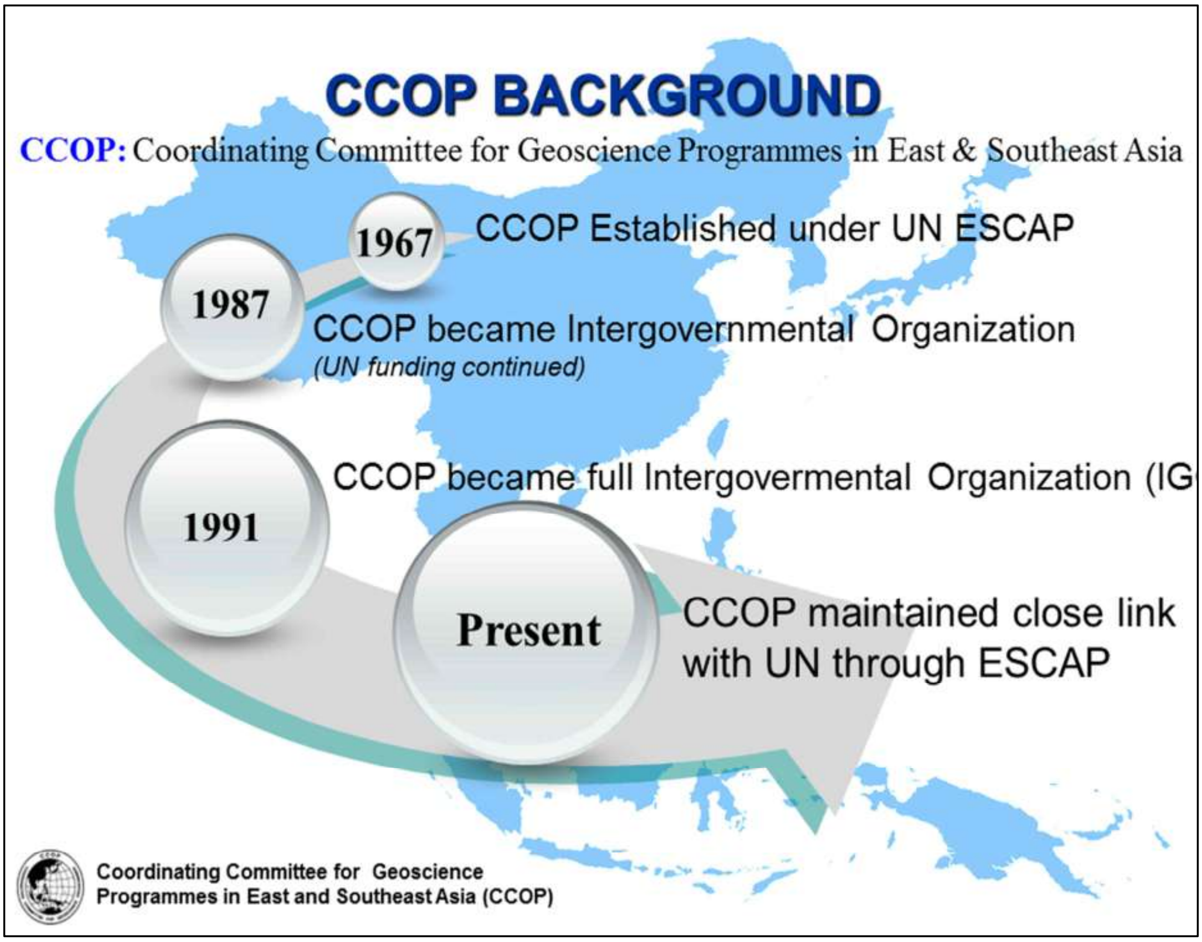
Market trends

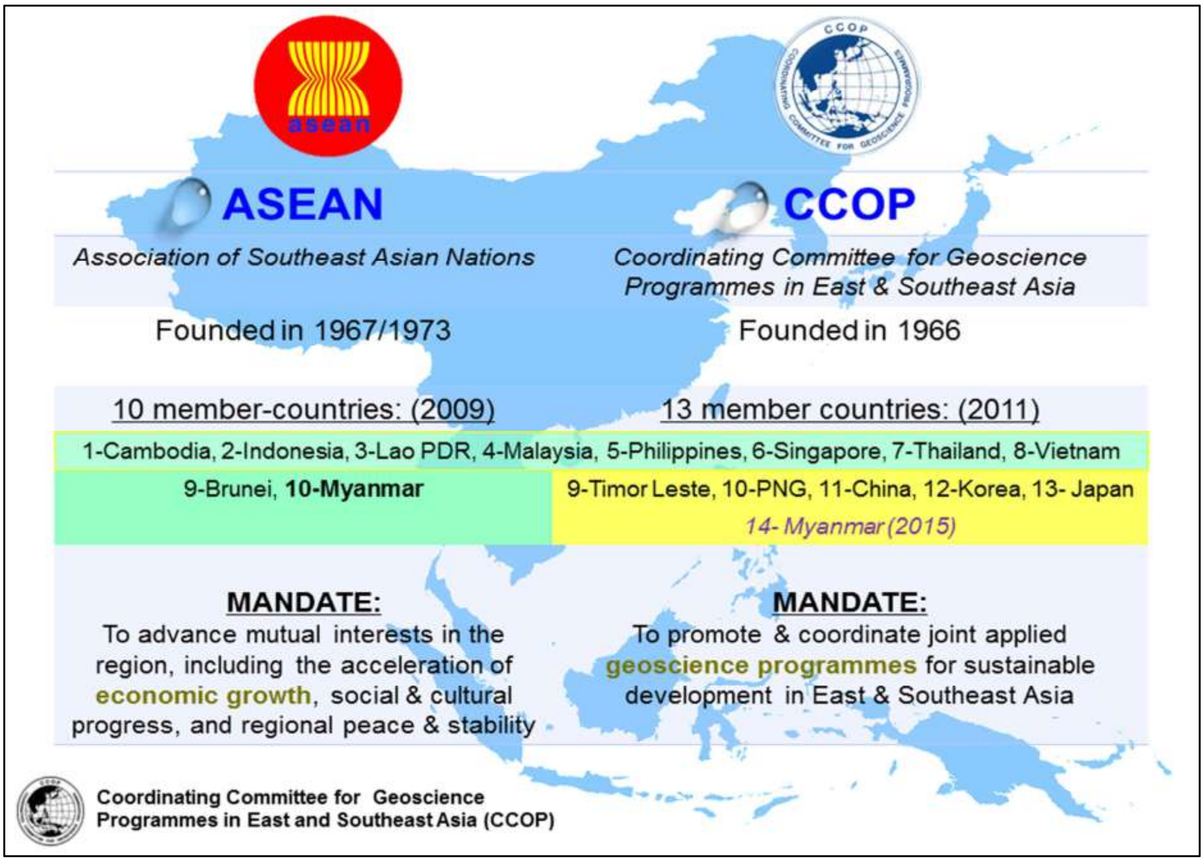
- Flavoured water is becoming increasingly popular with the international demand growing
- More recently, the genre of water can be vitamin-enriched and/or contain other functional elements for the consumer such as a calming relaxant or multi-vitamin reviver.
- Development of a functional water created for sports and energy use – a trend mirrored in the dairy segment.

Challenges

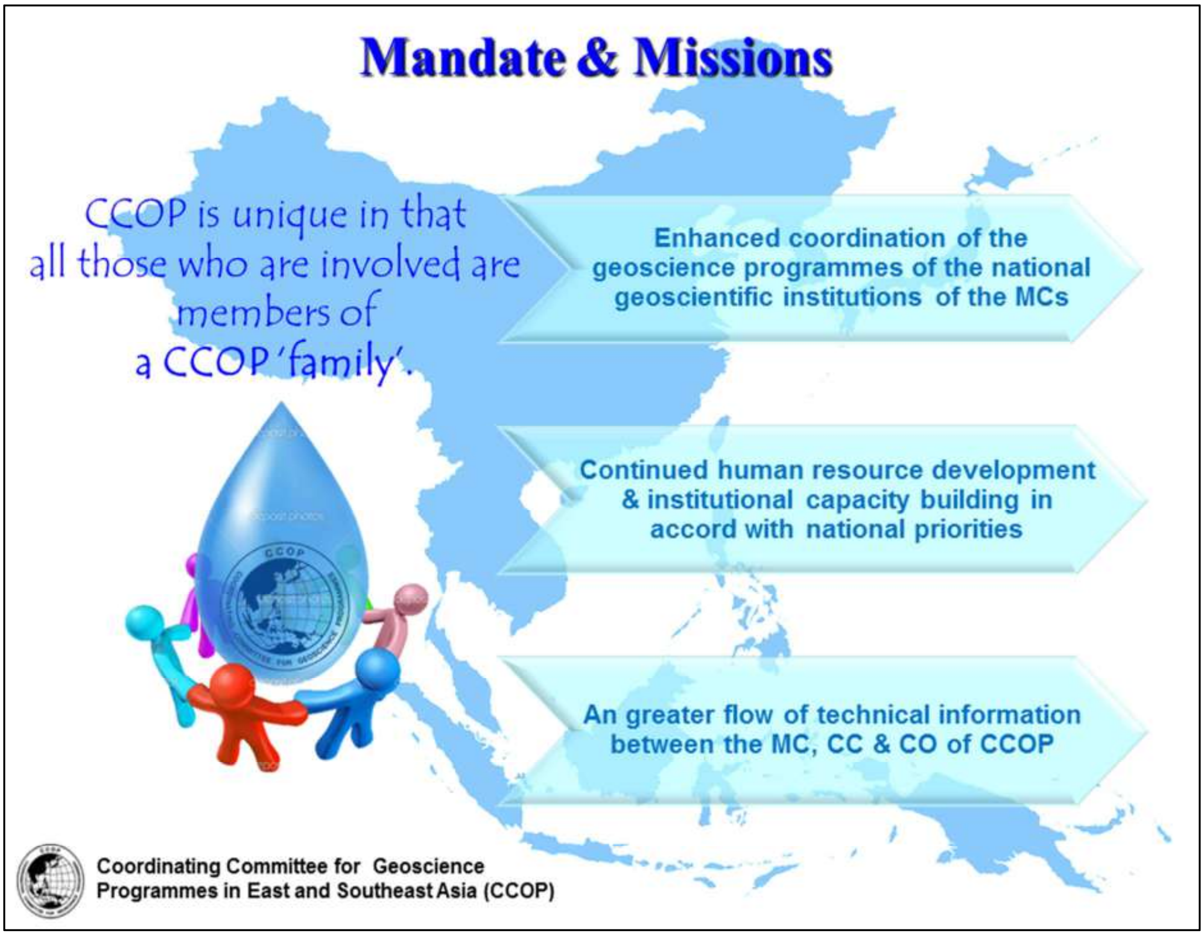
- The challenge for the bottled water industry is to keep up with the consumer demands for enhanced water industry while maintaining traditional plain water primary virtues of naturalness and hydration.
- Bottled water is currently under attack for its environmental impact (using vast amounts of energy in water, extraction, water processing, bottling and transportation, waste by empty bottles) and high prices.


WHAT IS THE ROLE OF REGIONAL ORGANIZATION ?
Despite the growing awareness amongst the general public and the efforts of wisely use of groundwater resource for human life, the demand for qualified drinking water have grown significantly over the last few decades and remain a considerable challenge to sustainable development in the world & CCOP region.
We should realize just using last century's schemes no longer solves challenges that today's groundwater related.
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

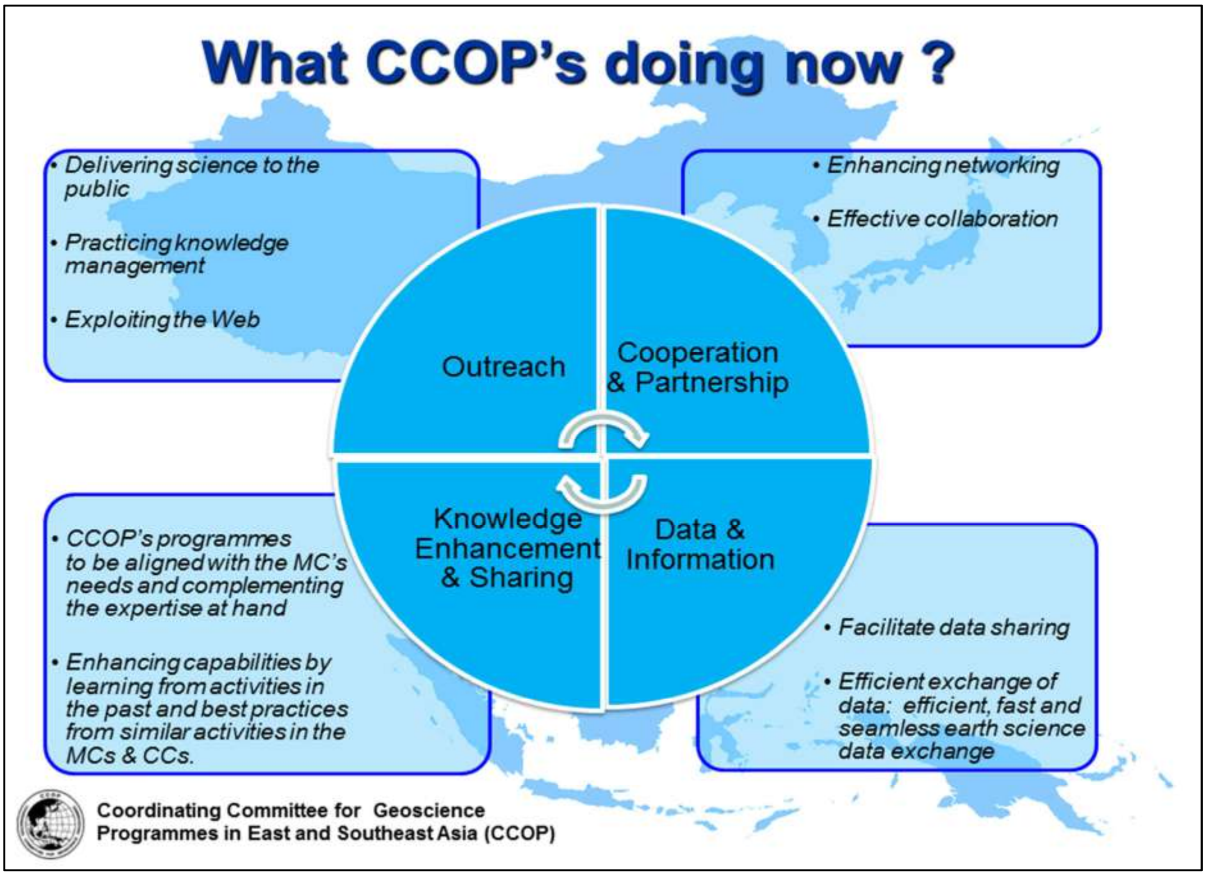

CCOP BACKGROUND
CCOP: Coordinating Committee for Geoscience Programmes in East & Southeast Asia
1967
CCOP Established under UN ESCAP
1987
CCOP became Intergovernmental Organization
(UN funding continued)
1991
CCOP became full Intergovermental Organization (IG
Present
CCOP maintained close link with UN through ESCAP
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

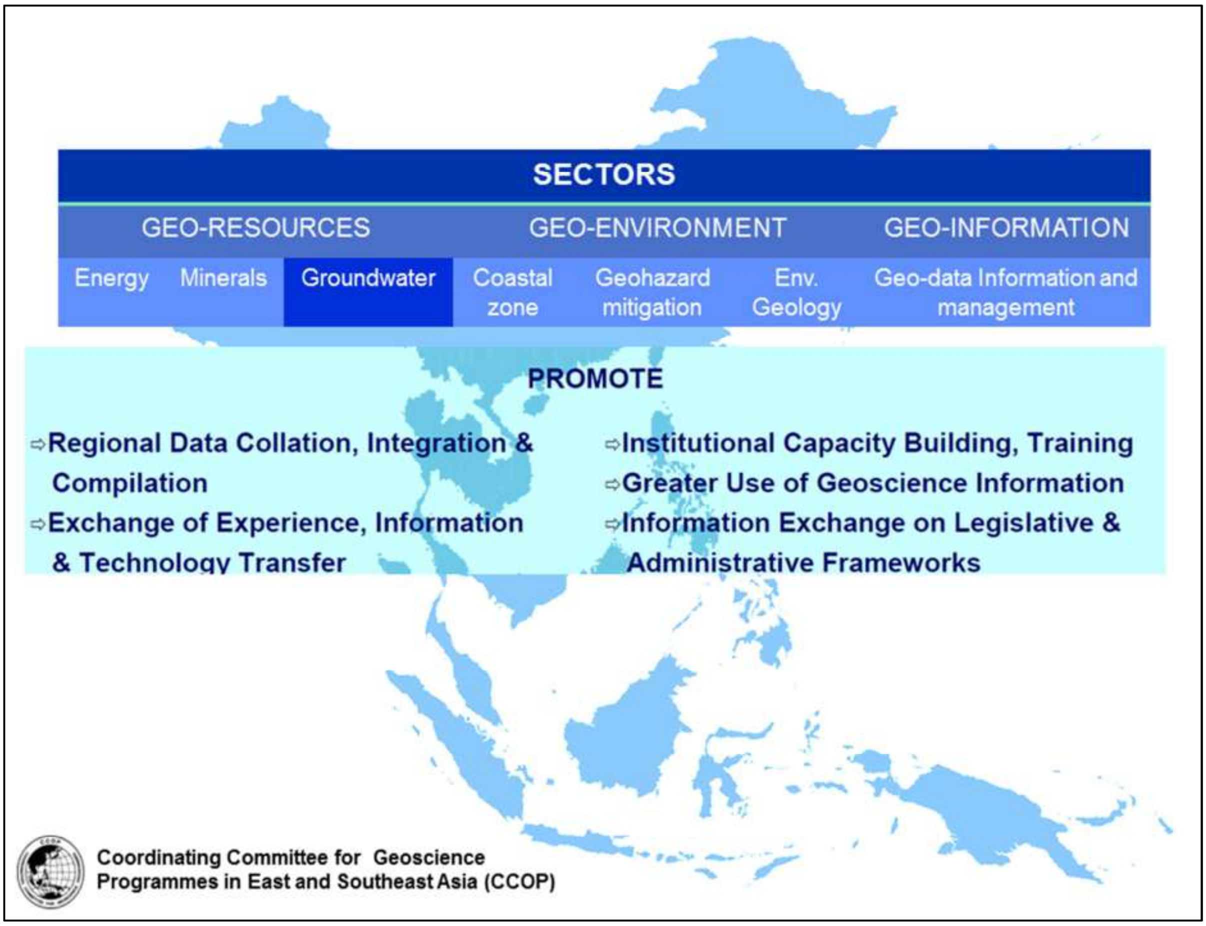


asean
ASEAN
Association of Southeast Asian Nations
Founded in 1967/1973
10 member-countries: (2009)
CCOP
Coordinating Committee for Geoscience Programmes in East & Southeast Asia
Founded in 1966
13 member countries: (2011)
1-Cambodia, 2-Indonesia, 3-Lao PDR, 4-Malaysia, 5-Philippines, 6-Singapore, 7-Thailand, 8-Vietnam
9-Brunei, 10-Myanmar
9-Timor Leste, 10-PNG, 11-China, 12-Korea, 13- Japan
14- Myanmar (2015)
MANDATE:
To advance mutual interests in the region, including the acceleration of economic growth, social & cultural progress, and regional peace & stability
MANDATE:
To promote & coordinate joint applied geoscience programmes for sustainable development in East & Southeast Asia
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)



Mandate & Missions
CCOP is unique in that all those who are involved are members of a CCOP 'family'.
Enhanced coordination of the geoscience programmes of the national geoscientific institutions of the MCs
Continued human resource development & institutional capacity building in accord with national priorities
An greater flow of technical information between the MC, CC & CO of CCOP
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)


What CCOP's doing now ?
• Delivering science to the public
• Practicing knowledge management
• Exploiting the Web
• Enhancing networking
• Effective collaboration
Outreach
Cooperation & Partnership
Knowledge Enhancement & Sharing
Data & Information
• CCOP's programmes to be aligned with the MC's needs and complementing the expertise at hand
• Enhancing capabilities by learning from activities in the past and best practices from similar activities in the MCs & CCs.
• Facilitate data sharing
• Efficient exchange of data: efficient, fast and seamless earth science data exchange
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)


SECTORS
GEO-RESOURCES
GEO-ENVIRONMENT
GEO-INFORMATION
Energy
Minerals
Groundwater
Coastal zone
Geohazard mitigation
Env. Geology
Geo-data Information and management
PROMOTE
⇨Regional Data Collation, Integration & Compilation
⇨Exchange of Experience, Information & Technology Transfer
⇨Institutional Capacity Building, Training
⇨Greater Use of Geoscience Information
⇨Information Exchange on Legislative & Administrative Frameworks
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

CCOP ACTIVITIES RELATED TO GROUNDWATER

Groundwater resources

- CCOP-AIST Groundwater Project (2004-2015)
  - *Phase I: Groundwater Assessment along Great River Basins in East and Southeast Asia (2004-2009)*
  - *Phase II: Groundwater Assessment and Control in the CCOP Region (2010-2014)*
  - *Phase III: Development of GeoInformation sharing infrastructure for ASEAN/CCOP countries (starting 2015)*
  - *Sub-project: "Development of Renewable Energy for Ground-Coupled Heat Pump system in CCOP Regions"*

Groundwater – Environmental & Geohazard issues

- CCOP-KIGAM Project "Solution for groundwater problems in CCOP region" (2013-2017)
- CCOP-Panya Consultant-DGR Land Subsidence Monitoring System Design Project Workshop/Meeting, 16-22 Jan 2011, Bangkok, Thailand

Groundwater and Bottled water market

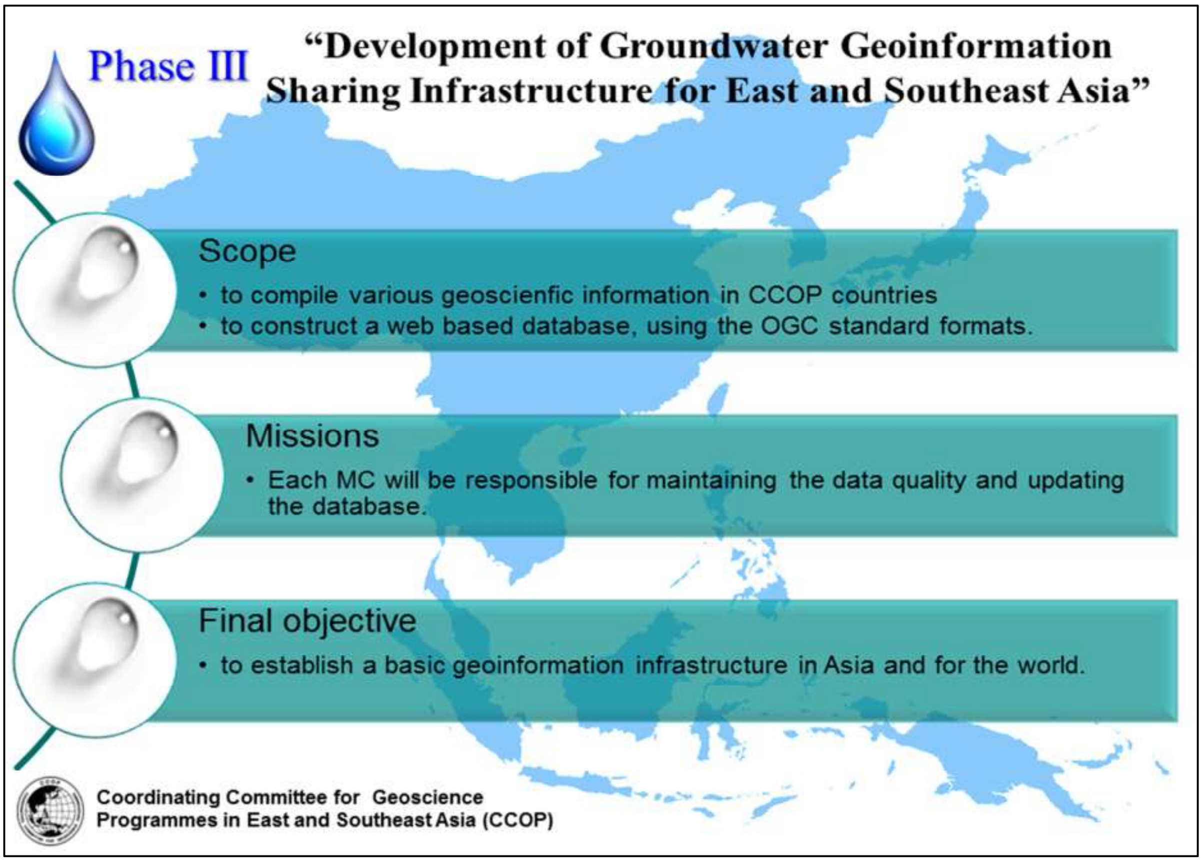
- The 6th JPDC-KIGAM-CCOP Jeju Water Forum on 6-9 October, 2014 in Jeju, Korea

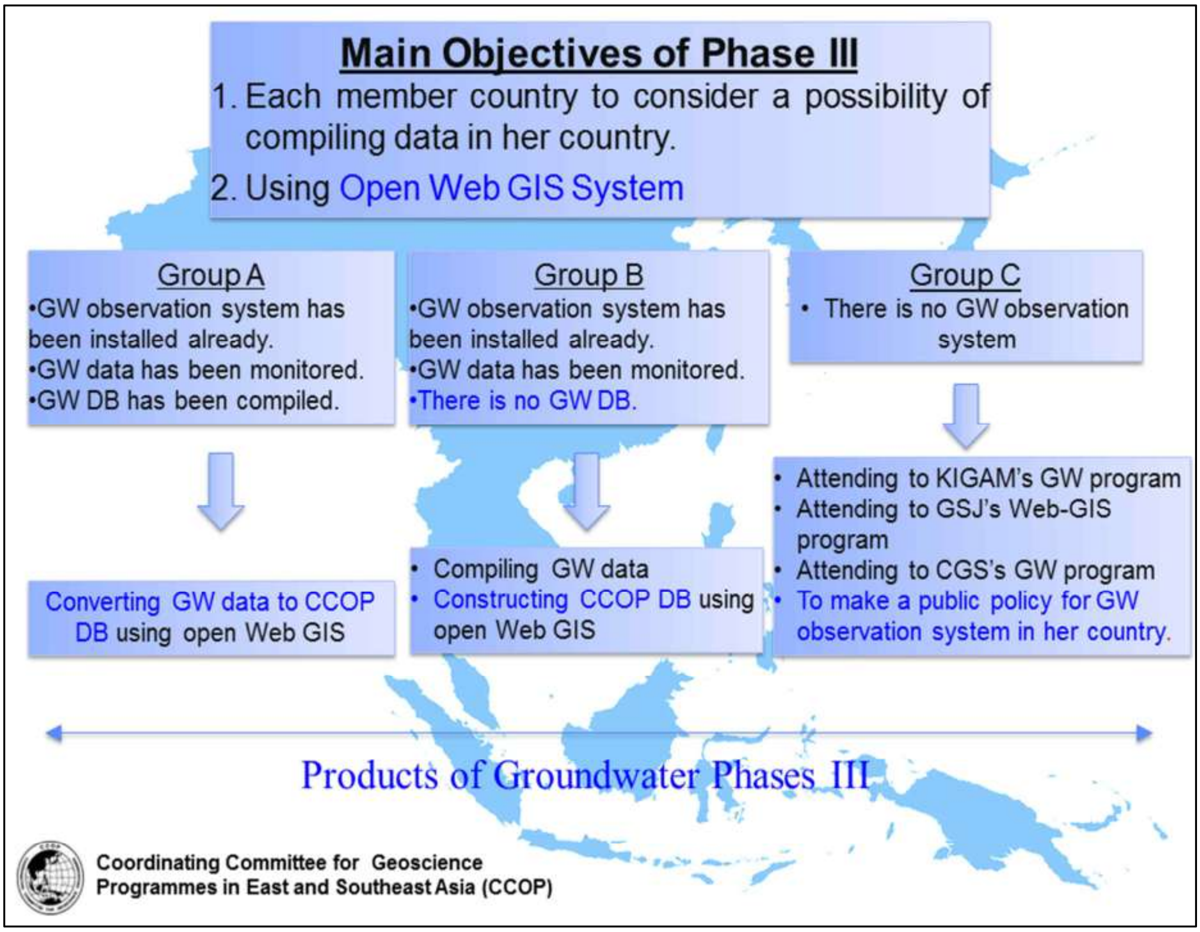
Deep Groundwater programme

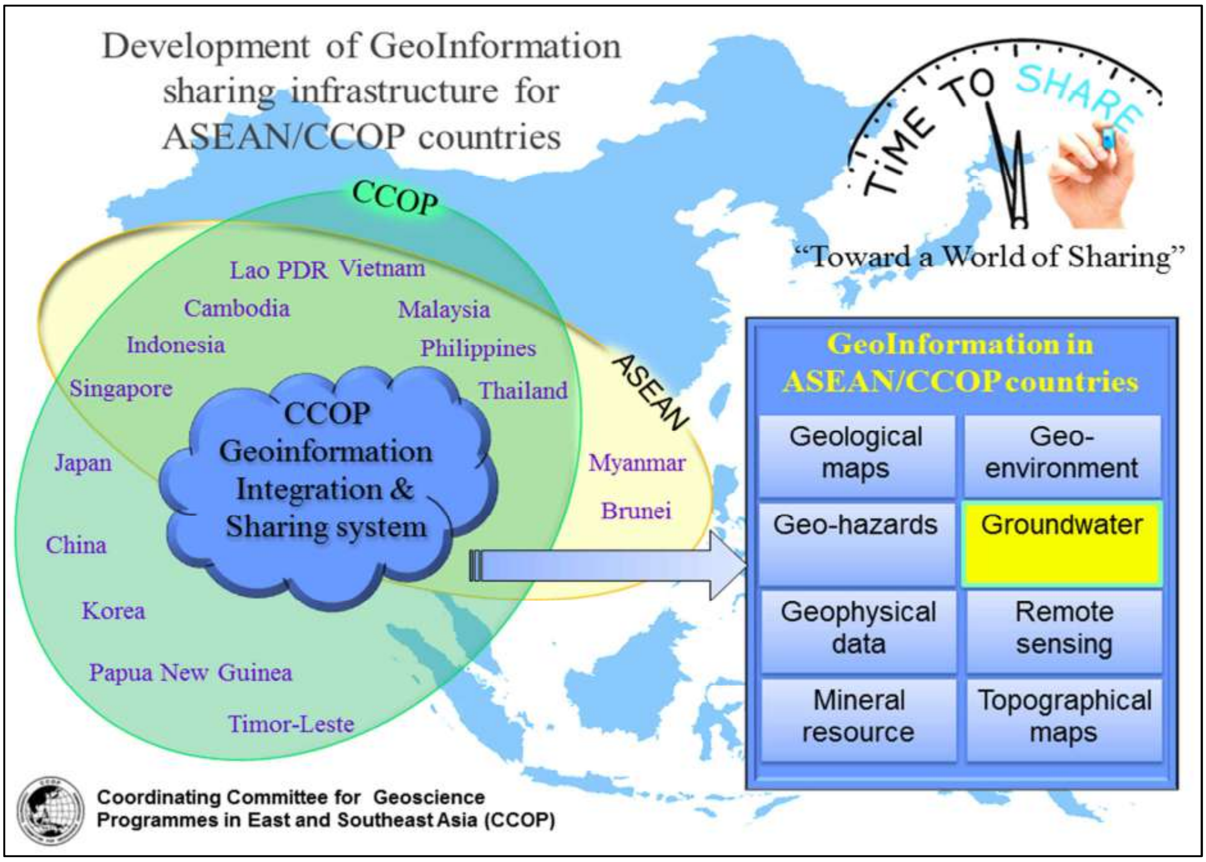
- PETRONAS-PETRAD-INSTOCK-CCOP Deepwater Subsea tie-back in Kuching, Malaysia on 24-26 Jan 2011
- Project Proposal on Deep Groundwater
  - *The project proposal has been prepared by CCOPT/S and submitted to the potential donor country for comment.*
  - *Seeking the support from potential donor country and agencies.*

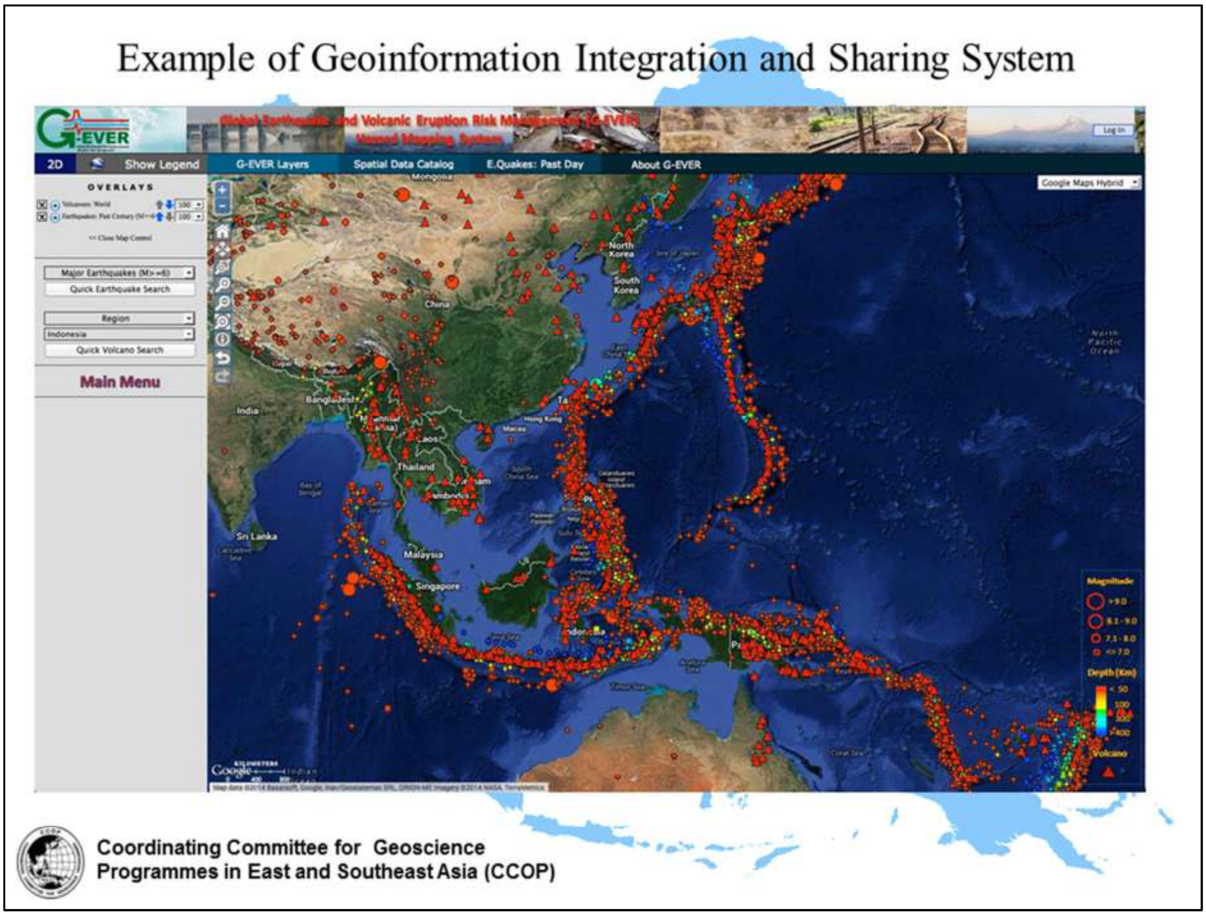
1) CCOP-GSJ/AIST Groundwater Project

Phase II *Groundwater Assessment and Control in the CCOP Region (2010-2014)*


Phase III
"Development of Groundwater Geoinformation Sharing Infrastructure for East and Southeast Asia"
Scope
• to compile various geoscienfic information in CCOP countries
• to construct a web based database, using the OGC standard formats.
Missions
• Each MC will be responsible for maintaining the data quality and updating the database.
Final objective
• to establish a basic geoinformation infrastructure in Asia and for the world.
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)


Main Objectives of Phase III
1. Each member country to consider a possibility of compiling data in her country.
2. Using Open Web GIS System
Group A
•GW observation system has been installed already.
•GW data has been monitored.
•GW DB has been compiled.
Group B
•GW observation system has been installed already.
•GW data has been monitored.
•There is no GW DB.
Group C
• There is no GW observation system
Converting GW data to CCOP DB using open Web GIS
• Compiling GW data
• Constructing CCOP DB using open Web GIS
• Attending to KIGAM's GW program
• Attending to GSJ's Web-GIS program
• Attending to CGS's GW program
• To make a public policy for GW observation system in her country.
Products of Groundwater Phases III
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)


Development of GeoInformation sharing infrastructure for ASEAN/CCOP countries
CCOP
ASEAN
TIME TO SHARE
"Toward a World of Sharing"
Lao PDR
Vietnam
Cambodia
Malaysia
Indonesia
Philippines
Singapore
Thailand
Japan
Myanmar
Brunei
China
Korea
Papua New Guinea
Timor-Leste
CCOP Geoinformation Integration & Sharing system
GeoInformation in ASEAN/CCOP countries
Geological maps
Geo-environment
Geo-hazards
Groundwater
Geophysical data
Remote sensing
Mineral resource
Topographical maps
Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)


Example of Geoinformation Integration and Sharing System
G-EVER
2D
Show Legend
G-EVER Layers
Spatial Data Catalog
E.Quakes: Past Day
About G-EVER
OVERLAYS
Major Earthquakes (M>=6)
Quick Earthquake Search
Region
Indonesia
Quick Volcano Search
Main Menu
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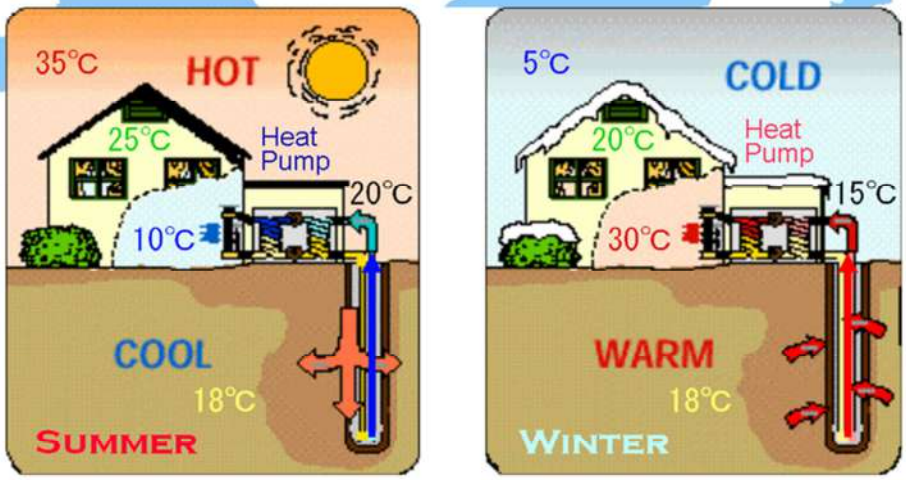
CCOP-GSJ/AIST Groundwater Sub-project

Sub-project: "Development of Renewable Energy for Ground-Coupled Heat Pump system in CCOP Regions"



Objects

➢To demonstrate GCHP system in case study areas

➢To develop adjustment of GCHP system for tropical region

➢To develop suitable maps for GCHP system in case study areas reflected large-scale groundwater flow/heat transport model using CCOP DB

2) CCOP-KIGAM Project
"Solution for groundwater problems in CCOP region" (2013-2017)

Step I (year 2013) : Understanding groundwater problems in the CCOP regions

- Identifying groundwater problems in each country
- Trust building and enhancing reliability to cope with groundwater problems among each country
- Groundwater training and workshop in KIGAM (2013. 7)
- Workshop in Bangkok (2013. 10)

Step II (year 2014) : Finding cooperative measures to solve the groundwater problems

- Establishment of the international network
- Priority decision making for solving the groundwater problems in the CCOP regions

Step III (year 2015 - 2017) : Cooperative actions to solve the groundwater problems

- Hydrogeological characterization of the selected area
- Finding and investigating solutions for the groundwater problems
- Taking cooperative actions and performance testing
- Monitoring and verification of the solution

CCOP-KIGAM-DGR-DMR-AIT Technical Workshop
"Solution for groundwater problems in CCOP region"
7-9 October 2013 in Pathumthani, Thailand

24 June – 9 July 2013 *30 June – 15 July 2014*
CCOP/KIGAM/IS-Geo training courses on Groundwater Theory and Application in Daejeon, Korea

Visit the project areas for "Groundwater supply for agricultural irrigation"
Suphan Buri province, Thailand

Visit the project areas for "Groundwater purification for drinking water supply for elementary school children"

3) Deep Groundwater Programme

PETRONAS - PETRAD - INTSOK - CCOP
DEEPWATER SUBSEA TIE-BACK
Damai Puri Resort & Spa, Kuching, Sarawak, MALAYSIA
24th - 26th January, 2011

DGW Project Proposal

"Management System and Technology Exchanges on Deep And Submarine Groundwater Aquifer Development in CCOP Member Countries"

GOALs

- To improve the reserves and reasonable use of the groundwater resources in order to possibly best meet more and more demands for the fresh water in the CCOP region.

Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

DGW Project Proposal

"Management System and Technology Exchanges on Deep And Submarine Groundwater Aquifer Development in CCOP Member Countries"

OBJECTIVES

- To enhance the capability and capacity of MC in:
  - *Assessment, management, operation and organization in the groundwater industry.*
  - *Exploration and exploitation of deep and submarine groundwater resources.*
  - *Carrying out the drilling and artificial recharge in the deep and submarine groundwater.*
- To enhance effectiveness of legal and institutional tools and water pollution control on groundwater resource management.

OUTPUTS

- Training personnel and networking of specialists in petroleum and groundwater sectors in CC and MC established and served as background for further cooperation.
- Management system on Health, Safety and Environment and legal framework in the groundwater industry.
- Potential areas of deep groundwater in MC and the roadmap to develop deep groundwater.
- A series of technical workshops, training courses, and seminars conducted.
- Case studies and dissemination of the results.
- DGW-dedicated website developed and regularly and updated by CCOP TS for knowledge storage, sharing, disseminating and reporting.
- Project report.

ACTIVITIES: 4 Projects with case studies, workshops, field works, seminars & expert visits

- Management Systems
- Environmental Issues
- Technology in exploration and dynamic Modelling
- Drilling and artificial recharge

Role of CCOP

CCOP plays an important capacity building role in the development of the groundwater in East & Southeast Asia.

CCOP has an active networking and friendship built through years of cooperation among geoscience organizations, including upstream regulatory agencies, companies, research organizations and academic institutions.

CCOP is willing for cooperation with other countries & organization to hold capacity building programs/activities & sharing of information in geosciences in general and groundwater management and exploitation, in particular.

Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

MAIN SUPPORTS BY CCOP
To East and Southeast Asia countries

Capacity building for East and Southeast Asia countries

- Be aligned with the Member Countries' needs and desires, complementing the knowledge and expertise at hand
- Enhanced awareness of groundwater resources, related environmental & geohazards problems

Created an open forum for participants to share information, expertise & experiences

- Learning from activities in the past and best practices from similar activities in the MCs, CCs & COs.
- Created an open forum for participants to share country reports, expertise & experiences on wisely use of groundwater, solving GW problems
- Invited experts, resource persons to give keynote lectures on research results, best practices, country's policy, etc.
- Raised discussion for developing cooperation activities among countries of common concern related to management & utilization of groundwater.

Develop the Groundwater network

- Governments – Researchers – Investors – Communities

Case studies in East and Southeast Asia countries

Dissemination results of completed project or bilateral cooperation projects to the other countries

Training, provide software & support on developing database

Cooperation to solve the trans-boundary problems

DISCUSSION ON Cooperation possibilities

CCOP to use its partnership and network and assist countries in need

CCOP to organize, co-organize, co-host the groundwater workshops in East & Southeast Asia

- Workshop advocated cooperative international, multi-nation approach to carry out the much needed work to address both short and longer term needs of people in concerned areas
- Disseminate the information/ Call for participation to the Member Country Geoscientific Network (13 member countries) & Cooperating Geoscientific network (15 countries)

CCOP to coordinate assistance efforts towards efficient and effective use of human, technical and funding resources

CCOP to facilitate, develop Multilateral/bilateral cooperation projects with partners from Asia/ Case study in selected countries

CCOP invited cooperation in providing resource persons for the on-going capacity building programs related to groundwater

CCOP offers support in connection and cooperation with geoscientific networks in East & Southeast Asia


"thank you for your ATTENTION :)"

The Opportunity and Challenge of the Bottled Water in China

Dr. Song Jianxin

Current Position

▶ Engineer, China Institute of Geo-Environment Monitoring (CIGEM) **(2009-present)**

Degrees

▶ Doctor of Engineering., Institute for Water Sciences of Beijing Normal University **(2012-present)**

▶ Master's degree, China University of Geosciences Beijing.
Major: Groundwater Science and Engineering **(2006-2009)**

▶ Bachelor's degree, China University of Geosciences Beijing, Major: Hydrology and water resources engineering

Research Interests

▶ Investigation and monitoring of groundwater, bottled water market and industry

Summary

1. Introduction

Bottled mineral water to enter the Chinese market is only 40 years. In recent 10 years, China's bottled mineral water production volume has increased dramatically. At present, China's mineral water production grows by an average of about 10%, high-end mineral water consumption is rising at an annual rate of 20%. Bottled water, especially the mineral water has become an indispensable part of people's life.

2. Development History

2-1 The scale and production

In China, the bottled water industry started in the 1970s, Laoshan brand was the only mineral water in China, the exploitation quantity was 1000t/y. After the Mineral water standard enacted, the development and production of the bottled water has been rapid development. Mineral water manufacturer brands reached more than 1100 in 1997. Large and medium-sized enterprises (output over ten thousand tons per year) accounted for 10%. Small and medium-sized enterprises accounted for more than 80% of the companies.

2-2 The brands

There are more than 1000 mineral water production enterprises in China, but not very famous enterprises and brands. China's mineral water industry has entered steady growth stage, Wahaha, Robust, Nestle are the first well-known brands, Tingyi, Coca-C ola, Cestbon are the second famous brands, therefore the existing enterprise competition is very fierce. Substitute for mineral water have tea drinks, carbonated drinks, diluted fruit juice drinks, functional nutritional drinks, etc., so the mineral water industry is facing the severe competition.

3. Current Situation

3-1 Quantity of Resource

China is rich in mineral resources and characteristics, but lack of per capita. The development takes up large amount of mineral water, however, the production is small; takes up large number of mine spots, but production scale is small. By 2103, the existing mine spots number of China is 4400, and the allowable exploitation quantity is more than $8\times10^{8}m^{3}$. In 2013, the bottled water production reached $0.67\times10^{8}m^{3}$, 19.2% higher than a year ago.

3-2 Consumption

Huge population base of consumption is the biggest potential of mineral water consumption market in China. According to the survey, in 2013 China's per capita consumption of mineral water was 10 litres, equivalent to one over ten of the developed countries, growing from 1.5 litres per capita in 2001. If the per capita consumption increased 1 litre, the mineral water production will increase more than the two-thirds, therefore, China's mineral water consumption market potential is very great. Now the main mine water consumption market in China is in the large and medium-sized cities and tourist areas.

4. Industrial Development

4-1 The trend of mineral water production

Degree of mineral water resources development and utilization is closely connected with the national economy overall development level, pollution of the environment and people's life idea transformation, but also promote the mine water consumption. Mineral water production enterprises to reduce, increase yield. A large number of medium and small mineral water production enterprises to collapse or be merged, larger companies and also only form a group, enhance the strength, create famous brands, improve the ability of survival and development. Under the condition, the mineral water in China is expected to yield increase, manufacturers will decrease year by year.

4-2 The new standard

In 2014, China will release a new bottled water standard, Packing Water National Standard. This applies to all packaged human direct drinking water, not suitable for natural mineral water. If the new standard has been approved, in addition to natural mineral water, artificial water, will be called "packing water" in the future. This will eliminate natural mineral water enterprise key barriers, namely the years cheap artificial bottled water on the identity of "intentionally" confusion, lays a foundation for drinking water system upgrade, further enhance business environment.

5. Plans for Cooperation

Chinese people drink concept is in escalating, drinking water from solving physiological needs to enjoying life as a modern way, become the consensus of more people, its annual sales of high-end mineral water increased by more than 20% a year. According to media reports, last year, a natural mineral water made a 5.7 billion sales miracle for 30 days.

High-end mineral water factory must have a beautiful natural environment, precious mineral water types and rich resources. As a result, CCOP members with China have broad prospects for cooperation.

6. Conclusion

China is rich in mineral resources, variety, has the large resource potential, the production potential and market potential, the mineral water industry in China has wide development prospects.

7. References

[1]The mineral water in China. Resource Industry, 2001. Tian Tingshan
[2]www.chyxx.com/industry, 2013
[3]www.cigem.gov.cn, 2013

CIGEM

The opportunity and challenge of the bottled water in China

Dr. Song Jianxin
China Geological Survey, CGS
China Institute of Geo-Environment Monitoring,CIGEM

CCOP-KIGAM-JPDC 6th Jeju Water World Forum
6-8 October 2014 in Jeju Island, Korea

CIGEM

Contents

6th Jeju Water World Forum 6-8 October 2014

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Development History

- In China, the bottled water industry started in the 1970s
  - The only mineral water in China
  - 1000t/m

6th Jeju Water World Forum 6-8 October 2014

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Development History

- In 1987, the Mineral water standard was enacted
  - The development and production of the bottled water has been rapid development.
  - Mineral water manufacturers reached more than 1100 in 1997.

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Current Situation

- In 2012, the bottled water production reached $0.56 \times 10^8 m^3$, 19.2% higher than a year ago.
  - Growing at 20% a year

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Quantity of Resource & Consumption

Quantity

Resource

mineral occurrence more than 4400 spots (2012)

allowable exploitation quantity $8 \times 10^8 m^3$

Consumption

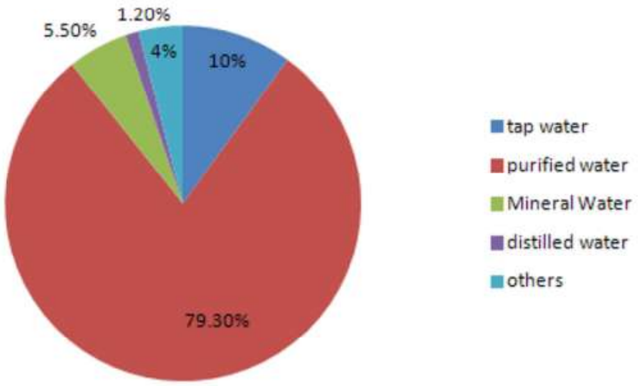
10 liters per capita (2013)

Equivalent to one over ten of Europe

6th Jeju Water World Forum 6-8 October 2014

Quantity of Consumption

- The Chinese water consumption structure



Quantity of Consumption

- Market survey

瓶装水消费者调查情况汇总表

品牌 / 选择人数 / 影响人数	康师傅 矿物质水 600mL 单价 0.8－1.0 元, 264 人选择		怡宝 纯净水 555mL 单价 1.1－1.5 元, 256 人选择		农夫山泉 天然水 550mL 单价 1.1－1.5 元, 229 人选择		大峡谷 纯净水 1.5L 单价 1.5－2.2 元, 121 人选择		益力 矿泉水 600mL 单价 1.4—2.0 元, 46 人选择		其他品牌 84 人选择		调查消费者人数 (1000 人)	
	选择人数	占百分比(%)	选择人数	占百分比(%)	选择人数	占百分比(%)	选择人数	占百分比(%)	选择人数	占百分比(%)	选择人数	占百分比(%)	选择人数	占百分比(%)
价格	245	92.8	67	26.1	53	23.1	117	96.6	2	4.3	19	22.6	503	50.3
质量	206	78.0	249	97.2	213	93.0	78	64.4	46	100	13	15.4	805	80.5
品牌	221	83.7	232	90.6	225	98.2	45	37.1	13	28.2	23	27.3	759	75.9
包装	81	30.6	149	58.2	132	57.6	32	26.4	7	15.2	38	45.2	439	43.9
广告	72	27.2	176	68.7	145	63.3	24	19.8	4	8.7	23	27.3	444	44.4

注:消费者可以在五项影响因素中任意填写一项或者以上。

6th Jeju Water World Forum
6-8 October 2014

CIGEM

Industrial Development

- Packing water national standards 2014
- Standard applies to all packaged human direct drinking water, not suitable for natural mineral water

6th Jeju Water World Forum   6-8 October 2014

CIGEM

Industrial Development

- Into the era of high-end water market
- From 2010 to 2013 , China's high-end water market is growing at 80% every year.
- According to the forecast, in 2015, China's high-end water market sales will reach 667000 tons, Retail market value will reach about 12.2 billion yuan.

6th Jeju Water World Forum   6-8 October 2014


CIGEM
水
Kam Sa Ha Mi Da!
Thank You !

The Bottled Water Market and Industry in Indonesia

Mr. Rudy Suhendar

Current Position

▶Head/Director, Center for Groundwater Resources and Environmental Geology (CGREG)-Geological Agency, Indonesia **(2013-Present)**

Experience

▶Division Chief, Environmental Geology, CGREG-GAI **(2010-2013)**

▶Division Chief, Program and Planning, CGREG-GAI **(2006-2010)**

▶Section Chief, Regional Environmental Geology, **(2001-2006)**

Directorate of Environmental Geology and Mining Area,

Directorate General of Geology and Mineral Resources

▶Staff of Directorate of Environmental Geology, Directorate General of Geology and Mineral Resources **(1989-2001)**

Degrees

▶Master's Degree of Applied Geomorpology and Engineering, Geology, ITC, ENSCHEDE The Netherlands **(1994)**

Summary

Water is an essential element for the human body. Most of the human body consists of water (55 to 78% depending on the size of the body). In order for the body to function properly, the human body needs water through drinking water.

Clean water services in Indonesia recently reached at 19%, this condition is still under expected. As an example some areas in Java and Bali are getting clean water services, namely Jakarta (48,13 percent), Bali (45,37%), the East Java (at 19 percent), Central Java (15,94%), and West Java (12.38%), and outside of Java and Bali are below the target.

PT. Golden Mississipi is one of the bottled water industries that built in 1973, launch the first production only 6 million liter per year in 950 ml size of glass bottle and it price was equivalent 2 times of the fuel price. The first step, this industry used the raw water from the water well and the next step in 1982 they use water from the natural springs. In 1985, this company earned the profit about 2 trillion Indonesia Rupiah.

Recently, the bottled water industries use the water through borehole dominantly and the other from springs and surface water.

According to the ASPADIN (national bottled water association) data, West Java province has the bottled water industries almost 28.82 % from the total similar industries in Indonesia . With the assumption of the percentage amount equivalent to the volume of factory production, the production of west Java in 2010 amounted to 3.689 million m^3. Estimates of groundwater flow in the groundwater basin of Soreang Bandung about 117 million m3 / year (Haryadi & Schmidt , 1991). Extraction of ground water to supply the drinking water needs for industrial raw water was about 3.14 %,

Consumption Trend of Bottled Water in Indonesia

The high rates of population growth in Indonesia will cause the increasing of clean water demand. The above population growth are not balanced with the provision of adequate clean water. The difficulty of getting access the water from the water supply network, bottled water is one alternative for simple water supply in daily subsistence. Consumption of bottled water is tend to increase although its more expensive than the water which is flow through the water supply network.

Based on data of bottled water production, its increase almost 11 to 12 percent per year. Currently, there are about 1.500 brands of bottled water and only 10 brands of its companies which control about 60% in national bottled water market.

The consumption of carbonated water is 33 liter per capita and the mineral water is 53 liter per capita. If the Indonesia population in 2015 is more 250 million, the bottled water industries have the opportunities to develop its capacity more than 25,250 million liter of water.

Characteristic of Groundwater Quality in Jeju Island and Proper Management

Dr. Hee Sun Moon

Current Position

▶ Senior Researcher of Groundwater Dept. at Korea Institute of Geoscience and Mineral Resources

Experience

▶ BK Professor, School of Earth and Environmental Science, Seoul National University, Seoul, Korea **(2009- 2013)**

▶ Research Associate, Dept. of Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA **(2007-2009)**

▶ Visiting Post-doc Fellow, Dept. of Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA (Korea Research Foundation) **(2006-2007)**

▶ Post-doc, School of Civil, Urban and Geosystem Engineering, Seoul National University, Seoul, Korea **(2005-2006)**

Degrees

▶ Graduate School of Seoul National University, Seoul, Korea (Ph.D) **(2000-2005)**

▶ Graduate School of Ewha University, Seoul, Korea (MS) **(1998-2000)**

▶ Dept. of Environmental Engineering, Ewha University, Seoul, Korea (BS) **(1994-1998)**

Professional Awards

▶ Best Poster Award, 2003 Annual Meeting of Korean Society of Civil Engineers **(2003)**

▶ Best Poster Award, The 2nd Annual Meeting of Young Scientists, Korea Society of Waste Management **(2003)**

▶ Best Paper Award, Korean Society of Soil and Groundwater Environment **(2012)**

Summary

1. Introduction

The groundwater in Jeju Island is vulnerable to contamination as recharge water easily percolates into the groundwater, especially after major precipitation events because the island is mainly composed of highly permeable geological units. Due to the geological features of the island, streams that are distributed in the island are ephemeral flowing only a few hours after precipitation events. For this hydrogeological reason, human water use in Jeju Island relies mainly on groundwater. Therefore, it is important to prevent or at least limit the contamination of the groundwater as it is the main source of potable and agricultural water. Especially, 28.6% of the land is used for agricultural activities In the western part of Jeju Island (Jeju Special Self-Governing Province, 2009). Interestingly, we investigated nitrate contamination in both a perched aquifer above an impermeable clay bed and the regional groundwater beneath this aquitard in the Gosan area which is located in western part of Jeju Island. Previous groundwater quality studies in Jeju Island focused only on the regional groundwater (Woo et al., 2001; Koh et al., 2005). Therefore, it is necessary to consider the water quality characteristics in the perched as well as the regional groundwater to fully understand the nitrate contamination in the aquifers of the Gosan area. In addition, Jeju Island has undergone a considerable change in land use over the past 15 years (1995–2009). The land use changes throughout 15 years may affect quality of groundwater. Therefore, it is also important to identify the tendency in long-term changes in NO_3-N according to land use change that induce groundwater contamination on Jeju Island for sustainable Jeju water development and management.

2. Case study of nitrate contamination: hydrogeochemistry of groundwater in the Gosan area

The δ18O and δD values indicate that the perched groundwater is recharged by local precipitation, whereas the regional groundwater is recharged mainly by regional flow from an adjacent mountainous region. The perched groundwater contained very high NO3–N concentrations of up to 87 mg/L. The isotopic composition of nitrate in the perched groundwater showed that synthetic fertilizers applied in high excesses of crop N needs were the main cause of aquifer pollution. Elevated nitrate concentrations were also observed in the regional groundwater especially after precipitation events. Concentration and isotopic data revealed that the inflow of shallow perched groundwater along the poorly cemented or uncemented annulus of regional groundwater wells was one of the main reasons for the nitrate contamination observed in the regional groundwater. In both aquifers, δ15N and δ18O values showed that the sources of nitrate were derived from synthetic fertilizers that had been recycled in the soil zone by nitrification and in some portions of the perched aquifer (dissolved oxygen concentrations <2 mg/L) indicated that denitrification occurred locally.

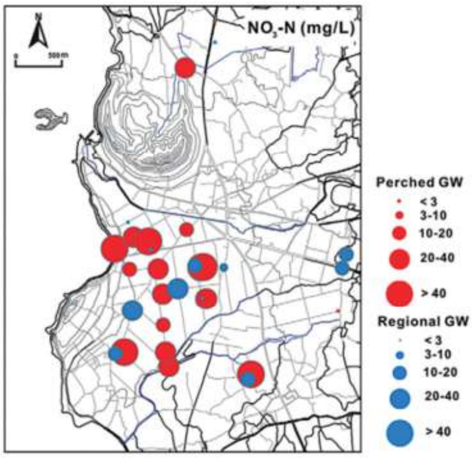


Fig. 1. Spatial distribution of the average NO_3-N concentrations in perched and regional groundwater (Koh et al., 2012).

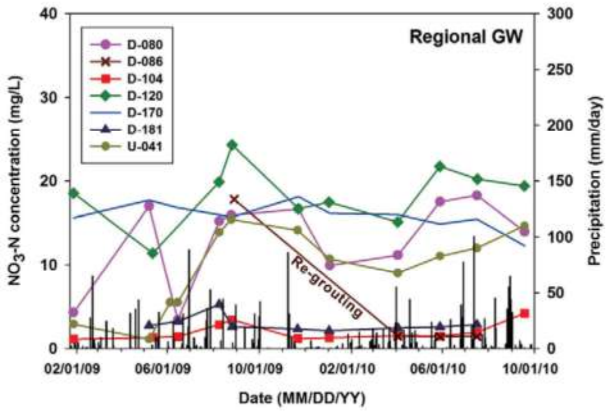


Fig. 2. Temporal variations of the NO_3-N concentrations in regional groundwater wells (Koh et al., 2012).

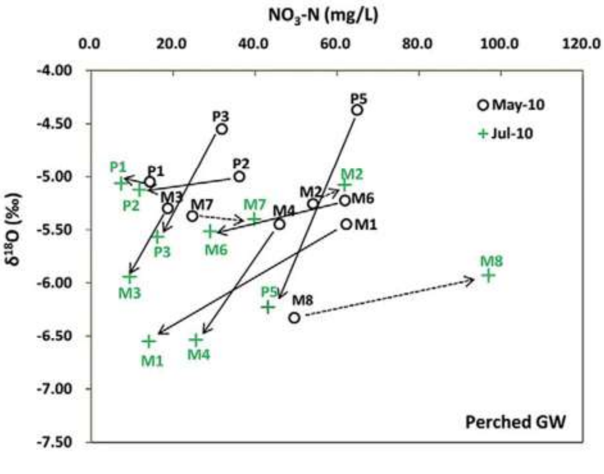


Fig. 3. Dynamic of NO_3-N and $\delta^{18}O$ values in the perched groundwater (Koh et al., 2012).

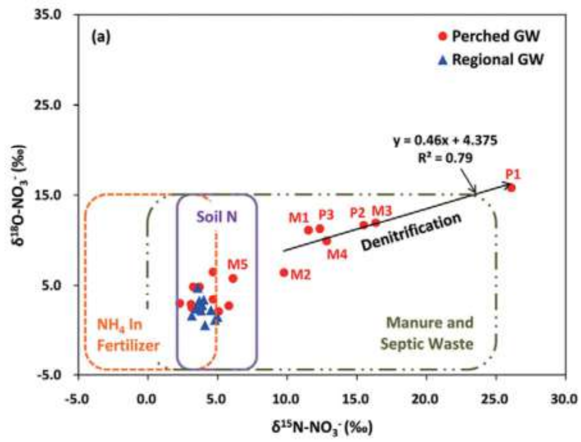


Fig. 4. Estimation of nitrate sources in the groundwater (Koh et al., 2012).

3. Land use change in Juju and long-term trend of nitrate content of groundwater

Data of NO_3-N concentrations in groundwater throughout the whole island were collected by the Institute of Water Resources of the Jeju Special Self-Governing Province from 1993 until 2012 and long-term trend analysis was conducted using statistical methods. For the overall island, groundwater contamination by NO_3-N is assumed to have continuously occurred in the future and this upward trend in NO_3-N concentrations is strongly related to the expansion of agricultural land where contaminations are discharged into the subsurface. Also, the urbanization positively affects the quality of groundwater in relation to a transition from agricultural to urban lands. Increasing tendency of NO_3-N concentrations was observed in the mid-mountainous area (altitude: 200–600 m) where the amount of agricultural land has abruptly been increased.

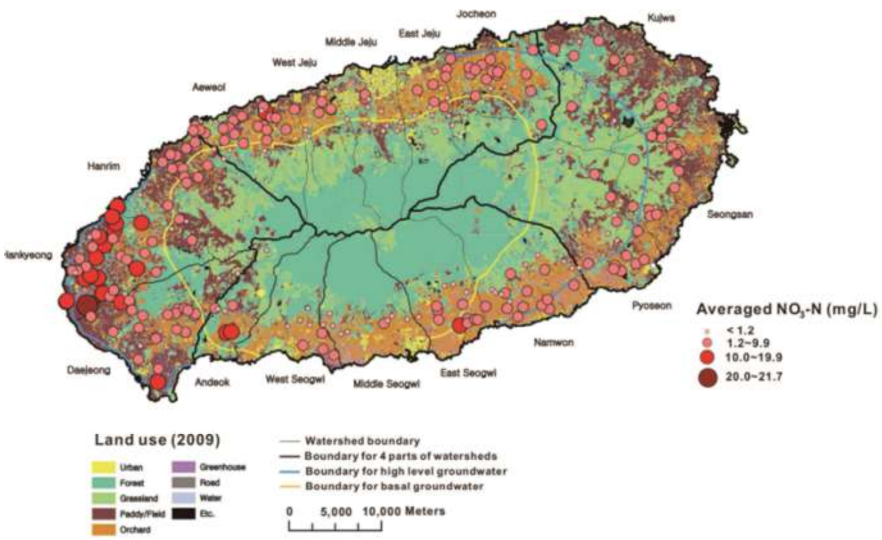


Fig. 5. Spatial variation of averaged NO_3-N concentration using the land use map of 2009 (Koh et al., 2014 submitted).

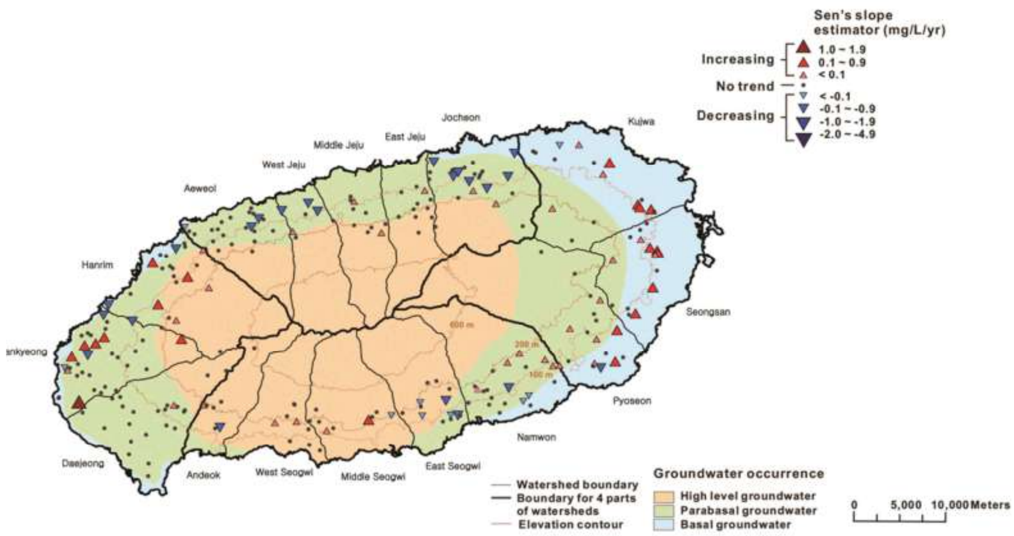


Fig. 6. Spatial distribution of long term trend of NO_3-N concentration (Koh et al., 2014 submitted).

4. Conclusions and Suggestions

We investigated the sources and biogeochemical transformations of the nitrate contamination in two unusual aquifer systems of the Gosan area by combining geochemical–isotopic approaches. We found that perched groundwater was directly recharged by local precipitation and that its water quality was severely affected by heavy overfertilization. In contrast, the regional aquifer was mainly recharged by water flows from the Mt. Halla and, compared with the perched aquifer, had relatively better water quality and lower nitrate concentration. Isotope analyses revealed that nitrate in both aquifers were derived from nitrification of N in chemical fertilizers after recycling in organic soils and that in some portions of the perched aquifer, denitrification had occurred locally. We demonstrated that nitrate-rich perched groundwater may affect the regional aquifer through imperfectly grouted wells facilitating groundwater contamination with nitrate. Therefore, we suggest examining well completions and regrouting the well annulus in combination with a reduction of fertilizer application rates as a quick and efficient way to reduce nitrate contamination of the lower regional aquifer.

Based on the results of a trend analysis of NO_3-N concentration in groundwater on Jeju Island over two decades, increase of NO_3-N was estimated to be continuing over the island. Upward trends in NO_3-N are associated with the expansion of agricultural lands converted from natural lands over the 15 years period. Especially, the continuous extension of agricultural lands in the mid-mountainous regions will cause groundwater quality degradation by increases of NO_3^-. From this study, we suggested that future periodic groundwater quality should be continuously monitored over the island based on land use to develop and manage sustainable Jeju groundwater. This could contribute to strengthen global competitiveness of Jeju water industry.

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KIGAM-CCOP-JPDC
Jeju Groundwater Workshop

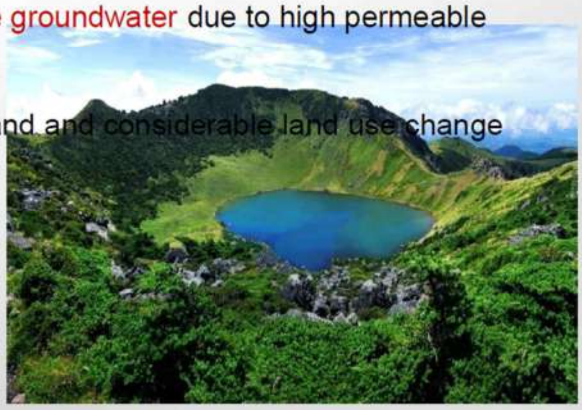
Characteristic of Groundwater Quality in Jeju Island and Proper Management

Hee Sun Moon[1], Eun-Hee Koh[2], Kang-Kun Lee[2], Kyoochul Ha[1]
[1]Korea Institute of Geoscience and Mineral Resources,
[2]Seoul National University

KIGAM

About Jeju Island

- Korea's largest island (1,847 km^2), located in the 140 km south of Korean peninsula
- Volcanic Island and Mt. Halla in the center
- UNESCO site in 2007
- High annual precipitation (2,061 mm) and heavy rainfall events during summer monsoon season (Jeju Special Self-Governing Province, 2013)
- Recharge water easily percolates into the groundwater due to high permeable volcanic rocks
- Large agricultural area over 30% of the land and considerable land use change



Groundwater as water resources in Jeju

- Only reliable source of water for drinking, industrial and agricultural needs
- Capable sustaining relatively large groundwater withdrawals resulting from abundant annual rainfall
- Vulnerable to groundwater contamination due to hydrogeological conditions and agricultural activity

Important to manage and develop groundwater properly based on understanding groundwater quality characteristic and the contamination trend

Gosan area

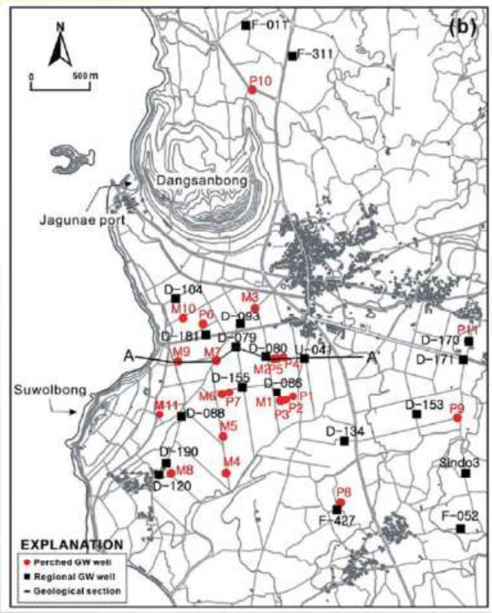


Fig.1. Perched and regional groundwater well information

- Located in the Hankyoung area in southwestern ($11.81\ km^2$)
- Significant agricultural activity
- High annual chemical fertilizer application (627.9kg N/ha)
- Water in furrow and stagnant pools in agricultural fields
- Both perched and regional groundwater existence
- 21 new well installed to access the perched groundwater
- Groundwater quality monitored for 1 year

4

Geology of the Gosan area

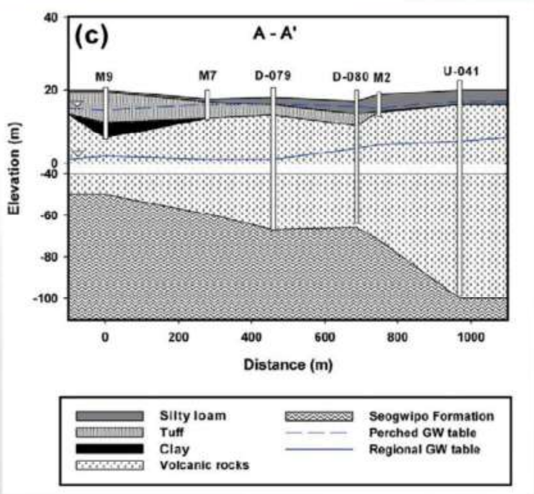


Fig. 2. Geological Cross-section of the Gosan site

- Silty loam, tuff, clay beds, porous volcanic rocks, and Seogwipo Formation
- Impermeable clay beds (max. 4.2 m) at the perched aquifer
- Thick and high permeable volcanic rock

5

Groundwater quality of Gosan

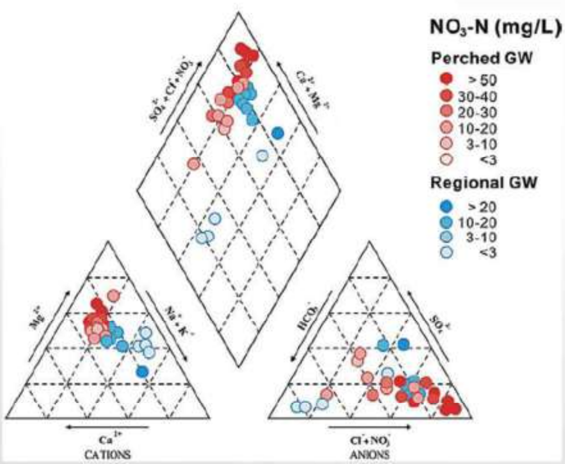


Fig. 3. Piper diagram of the perched and regional groundwater (May, 2010) (Koh et al., 2012)

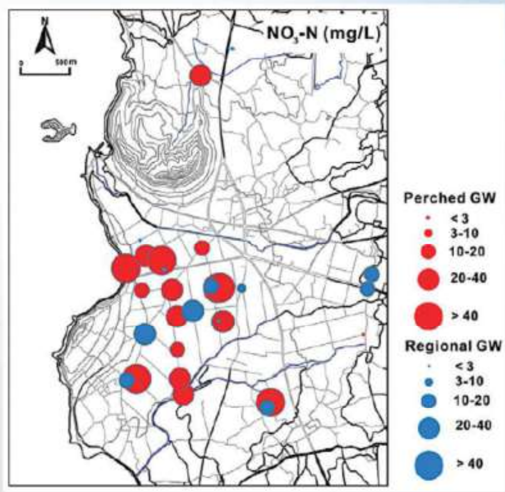


Fig. 4. Spatial distribution of the average nitrate concentration in groundwater(May, 2010) (Koh et al., 2012)

6

Temporal nitrate concentration in groundwater

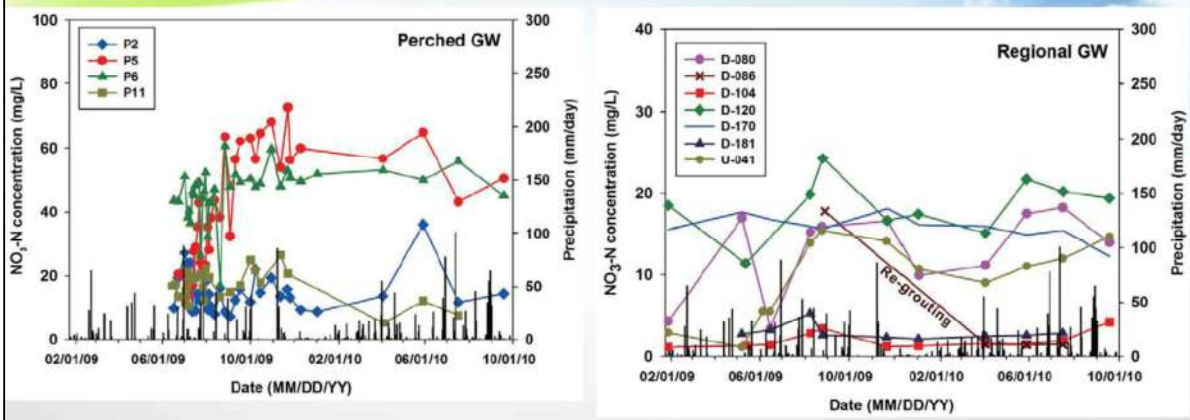


Fig. 5. Temporal variation of nitrate concentration in perched (left) and regional (right) groundwater (Koh et al., 2012)

- In the perched groundwater, nitrate concentration fluctuated more significantly during the monitoring period compared to regional groundwater
- Marked changes of nitrate concentrations in regional groundwater wells (D-080, D-120, and U-041) due to precipitation events.

7

Effect of grouted well casing: Well D-086

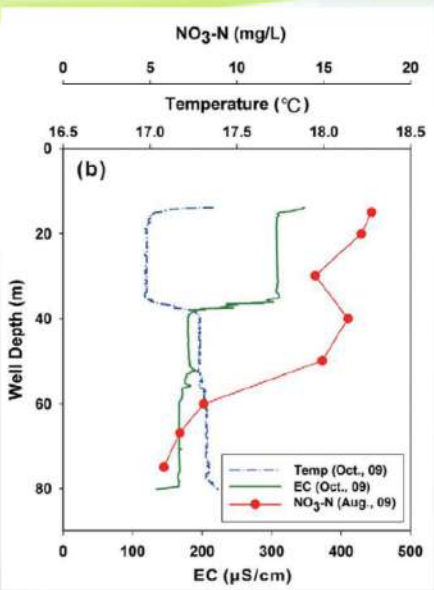
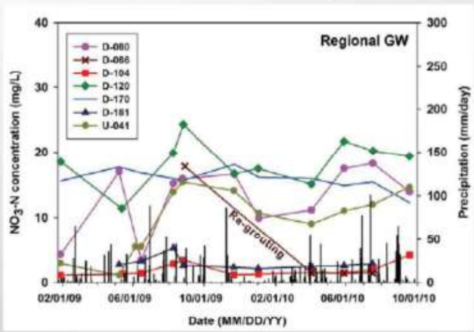


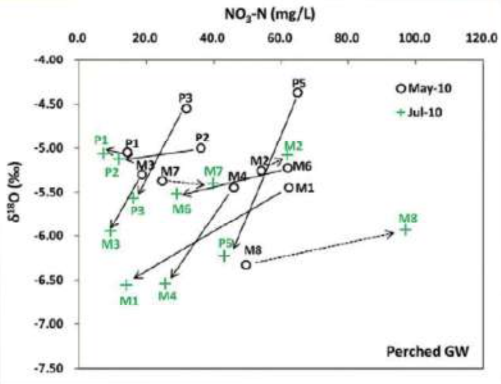
Fig. Vertical distributions of Temp, EC and nitrate concentration in the well D-086 (Koh et al., 2012)

- Leakage of groundwater from the perched aquifer into the regional aquifer resulted in elevated nitrate concentrations (14–18 mg/L) in the upper 50 m of well depth
- Regrouted in 2009 and monitored
- Groundwater quality could be rapidly impromed by proper well completions of casing



8

Effect of recharge characteristics



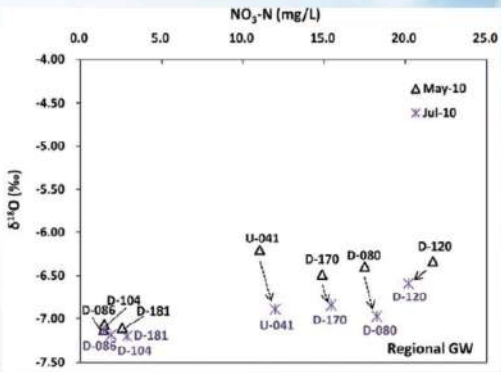


Fig.6. Dynamics of NO3-N and δ18O in perched (left) and regional (right) groundwater (Koh et al., 2012)

- Generally, nitrate concentration in the perched groundwater decreased after precipitation due to dilution effect by recharge
- Higher nitrate concentrations (>10 mg/L) after precipitation at the wells U-041, D-170, and D-080

9

Source of nitrate in groundwater

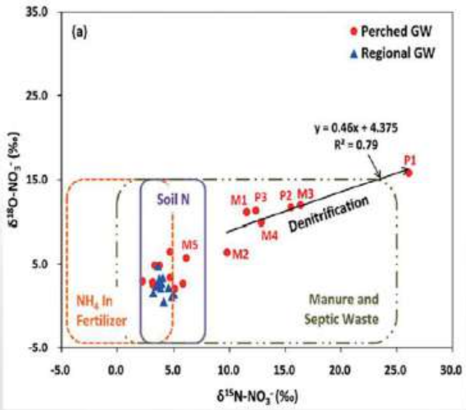


Fig. 7. Estimation of nitrate sources in groundwater (Koh et al., 2012)

- Synthetic fertilizers applied in high excesses of crop N needs were the main cause of aquifer pollution
- In both aquifers, δ15N and δ18O values showed that the sources of nitrate were derived from synthetic fertilizers that had been recycled in the soil zone by nitrification and in some portions of the perched aquifer indicated that denitrification occurred locally.

10

Land use change and Groundwater quality

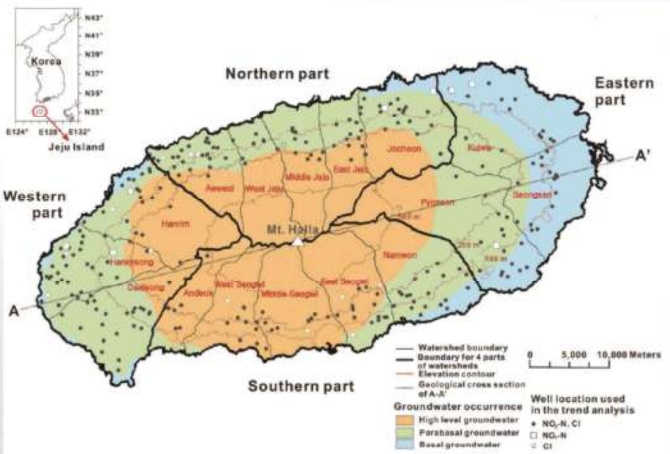


Fig. 8. Groundwater well locations for the trend analysis

- Groundwater quality data collected by the Institute of Water Resources of the Jeju Special Self-Govering Province from 1993 to 2012 (264 well for nitrate)
- Land use data (1995 and 2009)
- Three major categories (urban, agricultural and natural land)

Land use changes in Jeju

Table 1. Summary of land use changes in the four major sectors (with individual watersheds)

Land uses		Urban lands			Agricultural lands			Natural lands		
Parameter		1995 (km²)	2009 (km²)	Change ratio†	1995 (km²)	2009 (km²)	Change ratio	1995 (km²)	2009 (km²)	Change ratio
Whole island		101.3	102.3	1.0	616.6	750.0	1.2	1098.4	961.5	0.9
Eastern part	Kujwa	7.2	6.7	0.9	53.1	77.6	1.5	109.3	84.5	0.8
	Seongsan	5.3	5.5	1.1	44.7	62.9	1.4	63.1	44.4	0.7
	Pyoseon	5.8	6.2	1.1	42.4	58.0	1.4	158.1	141.2	0.9
Western part	Hanrim	8.8	7.0	0.8	43.7	63.4	1.5	88.6	71.0	0.8
	Hankyeong	5.3	4.7	0.9	54.3	69.3	1.3	42.3	28.1	0.7
	Daejeong	7.8	6.7	0.9	70.8	82.9	1.2	50.7	40.3	0.8
Southern part	Namwon	4.0	4.5	1.1	48.3	53.0	1.1	81.0	75.4	0.9
	East Seogwi	3.4	4.3	1.3	36.0	38.0	1.1	67.2	64.6	1.0
	Middle Seogwi	6.9	7.4	1.1	33.0	35.7	1.1	66.0	62.8	1.0
	West Seogwi	5.8	4.6	0.8	27.6	29.0	1.1	49.4	49.0	1.0
	Andeok	2.1	2.8	1.3	16.1	19.7	1.2	44.1	39.7	0.9
Northern part	Jocheon	6.1	6.0	1.0	43.1	57.0	1.3	76.1	61.7	0.8
	East Jeju	6.7	7.0	1.0	23.7	24.8	1.0	44.7	43.0	1.0
	Middle Jeju	17.1	18.0	1.1	19.9	20.5	1.0	52.4	51.0	1.0
	West Jeju	3.2	4.8	1.5	19.3	18.3	0.9	66.6	65.7	1.0
	Aewoel	6.0	6.2	1.0	40.4	39.8	1.0	38.8	39.2	1.0

† Area of land use in 2009 divided by that of 1995.

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Spatial distribution of nitrate conc. over the Island (2009)

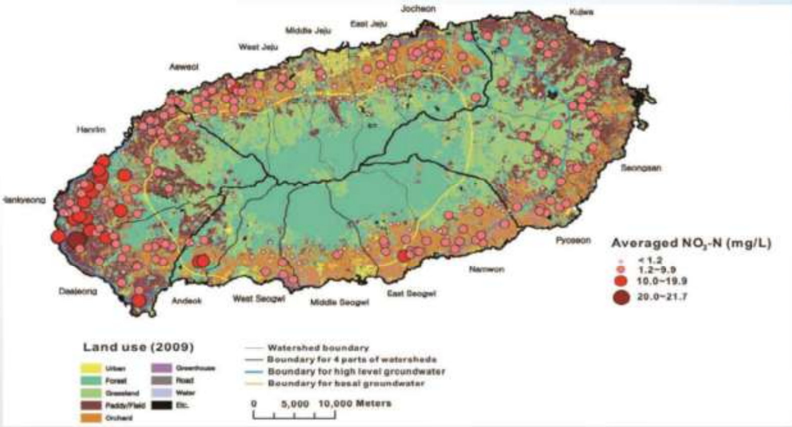

Fig. 9. Spatial variation of average nitrate concentration in groundwater according to land use of 2009

13

Spatial distribution of nitrate conc. trend

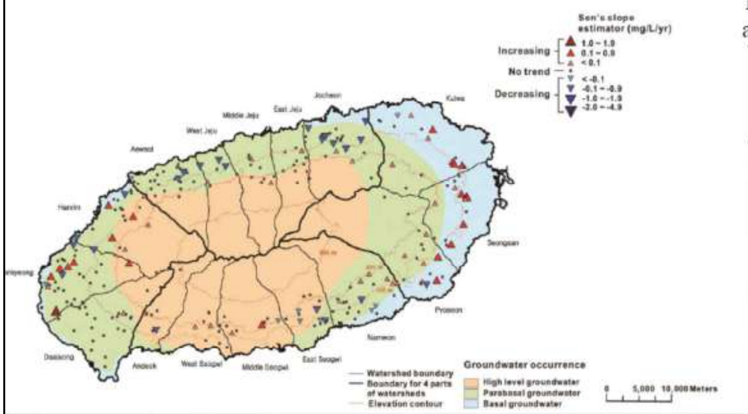

Fig. 10. Spatial trend of nitrate concentration over 15 years

Table 2. Trends of NO_3-N over the whole island and in each major sectors

Parameter	NO_3-N		
Trends	Increasing	No trend	Decreasing
Whole island	52† (20.0%)‡	176 (67.7%)	32 (12.3%)
Eastern part	21 (43.8%)	25 (52.1%)	2 (4.2%)
Western part	14 (17.5%)	60 (75.0%)	6 (7.5%)
Southern part	11 (18.0%)	38 (62.3%)	10 (16.4%)
Northern part	6 (8.2%)	53 (72.6%)	14 (19.2%)

† The number of wells showing the relevant trend.
‡ Numbers in parenthesis represent the percentage of each trend in the relevant region.

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Trend in nitrate conc. with elevation

Table 3. Changes in agricultural land use according to elevation

Elevation (m)	1995 (km²)	2009 (km²)	Change ratio
<100	398.4 (62.9%)†	431.4 (67.4%)	1.1
100-200	166.0 (46.0%)	200.0 (55.7%)	1.2
200-600	52.1 (8.8%)	204.2 (34.7%)	3.9

†Numbers in parenthesis refer the percentage area of agricultural land in relation to the total land area at a particular elevation.

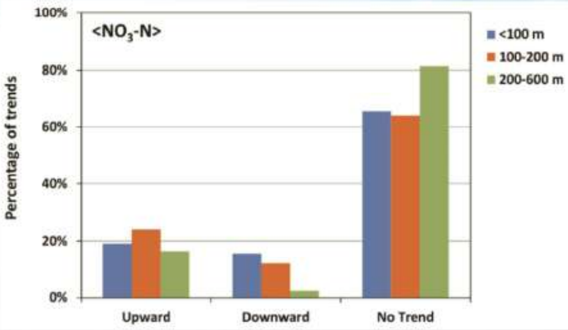

Fig. 11. Nitrate trend with elevation

- Increasing tendency of NO_3-N concentrations was observed in the mid-mountainous area (altitude: 200–600 m) where the amount of agricultural land has abruptly been increased

Conclusions and Suggestions

- ✓ Perched groundwater was directly recharged by local precipitation and its water quality was severely affected by heavy overfertilization.
- ✓ Regional aquifer was mainly recharged by water flows from the Mt. Halla and, had relatively better water quality and lower nitrate concentration.
- ✓ However, nitrate-rich perched groundwater may affect the regional aquifer through imperfectly grouted wells facilitating groundwater contamination with nitrate.
- ✓ Upward trends in NO_3-N are associated with the expansion of agricultural lands.
- ✓ We suggest examining well completions and regrouting the well annulus in combination with a reduction of fertilizer application rates to reduce nitrate contamination of the lower regional aquifer
- ✓ Also, periodic groundwater quality should be continuously monitored over the island based on land use change.

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Thank you for your attention!

The Direction of Managing the Water Resources of Jeju Island in Response to Climate Change

Dr. Giwon Koh / Hydrogeologist

Current Position

▶ Director, Water Industry research Center, Jeju Special Self-Governing Province Development Corp. **(2013-present)**
▶ Director, Jeju Regional Infrastructure Technology Management Center **(2014-present)**

Experience

▶ Director, Water Resources Development Department, JPDC **(2012-2013)**
▶ Director, Jeju Leading Industry Development for Economic Region **(2009-2012)**
▶ Director, Water Industry Department, Jeju Special Self-Governing Province **(2008-2009)**
▶ Researcher, Board of Water Supply, Honolulu City, Hawaii State **(2000-2001)**
▶ Instructor, Jeju National University **(1993-1999, 2014)**

Degrees

▶ Doctor of Philosophy, Hydrogeology, Pusan National University, Republic of Korea **(1997)**
▶ Master's Degree, Marine Geology, Jeju National University, Republic of Korea **(1987)**
▶ Bachelor's Degree, Oceanography, Jeju National University, Republic of Korea **(1984)**

Awards

▶ Local Administration Development Merit, Citation of Interior Ministry,Republic of Korea **(1995)**
▶ National Social Development Merit, Citation of Prime Minister, Republic of Korea **(1999)**
▶ Best Paper Award, The 24th Science and Technology Excellence Award, Republic of Korea **(2014)**

Expertise

▶ Hydrogeologist, for a period of 20 years in hydrology, geology, water resources management rule-making and law, water industry project etc.

Summary

1. Introduction

According to meterological observation data of the Jeju Regional Meterological Administration, 1,646.5mm of rainfall in total poured down on Wisse-oreum Volcanic Cone (1,673m above sea level) in Halla Mountain from August 1 to 3, 2014 when the 11th typhoon Nakri, hit the island. Of particular note, 1,182mm of rain fell on just August 2 alone, breaking the record for the largest amount of 1-day precipitation, which had been 878.5mm (August 18, 2004, Wisse-oreum Volcanic Cone). The cumulative precipitation over the 3-day period substantially exceeded the precipitation in Jeju-si (1,497.6m) and Gosan (1,142.8mm) in an average year. Also, when the 11th typhoon Nari, passed over the island on September 16, 2007, 420mm of torrential rain poured in the course of 12 hours, and this resulted in the biggest flood in history, which in turn caused 12 deaths and approximately 100 billion KRW in damages. In contrast, rain was not sufficiently received for 59 days from early July to late August in 2013, causing a severe drought across the island. This was recorded as the worst drought in 90 years.

Because Jeju is an island, far away from the inland, having a local water source is essential as it needs to be self-sufficient in water. On top of that, the groundwater, which is the main water source, has limited recharge rate and potential for sustainable use. Amid these conditions, a wide range of development projects such as the expansion of urban areas and the construction of tourism and recreational facilities have reduced the grassland and mountain forest areas, thereby causing a decline in the underground recharge area. Additionally, the practices of temporarily removing rainwater using artificial drainage channels for the prevention of floods, the increase in direct runoff caused by torrential rain, and the change in the flow of surface water caused by the interlaced roads all have had a negative impact on the groundwater recharge. Furthermore, there has been a growing number of potential pollution sources, which may deteriorate the quality of the groundwater, and floods caused by torrential rain have become more likely.

In this paper, the directions of managing the water resources of Jeju island according to climate change from the perspective of water use are proposed.

2. Projections of Future Changes in the Climate of Jeju Isand

2-1. Temperature

The average temperature is projected to increase compared to the present in both the RCP 4.5 and 8.5 scenarios. To be more specific, the temperature is projected to increase by 2.3℃ to 16.7℃ in the late 21st century in the RCP 8.5 scenario and by 4.6℃ to 19.0℃ in the RCP 4.5 scenario of KMA (2013). Also, the maximum and minimum temperatures are projected to increase by 4.5℃ and 4.6℃ and reach 22.6℃ and 15.6℃, respectively. As such, it is expected that with the rise in the average, maximum and minimum temperatures, the number of days with heat wave and tropical nights will increase (Table 1).

【Table 1】 Temperature Projections for Jeju According to the Scenario

	Present (2001–2010)	Scenario	Early 21C (2011–2040)	Mid–21C (2041–2070)	Late 21C (2071–2100)
Avg. temperature	14.4℃	RCP 4.5	15.1(+0.7)	16.1(+1.7)	16.7(+2.3)
		RCP 8.5	15.3(+0.9)	17.0(+2.6)	19.0(+4.6)
Max. temperature	18.1℃	RCP 8.5	19.0(+0.9)	20.7(+2.6)	22.6(+4.5)
Min. temperature	11.0℃	RCP 8.5	11.8(+0.8)	13.5(+2.5)	15.6(+4.6)
Number of days with tropical nights	9.5일	RCP 4.5	+6.3	+20.3	+29.1
		RCP 8.5	+10.5	+31	+56.3
Number of days with heat wave	1.6일	RCP 4.5	+3.2	+9.2	+14.0
		RCP 8.5	+5.6	+17.9	+39.6

<Source: Detailed Analysis Report on the Climate Change in Jeju, KMA, 2013>

【Table 2】 Precipitation and Torrential Rain Projections for Jeju According to the Scenario

	Present (2001–2010)	Scenario	Early 21C (2011–2040)	Mid–21C (2041–2070)	Late 21C (2071–2100)
Precipitation	2,168.1mm	RCP 4.5	2,479.2(+14.3%)	2,561.1(+18.1%)	2,709.7(+25%)
		RCP 8.5	2,456.1(+13.3%)	2,642.6(+21.9%)	2,942.5(+34.9%)
Number of days with torrential rain	4.7 days	RCP 4.5	+5.2(+110.6%)	+7.3(+155.3%)	+7.8(+166.0%)
		RCP 8.5	+3.1(+66.0%)	+5.6(+119.1%)	+9.5(+202.1%)
Rainfall intensity	19.4mm/day	RCP 4.5	+2.0(+10.3%)	+2.7(+13.9%)	+3.9(+20.1%)
		RCP 8.5	+1.7(+8.8%)	+3.3(+17.0%)	+5.6(+28.9%)

<Source: Detailed Analysis Report on the Climate Change in Jeju, KMA, 2013>

2-2. Precipitation

The precipitation is projected to increase compared to today in the RCP 4.5 and 8.5 scenarios. In the RCP 4.5 scenario, the precipitation is projected to gradually increase to 2,479mm, 2,561mm and 2,710mm from the early to the late 21st century, while in the RCP 8.5 scenario, the percipitation is projected to increase at a greater rate to 2,456mm, 2,643mm and 2,943mm (Table 2).

2-3. Number of Days with Torrential Rain and Rainfall Intensity

The number of days with torrential rain, defined as receiving more than 80mm of rainfall per day, is projected to increase in both scenarios compared to the present (4.7 days); to be more specific, it is projected to increase to 12.5 days (7.8-day increase) in the RCP 4.5 Scenario and to 14.2 days (9.5-day increase) in the RCP 8.5 Scenario.

The rainfall intensity is also expected to increase from the present (19.4mm/day) in both the RCP 4.5 and 8.5 scenarios; to be more specific, it is projected to increase by about 20% to 23.3mm/day in the RCP 4.5 Scenario and to 25.0mm/day in the RCP 8.5 Scenario.

2-4. Season Changes

Along with the temperature increase, the season changes in Jeju are forecast to occur at an accelerated rate. By the late 21st century, winter is expected to disappear and as a result, the spring and fall seasons will combine, and the summer season will last longer (Table 3). The projection was that summer will begin in May and be longer by up to 56 days compared to the present (RCP 8.5).

【Table 3】 Season Change Projections for Jeju According to the Scenario

	Present (2001-2010)	Scenario	Early 21st century (2011-2040)	Mid-21st century (2041-2070)	Late 21st century (2071-2100)
Spring	116 days (Feb. 13)	RCP 4.5	117 days (Feb. 6)	113 days (Feb. 4)	225 days (Oct. 9)
		RCP 8.5	115 days (Feb. 7)	230 days (Oct. 9)	201 days (Oct. 23)
Summer	108 days (Aug. 9)	RCP 4.5	117 days (June 3)	136 days (May 28)	141 days (May 21)
		RCP 8.5	122 days (June 2)	135 days (May 27)	164 days (May 12)
Fall	88 days (Sept. 25)	RCP 4.5	91 days (Sept. 28)	100 days (Oct. 11)	225 days (Oct. 9)
		RCP 8.5	88 days (Oct. 2)	230 days (Oct. 9)	201 days (Oct. 23)
Winter	53 days (Dec. 22)	RCP 4.5	40 days (1Feb. 28)	16 days (Jan. 19)	
		RCP 8.5	42 days (1Feb. 27)		

<Source: Detailed Analysis Report on the Climate Change in Jeju, KMA, 2013>

2-5. Rise in Sea Level

The rise in sea level of the south coast of the Korean peninsula near Jejudo Island is projected to increase by 53cm and 65cm by the late 21st century in the RCP 4.5 and 8.5 scenarios. The sea surface elevation is projected to increase by 65cm and 85cm by 2100 in the RCP 4.5 and 8.5 scenarios.

According to a study conducted on the flooding regions of Korea, taking into account the rise in sea level, tides, typhoons and tidal waves, etc. resulting from climate change, there is a possibility that 4.8% of the total area of Jeju will be submerged by 2100, and 24.6% of the submerged area will likely be agricultural regions.

2-6. Plant Growth Period

Due to the effects of global warming, the plant growth period in the mountainous regions is projected to increase. In the RCP 4.5 Scenario, it is projected to increase by 21.6 days by the late 21st century compared to the present (322.9 days), which means that it will be possible for plants to grow for more than 344 days a year. In the RCP 8.5 Scenario, on the other hand, the plant growth period is projected to increase to more than 355 days/year (a 32-day increase).

3. The Impact of Climate Change on the Water Resources of Jeju

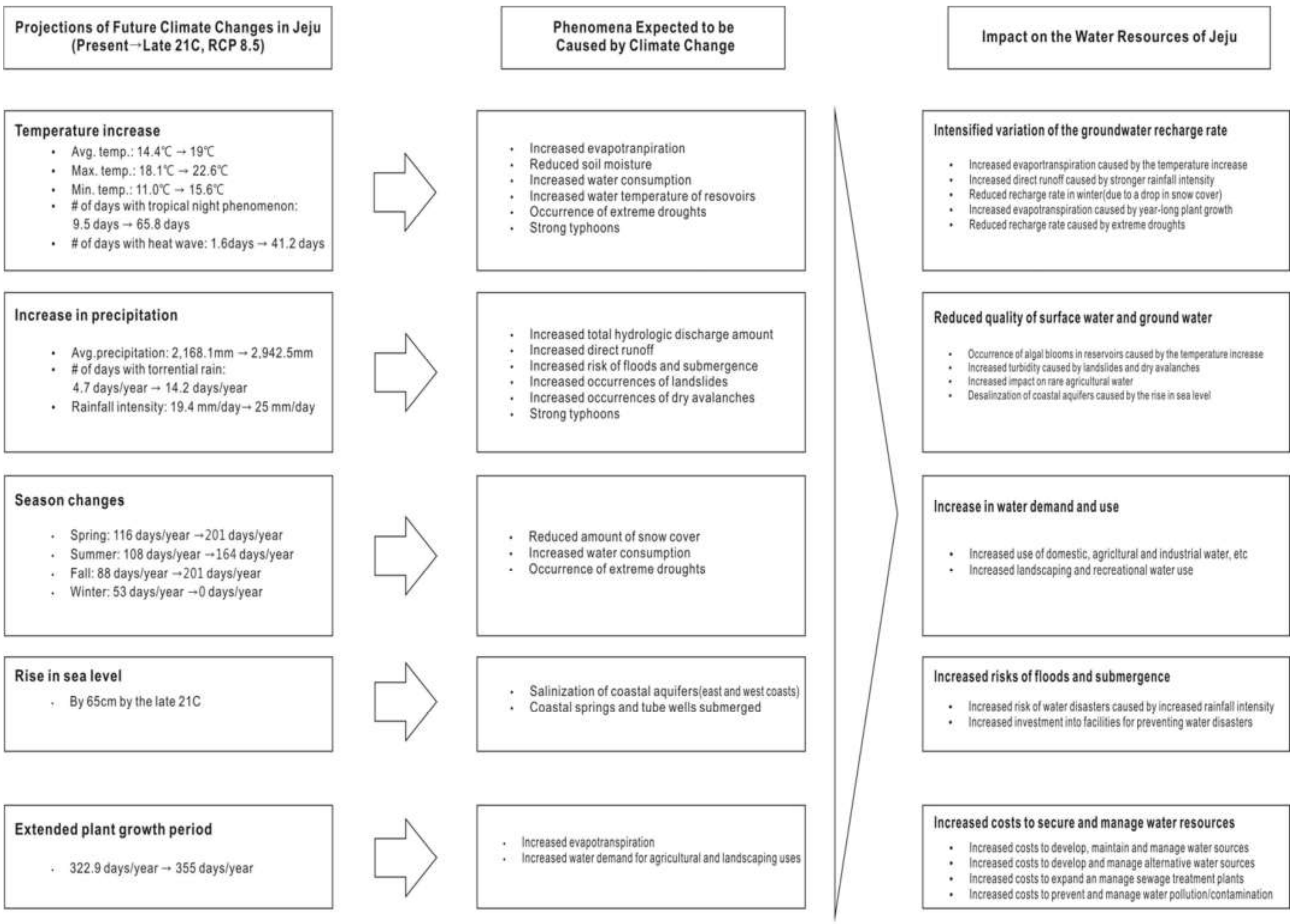
The direct and indirect impacts of climate change on the water resources of Jeju Island in the future include increase in the temperature, number of heat wave days and tropical nights, precipitation, number of days with torrential rain and rainfall intensity, as well as season changes, rise in sea level, extended plant growth period. The phenomena and impact on the water resources of Jeju Island that are expected to accommodate these changes in the future are summarized in Fig. 1.

4. The Direction of Managing the Water Resources in Response to the Climate Change Projections

4-1. Prediction of Water Demand Considering Climate Change

The water demand reported in the Comprehensive Water Resource Management Plan and the Agricultural Water Management plan of the Jeju Special Self-Governing Province does not properly reflect the changes in the demand for domestic, industrial and agricultural water caused by climate change (temperature increase, increased frequency of tropical nights, heat waves, and torrential rainfalls (according to the number of days), stronger rainfall intensity, extended plant growth period, longer summer season, etc.).

According to a study conducted by K-water (2003), there was a positive correlation between temperature and domestic water consumption, which reached its peak in summer, and of particular note, the average water consumption increased by at least 8% in the months in which the temperature reached above 30℃. The effects of climate change on the use of agricultural water can be examined from th aspects of two important factors: evapotranspiration and effective rainfall. Increased evapotranspiration heightens the use of agricultural water, while an increase in the effective rainfall causes its reduction. The factors contributing to the changes in the evapotranspiration include temperature increase, changes in the amount of insolation among others, while the factors contributing to the changes in the effective rainfall include changes in precipitation, seasonal deviations in rainfall, and changes in the rainfall intensity, etc. (Choi Jin-yong et al., 2012).



【Fig. 1】 Possible Phenomena and Impacts on the Water Resources of Jeju Caused by Future Climate Changes(RCP 8.5)

Thus, the future water demand in Jeju needs to be predicted in reflection of the climate changes that exert a direct impact on the water demand.

4-2. Establishment of a Water Resource Management Plan Considering the Water Demand

An issue that must be urgently addressed in addition to making appropriate predictions of the future water demand, considering climate change, is to establish a water resource management plan based on the water demand. First, it must be considered whether the available water resources in certain regions and time periods that can be obtained from the natural water cycle system can meet the demand for domestic and agricultural water. However, the water resource management plans established by the Jeju Special Self-Governing Province to date were devised based on the water balance in the process of the water cycle occurring in the natural system, and did not sufficient reflect the allocation and management plan for water resources that are available in certain regions and time period. As a result, the sustainable capacity of groundwater in the body of water concerned was exceeded, causing the need to develop groundwater, and also, intensive collection of agricultural water in the event of a drought in the fall caused the salinity in the coastal aquifers in the west coast to rise.

4-3. Maintenance of the Groundwater Recharge Rate by Artificial Recharge

Considering the heavy reliance on groundwater for all purposes including drinking water, a reduction in the groundwater recharge rate due to climate change may cause serious water problems. Thus, there must be measures through which the groundwater recharge rate can be increased or maintained in preparation for the growing water demand in the future, and the possible measures are as follows: (i) installing artificial recharge detention ponds, (ii) installing artificial recharge wells, (iii) installing a rainwater penetration tank (residential houses, public buildings, greenhouses, etc.), (iv) creating artificial recharge forests, (v) installing artificial recharge beams on rivers, etc. However, with respect to the groundwater artificial recharge, the following matters must be reviewed thoroughly in advance: (i) facility location, (ii) quality of water to be artificially recharged, (iii) artificial recharging method, (iv) side effects arising from an increase in the groundwater level in the downstream area, (v) maintenance and management of artificial recharge faciliites (Koh G. W., 2013).

4-4. Expanded Use of Alternative Water Resources

There is a need to increase investment into the projects on developing and using water resources (alternative water resources) that can be used in place of groundwater. This is the only way to actively respond to the threats that can occur when using water resources such as the uncertainty in the availability of water resources, increased demand for domestic and agricultural water, obstacles to using coastal aquifers, reduction in the groundwater recharge rate, etc. Considering the circumstances of Jeju, potential alternative water resources for development include rainwater, river runoff, water discharged from sewage treatment plants, and saline groundwater (Koh G. W., 2013).

4-5. Expanded Supply Capacity of Waterworks

As of 2012, the waterworks capacity of the Jeju Special Self-Governing Province is 453,000㎥/day, while the daily average water demand was projected to increase by 47,000㎥/day from 360,000㎥/day in 2015 to 407,000㎥/day in 2025. Also, the daily maximum water demand was projected to rise by 58,000㎥/day from 455,000㎥/day in 2015 to 513,000㎥/day in 2025 (Jeju Special Self-Governing Province Comprehensive Water Resource Management Plan, 2013). This means that water supply shortage can be expected to occur starting in 2015, simply based on the daily maximum water demand alone. Moreover, taking into account the increased water use caused by temperature increase and the water flow rate, it is highly urgent to expand the supply capacity of the waterworks. Of particular note, the springs (9 springs, facility capacity of 136.7,000㎥/day) undergo a substantial decrease in the amount of retained water in the event of an extreme drought.

4-6. Improvement of the Agricultural Water Supply System

It will be difficult to overcome extreme droughts with the current agricultural water management system. In other words, although for public agricultural water, there are small-scale wells that can pump about 1,000㎥ of water per day, distribution tank that can store 100㎥ of water, and supply to about 50ha, in the event of a drought, the supply volume is considerably smaller compared to the supply area, and this has been causing crop damages. Considering these factors, there is a need to integrate the agricultural water supply systems in the Ri (Village) levels first, and then gradually expand them into a broader area, step by step, to Eup and Myeon. There is also a need to deviate from the primary reliance on groundwater, and instead, build a network system to supply agricultural water using the large-scale rainwater retention facilities and the water discharged from sewage treatment plants. Also, there is a need to commission a specialized organization to manage and maintain the wells with issues related to water quality and quantity.

4-7. Reinforced Surveys and Research on Water Resources

In order to use the limited source of water more efficiently, it is essential that basic surveys and research on water resources as well as research on the trends and tendencies shown through internal and external environmental changes are conducted consistently. For instance, the aim of the research should be to answer the following questions: (i) How will the groundwater recharge rate change depending on the climate change scenario? (ii) How will the water demand change as a result of an increase in temperature? (iii)What will be the extent of the salinization of coastal aquifers as a result of the rise in the seal level? In addition, in order to perform such reesarch, there is a need to establish and operate a water resource observation network (groundwater level, water quality, amount of use, river runoff, evapotranspiration, precipitation composition, soil moisture, etc.) on an ongoing basis. A boring investigation must also be conducted in an expanded scope to identify the characteristics of groundwater bearing hydrogeological characteristics of alpine regions including the mid-mountain areas.

5. Conclusion

Global climate change is also affecting Jeju Island. This is evidenced by the fact that the average temperature, which had been 15.6℃ between 1971 and 2000, increased by 0.3℃ to 15.9℃ in the 1981~2010 period. As for precipitation, in the case of Jeju-si, the average precipitation at the time of initial observation (1931~1940) was 1,401.7mm, but the recent observations (2001~2010) showed an average precipitation of 1,516.4mm, which was about a 114mm increase. Also, in the case of Seogwipo-si, the average precipitation at the time of initial observation (1961~1970) was 1,707.6mm, but the recent observations (2001~2010) showed an average precipitation of 1,993.4mm, which was about a 286mm increase.

The climate change in Jeju is expected to occur at an accelerated rate in the future. According to the RCP 8.5 scenario, the island in the late 21st century will be characterized a subtropical climate with the average temperature reaching 19.0℃, a 4.6℃ increase from the present day. Also, the average rainfall will increase by 775mm, with more runoff resulting from the increase in the number of days of torrential rain and rainfall intensity. Moreover, the sea level will be 65cm higher than today.

Such climate changes will have direct and indirect effects on the quantity of water resources and water quality, resulting in negative outcomes such as an increase in the direct runoff, evapotranspiration rate and water consumption, deteriorated quality of surface water and groundwater, salinization of coastal aquifers, as well as reduction in the groundwater recharge rate and volume of groundwater for sustainable use (sustainable capacity of groundwater).

Seven directions of water resource management were proposed in response to climate change: (i) predicting the water demand, taking climate change into account; (ii) establishing a water resource management plan, taking water demand into account; (iii) maintaining the groundwater recharge rate by the means of artificial recharge; (iv) expanding the use of alternative water resources; (v) enhancing the water supply capacity; (vi) improving the agricultural water supply system; and (vii) reinforcing the surveys and research on water resources.

기후변화 대응을 위한 제주도 물관리 방향

고기원, 문수형
제주물산업연구센터

순 서

1. 전지구적 기후변화 전망
2. 제주도 기후변화 추세와 전망
3. 기후변화가 수자원에 미치는 영향
4. 제주도의 수자원 이용과 향후 수요
5. 제주도의 물 관리 방향

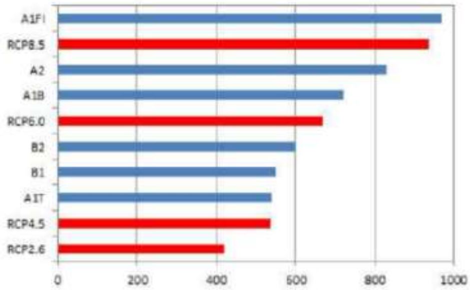
1 전지구적 기후변화 전망

1-1. 이상기후에 시달리는 세계

- 홍수, 태풍, 폭설, 가뭄, 해수면 상승, 열대야 등 세계 도처에서 발생
- 기후변화가 인류의 생존을 위협하는 대재앙으로 다가오고 있음

1-2. IPCC 제5차 보고서 RCP 시나리오

SRES (AR4)	CO_2 농도	RCP (AR5)	CO_2 농도
A1FI	970		
A2	830	RCP8.5	936
A1B	720	RCP6.0	670
B2	600		
B1	550	RCP4.5	538
A1T	540	RCP2.6	421



RCP : Representative Concentration Pathways 〈2100년 CO_2 농도 (ppm), SERS(청색), RCP(적색) 〉
SRES : Special Report on Emissions Scenarios

〈 SRES 시나리오 〉 ※ 미래 사회구조를 중심으로 선정	〈 RCP 시나리오 〉 ※ 기후변화 대응정책과 연계하여 선정
	○RCP 2.6 : 온실가스 배출을 당장 적극적으로 감축하는 경우
○B1(지속발전형 사회) : 지역간 격차가 적고, 인구감소, 청정자원 절약기술 도입	○RCP 4.5 : 온실가스 저감 정책이 상당히 실현되는 경우
○A1B(고성장 사회) : 화석에너지와 비화석에너지원 균형, 신기술, 고효율화 기술 도입	○RCP 6.0 : 온실가스 저감 정책이 어느 정도 실현되는 경우
○A2(다원화 사회) : 인구증가, 경제성장은 낮고, 환경에의 관심도 상대적으로 낮음	○RCP 8.5 : 현재 추세(저감없이)로 온실가스가 배출되는 경우(BAU 시나리오, 실현 불가)

1-3. 전지구적 기후변화 전망(IPCC, 2013.9.)

■ 현재와 같이 온실가스를 배출(RPC 8.5)할 경우, 금세기말

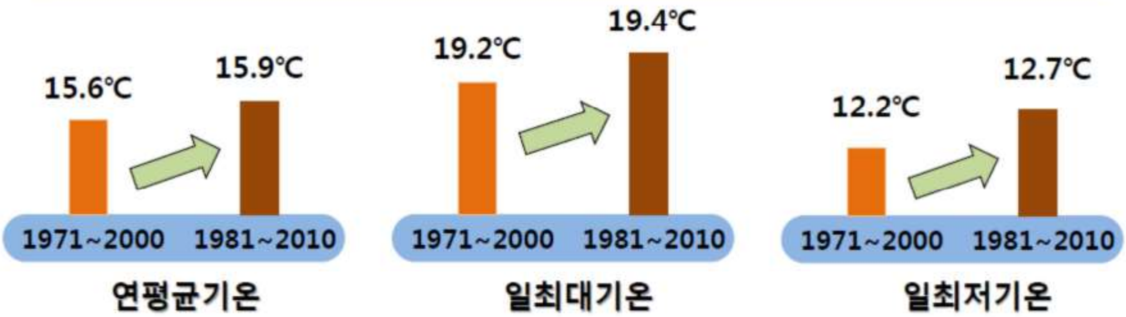
- 지구 평균기온은 1986~2005년에 비해 3.7℃ 오르고, 해수면은 평균 63cm 상승
- 동아시아 평균기온은 1986~2005에 비해 2.4℃ 오르고, 강수량은 7% 증가

RCP 시나리오	기 온(℃)		해수면(cm)	
	2046~2065년	**2081~2100년**	2046~2065년	**2081~2100년**
RCP 2.6 (CO_2 421 ppm)	1.0(0.4~1.6)	1.0(0.3~1.7)	24(17~32)	40(26~55)
RCP 4.5 (CO_2 538 ppm)	1.4(0.9~2.0)	1.8(1.1~2.6)	26(19~33)	47(32~63)
RCP 6.0 (CO_2 670 ppm)	1.3(0.8~1.8)	2.2(1.4~3.1)	25(18~32)	48(33~63)
RCP 8.5 (CO_2 936 ppm)	2.0(1.4~2.6)	**3.7(2.6~4.8)**	30(22~38)	**63(45~82)**

2 제주도 기후변화 추세와 전망

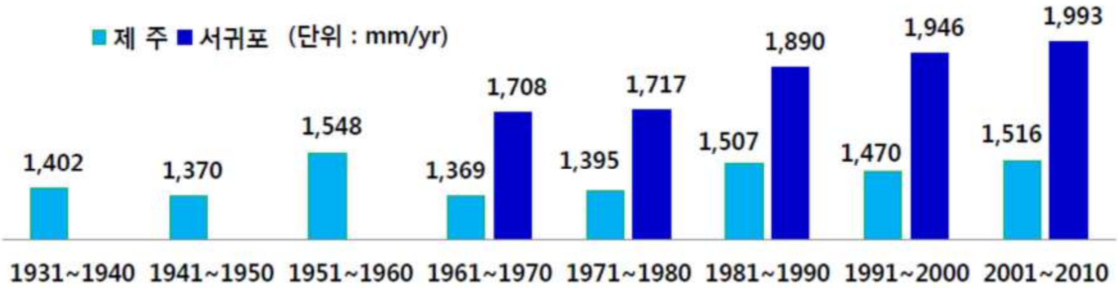
2-1. 제주도 기후변화 추세 : 기 온

- 제주도는 지난 40년간 연평균기온, 일최대 및 최저기온 모두 상승 추세
- 겨울철 지속기간이 짧아지고, 여름철 지속기간은 늘어나고 있음

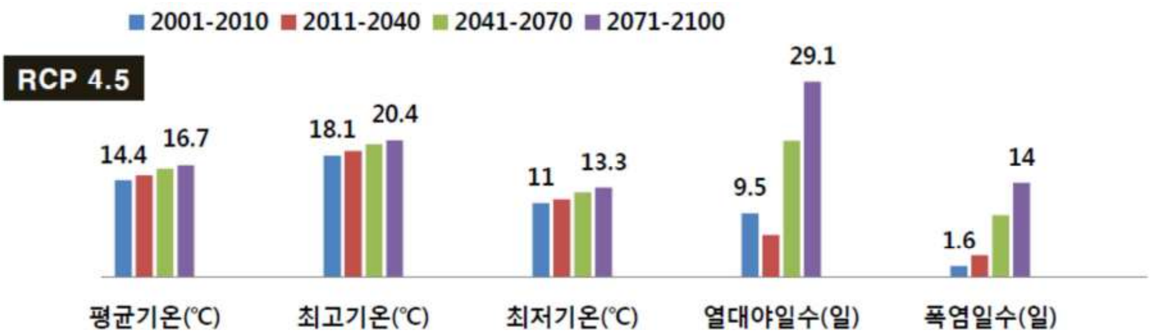


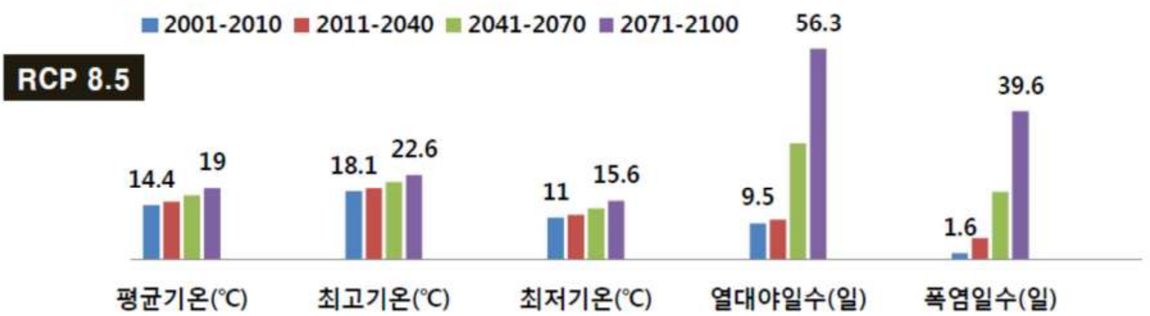
2-2. 제주도 기후변화 추세 : 강수량

- 제주시지역은 1931~1940년 10년 평균 대비 2001~2010년에 114mm 증가
- 서귀포지역은 1961~1970년 10년 평균 대비 2001~2010년에 286mm 증가



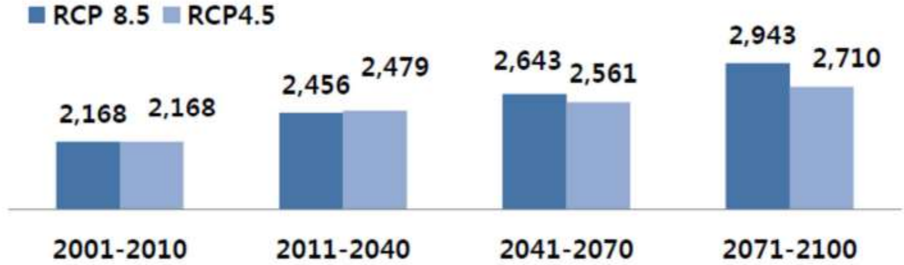
2-3. 제주도 미래 기후변화 전망 : 기 온



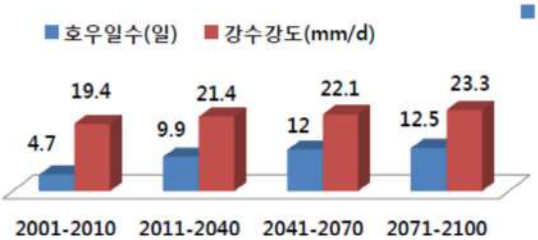


2-4. 제주도 미래 기후변화 전망 : 강수량

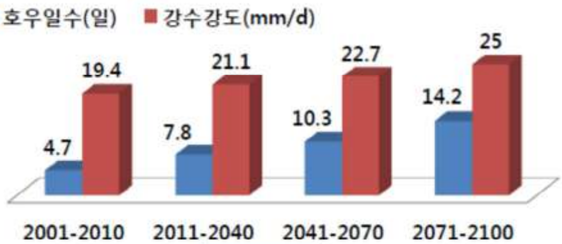
강 수 량



호우일수, 강수강도



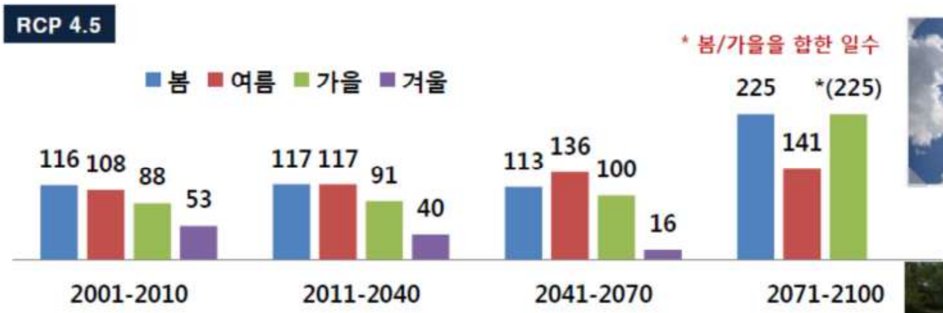
RCP 4.5



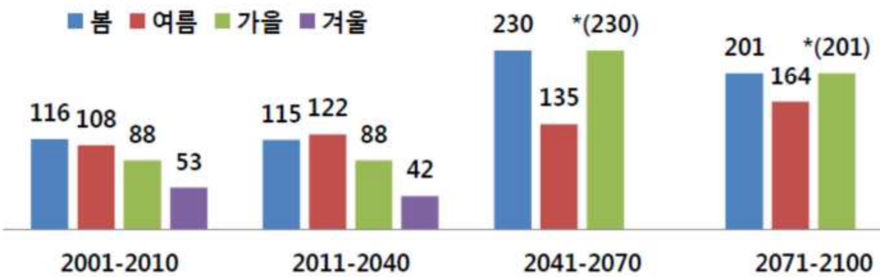
RCP 8.5

2-5. 제주도 미래 기후변화 전망 : 계절변화

RCP 4.5



RCP 8.5

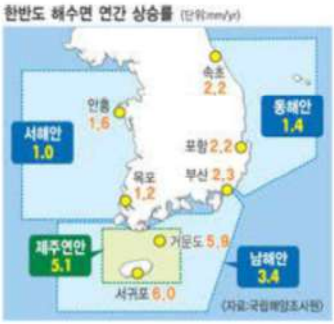


2-6. 제주도 미래 기후변화 전망 : 해수면상승

지난 43년(1964~2006년)간 한반도 주변 해역의 해수면은 약 8cm 상승하여 세계 평균보다 약간 높은 1.9mm/년의 상승률을 나타냄. 특히, 제주 주변해역의 연평균 해수면 상승률은 5.1mm/년으로 약 22cm가 상승하였음

21세기 후반기, 제주도에 인접한 남해안의 해수면 상승은 RCP 4.5 시나리오에서 53cm, RCP 8.5에서 65cm가 상승할 것으로 전망

한반도 해수면 연간 상승률



3 기후변화가 수자원에 미치는 영향

3-1. 기후변화가 수자원에 미치는 영향 연구 사례

■ 강수량 증가에 따른 유출율 변화

- 용담유역 21세기 중반 RCP 8.5에서 유출율 59.7~63.0%까지 증가(박종혁 외 3인, 2014)
- 5대 강유역의 유출율 RCP 2.6, RCP 4.5, RCP 8.5에서 각각 10~24%, 7~30%, 11~30% 증가(은코모제피와 정상옥, 2014)

■ 강수량 증가 및 기온 상승에 따른 증발산량 변화

- North America 지역은 지난 세기 동안 기온상승으로 증발산량 증가(Myeni et. Al., 1997)
- 중국은 일최대 기온이 상승했으나 기준증발산량/팬증발량은 오히 감소(Thomas, 2000)
- 사우디아라비아에서 연구한 결과, 기온이 1℃ 증가하면 기준증발산량은 1~4.5% 증가

■ 기온 상승에 따른 지하수 함양량 및 물 사용량 변화

- 미국 Ogallala 대수층의 경우, 기온이 2.5℃ 상승할 경우 함양량이 20% 이상 감소
- 기온이 30℃ 이상인 달의 평균 물 사용량은 8% 이상 증가(한국수자원공사)

3-2. 기후변화가 수자원에 미치는 영향

❖ 기온 상승
- 평균기온 : 14.4℃ → 19.0℃
- 최대기온 : 18.1℃ → 22.6℃
- 최저기온 : 11.0℃ → 15.6℃
- 열대야일수 : 9.5일 → 65.8일
- 폭염일수 : 1.6일 → 41.2일

⇨
- 증발산량 증가
- 토양수분 감소
- 물 사용량 증가
- 저수지 수온 상승
- 극단적 가뭄 발생
- 강력한 태풍 내습

❖ 강수량 증가
- 평균강수량 : 2168.1 mm → 2942.5mm
- 호우일수 : 4.7일/년 → 14.2일/년
- 강수강도 : 19.4mm/일 → 25.0mm/일

⇨
- 수문총량 증가
- 직접유출량 증가
- 홍수/침수 위험도 증가
- 산악지역 산사태 증가
- 토석류 발생 증가
- 강력한 태풍 내습

❖ 계절변화
- 봄 : 116일/년 → 201일/년
- 여름 : 108일/년 → 164일/년
- 가을 : 88일/년 → 201일/년
- 겨울 : 53일/년 → 사라짐

⇨
- 겨울철 적설량 감소
- 물 사용량 증가
- 극단적 가뭄 발생

❖ 해수면 상승
- 21C 후반기 65cm 상승

⇨
- 해안 대수층 염수화 (동서부 해안지역)
- 해안 용천수/관정 침수

❖ 식물성장 가능기간 연장
- 322.9일/년 → 355일/년

⇨
- 증발산량 증가
- 농업/조경용수 수요증가

❖ 지하수 함양량 변동 심화
- 기온상승에 의한 증발산량 증가
- 호우강도 증가로 직접유출량 증가
- 겨울철 함양량 감소(적설량 감소)
- 연중 식물성장으로 증발산량 증가
- 극단적 가뭄시 함양량 감소

❖ 지표수 및 지하수 수질 저하
- 기온상승으로 저수지 녹조 발생
- 산사태/토석류에 의한 탁도 증가
- 농업용수 회귀수에 의한 영향 확대
- 해수면 상승으로 해안대수층 염수화

❖ 물 수요 및 이용량 증가
- 생활/농업/공업용수 등 이용량 증가
- 조경용수/레크리에이션용수 증가

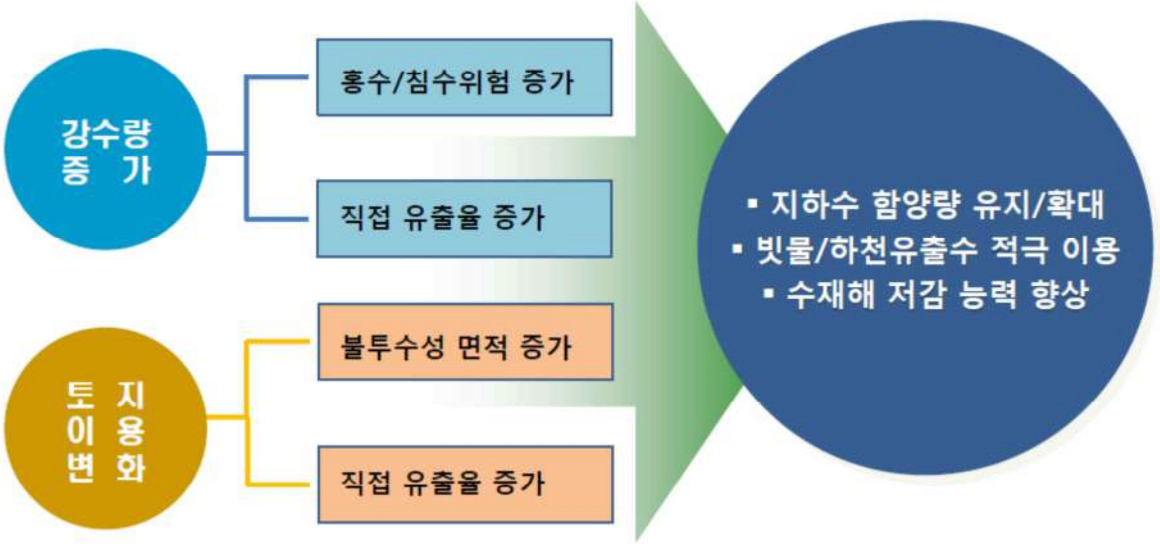
❖ 홍수 및 침수피해 위험 증가
- 호우강도 증가로 수재해 위험 증가
- 수재해 방지 관련 시설투자비 증가

❖ 수자원 확보 및 관리 비용 증가
- 수원개발 및 유지관리비 증가
- 대체수자원 개발 및 관리비용 증가
- 하수처리시설 확대 및 관리비용 증가
- 수질오염 방지 및 관리 비용 증가

❖ 빗물 및 하천유출수 이용여건 호전
- 하천 유출일수 및 유출량 증가
- 강수일수 및 강수량 증가

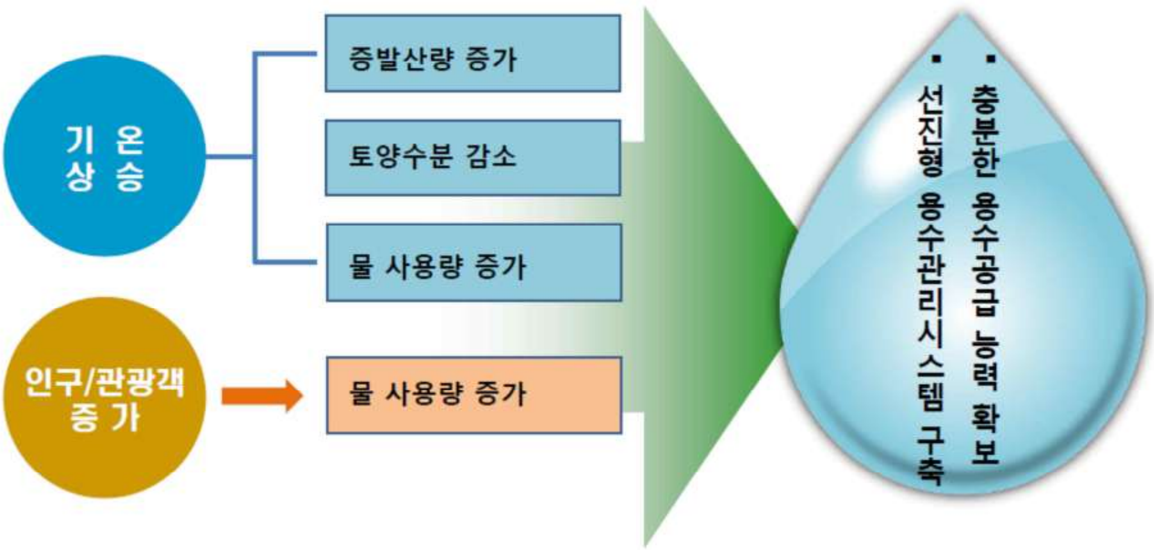
3-3. 강수량 증가에 따른 영향

- ■ 21세기 후반기 제주도의 연강수량은 2,700~2,900mm로 증가할 전망
- ■ 호우일수 및 강우강도 증가로 강수량 증가가 지하수 함양에 얼마나 도움이 될지는 미지수
- ■ 특히, 각종 개발사업과 도시확장 등 토지이용 변화로 인하여 유출율은 더 증가할 전망



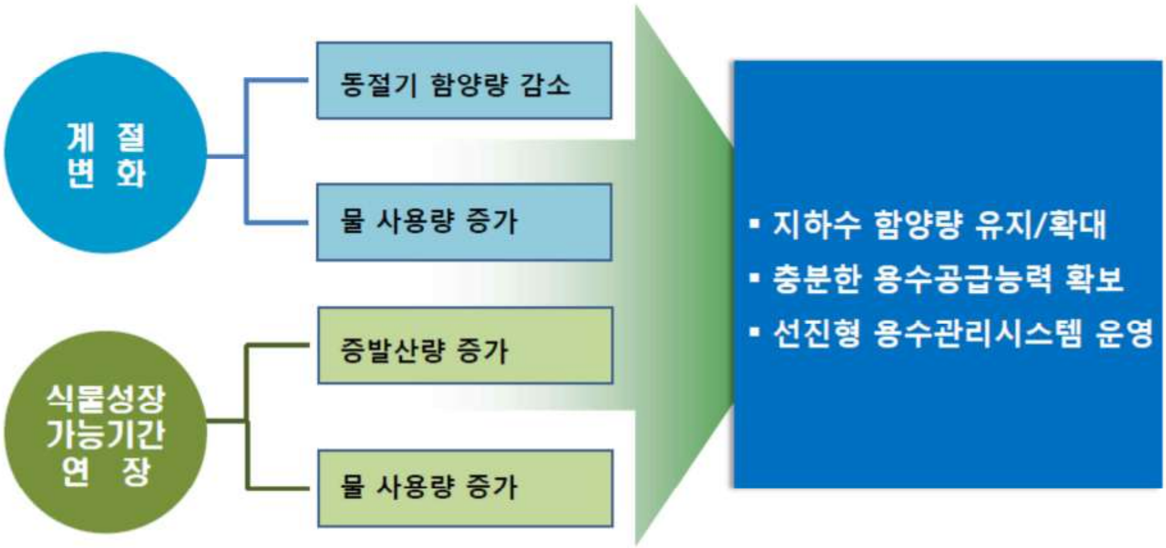
3-4. 기온 상승에 따른 영향

- ■ 21세기 후반기 평균기온은 현재보다 2~4℃ 높은 16.7~19.0℃ 범위로 상승할 전망
- ■ 열대야 일수도 현재(9.5일)보다 29~56일 늘어난 38~66일에 이를 것으로 전망
- ■ 폭염일수도 현재(1.6일)보다 12~37일 늘어난 16~41일 범위로 증가할 전망



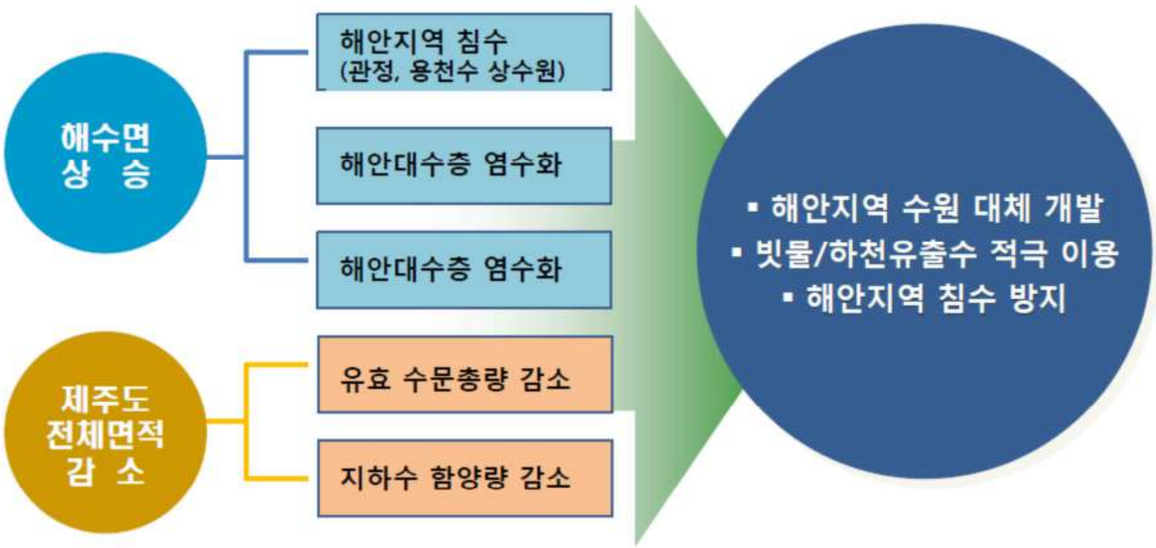
3-5. 계절변화에 따른 영향

- 21세기 중반기부터 제주도에는 겨울이 사라지고, 식물도 연중 성장이 가능해질 전망
- 21세기 하반기에는 여름기간이 141~164일로 현재(108일)보다 33~56일 증가
- 겨울이 봄과 가을로 합쳐져 봄/가을 기간은 201~225일로 늘어날 전망



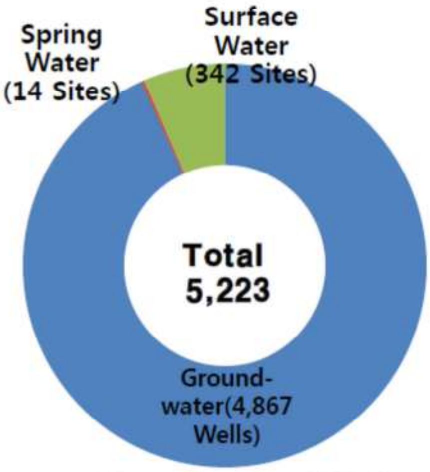
3-6. 해수면 상승에 따른 영향

- 21세기 후반기 제주도 주변 해수면은 53~65cm 상승할 전망
- 해수면 상승으로 제주도 전체면적의 4.8%(약 89㎢) 정도 바닷물로 침수될 전망

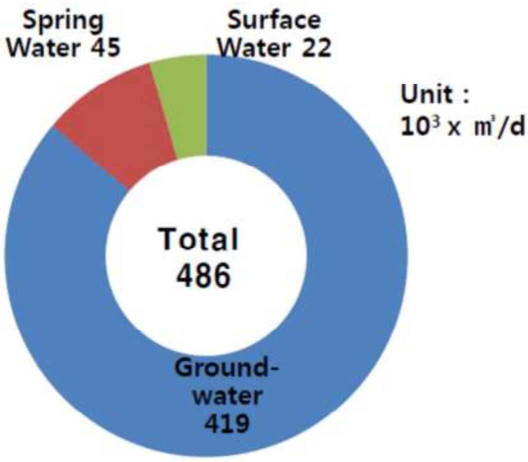


4 제주도의 수자원 이용과 향후 수요

4-1. 제주도의 수자원 개발 및 이용 현황

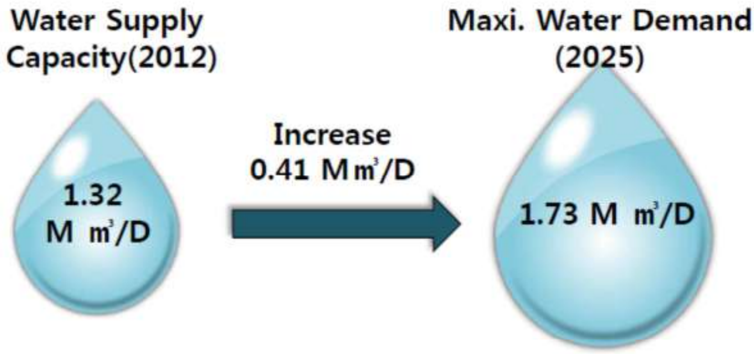


Water Sources(2012)



Water Usage(2011)

4-2. 제주도 용수수요 전망(2025)

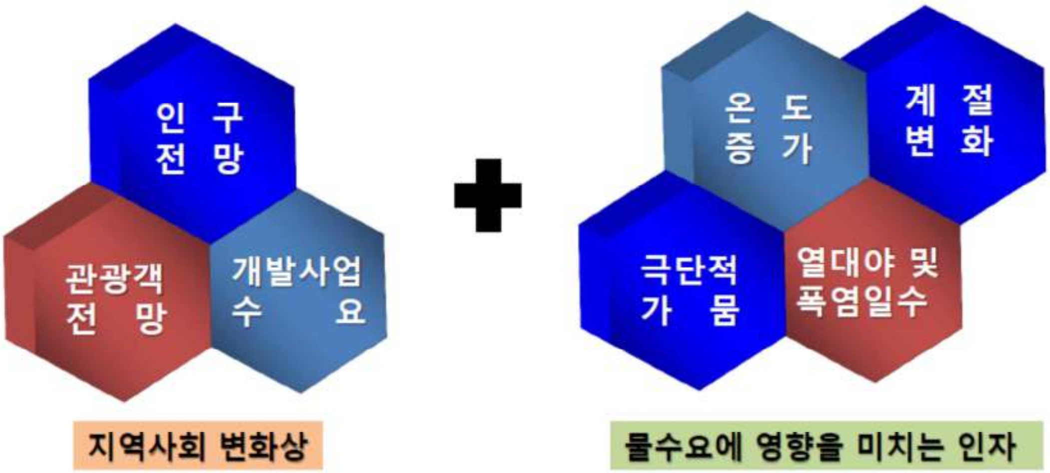


구 분		2015년	2020년	2025년
생활 및 공업용수	일최대 수요량	455,311	481,864	513,403
	정수장 시설용량	419,825	419,825	419,825
	과부족량	**△35,486**	**△62,039**	**△93,578**
농업용수	일최대 수요량	1,214,310	1,214,310	1,214,310
	기존 공급능력	898,336	898,336	898,336
	과부족량	**△315,974**	**△315,974**	**△315,974**

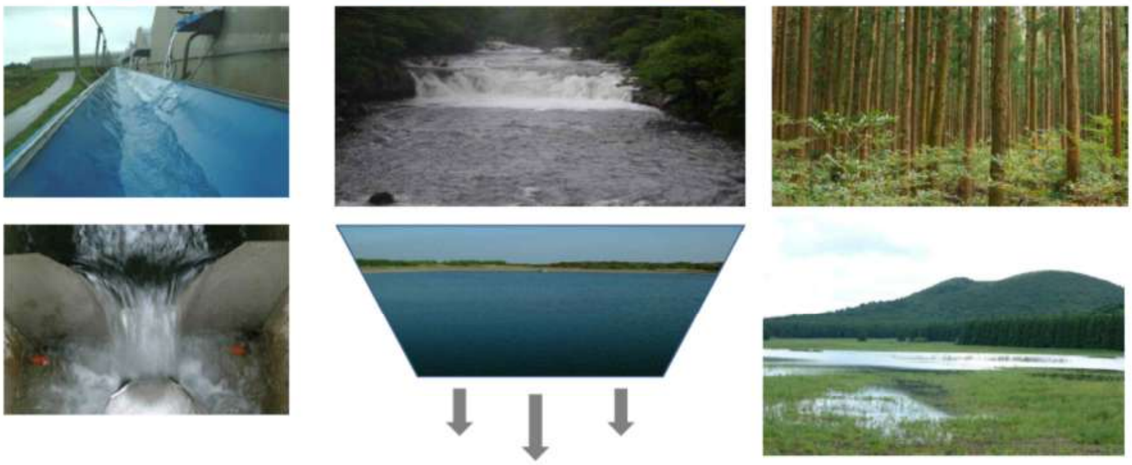
5 제주도의 물 관리 방향

5-1. 기후변화를 고려한 물 수요 예측

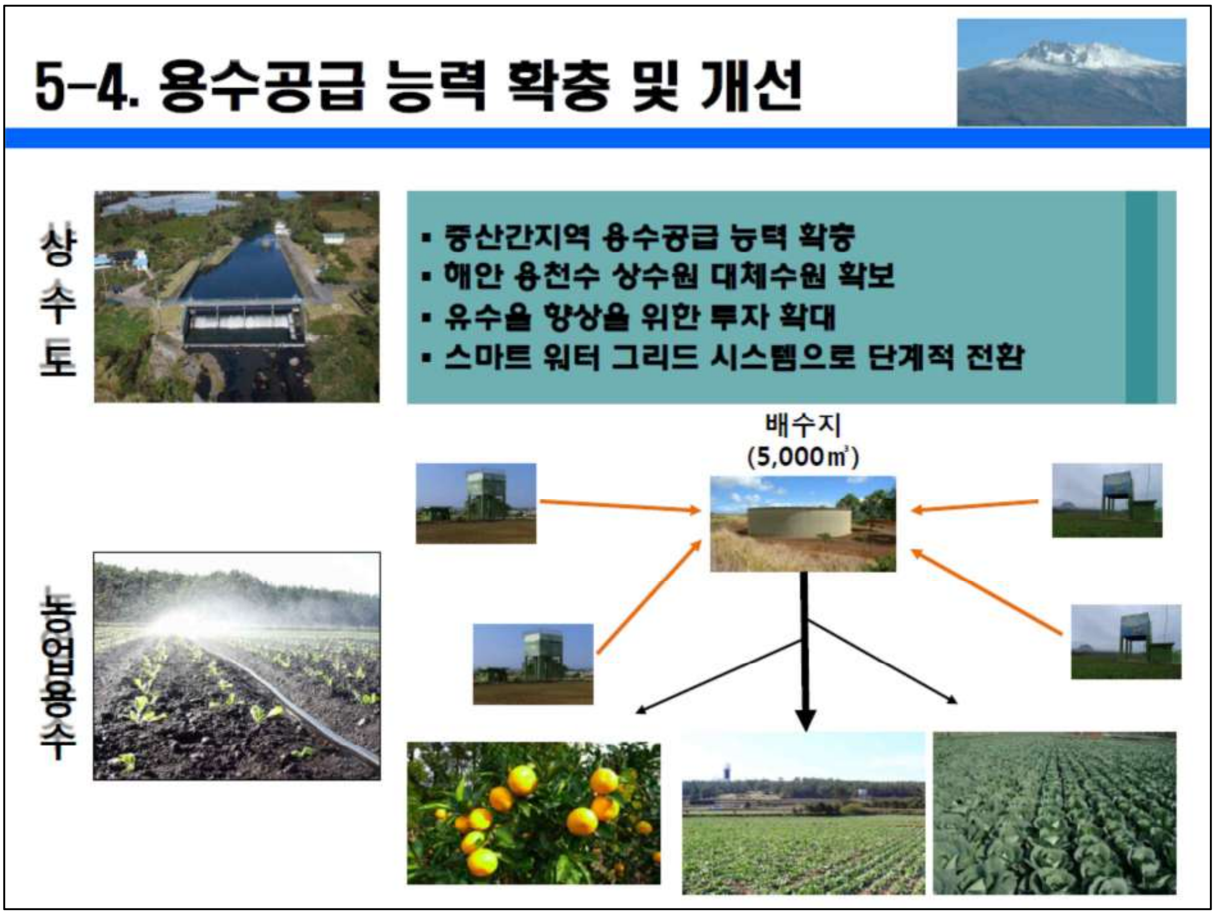
- 현재 제주도의 물 수요는 지역사회 변화상만을 반영하고 있어 기후변화 대응에 취약
- 기후변화로 인한 물 수요 증가량을 반영하고, 이에 대응하기 위한 중장기 대책이 필요



5-2. 지하수 함양량 유지 및 확대




5-3. 대체수자원 이용 확대
빗 물
하천유출수
하수방류수 처리수
▪ 농업용수 수요량의 15% 수준까지 확대
▪ 농업용수/ 골프장/ 조경용수 등으로 이용


5-4. 용수공급 능력 확충 및 개선
상수도
▪ 중산간지역 용수공급 능력 확충
▪ 해안 용천수 상수원 대체수원 확보
▪ 유수율 향상을 위한 투자 확대
▪ 스마트 워터 그리드 시스템으로 단계적 전환
배수지
(5,000㎥)
농업용수

5-5. 기후변화 대응 연구 강화

수문성분 변 화

- 강수량 증가와 직접유출율/지하수 함양량과의 관계
- 기온상승과 증발산량과/지하수 함양량의 관계
- 계절변화와 증발산량/지하수 함양량과의 관계
- 해수면 상승과 해안 대수층/담수렌즈와의 관계
- 겨울철 적설(snow)과 지하수 함양량과의 관계

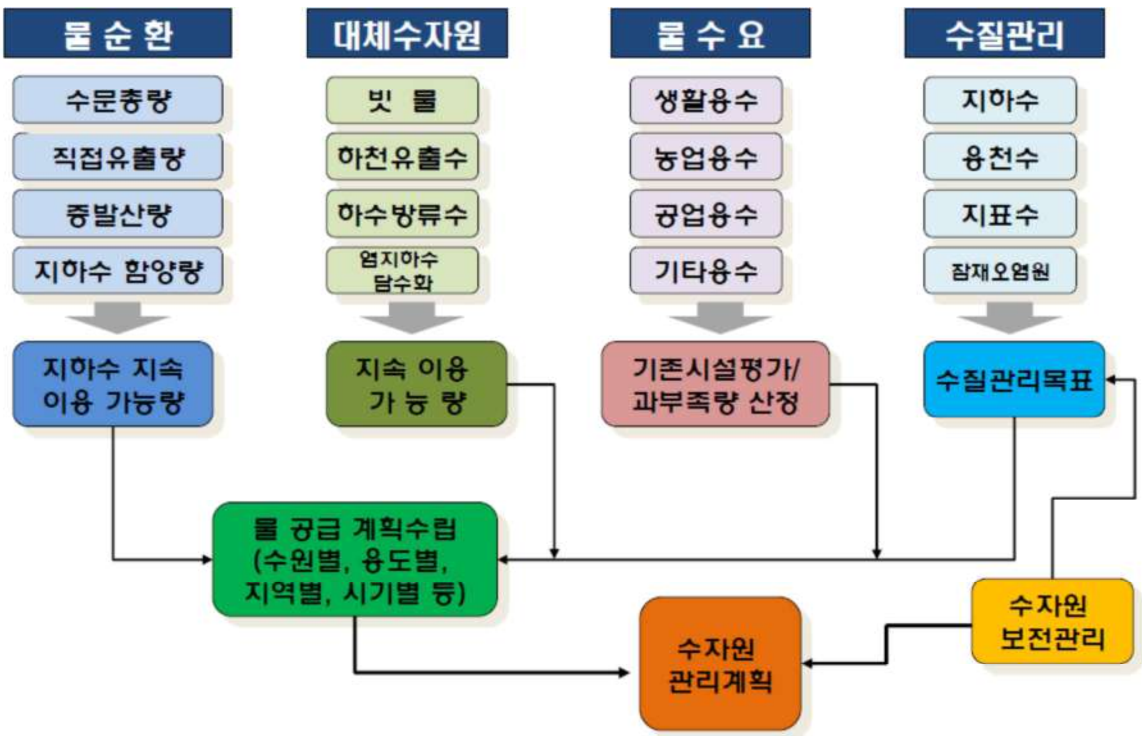
안정적 용수확보

- 기온상승/폭염 및 열대야 일수 증가와 물 사용량과의 관계
- 계절변화와 물 사용량과의 관계
- 지하수 함양량 유지/확대를 위한 기술개발
- 기온상승과 수질과의 관계
- 농업용수 최적 관리 기법 개발

수자원 모니터링

- 지하수위/수질/하천유출량 모니터링
- 용도별 지하수 이용량 모니터링
- 토양수분/강우조성/담-염수 경계면 모니터링
- 모니터링 자료를 활용한 수위-수질변화 추세 분석

5-6. 기후변화를 고려한 수자원관리계획수립




감사합니다

Country Report

태국

< Thailand >

Submitted by

Mr. Adisai Charuratna

Department of Groundwater Resources(DGR)

System of Treated Groundwater Plant for Drinking Water in School of Thailand

1. Summary

Various state agencies in Thailand are in charge of water management under departments and ministries. Department of Groundwater Resources (DGR) is directly an organization to control resources of subsurface water both in their potential and law regulator. Basic hydrogeological maps were published in scale of 1: 500,000 over the country separating four regions during 1970 to 1980 by using a standard of UNESCO and IAH. The most groundwater quality concerns with geological characteristics and intrinsic minerals such as contents of fluoride, arsenic, rock-salts, iron, manganese etc. Some cases showed that people drank regularly untreated groundwater, had been an unprecedented problem of their health like cancer or skin diseases. To eliminate these problems, DGR initiated a project so called “A suitable water treatment plant for hygienic drinking water in school” throughout the country. The treatment plants are concentrated in water softener or reverse osmosis systems. Recently, a total of 2,478 schools have been completed since 2013 and 6,832 schools are going to carry out until the end of 2017. Nevertheless, DGR continuously promotes their schools to extent making bottled water production.   Private sectors are interested to support this project as their corporate social responsibility program (CSR) in some schools.

2. Hydrogeological Setting

A land area of Thailand is a total of 513,115 km2. Basically, hydrogeological maps had been published into four regions or four map sheets in general, scale of 1 : 500,000 during 1970 to 1980. The details had followed the standard of UNESCO and IAH in terms of colors and ornaments showing groundwater potentials and aquifer occurrences respectively. Generally, water bearing-rocks are divided into two types that are unconsolidated rocks as in blue-tone colors and consolidated rocks as in brown or green-tone colors. The overall hydrogeological map of Thailand is demonstrated in scale of 1 : 1,000,000 (Fig.1). In case of consolidated rocks, groundwater can be commonly obtained from fissure structures of fractures or faults. The maps imply that their characteristic aquifers are different in each region according to specific geological conditions. The four hydrological maps are composed of northern, northeastern, central plain and southern regions.

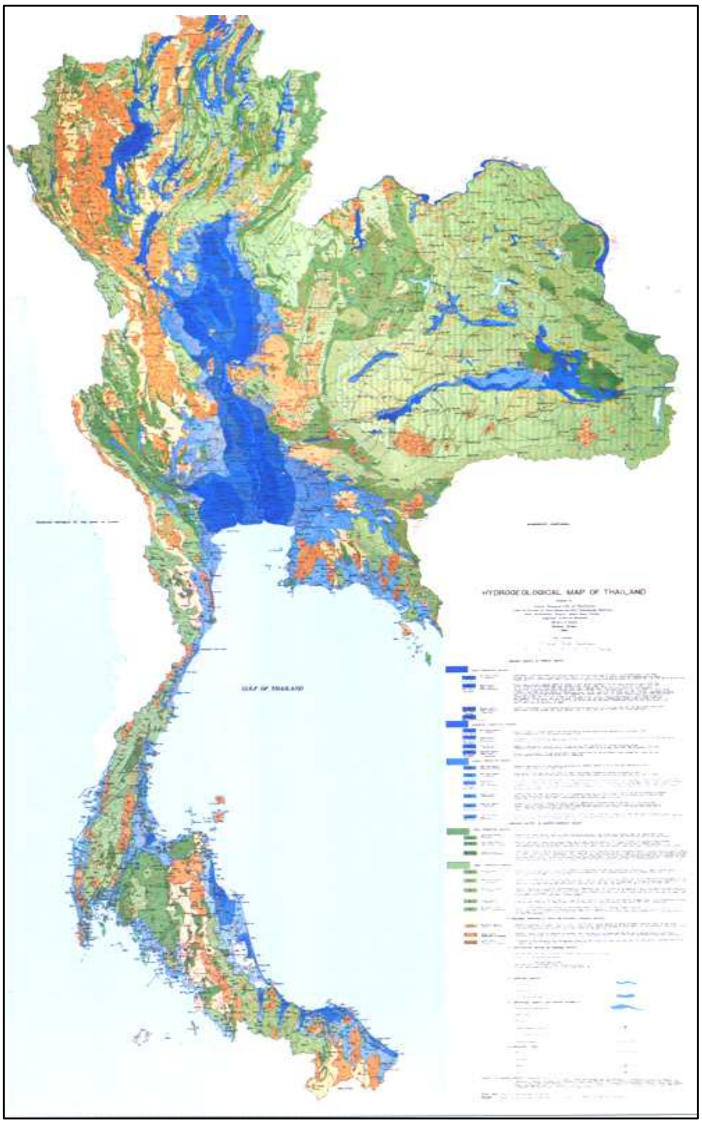


Fig. 1 The overall of hydrogeological map of Thailand in scale 1 : 1,000,000

(Wongsawat and Dhanesvanich, 1983)

Geomorphologically, in the northern part is many small-narrow plains elongated in almost north-south direction alternative with a large number of complicated high mountain ranges. Many kinds of different metamorphic, sedimentary or igneous rocks have been described from Precambrian to Quaternary period while in the northeastern part mostly consists of various sedimentary rocks as mainly shale and sandstone so called "Khorat Plateau"; which of them in Triassic to Cretaceous period are forming topographically flat-terrain or relatively table land by having thick layers of rock salts are underneath. In central plains including east and west regions are normally large flat-plain of alluvial deposits of Chao Phraya River where Bangkok city located. The last one is southern part forming a peninsular which the land is sandwiched with Andaman Sea in the west and Gulf of Thailand Sea in the east. The structural landscape is the ranges of complicated high mountains as mostly granitic rocks located at the middle of two coastal plains.

3. Status of Water Resources

3-1 . Status of Water Resources

Due to many state agencies working in water management, there are, for example, Department of Water Resources (DWR), Department of Groundwater Resources (DGR), Royal Irrigation Department (RID), Electricity Generation Authority of Thailand (EGAT), Provincial Waterworks Authority (PWA), Metropolitan Waterworks Authority (MWA), Pollution Control Department (PCD) etc. They come from different ministries. Each agency is working in specific or similarly water-related function that the overview of water management in the country is not united in planning and policy unlikely in other countries. In facts, water derives from: atmosphere, surface and subsurface resources. Instead of planning and expenditure in the same direction, they must distribute to every agency losing in waste time and budget for water development. However, surface water like main rivers will continuously be tested and made sure that water quality is safely suitable for water supply even widely development of land use.

As well as a systematic drinking water production, various steps of operation are designed by their own agency, cannot be considered it in the same patterns which overall cost would be reduced. Due to rapid growth in population and economic, water-related contamination would be increased throughout the country from agricultural, industrial and urban development such as pesticide, fertilizer, heavy mineral etc. Clean drinking water is important for human health. In former time, natural raw water directly used as drinking water but recently people are likely to drink bottled water replacement. However, PCD and DGR monitor the quality of water both in surface and subsurface water to make sure that their water will not harm for human health.

3-2 Groundwater Resources

Approximately 70 percent of drinking water comes from groundwater resources, particularly in rural areas where surface water is scarcely found. Normally, groundwater is mainly recharged by rainfall and discharged further to stream or sea. On its movement, water constitution as acidic water will act as solvent to dissolve more substantial elements from surrounding rocks. Possibly, these minerals over the standard of drinking water and maybe directly affected for human health. For example, some cases in the west and northern part of Thailand, a large amount of fluoride content are over 2 milligram per liter due to hydro-geothermal occurrence (Atikhomrangsarit, 1984) whereas standard for drinking water is 1.5 milligram per liter. People living in there directly drank regularly untreated water from dug wells or deep wells. Finally, they have been fluorosis deceases – dental or skeletal fluorosis from high content of fluoride. As well as the other case in the eastern part, people in a house died whole by drinking water in a dug well located inside of their house. As a result, there was more high lead content in blood. They did not know their land that was a landfill before. Geologically, in the northeastern part, most of water quality is salty water due to rock salts layers underneath the surface. Somewhere, rock salts or salt domes are closely reached the surface and causing water quality to be salty. Practically, surface water in these areas is provided by a artificial pond construction, rivers or natural canals for domestic uses. The other case is high nitrate content in groundwater up to a hundred milligram per liter contaminated by domestic animal or human wastes leakage to the aquifer (Charuratna and Sukarawat, 2012) whereas the standard of drinking water is less than 45 milligram per liter. For long time ago, people fed cattle as domestic animal nearby or under their houses and drinking water came from the shallow aquifers. Although, harmful health evident cannot prove directly its connectivity in the field, high nitrate of drinking water maybe the cause of human carcinogenesis or cancer or blue baby.

In central plain, the most aquifers occurred from unconsolidated sediments like sand and gravel were classified into multiple layers. Normally, water quality has high content of iron in some places and salty water in upper layers. In the period of tin- mine blooming at Ron Phibun district of the southern part, arsenic content was found in shallow groundwater wells up to 10 milligram per liter leakage from mineral piles or its nature (Intrasuta, 1988) while a standard of drinking water is less than 0.05 milligram per liter. Some people were found arsenic poisoning symptoms.

4. Groundwater Resources Management and Policy

DGR is only a state agency to control groundwater resources both potential and law enforcement in order to have sustainable management and clean drinking water. 20-30 years ago, untreated raw water either surface or subsurface was directly drunk. Currently, the most people are interested their health and world wild communication by propaganda and social media, particularly young people to drink hygienic clean water replacement. To solve the problem, DGR initiated a project for providing clean drinking water for students in elementary and secondary schools by constructing a small treatment groundwater plant. The various systems are designed for properly water in the field. However, for groundwater supplies as general domestic or agricultural uses - not drinking are still carried out by common method or using only rapid sand filter tank.

5. Plans for Operation

In order to alleviate a vulnerable groundwater, DGR has constructed the formats of treatment plant for supporting elementary or secondary schools. The first concept of objective is that their students must have clean drinking water for basic living and ordinary people can afford as well in their places. The common process of preliminary treated groundwater is a rapid sand filter tank (fig.2) that groundwater is pumped to an elevated tank and released to filtrate roughly iron or sediments at the tank before distributing to water supply lines. However, a back-wash process has to frequently practice for clean it up. As for drinking water systems, more additional multiple steps (Klongkaew, 2008) are provided as following: for a water softener process (fig.3) is that after water passing through the rapid sand filter tank is coming to storage tank and pumped to iron or manganese treated tank by anthracite and manganese greensand. Next to color and odor treated tank by activated carbon before to resin tank for carbonate - reduced tank, 5 micron particles treated tank, storage tank, 1 micron particles by ceramic tank, UV tank for infected treatment and bottled water filling respectively. In case of high total dissolved solid like brackish water or health harmful minerals will be replaced by osmosis system instead of a resin tank. By adding a step of 1 micron particle - treated tank for membrane protection and RO set respectively before to the storage tank (fig.4). DGR has carried out this project completely a total of 2,478 schools since 2008-2013 and planning forwards to a large number of 6,832 schools at the end of 2017. Regarding to water quality in each location, DGR is studying to classify degree of filtration to reduce the cost and properly water quality in 2015, possibly consideration to be 4-5 types both in quality and quantity.

6. Conclusion

According to a variety of groundwater quality in Thailand, occurring from geological properties, the affected people in the past of some areas were seriously health because of regularly untreated water drinking. DGR has to eliminate this problem throughout the country. The schools of bad groundwater quality will be prioritized to set a hygienic drinking water plant at first. Nevertheless, DGR is still to promote their schools to further extend making bottled water to sell in surrounding community to get income for system's maintenance. Some private sectors supported the budget to do as well or CSR program. In the future, the project like this will be operated in the people living in the rural villages also.

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Country Report

말레이시아

< Malaysia >

Submitted by

Mr. Mohammad Nazan

Minerals and Geoscience Department

Water Resources Management and Policy in Malaysia

Compiled by:

Mohammad Nazan

Water is a gift of God and Malaysia is rich in water resources. The holly Quraan said ***"And We send down water from the sky in according to (due measure), and We caused it to soak in the soil and We certainly are able to drain it off (with ease)"***{Al – Mukminuum 23:18}. Water resources have fueled socio-economic development of the country during the past decades. Dams and thousands kilometres of pipes and canals divert water from the rivers to sustain domestic, industrial and agricultural needs. Lately, the water situation for the country has changed from one of relative abundance to one of relative scarcity because of the population growth and the expansion in urbanisation, industrialisation and irrigated agriculture are imposing rapidly growing demands and pressure on the water resources, besides contributing to the rising water pollution and climate changes .

With that scenario, water resources and demand management should be and improve and all water users need to adjust their needs to the available water. The water resources management should be within the broader context of integrated water resources management (IWRM), an an approach towards integrating and effectively coordinating policies, programs and addressing the water issues which takes into consideration the socio-economic development and the conservation of the environment.

1. Introduction

Development is not possible without water. Therefore, water resources must be developed and managed in a sustainable manner to ensure the social, economic and environmental development of the current and future generations are not jeopardized. Because of the strong water-development linkage, and as water is a common factor that cuts across all sectors of development, monitoring the sustainability of water resources can effectively provide an indication of sustainable development in a country. This paper presents the assessment of major issues pertaining to the sustainability of water resources use and development in Malaysia.

2. Water Resource Availability In Malaysia

Malaysia is considered a country "rich" in water resources with a total of 2986 river basins (Table 1). The country receives an average of about 3,000mm rainfall annually which makes up a total volume of some 990 billion cubic meters (BCM) of total annual water resources. Of this amount, 360 BCM comprise unavailable water that is needed to maintain the process of evapo-transpiration within the water cycle. The remaining 630 BCM (i.e. groundwater of 64 BCM plus surface runoff of 566 BCM) constitute the country's total available water. This amount translates to approximately 20,000 cubic metres of water available per person per year. However, due to the degradation of water resources and water catchments, the amount of available and usable water may be much less than this figure.

Table 1. Water Availability In Malaysia

Water Resources in Malaysia
(based from JICA study 1982)

Water Resources	Quantity (billion m³)	
Annual rainfall		990
- Surface runoff	566	
- Evapotranspiration	360	
- Groundwater recharge	**64**	
Surface artificial storage		25
Groundwater storage		**5000**

River Basin In Malaysia

Region	No of Basin	Major River basin (>80km²)
Semenanjung Malaysia	1,235	74
Sabah	1,468	75
Sarawak	283	40
Jumlah	2,986	189

3. Malaysian Political Water Scenario

Under the Constitution, matters pertaining to natural resources such as land, mines, forest and water supply fall under the jurisdiction of the states. Water supply becomes a federal matter only if a dispute arises in the case of a river basin, which crosses state boundary. State Governments are responsible for the development, operation and maintenance of water supplies. Since water is important for socio-economic development of the nation, the Federal Government provides soft loans to State Governments for public water supply infrastructure and grant for rural water supply development. At the federal level, the National Water Resources Council (NWRC) was set up in 1998 to pursue a more effective water management, including the implementation of inter-state water transfers. To ensure sustainable water resources and efficient water supply services, the Federal Government is moving towards greater involvement in the management of water resources and water supply services, and the implementation of integrated water resources management.

The national water supply coverage in 2003 is 93 percent, that is 97 and 86 per cent for urban and rural areas, respectively. The estimated population in 2003 is 24.5 million with urban-rural proportion of 60:40.

4. Water Supply Sector

The increased demand for clean water has led to competition in water use among the various water user sectors and the continued economic growth will magnify this even more acutely. The practicable limit of surface water resources development has been reached in regions of high demand, and it has become necessary to consider inter-basin and inter-state water transfers.

The current approaches towards water supply in cities are supply driven – when there's a "shortage", new sources are developed. This 'business as usual' approach is no longer sustainable because of the ever-increasing water demand. Water demand management that focuses on conservation measures to make better use of limited supplies, would be an appropriate approach.

◆ ***Inter-state raw water transfer***

The government is planning to implement a major inter-state raw water transfer project that is, from Pahang in the east to Selangor on the west. The project will transfer 2260 million litres of water per day (mld) via the tunnel cross the Main Range to Water Treatment Plant (WTP) in Selangor. The length of the tunnel is 44.6 km and its diameter is 5.2 m.

◆ ***Develop the new sources***

i. Groundwater resource
ii. Rain harvesting

5. Integrated Water Resources Management (IWRAM)

The management of water resources should be based on sound policies and strengthened institutional arrangements. The first step towards IWRM in Malaysia as a model was realised with the formation of Selangor Water Management Authority in 1999. This authority is commonly known as LUAS (Lembaga Urus Air Selangor-*Selangor Water management Authority*) and was formed with the aim of adopting and implementing IWRM at the river basin level within the State of Selangor.

An integrated river basin management project is being undertaken in two river basins, namely Selangor River and Kedah River, in order to establish a framework for integrated management of river basins and their water resources. A Sarawak IWRM Master Plan Study will also be implemented during the remaining Eighth Malaysia Plan Period (2001-2005) with the objective of formulating a master plan for the integrated development and management of Sarawak water resources.

6. The Way Forward

There is a political will to improve the Malaysian water sector. The national water sector is now being addressed with respect to improving services and conserving resources through the formation of the Ministry of Energy, Water and Communications, and the Ministry of Natural Resources and Environment, respectively. The Department of Irrigation and Drainage (DID) in the Ministry of Agriculture will be transferred to the Ministry of Natural Resources and Environment. DID is the custodian of the National Hydrological Network and is responsible for flood forecasting and the management of floods, urban drainage/stormwater runoff and coastal zones. In other words, DID is responsible for surface water resources. The Department of Mineral and Geosciences (MGD) that is responsible for groundwater resources is already in the Ministry of Natural Resources and Environment.

An individual problem in the national water sector, such as NRW, cannot be solved in isolation. It can only be effectively addressed after the core problems have been resolved. These problems include poor governance, low tariffs and lack of funds. Measures to resolve the problems may include transparent policies, independent regulatory bodies, a paradigm shift in tariffs, the involvement of civil society and the involvement of Federal Government in water services and management of water resources.

The effective implementation of IWRM (Integrated Water Resources Management) will contribute to the realisation of a sustainable national water sector. Reforms and initiatives are needed towards providing adequate as well as an enabling environment for the effective implementation of IWRM. The scope of IWRM is wide and it may be addressed in the following ways; integration of different components of water; integration of water with related land and environmental resources; and, integration of water with social and economic development.

Utilization of Groundwater Resources in Malaysia

Compiled by:

Mohammad Nazan

Groundwater constitutes an important source of water supply for various purposes such as domestic, industries and agricultural needs. In the hydrological cycle, groundwater occurs when surface water seeps to a greater depth filling the spaces between particles of soils or sediment or the fractures within the rock. For Peninsular Malaysia, where 324.2 billion cubic meters a year rainfall received, estimated about 8% or 20 billion cubic meters a year enters groundwater storage. From that amount only about 0.324 billion cubic meters used as water supply for various purposes such as domestic, industries and agricultural needs to meet national water demands. Besides reviewing of current size of groundwater utilization in this country, this paper also explored the Design Criteria, Specification And Method of Construction Used In The Production Well Development. The paper also has discussed the law and regulation related to groundwater abstraction and highlights the adverse effect on environment due to over abstraction of groundwater in Malaysia.

1. INTRODUCTION

In Malaysia, the countries where surface water is the most easily accessible, groundwater represent only about 3% of the National water supply. Although the shallow well are common for every houses in rural area since thousands years in Malaysia, its will become abundant when piped water supply reach nearly every houses in the near future.

Constructing dams for sources of water supplies besides river intake is the best alternative for Malaysia. But the fact that the reserve stored behind these dams and sources from river intake becomes insufficiently in the drought season which is normally occur up to 4 months in certain year. Due to this factors, Government of Malaysia since years ago continuously explored the availability of groundwater resources as a supplement to the existing supplies. Based on this fact, it is needed to explore further on utilization of our huge amount of groundwater resources.

Among the issues arises in exploration of groundwater are the quality of groundwater to be abstract and effects of the over exploitation. The emphasis on protection of groundwater quality from various sources of pollutant such as disposal of waste by landfill, septic tanks, industrial wastes and fertilizer and pesticides from agriculture activities are needed. Over exploitation of groundwater may lead to ground subsidence, saltwater intrusion, treat to wetlands and accelerates movements of pollutant also must be monitored. Existing law on both issues (controlling groundwater quality and over exploitation) will be implemented, revise and upgrade time to time.

2. WATER SUPPLY RESOURCES AND DEMANDS IN AT GLANCE

Peninsular Malaysia received annual rainfall about 2,470 mm, its equivalent to 324.2 billion cubic meters a year. From that amount, estimated about 8% or 20 billion cubic meters a year enters groundwater storage. Table 1 shows the portion of groundwater recharge as part of hydrological balance of Peninsular Malaysia, (EPU, 2000).

Drought season can be happen up to 4 months a year. In the future planning to overcome the probable shortage of water supply the Government of Malaysia will construct 47 numbers of dams. Beside dams, river intake, water transfer tunnel and exploration of groundwater also included. Perhaps these strategies will meet water demands by the year 2050.

Table 1: Hydrological Balance for Peninsular Malaysia in Billion Cubic Meter Per Year, (EPU, 2000)

State	Rainfall	Evapo-Transpiration	Surface Runoff	Ground-water Recharge	Land Area (km^2)	Water Supply Demand (2000)	Irrigation Demand (2000)	Total Demand (2000)
Perlis	1.56	1.07	0.41	0.09	795	0.03	0.09	0.12
Kedah	20.86	12.01	7.65	1.23	9,426	0.29	2.61	2.90
P.Pinang	3.04	0.86	1.87	0.32	1,030	0.27	0.40	0.67
Perak	44.29	20.24	20.39	3.67	21,005	0.42	1.46	1.88
Selangor	25.06	8.83	13.63	2.60	7,950	1.11	0.69	1.80
N.Sembilan	2.56	1.51	0.96	0.09	6,642	0.18	0.11	0.29
Melaka	3.35	2.34	0.88	0.14	1,650	0.12	0.11	0.23
Johor	52.53	27.90	20.92	3.71	18,985	0.51	0.04	0.55
Pahang	90.20	46.83	39.22	4.15	35,964	0.27	0.16	0.43
Terengganu	40.53	14.42	24.12	1.99	12,955	0.20	0.41	0.60
Kelantan	40.31	15.99	22.28	2.04	14,942	0.08	1.26	1.36
Peninsular Malaysia	324.29	152.00	152.33	20.03	131,344	3.48	7.36	10.85

3. BRIEF HISTORY OF UTILIZATION OF GROUNDWATER IN MALAYSIA

Groundwater as resources of water supply for basic necessities in Malaysia, like rest of the worlds, is not new. Before modern technology like pipe water reticulation systems introduced here by more civilize people, especially the west, traditional shallow/dug well widely used beside river or stream. This traditional shallow well normally hand dug and without any concrete lining around the wall.

Before independence (1957), British Government who overruled Malaya (then) developed and upgrading water supply system especially for township area. British started introduced deep well as main sources public water supply in Kelantan since early as 1935.

Under Health Program The government introduced pipe well with hand-pump for the better water quality in the rural area. These programs were continuously extending by Government until proper pipe water supply reached the area. When water pipe reach nearly every houses, than traditional shallow well become unimportant anymore. Thousand of these traditional shallow well are now abundant and buried.

Now-days groundwater utilization present only around 3% of the total supply of the Nation pipe water, Another 978% are from surface water, mainly from river intake, lakes and dams. Noted that 97% of the global fresh water resources are from groundwater, and the balance of 3% are from river, lake and dams.

Now days, groundwater only used in remote area where pipe water is not reachable at the area, or when surface water is not adequate during drought season, or as a supplement to existing treatment plant and lastly for commercial; bottled as mineral water and sold at high price. But lately with the rapid development and population growth, pollution of river and effect of climate change, groundwater become popular as an alternative water source.

4. CURRENT SIZE OF THE UTILIZATION

Currently utilization of groundwater resources is growing increase. Beside Kelantan (since 1935), Terengganu, Pahang, Selangor and Perlis are among the states using its rich groundwater resources of public supply, EPU (2000).

As a center of industrial activities, Selangor takes the lead of using groundwater for industrial purposes, especially in Klang Valley. Among the industries using groundwater as main sources of water supply in Selangor are mineral water bottling, breweries, steel mills, ceramic and rubber processing factories.

In agricultural industries, Kelantan is the most prevalent in using groundwater followed by Terengganu, Pahang, Perlis and Kedah. Along the east coast groundwater is used on a number of agricultural schemes like the Kemasik-Semarak project, the Kandis resettlement scheme, and the Bendang Pauh, Meranti and Sri Pinang irrigation schemes. In Kedah and Perlis groundwater is mainly used in sprinkler system for the irrigation of sugar cane plantations. Groundwater is also used by individual farmers for irrigation of non-padi crops like tobacco, fruits and vegetables, livestock and aquaculture.

Below is the brief information on the current utilization of groundwater in the five users state as mention before.

a. Kelantan

Utilization of groundwater as a main public water supply was introduced to Kelantan as early as 1935. To date Kelantan still the most important State where groundwater is utilized for public water supply. Groundwater resources contribute about 83 million liter a day or 45% of the total water supply in the State.

Kelantan River Basin is rich of groundwater resources. The total groundwater capacity from shallow and deep aquifers over the whole basin has been assessed as approximately 488 Mld. The total abstraction capacity of the old and new wellfields is about 188 Mld. That means there is still in excess of 100 Mld available to be tapped from this rich underground sources.

At present there are a total of 24 wellfields in Kelantan River Basin, 9 old and 15 new wellfields. The old wellfields can produce about 72.84 Mld whereas the new wellfields can provide about 115.6 Mld.

b. Perlis

The early years of modern history of the State, public water supply was sourced from groundwater or off-takes from irrigation canals. Noted that Perlis not only the smallest State in Malaysia, it is also the driest State of Malaysia. Then, there are 5 groundwater schemes in the State, with the largest being at Arau where the bulk of groundwater and surface water is mixed and treated. The schemes in Perlis with their yields are given in Table 2. below.

Table 2: Details of Wellfields in Perlis

No.	Wellfield	Yields (mld)
1	Arau	7.00
2	Felda Chuping	2.60
3	Abi headworks	2.00
4	Semadong	6.00
5	Perlis Plantation Bhd	6.00

Now days the main sources of public water supply in Perlis was from the Timah-Tasoh dam. When the Timah-Tasoh dam was built, the Abi headworks extension and Semandong groundwater supply were shut down, left only the Arau and Felda Chuping groundwater supply in operation with a total yield of 9.6 mld.

In agriculture activities especially the sugar-cane plantation at Chuping, groundwater resources are fully utilize. There are about 15 wells with a total yield about 6 mld tapping groundwater from the Chuping Limestone Formation and the semi-consolidated Batu Arang Formation. Beside that, individual farmers also use groundwater from dug wells throughout the State for irrigation of non-padi crops.

c. Pahang

In the State of Pahang, there are six wellfields which is constructed between 1980 to 1989 for public water supplies. The six wellfields with their respective yields in Pahang are listed in Table 3.

Now days the only wellfields that are in operation are at Kg. Padang and Nenasi. Others wellfields were shutdown either due to high operational cost or due to availability of surface water supplies.

The aquaculture activities (eel farm) along the Pekan-Nenasi costal road used groundwater resources as their main supplies. There are about 300 wells with capacity of 22 mld of water pumped into the eel ponds. This large scales abstraction has lowered regional water levels.

Individual farmers especially along coastal stretch of the State use groundwater from dug wells for tobacco, vegetables and fruit farms.

Industrial areas at Gambang, Lanchang, Jengka, Kemayan, Benta, Bentong and Janda Baik utilise groundwater resources but the total product does not exceed 5 mld.

Table 3: Details of Wellfields in Pahang

No.	Wellfield	Yields (mld)
1	Sg. Pulau Manis	0.18
2	Kg. Sg. Ular	8.00
3	Kg. Bohor Bharu	0.46
4	Kuala Rompin	3.00
5	Kg. Padang	16.00
6	Nenasi	0.17

d. Selangor

Industrial are the predominant activities in utilizations of groundwater in the State of Selangor. In the State, abstracting of groundwater by Selangor Water Works Department for public water supply only at Olak Lempit and Wangsa Maju. Groundwater abstracted from this two site used only as supplements of existing surface water supply in the areas. Only two wells are documented use as sources of water supply for agricultural purposes in the State and it is located at Kuala Selangor district.

The Geosciences Department wellfield at Olak Lempit comprises of 6 wells tapping an alluvial aquifer. 5 wells can produce 2.3 mld each whilst the remaining well which is installed with a 24 m length of 300 mm diameter stainless steel screen can produce 4.56 mld giving a total production of 16 mld from these wellfield.

The Wangsa Maju wellfield is manage by Puncak Niaga Sdn Bhd and consists of 3 wells with a total yield of 3 mld.

Megasteel / Amsteel factory located at Brooklands Estate in Kuala Langat district is the largest abstraction of groundwater for industrial purposes in the Country. The huge amount of water abstracted when the factory running at their full capacity. 13 wells which penetrate to a depth of 50 m into the underlying semi-confined alluvial aquifer giving a yield about 40 mld.

In the agricultural activities, Agrovation Sdn Bhd and Sime Darby Plantation Sdn Bhd are abstracting about 0.86 mld and 0.27 mld respectively. These two agricultural companies are based at Kuala Selangor district. Like other State, in Selangor individual farmers also abstract groundwater from dug wells for vegetables, fruit and livestock farms which rear chicken and pigs, aquaculture for breeding prawn, etc.

In the whole State of Selangor, at present a total groundwater utilization for industrial, agricultural and public water supply from available data is in excess of 75 mld based on 24 hours pumping and assuming Megasteel factory at Brooklands Estate working at their full capacity.

f. Terengganu

Terengganu is one of the water rich States in Peninsular Malaysia and hence most if not all of the public water supply is sourced from surface water. There are two wellfields constructed in the State; at Kg. Kepong and Kg. Serada for public water supply purposes. There are 5 numbers of wells at the Kg. Kepong wellfield with a combined yield of 13 mld. For the Kg. Serada wellfield there are 2 numbers of wells with a combined yield of 36 mld. The 18 mld well at Kg. Serada are the single largest producing wells recorded in Malaysia to date. Both wellfields have been shut down by Terengganu Water Works Department.

The resort island, Pulau Perhentian Besar has a wellfield consisting of 7 numbers of wells with a combined yield of 0.45 mld.

For agricultural purposes, groundwater is extensively used at the Sri Pinang irrigation scheme in Besut where 4 wells are conjunctively used with surface water from the Sg. Besut for irrigation. Single well with a yield of 4.8 mld at Sri Pinang irrigation scheme is the main supply for about 40 hectare of padi field in the area. The two wells at Banggol Katong with a yield of 6.5 mld which is used for the irrigation of vegetables and other cash corps. Individual farmers also abstract groundwater from dug wells for the irrigation of their farm.

There is minimum utilization of groundwater for the industrial purposes in the State. Noted that there are numbers of multinational firms in the Kertih - Kemaman industrial area and Kuala Terengganu.

5. THE WAY FORWARD

In order to promote groundwater usage the agencies which dealing with water resources currently encourage the use of groundwater in new townships and government complexes with the final objective of realising water neutral development. Water neutral development is a concept of utilising local water resources (rainwater, river water, and groundwater) and implementation of water recycling and reclamation

Several action plans are in the list to promote, utilise and protect groundwater resources such as;

- To develop hydrogeological database and 'One Stop Centre' for timely dissemination of groundwater information
- Implement Integrated Land and Water Resources Management (ILWRM) because the traditional approach of managing water resources separately from land-use is becoming increasingly untenable.

- To regulate and certify all groundwater players including water well drillers, pump suppliers and installers as well as groundwater supply operators in order to achieve a sustainable groundwater industry and to license and control groundwater use by the State Water Resources Regulators in order to avoid negative impacts consequent to groundwater abstraction
- To study the potential of groundwater in alluvial basins and hard rock aquifers in order to establish the database for areas that are underlain by promising aquifers and to establish Managed Aquifer Recharge (MAR) systems to improve the groundwater resources by artificially injecting excess river water and storm water into the groundwater system. These systems eradicate downstream flooding.
- To establish groundwater wellhead protection zones and protection of groundwater recharge areas in order to quantify the recharge for the purpose of groundwater resources evaluation and to establish proper groundwater monitoring network nationwide for the purpose of evaluating the groundwater quantity and quality, potential contamination sources, prevention of land subsidence and sinkholes, salt water intrusion and over development of groundwater resources.
- To do capacity building for manpower planning through training, purchasing of new equipments and use of latest technology.

WATER RESOURCES MANAGEMENT IN MALAYSIA

Compile by:
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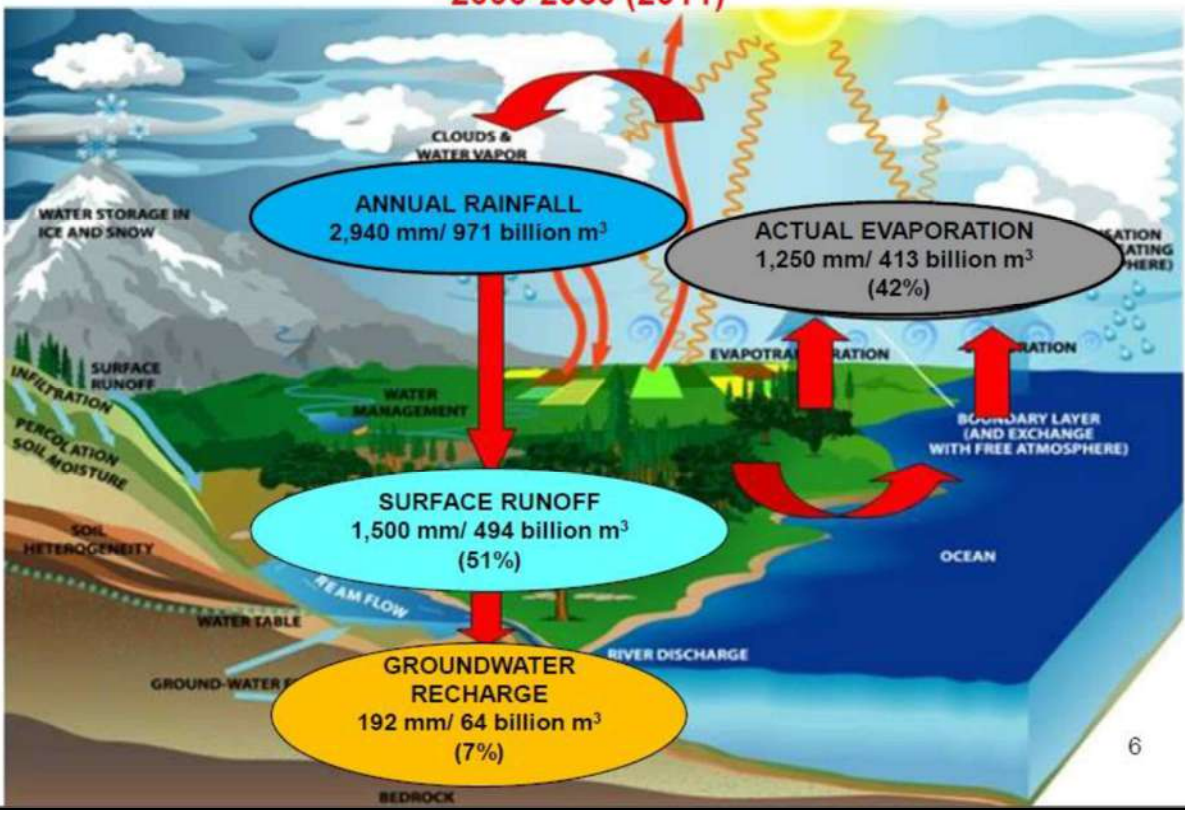
Mineral And Geosciences Department
Malaysia

WATER AVAILABILITY IN MALAYSIA (Based on The Review of The National Water Resources Study 2000-2050 (2011)

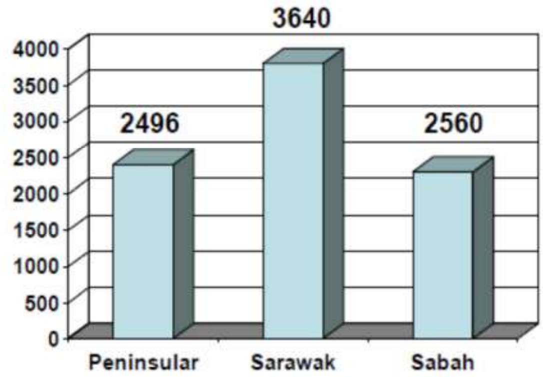


6

ANNUAL RAINFALL

- Water is abundant
- Excess during wet season but still shortage during dry season
- Management Problem?

Average Annual Rainfall (mm)



Average Annual Rainfall for Malaysia: 2,940 mm

WHAT HAVE BEEN DONE AND WHAT MORE NEED TO BE DONE…

1. Formation of the National Water Resources Council (NWRC)- 1998

- Chaired by Deputy Prime Minister
- Pursue effective water management and services
- Involvement of Federal and State Government in the water sector
- Formulation of IRBM Master Plans for all river basins

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Continue..

2. NATIONAL WATER RESOURCE POLICY (NWRP)

Approved by Malaysia Cabinet in the year 2012

Several policies related to the water resources (out of 17)

- *National Policy on Environment*
- *National Biodiversity Policy*
- *National Policy on Climate Change*

3. Legislation

- Federal Constitution amended in Jan 2005 to shift water services from state list to concurrent list
- New law on Water Services Commission passed by Parliament in 2007
- 2008 – Water Services Industry Act enforced
- 2012- National Water Resources Act drafted (currently in consultation process)

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Continue..

4. Apex Bodies formed

- Selangor Waters Management Authority (LUAS) - formed on 1st August 2000 - aim of adopting and implementing IWRM/IRBM at the river basin level within the State of Selangor, besides conserving coastal resources and the environment.
- Water Resources Department of Sabah.
- Natural Resources and Environment Board (Sarawak).
- Kedah Water Management Board (LUAN) – yet to be fully implemented.

Continue.. 37

5. Storm water Management Manual
6. Water Plans
7. Civil Society
8. Studies
9. River Basin Master Plans
10. Capacity Building
11. National and international forum/training Workshop
12. National Sewerage Project
13. Guidelines of installing Rainwater Collection and Utilization
14. National Recycling Campaign
15. Implementation Of Best Management Practices, Public Awareness Capacity Building

NWRP

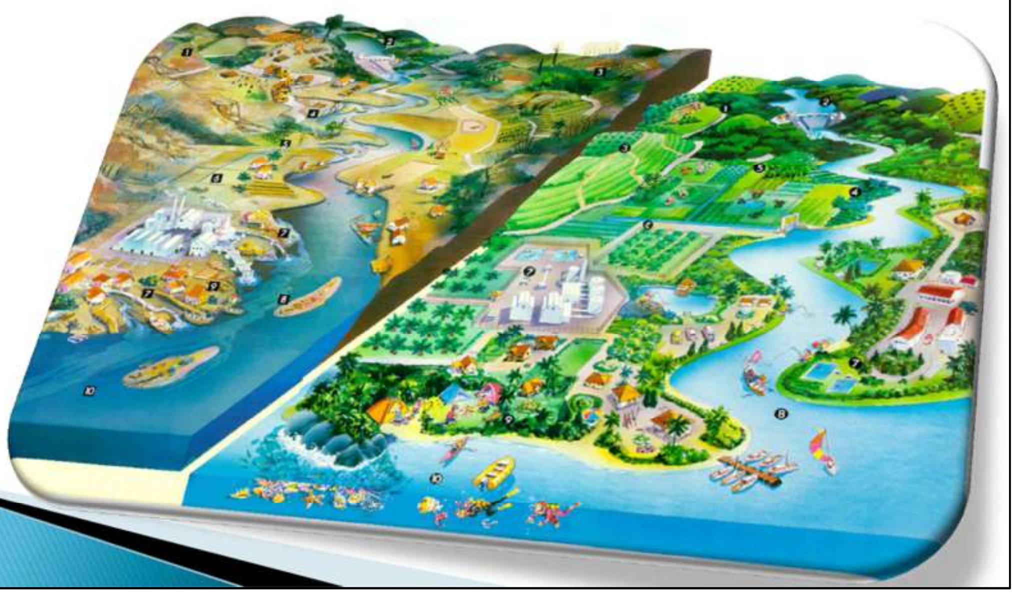
1. water resources security

"Water is enough for present and future consumptions"

NWRP

2. water resources sustainability

Optimise the usage and minimise the wastage



NWRP

3. *collaborative governance*

IMPLEMENTATION OF

THE INTEGRATED WATER RESOURCES MANAGEMENT
(IWRM)

INTERGRATED APPROACH

- Integrated Water Resources Management (IWRM)
- Integrated River Basin Management (IRBM)
- Integrated Lake Management (ILM)
- Integrated Coastal Zone Management (ICZM)
- Integrated Shoreline Management Plan (ISMP)
- Integrated Flood Management (IFM)

The approaches will support the current structure of water management in order to archive better and holistic outcome

Integrated Water Resources Management (IWRM)*

- New Paradigm for 21st Century Water Management
- *"A process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"*

*A sub-set of Integrated Natural Resources Management (INRM)
(Land, Water, Forests, Minerals, Wildlife, Fisheries)

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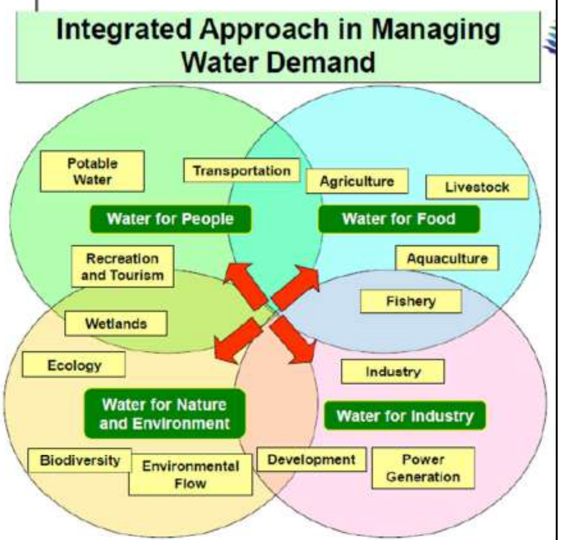
IWRM COMPONENTS

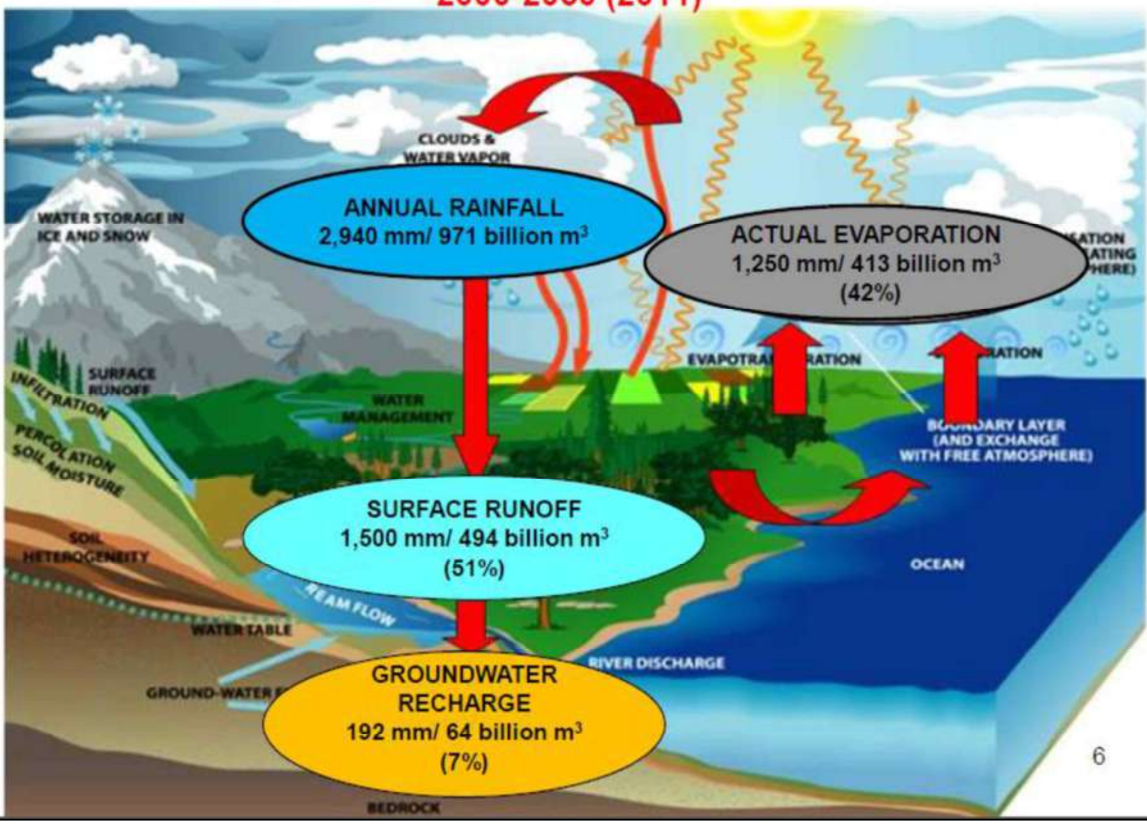



TERIMA KASIH

GROUNDWATER RESOURCE S MANAGEMENT AND POLICY

MOHAMMAD NAZAN
MINERAL AND GEOSCIENCES DEPARTMENT MALAYSIA

WATER AVAILABILITY IN MALAYSIA (Based on The Review of The National Water Resources Study 2000-2050 (2011)



BACKGROUND

Currently, high dependency on surface water
- public water supply is affected by droughts

- Dry reservoirs

- Public suffers

- Economic losses

- **"Review of National Water Resources Study 2000-2050" (2010) recommends nationwide groundwater resources assessment (26 river basins).**
- ***"And We send down water from the sky in according to (due measure), and We caused it to soak in the soil and We certainly are able to drain it off (with ease)"***

(Al – Mukminuum 23:18)

BACKGROUND

Coloured surface water

Clear groundwater

STATUS OF ACCOMPLISHMENT

Department of Minerals and Geosciences

- Groundwater monitoring and modelling
- Groundwater development for peat fire fighting and rural water supply
- Riverbank filtration (RBF)
- Groundwater database (HYDROdat)

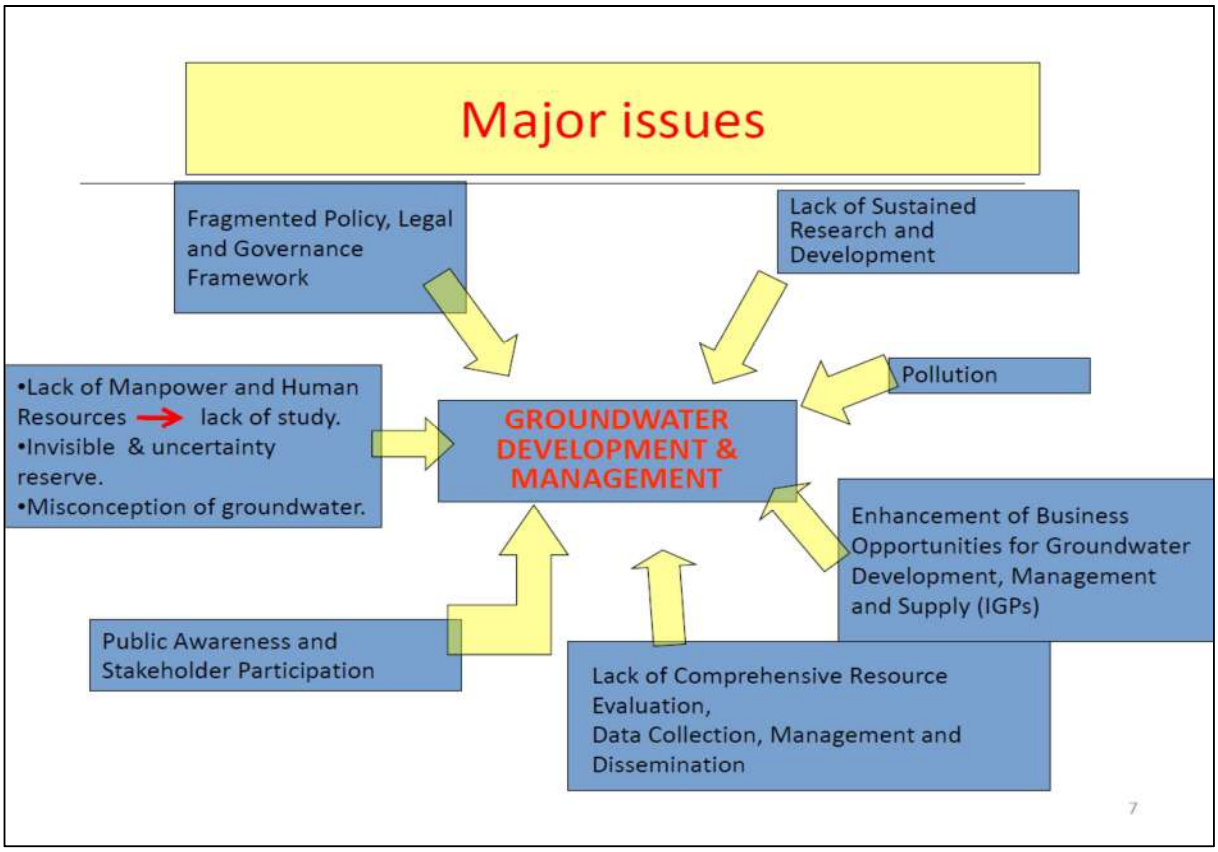
National Hydraulic Research Institute M'sia

- Managed aquifer recharge (MAR) in small islands
- Inverted wells in Negeri Sembilan
- Conjunctive use of surface water and groundwater
- Groundwater recharge estimation in Pahang River Basin

WAY FORWARD

Sustainable groundwater exploration and development

Short Term Programme	• **water stress areas** • **protection against drought** • **peat firefighting**
Long Term Programme	• **Nationwide assessment of groundwater potential in hard rock and alluvial aquifers that include the utilisation of GIS, remote sensing and numerical modelling**
Policy	**•Policy on groundwater usage (20% groundwater supply by 2020)**



Suggested Interventions

- ***Development of a strategy framework for groundwater development and management***

Strategy I	**Identify and Empower a Lead Ministry/Agency at Federal Level**
Strategy II	**Facilitate States to play a leading role in groundwater management**
Strategy III	**Establish a National Groundwater Research Centre under NRE**

Strategy IV	**Establish a Standing Committee on GW within the purview of the National Water Resources Council**
Strategy V	**Establish Groundwater Management Committees at State Level**
Strategy VI	**Pass appropriate legislation to strengthen existing legal framework.**
Strategy VII	**Change public perceptions towards groundwater**
Strategy VIII	**Development of a Detailed Action Plan**

Thank You

9

Country Report

중국

< China >

Submitted by

Mr. Li Changqing

China Institute of Geo-environmental Monitoring

The National Groundwater Monitoring Project

1. Summary

Water is the source of life and material basis of human existence and social development. As a vital part of water resources, groundwater plays an important role in human production and life, as well as the development of national economy. Now, groundwater is a major source of drinking and irrigation water in the rural areas, which irrigates 40 percent of the national cultivated land. However, unreasonable exploitation and utilization of water resources has caused serious ecological environment problems such as over-mining funnels, salt water intrusion, soil salinization and pollution. To solve these problems, the national groundwater monitoring project is officially launched in 2014, which is implemented by the Ministry of Land and Resources and the Ministry of Water Resources together. Based on the existing monitoring station network and communications facilities, a relatively comprehensive groundwater monitoring system that integrates information collection, transmission, processing, analysis and service will be established to effectively control the groundwater dynamic all over the country. It affords a real time monitoring in key areas and regional monitoring in large plains and basins. In additional, this project provides information for society and proposes reference for national significant strategic decision.

2. Characteristics of Water Resources

Water is the source of life and material basis of human existence and social development. The spatial and temporal distribution of water resources in China has the following characteristics. Firstly, China is rather abundant in total water resources volume, but poor in per-capita resources volume. The mean annual water resources are 2812400000000 m3 and runoff depth is 284.8 m, which occupy the sixth and seventh in the word separately. However, the average annual per-capita runoff is only 2260 m3, less than a quarter of the world average. Secondly, water resources are unevenly distributed in space and time. The precipitation is the main recharge source of runoff in China. Determined by the land-sea contrast and the topography, the annual precipitation and runoff depth decrease from the southeast coast to the northwest inland. The average runoff depth is 1200mm in the southeast coast, but is less than 50 mm even zero in the northwest. Last, the regions differ in the combination of water, land and light resources. The northeast possess much land, rich water and poor light while northwest has much land, limited water and abundant light.

As a vital part of water resources, groundwater plays an important role in human production and life, as well as the development of national economy. Especially in the regions where surface water is scare or polluted, groundwater is irreplaceable. In China, the development and utilization of groundwater on a large scale began in the 1970s. Now, groundwater is a major source of drinking and irrigation water in the rural areas, which irrigates 40 percent of the national cultivated land. Among 661 cities of China, More than 400 cities utilize groundwater. The percentage of water supply contributed by groundwater is shown in table 1. Moreover, groundwater importantly supports the ecosystem and environment. It prevents seawater intrusion in coastal regions, provides water for lakes, oasis and marsh in arid regions, keeps caves stable in karst areas and offers a solid base of loose strata in plains. However, the groundwater is buried deeply and renews slowly. Once the groundwater is polluted, the cost on the management must be great.

Tab.1 the percentage of water supply contributed by groundwater

Admini-strative	Percentage	Admini-strative	Percentage	Admini-strative	Percentage	Admini-strative	Percentage
Hebei	79.8%	Heilongjiang	43.0%	Anhui	8.9%	Jiangxi	4.3%
Beijing	61.4%	Jilin	38.3%	Guizhou	7.0%	Hubei	3.1%
Shanxi	58.4%	Tianjin	26.1%	Xizang	8.4%	Fujian	2.4%
Henan	59.5%	Gansu	19.9%	Ningxia	7.2%	Zhejiang	2.5%
Neimenggu	48.3%	Qinghai	16.3%	Hunan	6.4%	Chongqing	2.1%
Liaoning	47.2%	Xinjiang	17.0%	Guangdong	4.5%	Jiangsu	1.6%
Shandong	44.1%	Hainan	7.9%	Yunnan	2.8%	Shanghai	0.2%
Shanxi	39.3%	Sichuan	7.3%	Guangxi	3.8%		

3. Status of Water Resources

According to the second investigation and evaluation on the national water resource, the average annual quality of ground water resource was 821.9 billion m^3 between 1980 and 2000. Over 97% of the average annual quality has a degree of mineralization is less than 1 g/L. The quality of ground water resource stored in mountainous area and plain area was 82% and 18%, respectively. Approximately 30% of ground water resource was stored in the northern areas and the rest 70% was stored in the southern areas.

The amount of ground water supply in the total amount of water supply was significantly different for the northern and southern areas. Ground water and surficial water was the primary water source for the southern and northern areas, respectively. Comparing the results from the two investigations on national water resource in 1980s, following aspects regarding to the national water resource and development on utilization can be found:

(1)The total quality of water resource was fairly consistent. Comparing to the results from the both investigations, the reduction of total water resource is 6.2 billion m^3 or approximate 0.75%. However, this value varies significantly in some areas. For instance, the total amount of water resource decreased 10% in Hehai plain area.

(2)The quality of water supply showed an increasing trend, especially for the northern areas. Between 1980 and 2000, the national water supply increased 1.23% annually; the ratio of ground water supply in total amount increased from 14% to 18.4% since 1980s.

(3)The development and utilization of ground water resource is more advanced in northern areas than in the southern areas. From 1990 to 2000, the utilization of ground water resource in superficial layers has reached 44% in the northern areas.

(4)The pollution problem of ground water has become increasingly significant. The ground water resource in 26% of superficial layer of total plain area has been contaminated by human activities, and it showed an increasing trend.

4. Problems Related to Water Resources

With the increase of economic development and exploration technology of ground water resource, the utilization and development of ground water resource also continuously increase. Ground water has become the primary source for drinking water and irrigation in two thirds of cities in China. However, due to the irrational and excessive abuse of ground water resource, a series of ecological problems have been caused as explained below:

(1)The continuous drop of ground water elevation has led to the increase of core depressions. Due to excessive exploitation of ground water resource, regional ground water elevation has dropped significantly, and numerous core depressions with various sizes have occurred in numerous areas where the degree of exploitation was intensive. According to an investigation of the core depressions in 168 cities in 31 provinces, in the yearbook of Ground Water Monitoring in 2009 on, a total of 222 core depressions have been found and recorded. The total area of these core depressions was about 91000 km^2.

133 of the recorded 222 core depressions were located in surficial layer; the area of core depressions remained nearly consistent for 54 of 222 and another 42 showed an increasing trend (Figure1). The size of 11 core depressions were found to be greater than 500 km2, and 57 of 222 were found that the ground water elevations in the central part of core depressions were less than 20 m below the ground surface (Figure2-1).

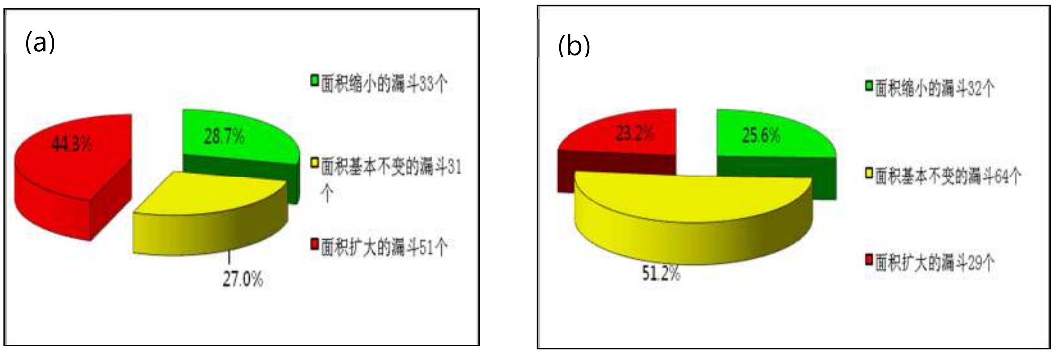


Figure1. The change of groundwater depression cone in 2009:(a) shallow (b)deep

The distributions of core depressions located in deep layer were found similar to the ones located in surficial layer, but the area of core depressions was greater. Among the 89 core depressions in deep layer, the areas of 18 were found to be greater than 500 km^2, and the ground water elevations were found less than 20 m for 96 core depressions of the 222 (Figure2-2).

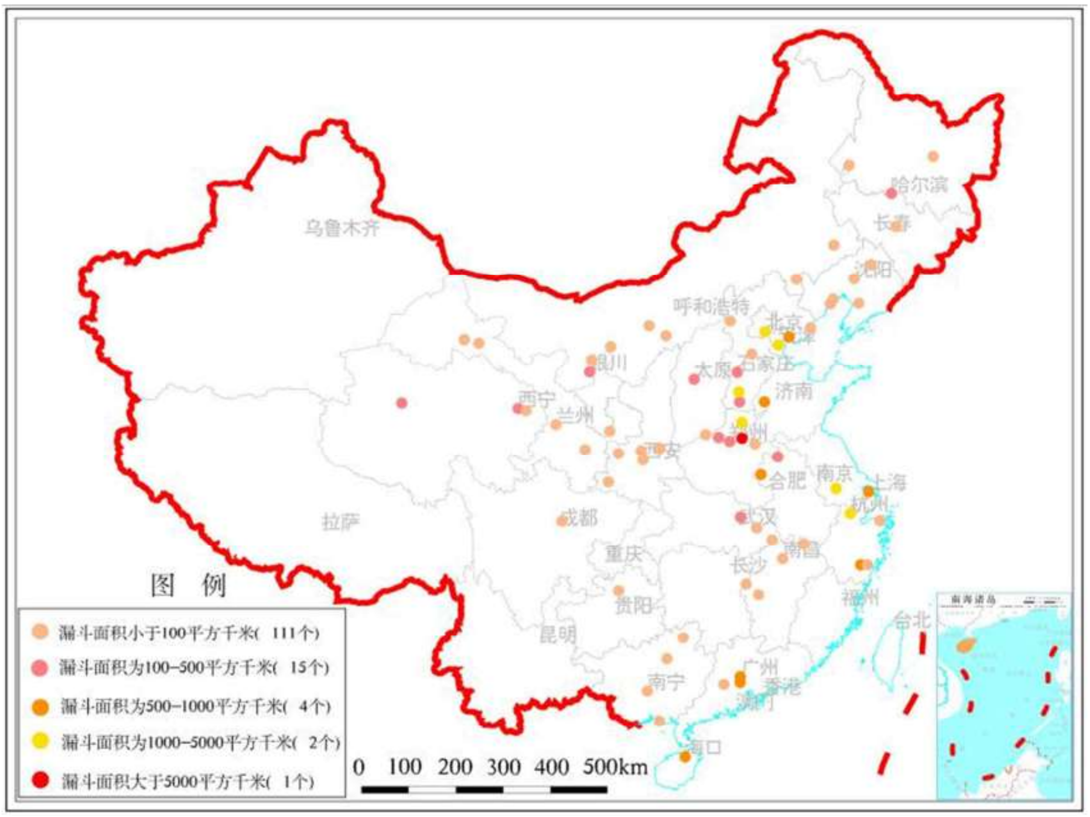


Figure2-1 The distribution map of shallow groundwater depression cone in 2009

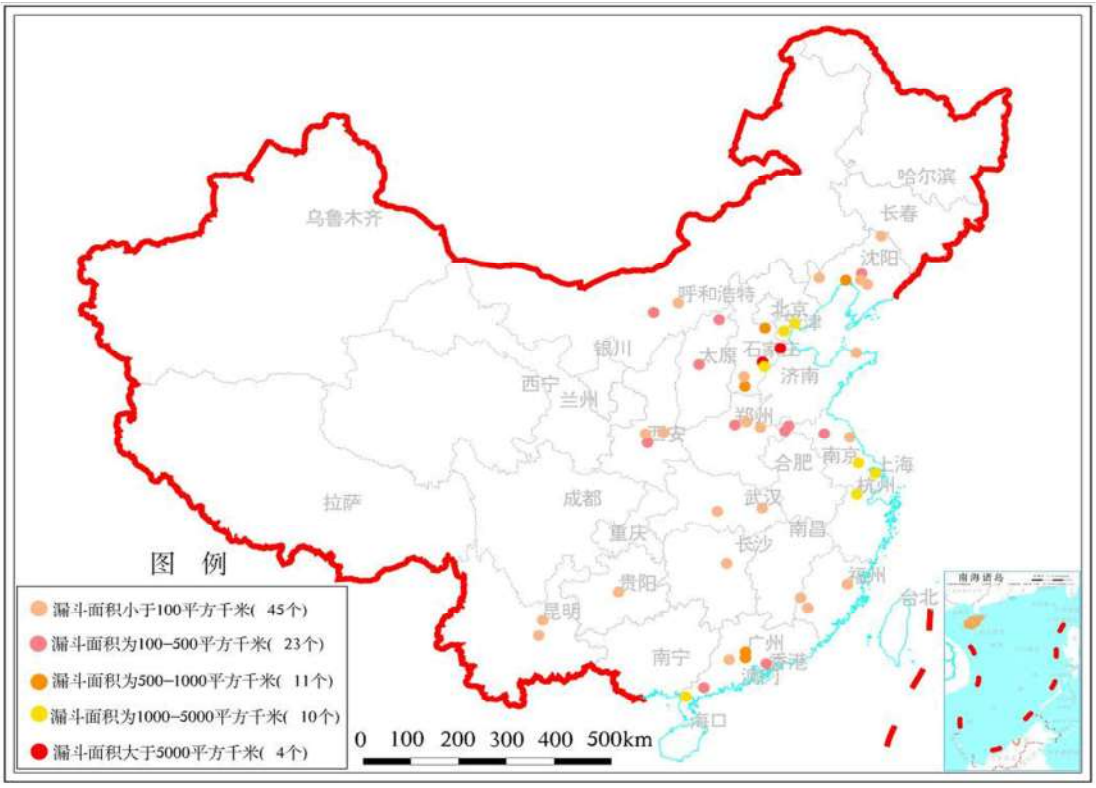


Figure2-2 The distribution map of deep groundwater depression cone in 2009

(2)Subsidence of ground surface

Subsidence and fissures of ground surface have become increasingly severe in Yangtze River delta area, north China plain area, and the Linwei basin area. Based on a preliminary statistics, subsidence of ground surface has caused damages of various degrees in 16 cities and provinces including Beijing, Shanghai, Tianjin and Hebei province. Ground surface subsidence was also found in 50 cities in China. Subsidence of ground surface could cause the settlement of foundation, crack of buildings, damage of pipelines, floating of manhole and severe flood in urban area. The influence of damage and economic loss were significant. Based on a rough estimation, the economic loss caused by subsidence of ground surface and fissures has reached to 800 billion RMB since the founding of P.R.C.

The subsidence area in the north China plain area is a combination of numerous smaller pieces of subsidence area. The total subsidence areas in China where the accumulated amount of subsidence is greater than 1000 mm, 500 mm and 200 mm have reached to 87000 km^2, 32000 km^2 and 62000 km^2, respectively. The accumulated amount of subsidence has reached 3224 mm and 2457 mm for Tianjin and Cangzhou, respectively. In addition, over 700 ground fissures have been observed in numerous places in Cangzhou, Hengshui, and Baoding

(Figure3).

(3)Ground surface fissures

Due to the differential ground surface subsidence, severe ground fissures have occurred to numerous places in the north China plain area, Yangtze River delta area and the Linwei basin, especially in the Shaanxi, Shanxi, Hebei, Henan, Shandong, Jiangsu, Anhui province. According to a statistics, over 6000 ground fissures have been observed in China recently.

(4)Collapse

The Karst collapse distributes widely in China. In Karst areas, ground fissures and loss h ave been frequently induced by the excessively exploration of ground water and mine drainag e. The size of fissures also gradually increased and lad toward to cities and mines. Based on th e investigation conducted in 2005, the total Karst areas in China was about 363000 km2, and t he majority was in the southern areas such as Guangxi, Guizhou, Jiangxi, Sichuan and Hubei provinces.

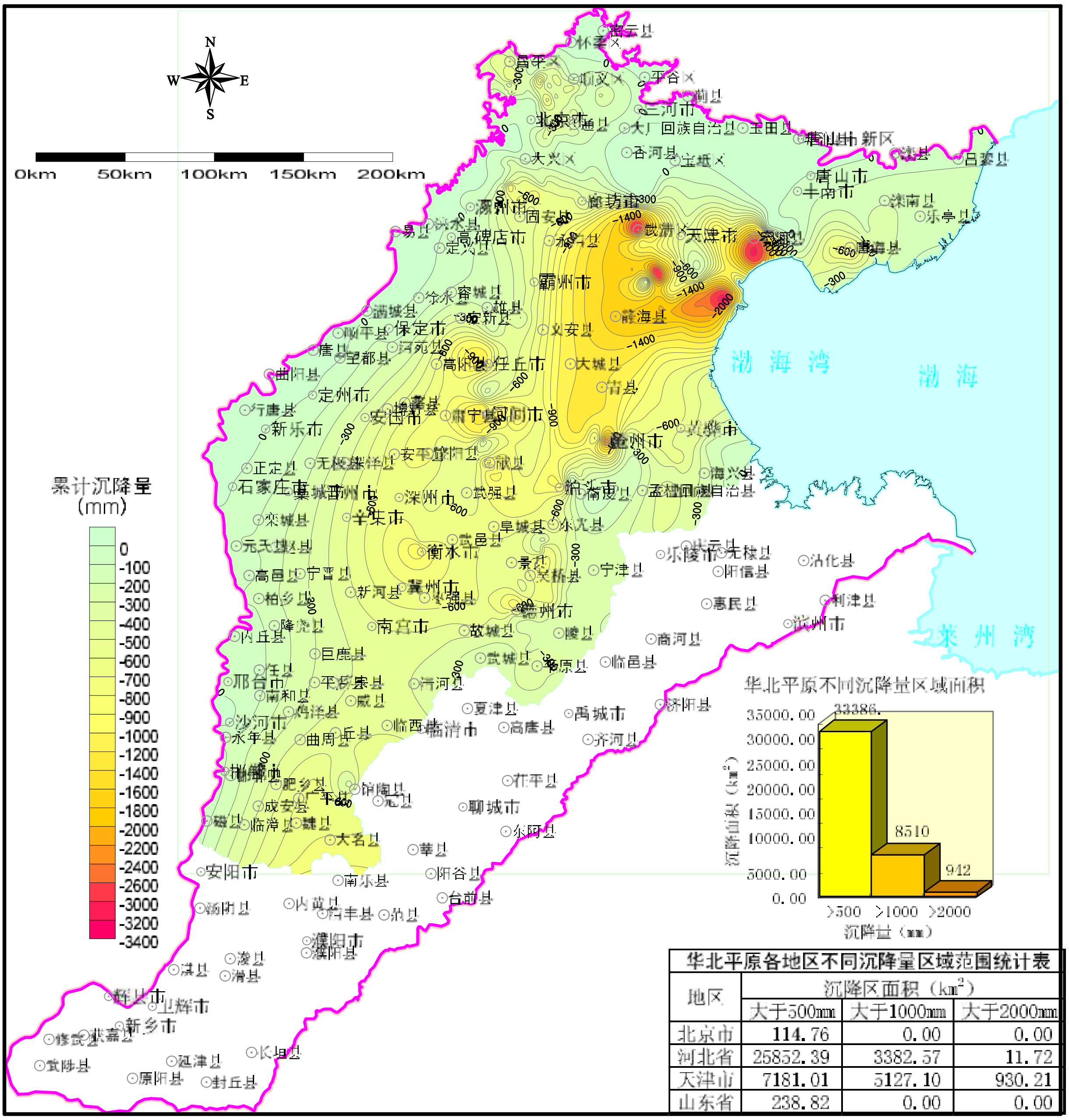


Figure3 The distribution map of land subsidence in North China in 2007.

(5)Drought of rivers

Due to the excessive exploration of ground water, the elevation of ground water has dropped heavily, which lead to the drought of numerous rivers. For instance, numerous rivers in Tanhang mountainous area have dried out. The Miao River, Jifeng River, Jiju River, Honghua River, and Shen River in Baoding all have dried out.

(6)Drought of Lakes, degradation of wet lands and desertification

Due to the excessive exploration of ground water, the elevation of ground water has dropped significantly, which lead to a decreased water refill to lakes and wetlands. Furthermore, it may also cause the drought of lakes, degradation of wet lands, and threat the diversity of ecological system. For instance, the wet land near Tianjian used to occupy over 40% of this place, and has been reduced to 7% currently.

(7)Cut-off of rivers

The decrease of groundwater elevation also reduce the refill to surficial water. With the infiltration of surface water, numerous rivers have been cut off due to drought. Haihe area, for instance, the ground water resource has not been well exploited in 1960s, and 15 out of 20 rivers being investigated showed a 84 days of drought period, and the total drought length was 683 km; Recently, all 20 rivers have been dried out during the year.

(8)Decrease of water compensation into ocean, and ecological environment deterioration

The water compensation from Haihe area into ocean has been gradually decreased since the founding of P.R.C. From 1950s to 1990s, the annual amount of water compensation into ocean is 24.1 billion, 16.1 billion, 11.6 billion, 2.69 billion and 6.85 billion m^3. Therefore, the balance between water and sand has been changed, which cause the clogging of river channel. More importantly, the ecological system has changed from an open system to an isolated system.

(9)Invade of ocean water

In some coastal areas, excessively exploration of ground water may change the dynamic balance and cause a significant drop of ground water elevation, which lead to the invade of ocean water and the contamination of ground water resource.

(10)Contamination of ground water

The excessive discharge of polluted sewerage water, industrial waste water, pesticide from irrigation have caused the contamination of ground water resource, and it showed the trends from point to line, from superficial to deep, from urban to rural areas. According to the second investigation of national ground water resource, about 26% of ground water in surficial layer has been contaminated by excessive human activities, and the contaminated area has reached to 510000 km2, of which the area with minor and severe contamination was 13.4% and 12.7%, respectively. The severely contaminated area in Yangtze River area including Tai Lake, Liao River, Huai River and Hai River is 45% of the totally contaminated area.

5. Water Resources Management and Policy

The groundwater monitoring work of China, whose pattern contains management system, technical architecture and stations network has been established since early 1950s. The monitoring items include groundwater level, quality, quantity, temperature and so on. The monitoring tools include measuring line, tape measure and test clock. The frequency of monitoring is one day, five days, ten days or fifteen days at a time. The Ministry of Water Resources carried out water resources evaluation on a large scale in the 1980s and earlier this decade separately. The Ministry of Land and Resources began to compile the China ground water monitoring yearbook in the 1960s and publish China geological environment monitoring groundwater level yearbook in 2005. Based on the groundwater resources evaluation completed in 1984 and 2002, the buried distribution characteristics of groundwater as well as ecological and environmental issues are basically mastered.

6. Plans for Cooperation to Solve the Problems

Thanks to the development in the past 50-plus years, a certain foundation for the groundwater dynamics monitoring work has been established. Yet, it is still too weak to meet the demand of social and economic development. The layout of the ground water monitoring stations is unreasonable. The special well for monitoring is too few. The monitoring items are relatively unitary. The information management is weak. The techniques for information collection and transmission are backward. The operation and maintenance expense is seriously insufficient. To solve these problems, the national groundwater monitoring project is officially launched in 2014, which is implemented by the Ministry of Land and Resources and the Ministry of Water Resources together.

Based on the existing monitoring station network and communications facilities, a relatively comprehensive groundwater monitoring system that integrates information collection, transmission, processing, analysis and service will be established to effectively control the groundwater dynamic all over the country. It affords a real time monitoring in key areas and regional monitoring in large plains and basins.

In additional, this project provides information for society and proposes reference for national significant strategic decision.

The project construction area contains 31 provinces, autonomous regions and municipalities other than Hong Kong, Macao and Taiwan, with the control area of 3.5 million square kilometers.

The total investment in the project is two billion. 2 ministerial monitoring centers, 7 basin centers, 63 provincial centers and information nodes as well as 280 city nodes will be constructed. The total number of monitoring stations is 20401 and the total length of drilling depth is 1184791m. Meanwhile, three proving grounds for monitoring groundwater and one comprehensive station for analyzing the interaction between groundwater and sea will be newly-built or renovated. The total area of national groundwater monitoring center is 7985 square meters. The total number of dedicated monitoring station building is 6253 and that of well protection installations is 13898. 20401sets of automatic collection and transmission instrument will be installed in the monitoring wells. This national groundwater monitoring project will be finished in three years.

The Ministry of Land and Resources takes charge of constructing 10103 groundwater monitoring stations (This includes 30 spring flow monitoring stations), distributed in sixteen hydrogeological units which are divided according to the geological and hydrogeological conditions. The layout of monitoring network mainly depends on hydrogeological conditions, and then takes administrative division into consideration appropriately. For the convenience of the construction and management, the whole country is divided into five large monitoring regions that are north China, northeast, south central and southeast, northwest and southwest separately. All the monitoring stations are located in the backbone profiles (Figure4).

Figure 4 The layout plans of national groundwater monitoring stations.

Last, the preliminary engineering design of five large monitoring regions is introduced.

(1) Northeast

Songnen Plain, Sanjiang Plain, Xingkai lake Plain and Liaohe Plain are major grain production base in China, where maintaining ecological balance and retaining the biodiversity are important. So the construction of groundwater monitoring network requires a combination of shallow and deep pore water. In Changbai Mountains, Liaoxi Mountains and Hulun buir Plateau, the groundwater monitoring network is constructed to monitor the groundwater exploitation in major cities and large mines, aiming to ensure the water for industry and life in the cities.

(2) North China

Yellow river-Huaihe river-Haihe river Plain is one of the important farm belts in our country. In this area, the emphasis of monitoring is pore water buried in shallow, medium and deep aquifer, distributed in the areas of groundwater over-exploited, heavy polluted, seawater intrusion, land subsidence and regional drawdown funnel. For hilly area, the emphasis of monitoring is karst water in central and southern while pore-fissure water in eastern mountainous area of Shandong province.

(3) South central and Southeast

In Yangtze River delta, the Pearl River delta and southeast coastal regions, the groundwater pollution, land subsidence, ground fracture and seawater intrusion caused by excess extraction of deep groundwater are major environmental and geological problems. Correspondingly, the construction of groundwater monitoring network requires a combination of shallow and deep pore water and karst water. In Jiang han Plain and Dongting Lake Plain, exploitation and utilization of groundwater has a good perspective, so the construction of groundwater monitoring network aims to enhance the understanding of hydrogeological condition and grasp the dynamic characteristic of groundwater level and quality.

(4) Northwest

In Hetao Plain, where the ecological environment is very fragile, the lack of scientific use of regional water resources management causes the contradiction of desertification and salinization. It is important to monitor the development trend of de pression cone in water supply field and water dynamic in salinization area. In the Tarim Basin, monitor water level and quality to protect groundwater environment and improve ecosystem service.

(5) Southwest

In the Karst area in Southwest China, groundwater is more vulnerable to contaminants. As a result, the points of monitoring water quality should be built. The economically developed areas, some important cities and famous tourist landscape, in which exploit and utilize groundwater heavily, should be monitored more densely.

7. Conclusion

Groundwater plays an important role in human production and life, as well as the development of national economy. However, unreasonable exploitation and utilization of water resources have caused serious ecological environment problems. So it is urgent to stablish the national groundwater monitoring project, which provides information for society and proposes reference for national significant strategic decision. This project is implemented by the Ministry of Land and Resources and the Ministry of Water Resources together. The total investment in the project is two billion. 2 ministerial monitoring centers, 7 basin centers, 63 provincial centers and information nodes as well as 280 city nodes will be constructed. The total number of monitoring stations is 20401 and the total length of drilling depth is 1184791m. Meanwhile, three proving grounds for monitoring groundwater and one comprehensive station for investigating the interaction between groundwater and sea will be newly-built or renovated. 20401 sets of automatic collection and transmission instrument will be installed in the monitoring wells. The Ministry of Land and Resources takes charge of constructing 10103 groundwater monitoring stations (This includes 30 spring flow monitoring stations), distributed in five large monitoring regions and sixteen hydrogeological units which are divided by the geological and hydrogeological conditions. All the monitoring stations are located in the backbone profiles.

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Country Report

인도네시아

< Indonesia >

Submitted by

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Center for Groundwater Resource and Environmental Geology

Water Resources Management in Indonesia, Problem and Solution

1. Summary

Water is essential for life; without water all life on earth will be extinct. At current and future, water as a natural resource (includes groundwater) is a very important factor for the development. There would be no development without guarantee of water availability. The role of water to support the development becomes more and more strategic and it becomes a reliable resource of income to the government and people. Therefore God's gift should be managed properly in order to maintain groundwater sustainability for the benefit of mankind.

In Indonesia, groundwater resources, primarily shallow groundwater, have been developed for centuries. The groundwater from the deep aquifer systems, however, was initially developed in the mid of 19th century, after a deep well was successfully drilled in 1848 at Fort Prins Hendrik, a fortress in Batavia (presently Jakarta). Since then, deep groundwater has become one of sources of raw water for drinking water for several towns in Java and the Government of Dutch Indies in that time needed to manage the groundwater and put into effect a series of water regulations in Java and Madura.

Since the last three decades, in the era of developing of the country, populous cities serving as centers of development for services, education, tourism and other sectors are growing in the whole of Indonesia, primarily in Java. The need for water, therefore, is increasing correspondingly to the population and economic growth. Unfortunately, to meet the demand for water, there is still a need to rely on groundwater resources. It is estimated about 80 % of the total clean water supply for rural and urban areas rely on groundwater, whereas industry relies nearly 90 % of its water need on groundwater resources. Consequently, degradation, both quantity and quality of those resources is already an evidence. Therefore, proper management of groundwater is essential to ensure its availability both its quality and quantity and hence, its sustainability can be utilized for the benefit of the people of Indonesia.

2. Hydrogeological Setting

2-1 Groundwater Occurrence and Distribution

The occurrence and properties of groundwater, its origin, movement and chemical, constituents, are controlled by the geological frame work; that is, the lithology, structure and porosity of rocks and sediment through which the groundwater moves. Based on the geological setting, in general the occurrence of groundwater in Indonesia can be distinguished into four regions; groundwater in unconsolidated and semi-consolidated rocks, groundwater in Quaternary volcanic products, groundwater in carbonate rocks, and groundwater in consolidated rocks (Fig. 1).

Groundwater in Unconsolidated and Semi-Consolidated Rocks

In Indonesia, the Quaternary sedimentary rocks comprising unconsolidated and semi-consolidated rocks are generally permeable enough to yield large quantities of water to wells. The unconsolidated rocks displayed by fluvial deposits are composed of gravel, sand, silt or clay.

The types of occurrence of these aquifers may be broadly grouped as coastal plain, intermountain basin, and river valley, whereas the mode of saturated flow within these aquifers is intergranular.

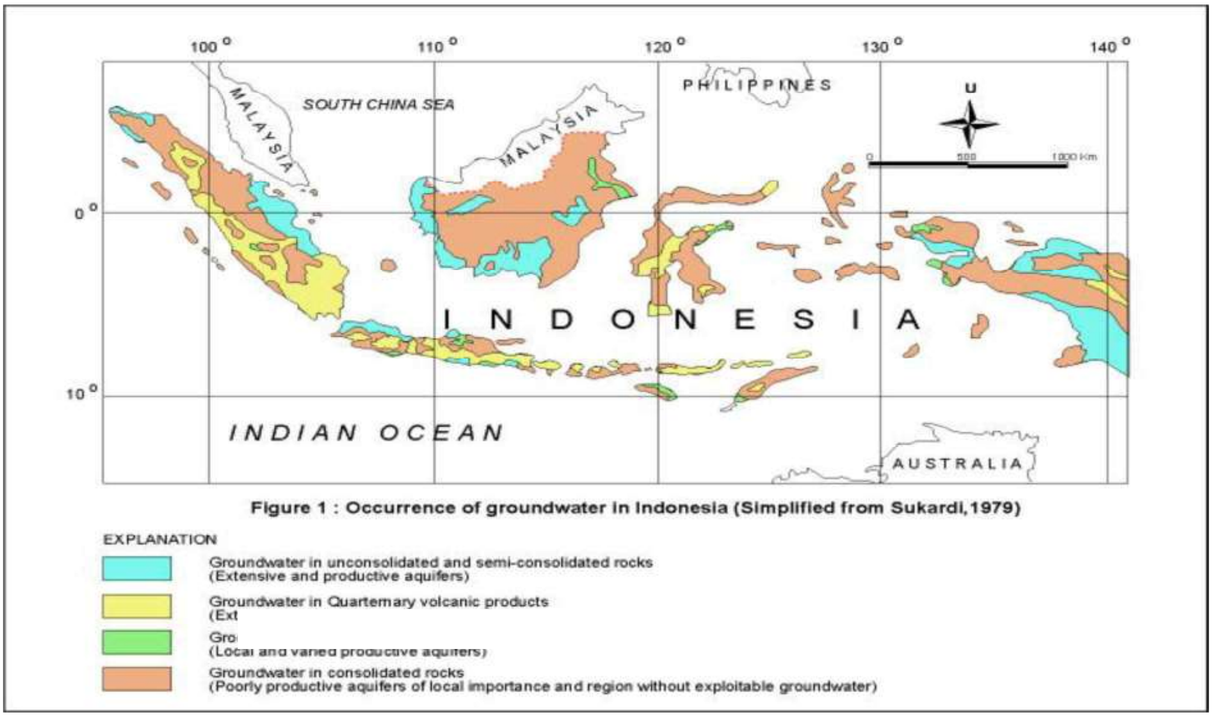

Figure 1. Occurrence of groundwater in Indonesia (simplified from Sukardi, 1979)

Fluvial materials occur in nearly all regions and the aquifer of fluvial origin are important sources of water supply, such as in eastern Sumatera, northern Java, coastal plain of Kalimantan, and southern Papua. The delineation of aquifer zones in these deposits using borehole data is difficult task, because the variability of sediment sources and flow.

The fluvial deposits that located in the intermountain basins e.g. Bandung, Madiun, Kediri, and Bondowoso basins consist of sand and gravel and these basins are major source of groundwater supply for these areas.

Groundwater in Quaternary Volcanic Products

The Indonesia archipelago contains one of the most extensive volcanic regions in the world with 129 active volcanoes, approximately 333,400 km2 in area or 12.5 % of the whole Indonesia territory. The material of Quaternary volcanic products is composed by lava, gravel, volcanic sands, and fine materials of volcanic origin. Groundwater flows in Quaternary volcanic products, either through granular interstices or through fissures. As in the fluvial deposits, groundwater in Quaternary volcanic products which cover extensive regions along Sumatera, Java, Sulawesi, Bali, Lombok, and Sumbawa are high potential groundwater resources in Indonesia.

Groundwater in Carbonate Rocks

Carbonate rocks, in the form of limestone and dolomite are widely spread in Indonesia, although they occupy only a few percent of the entire territorial area of Indonesia and they are exposed in Sumatera, Java, Bali, Lombok, and Sulawesi until Papua.

The carbonate rocks generally are good groundwater bearing formations in Indonesia. The occurrence of groundwater in limestone is governed by the presence of secondary porosity. The groundwater is, therefore, unevenly distributed, and its potential depends mainly on the intensity of solution channeling. The intensive development of groundwater in the carbonate rocks has been done in Southern Mountain Area of Yogyakarta.

Groundwater in Consolidated Rocks

Since rocks generally have low permeability, the occurrence of groundwater in consolidated rocks in Indonesia has little significance. Groundwater especially fills fissures, cracks and bedding planes. However, the occurrence of groundwater is limited because the fissures system is closed and is not interconnected. The occurrence of groundwater of this type is spread over areas in North and South Sumatra, West and Central Kalimantan, South Sulawesi, East Timor, and Papua.

2-2 Groundwater Potential

Government Regulation number 43 year 2008 on Groundwater, article 4, as stated in the Act number 7 year 2004 on Water Resources, article 12 paragraph 2, has mandated groundwater management policies based on the groundwater basin. This was followed by the issuance of Presidential Decree number 26 year 2011 on Stipulation of Groundwater Basin which establishes the distribution of groundwater basins in the entire territory of the Republic of Indonesia as the basis of the groundwater management.

Based on the above presidential decree, the Indonesian territory consists of 421 groundwater basins spread over the islands (Fig. 2). The groundwater basin boundary is the basis for the implementation of groundwater management with the stages authority according to the scope of its administrative boundaries.

The results of groundwater potential calculation at each groundwater basins which is conducted by the Ministry of Energy and Mineral Resources are generally divided into two groups of aquifers, the upper aquifer and the deep aquifer, with the total groundwater potential is 496,217 million m3/year (Table 1).

The highest ground water potential is the Papua Island but a low percentage of the national total population, while the highest number of population is the Java Island but the potential of groundwater is low, so that the water crisis and conflict is generally occur on the Java Island (Fig. 3).

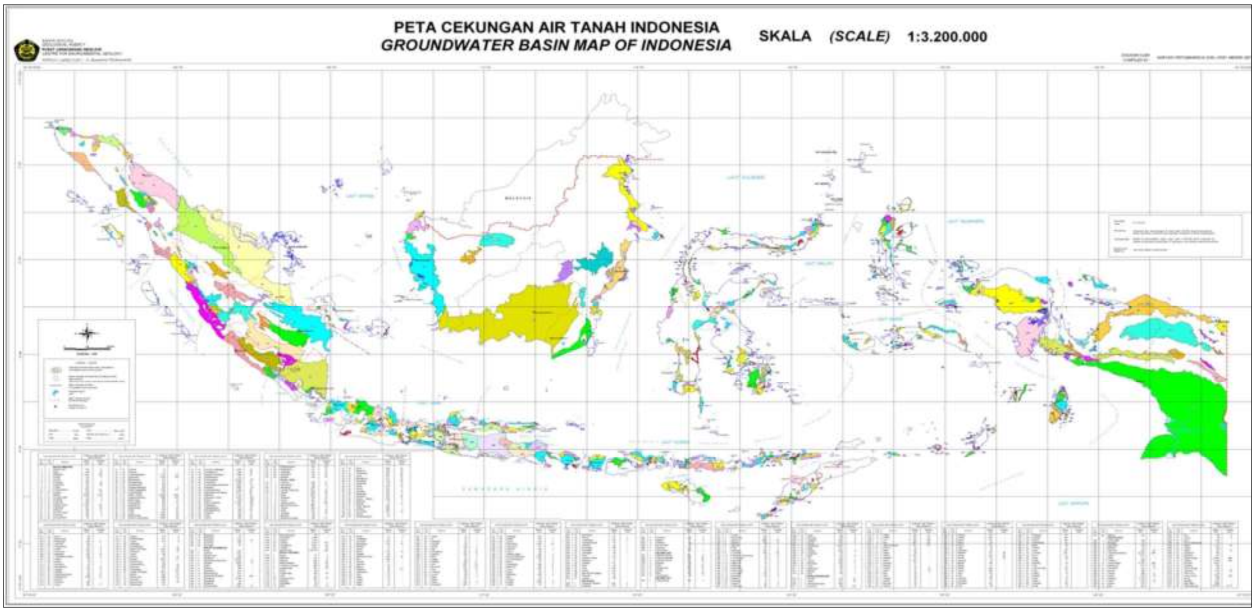

Figure 2. Groundwater Basins Map of Indonesia

Table 1. Groundwater Basins Potential

No.	Location	Groundwater Basin (GB)			
		GB Nr	Area	Potential [10^6 m^3/th]	
			[Km^2]	Upper Aq (Q1)	Deep Aq. (Q2)
1	Sumatera	65	272.843	123.528,00	6.551
2	Jawa & Madura	80	81.147	38.851,00	2.046
3	Kalimantan	22	181.362	67.963,00	1.102
4	Sulawesi	91	37.778	19.694,00	550
5	Bali	8	4.381	1.577,00	21
6	NTB	9	9.475	1.908,00	107
7	NTT	38	31.929	8.229,00	200
8	Maluku	68	25.830	11.943,00	1.231
9	Papua	40	262.870	222.524,00	9.098
TOTAL		421	907.615	496.217,00	20.906

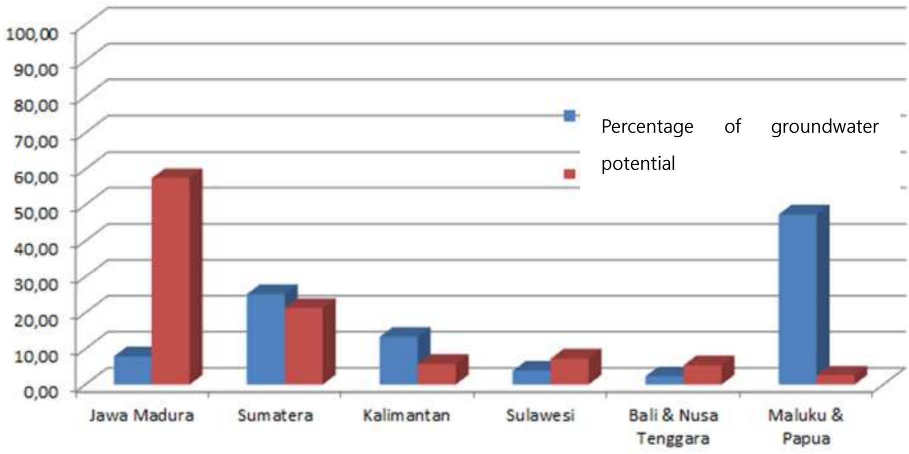

Figure 3. Percentage of groundwater potential and national population

3. Status of Water Resources

3-1 Distribution of Raw Water

Based on the results of the distribution calculation of surface water by the Ministry of Public Works (Fig. 4), the raw water potential that available is 3,906,500 million m3 per year, which it can be utilized only 691.300 million m3 per year or about 18 percent.

The potential of water resources of the 18 percent which can be utilized is only 175,100 million m3 per year or about 25% that has been utilized. The amount of water that has been utilized about 19.5% is used for domestic consumption and urban while the remaining 80.5% is used for irrigation.

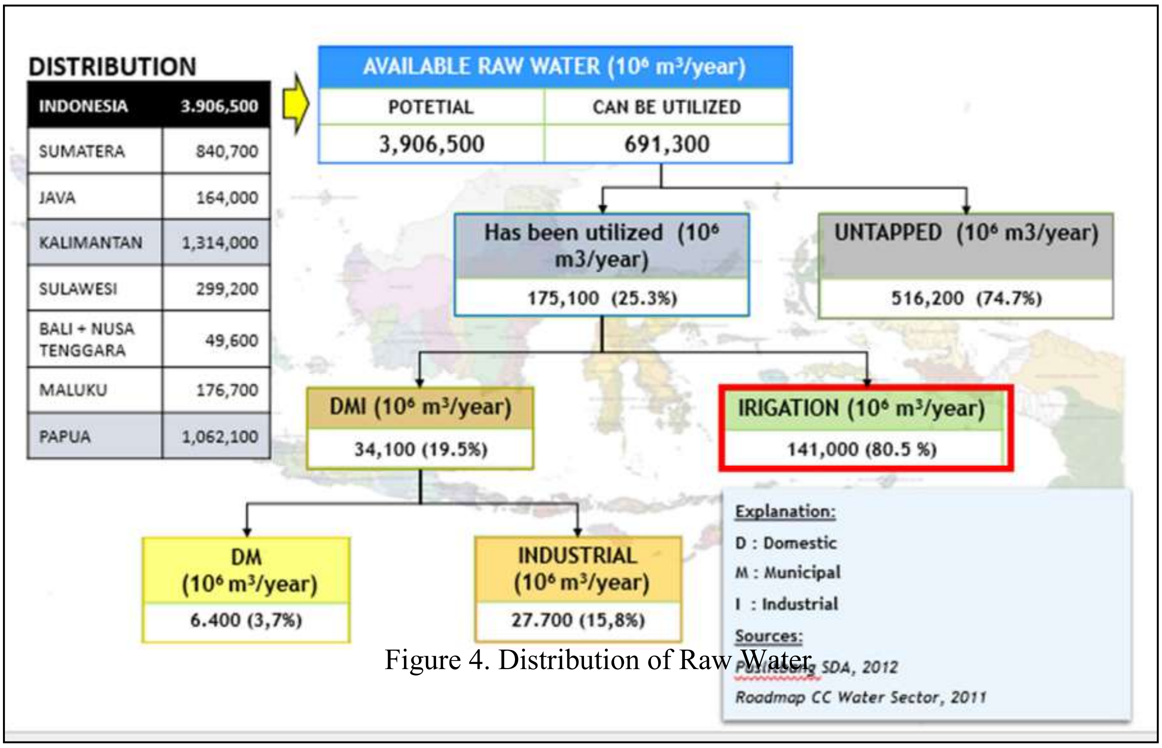

Figure 4. Distribution of Raw Water

3-2 Per Capita Water Storage Indicator

Per Capita (per person) Water Storage is measured as the volume of water available in reservoirs (m^3) per person in the population. However, it is important to note that unless planned for multiple purposes, dams can bring fewer benefits than envisaged and may cause environmental damage.

The biggest water potential in Indonesia is Kalimantan which total water potential about 1,314,000 10^6 m^3 per year and the biggest per capita potential is Maluku and Papua that about 364,274 m^3/person/year. The lowest per capita storage is Sumatera which capacity is 20m^3/person/year (Fig. 5)

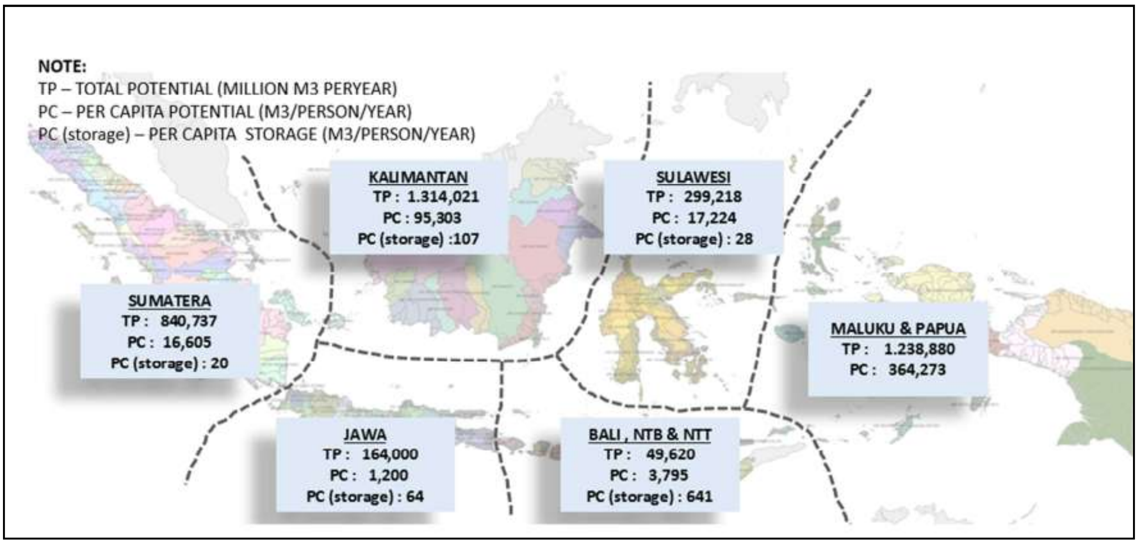

Figure 5. Per Capita Water Storage

4. Water Resources Management and Policy

Indonesian region has thousands of islands and rivers that flow in it, then the article in Article 86 paragraph 4, of Law no. 7 of 2004 on Water Resources mandated, need to set up a forum for coordinate of water resources management, in order to integrate the interests of various sectors, regions and stakeholders in managing water resources.

Coordination forum is called the Water Resources Board in the National and Provincial levels, also can be formed at district level.

To implement Article 86 paragraph 4 of Law No.7, has established the Presidential Regulation No. RI. 12 of 2008 on Water Resources Board, which commissioned the National Water Resources Board to:

1. Prepare and formulate a national policy and strategy for managing Water Resources (National Policy on Management of Water Resources has been completed).
2. Giving consideration to establish the river basin districts and groundwater basins (Figure 2).

3. Monitoring and evaluating follow-up the zoning of river basin districts and groundwater basins, and proposing changes in the its zoning, and

Prepare and formulate a policy of the hydrology, hydrometeorology, and hydrogeology information systems management at the national level.

The region boundaries of river basin districts and groundwater basins are in the process to set as the Presidential Decree that will be the reference in the water resources management in Indonesia. The number of river basin districts already identified as 133 districts, while the groundwater basins as 421 basins.

In article 17, paragraph 4, Presidential Decree No. 12 of 2008, as well set about the composition of the membership of the National Water Resources Board composed of representatives from Government and Non-Government elements which is balance on the principle of representation.

The above member's composition of the National Water Resources Board is expected to provide solutions for water resources management in Indonesia, in arranging and managing in accordance with the principles of integrated water resource management, so that the Indonesia can fulfill the need for water and help preserve the water resource.

The keyword that needs to examine is the coordination between water resource managers and the water users, in achieving the final goal of development water resources management in Indonesia.

5. Problems Related to Water Resources

The main issues that need to be examined in relation to water resources management in Indonesia is the increasing demand for water from various sectors, such as the development of settlements in urban areas, industrial development, mining, and increased demand for electrical energy, while the limited potential of water resources. Several other issues, which as well need attention are:

1. Conflict in Water Use

   Due to the imbalance between the availability of water needs, during the dry season often occurs in the use of water disputes between farmers, water users, people living in the region both upstream and downstream and groups among areas of government administration.

2. Limitations of the Public and Business Roles

   Limited knowledge and understanding of society and business sectors in water resources management causing the lack of attention and their role towards the preservation of water resources and the maintenance of facilities and infrastructure.

3. Overlapping the Roles of Institutional Water Resource Management

   Management of water resources across sectors require integration. There are many overlapping and gaps in implementation of tasks and functions among agencies, resulting in water resources management becomes ineffective and inefficient.

4. Limitation of the accurate water resources information

   Overlap in data collection and inconsistent data across sectors is still often occurs because each agency works according to their individual interests. Data and information to support water resources decision-makers at various levels not guarantee its accuracy.

The increasing number of population and housing and industrial development will increase the need for water. Increased economic conditions are likely to improve the water needs of the community including the utilization of ground water for water supply of raw industrial and residential.

The fulfillment of the MDGs (goal 7 targets 10): Reduce by half the proportion of people without half sustainable access to drinking water and safe sanitation, in 2015.

Limitations of the raw water supply infrastructure for water supply from surface water causing ground water exploitation.

The weakness of monitoring and enforcement of laws against the use of illegal or excessive ground water.

6. Plans for Cooperation to Solve the Problems

Some of plans for cooperation to solve the problems in water resources management as follow:

- Capacity building of human resources in the management of groundwater resources through training course, workshop, also master degree and PhD program scholarship.
- Cooperation in groundwater monitoring management and technology.
- Cooperation in detail groundwater exploration using precision geophysics method.
- Share the expertise, experiences and transfer of technologies

7. Conclusion

The science and technology of water resources management are constantly being developed by other countries is a challenge for Indonesia continues to develop. Research, application of science and technology and development of human resource improvement is necessary, in order to Indonesia more capable and independent in the management of water resources. Cooperative of water resources management between countries is needed because Indonesia has several Trans boundaries of the river basin and aquifers.

Country Report

베트남

< Vietnam >

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Vietnam water resources, status and solutions

1. Summary

Water has very important role for human life and is the motivation to promote the country's development, especially for mountainous areas and subareas development. In recent years, Vietnam government pay more attention for lead and investment to build the Water Resources Law (2012 year) and more guidelines for water resources management, investigation and planning. So far, in the groundwater sector has been completed and covered the hydrogeological map scale 1: 200.000 for whole Vietnam territory, especially in the key region such as regions are urged for economic development has completed the hydrogeological map scale 1:100.000 and scale 1:50.000; in the surface water sector, completed the projects for water resources assessment of nice biggest river basin and implementing water resources planning for biggest river basin of Vietnam. Besides that, for water resources information, the water resources monitoring in the 5 regions was developed and has monitoring data of nearly 25 years.

2. Hydrogeological Setting

In Vietnam, the hydrogeological national map scale of 1: 1.000.000 was created, which divided into 7 hydrogeological regions. 1) West Bắc Bộ HGR located in folded mountain structure in West Bắc Bộ. This is a complicated hydrogeological region (HGR). 2) East Bắc Bộ HGR belonging to formation of mountain ous area in East Bắc Bộ. 3) Bắc Bộ Delta HGR including the whole delta plains in North Việt Nam, which extends from Việt Trì City to the East Sea. This delta is built up by Red and Thai Binh River systems. 4) North Trung Bộ HGR including coastal plain provinces in the north of Central of Việt Nam such as Thanh Hóa, Nghệ An, Hà Tĩnh, Quảng Bình and Thừa Thiên – Huế. 5) South Trung Bộ HGR including coastal plain provinces in the south of Central of Việt Nam such as Tuy Hoà, Bình Thuận and Nha Trang – Khánh Hoà. 6) Central highlands region including Gialai, LamDong, Kontum, Daknong and Daklac provinces. 7) Nam Bộ Delta HGR including the whole delta plain belonging of Mekong and Đồng Nai River systems.

Groundwater on the Vietnamese territory exists in following formations:

a. Groundwater in loose sediments

Groundwater in loose sediments is distributed mainly in two large deltas: the Bắc Bộ delta plain in North Việt Nam and the Nam Bộ delta plain in South Việt Nam, which are correspond to two hydrogeological regions. A part of it exists in loose sediment of coastal plains of Central Việt Nam.

In the Bắc Bộ and Trung Bộ, groundwater exists mainly in two aquifers, namely the Holocene aquifer in the upper part and the Pleistocene in lower part. In general, these aquifers are rather abundant in reserves, with the water of high quality therefore they can meet the water demand. In some areas, the water is salted or has pollution manifestation by exogenous factors.

In the Nam Bộ plain of South Việt Nam, groundwater is abundant but the upper part is mainly salted, so that it cannot be used for living activities. The freshwater is distributed in rather great depth part. It has high quality and can satisfy large water demand of the life.

In the coastal plains Central Việt Nam and loose sediments in piedmont areas, the groundwater has good quality but small reserves. It can meet the demand of medium or small scale, except some areas where it can supply with large amount.

b. Groundwater in basalts

Groundwater in basalts is distributed mainly in Tây Nguyên the plateau belonging to the Kon Tum, Gia Lai, Đắc Lắk, Lâm Đồng Provinces and some provinces of South Trung Bộ and East Nam Bộ Groundwater in basalts has complicated hydro-dynamic system because formed from many volcanoes during different geological times. Therefore, water-bearing basalt and dry basalt formations are interculated, that makes the hydrological characteristics more complicated.

This water source has small discharge with water springs having the discharge of from 0.11 to more than 1 liter/s. The water-bearing property of this formation is inhomogeneous. The change of groundwater level is 2-4 months slower than the change of rain in the area.

Groundwater in basalts has good quality. Normally, it is fresh or ultra-fresh and satisfies the water requirement in many using purpose.

c. Groundwater in carbonate (karst water)

Groundwater in carbonate occupies an area of 50,000 km^2. It occurs in many localities such as Quảng Ninh, Bắc Sơn, Cao Bằng, Trùng Khánh, Sơn La, Mộc Châu, Hòa Bình, Ninh Bình, Thanh Hoá and so on. Groundwater in carbonate and carbonate formations themselves play an important role in industry and construction fields.

Groundwater in carbonate has very complicated and inhomogeneous water level fluctuation. It is being exploited for living activities, especially the water used in Bỉm Sơn Townlet reaches 20,000 m^3/day.

d. Groundwater in other crushed formations (terrigenous sediments, effusives, intrusives and metamorphic rocks)

Terrigenous sediments, effusives, intrusives and metamorphic rocks are popular in Việt Nam, but they have low water-bearing capacity except the places of tectonic faults, crushed zones folds and contact zones.

Groundwater in crushed formations usually has good quality and satisfies the water demands. However, because of small reserve, its exploitation is scattered with each well of only some cubic meters per day of output.

3. Status of Water Resources

3-1 Groundwater potential

Việt Nam has high rainfall so that supplement capacity rainy water to groundwater is rather high. Nevertheless, due to topographic factors and influences of climate and weather the rainy supplement is irregular by time and space. The total dynamic natural reserves of groundwater in Việt Nam territory is 128,500,000 m3/day.

In North Việt Nam, A, B, C1, C2 the categories calculated reserves are 600.503, 554.673, 897.521 and 5.284.951 m^3/day, respectively.

In coastal area of South Việt Nam and Tây Nguyên Plateau, potential exploitation reserve is 29.335.000 m^3/day and supply capacity is 1.76 m^3/day per person.

In the Mekong Delta plain, the total industrial exploitation reserve is 250.000m^3/day in the 2014 year, the static reserve is 6.000.000 m^3/day.

In the Hà Nội city, at present, the exploitation is approximately 800,000 m^3/day. In 4 years to come, it will be lest than 800.000 m^3/day for groundwater protection and prevent ground subsident.

However, the water distribution is not regular. The reserves of the formations and areas are shown in Table 1. And calculated results of water use demand in Việt Nam are in Table 2.

Table 1. Natural dynamic reserves of groundwater in Việt Nam territory

Water-bearing formation	Natural dynamic reserve (m^3/s)					
	East Bắc Bộ	West Bắc Bộ	Bắc Bộ D elta	North Na m Bộ	South Trun g Bộ	Nam Bộ Delta
Loose sediments	2.25	9.095	88.865	83.17	48.535	158.25
Basalts	-	-	-	13.005	51.300	-
Carbonate	12.55	40.97	-	22.8	-	-
Terrigenous sediments	35.85	27.97	-	120.517	47.530	-
Metamorphic rocks	27.65	86.945	-	69.565	62.84	-
Intrusives	47.128	40.79	-	72.904	108.62	-
Mixed formations	114.165	47.742	-	85.032	-	-
Total	239.4	214.832	88.865	466.966	312.825	158.25

Table 2. Forecasted water demand until 2014 [1, 3, 4]

No	Area	2010 (m^3/ng)			2014 (m^3/ng)		
		Urban area	Rural area	Total	Urban area	Rural area	Total
1	Bắc Bộ Plain	1004600	633170	1637770	1452860	1252700	2705560
2	Midland and mountainous area in Bắc Bộ	265600	345160	610760	417100	726550	1143250
3	North Trung Bộ	204600	411710	616310	372600	739600	1112200
4	South Trung Bộ	272800	248990	521790	410900	348500	750400
5	Tây Nguyên	77800	130400	208200	108000	333730	441730
6	East Nam Bộ	1280600	226740	1507340	1632300	425380	2057380
7	Nam Bộ Plain	360600	520410	881100	470700	608650	1079350
8	Total	3466600	2516580	5983180	4855460	4435110	9290500

3-2 Surface water resources

The total average annual of surface water in Vietnam has about 830 billion m^3. Nearly 57% of this flow contributed from the Mekong River basin, more than 16% in the Red River basin, and more than 4% in Dong Nai river basin, where most of the economic and social development. More than 60% of Vietnam's surface water is produced overseas, an average of only 309 billion m^3 per year are produced in the territory of Vietnam. There are six basins depends on the flow coming from other countries. In the Mekong River basin, nearly 95% of the average annual surface flow is produced in the upper Mekong countries. Nearly 40% of the surface water in the Red River basin originates from China; 30% of the Ma River basin flow and 22% flow of it from the River Basin is come from from Laos; and nearly 17% flow of Dong Nai river basin is from Cambodia. The flow of the river basin Bang giang-Ky Cung flowing from China into Vietnam, and back to China. SrePok and Se San River flows contribute to Cambodia. Vietnam's surface water resources are unevenly distributed, not only in terms of space but also in time changes throughout the year. In the north, the dry season starts from October or November and in central and southern dry season starts later, usually in January 1st, dry season duration usually as 6 or 9 months. The river basins in the central area usually face on the longest dry seasons. Natural flow in the dry season accounts for 20-30% of the total annual flow. Water storage in reservoirs and water transfer related in dry season can create a big difference in the ability of water sources in dry season. Assuming this volume of water was used during the dry season that made flow in dry season of the rivers will rise to 23% - 46% of the total annual flow. Even count water storage and water transfer, there are still 6 basin received less than one third of the total surface water flow during the dry season. Most water demand occurs during this period. Considering the total annual flow of the river is not visible impact in the dry season, most of the basin and led to the thought that Vietnam has abundant water resources. But this figure varies reserves in the basin. An international standard for adequate water level is 1.700m^3 per year, and if water capabilities ranging from 1.700m^3 per year to 4.000m^3/year, the possibility of local water abnormalities are occurs. Meanwhile, even if the extra storage capacity of the reservoir (assuming that the reservoirs are fully charged at the end of the rainy season and the amount of water that can be used in the dry season) and the basin water transfer according to this standard with the current population of the Dong Nai river basin and eastern rivers clusters are at risk of water shortages unusual or local, and the Red River basin, Ma and Kon Rivers are approaching this level.

4. Water Resources Management and Policy

4.1. Groundwater resources

1. Management of quantity

Although the natural dynamic reserve present in table 1 shows great capacity of exploitable water (128,500,000 m^3), the real of economic and suitable exploitation is different from calculation. The groundwater exploitation is based on the use demand, supplementary resources and product cost.

At present, in the whole country, there are many water exploitation works. Fresh water requirement is always a worth problem.

To manage the quantity of groundwater, there are many projects with different solutions, but in general, following problems should be concentrated:

- To assess the potential reserve of each area, each region and each locality for advising the management and exploitation. Professional monitoring data, good background investigation and suitable methodology can help in evaluating reserve by time believably and quickly. But in general all of thing still lack or limited.

- To investigate and assess the current status of exploitation and use of groundwater in the whole country as well as its influence to the hydrosphere for finding the solution of management and planning and exploiting reasonably in time and space.

- To plan the exploitation area on the basic of equilibratory and sustainable development. For example, in Hà Nội city, the well fields are disposed along the Red and Đuống Rivers to ensure the supplementary source of the Pleistocene aquifer.

2. Management of quality

The quality of water is the most important factor in water supply. At present, all water sources have been polluted by human activities, that makes the quality of water declined and then, can not be used. Factors leading to the pollution of groundwater are shown in Table 3.

Issue of quality management is an urgent problem not only at present but also in the future. To manage and control the quality of water sources, we need to perform the following works:

- Obeying strictly protective requirements for water sources during the time of exploitation and use;

- Establishing protective areas and belts to protect aquifers;

- Managing successfully and controlling strictly waste and pollutant sources that lead to the degradation of water quality...

- Developing monitoring network for whole territorial, specialy for 6 hydrogeologycal as show above;

- Assessing the environmental impact to factors causing pollution and exhaustion of water sources, such as annulations of natural recharge source (forests, rivers, streams…), exploitation of water with large output and in long time, mineral exploitation causing serous influence to groundwater quality and reserves.

- Developing groundwater resources investigation and assessment in large scale and step by step to complete the water resources planning at least for the regions with more water demands.

Table 3. Factors leading to the pollution of groundwater in Việt Nam

No	Hydrogeological region	Factors leading to the pollution
1	West Bắc Bộ	Garbage, waste, fertilizer
2	East Bắc Bộ	Garbage, industrial waste, fertilizer, waste water, mining
3	Bắc Bộ Plain	Garbage, waste, fertilizer, pesticide, organic substance, Fe, Mn, nitrite compound, As, Hg, heavy metals, cyanide, cemetery, dump, trade village
4	Northern Trung Bộ	Garbage, waste, fertilizer, insecticide, chemical substances, ecological and chemical toxicants, organic matter
5	South Trung Bộ	Garbage, industrial waste, chemical substances, fertilizer, chemical toxicants, fluorite, metal elements...
6	Nam Bộ Plain	Garbage, industrial waste, fertilizer, insecticide, Fe, Al, heavy metals, chemical toxicants, organic matter...

4.2. Surface water resources

Currently, Vietnam water demands of each year approximately 80.6 billion m3, most of that volume comes from surface water. By 2020, this number is expected to rise to about 120 billion m3, with an increase of 48%. In which irrigation water is expected to increase by 30%, an industrial water demands increase of nearly 190%, 150% for urban and 90% for aquaculture. By 2020, although the use of water for irrigation has increased significantly and is still the largest user of water, but this share will decrease from 82% to 72%. Note that, all of that demands not includes for hydro electricity because this use 'do not consume' water, although water use by this sector can significantly alter flow distributions and sometimes leads to transfer water from this river to other rivers. It is expected that the river basin is a large increase such as Tra Khuc, Kon River, three clusters eastern rivers such as Sre Pok and Se San River.

4.3. Institutional arrangements and law

This is the inevitable problem with water sector because it related with a lot of other industry sectors with more dark patches and a lack of clarity institutional arrangements. In government organizations, they often focusing on a stable of one organization rather than legal and requirements set out by the Government, and how to meet these requirements. There are much to do and requires a major change in thinking, to perform proper institutional arrangements based on the separation between the manager/executive resources from resource extraction operation.

5. Problems Related to Water Resources

There are a number of challenges issues across all disciplines of water, and the whole industry in general. If no action for this fundamental problem, what can be affected on not only water resources and water ecological systems but also on the whole of industry that leading to inefficient investment, unsustainable, and results can made not optimum of the economic and social.

In general, groundwater resources in Vietnam are not overexploited, but if we consider the concentrated water extraction, the situation is different. In Hanoi, the groundwater level has dropped more than 1m per year in some areas, and has reduced total 30m. Many places in Ho Chi Minh City, the underground water level is reduced to 30 m, and in many other places in the Mekong river basin, groundwater levels also decreased greatly. In Taynguyen Plateau areas where coffee plantations development, the groundwater levels there drawdown quickly because overexploited for irrigation. According to the investigation collection, the water levels here sometime decreases 2.5m per year. Reduced groundwater levels can also increase land subsidence in some areas in Hanoi, although the effect of lowering the water level, as opposed to the impact of construction techniques, however, this issue has not been studied. Reduced groundwater levels also increase arsenic concentrations in the deeper aquifers that are currently exploited for public water supply (being absorbed into the floor from the shallow aquifer).

Vietnam facing more challenges with shallow groundwater contamination what affected by over exploitation, industrial facilities, and due to the use of fertilizers and pesticides in agriculture, fisheries activities by mining, and waste. Currently there is no detailed scientific assessments, the areas "vulnerable" is before the impact of groundwater pollution are areas where aquifers are not limited to, a high concentration of activities potential pollutants and where communities and cities depend on ground water as drinking water supply activities. This particular issue also occurs on the coastal provinces beside water intrusion. As approved by many scientists that contaminated groundwater is very difficult to clean with very high cost. If not avoid that pollution or remedy the groundwater contamination groundwater pollution not only causes a major threat to public health, but also for operations and other industries requiring groundwater high quality.

The water resource information very necessary for decision making and water resources management. The national water resources monitoring network only concentrated in a few areas but with low density and measurement by hand. For water resources assessment, this lack needs to be resolved.

6. Plans for Cooperation to Solve the Problems

To well perform the task of management and protection of precious groundwater resource, we need realize the following works:

- Urging perform law of water resources;
- Strictly realizing guides, decrees and under-law documents. Managing successfully the works of drilling for groundwater exploitation. Listing water exploitation works to establish database for different works;
- Propagandizing broadly to people the ways to exploit and use water effectively and economically. By late years of this decade, all people should have good sense in the protection of water resource;
- Research for building protecting zones for water sources, especially in present exploiting areas such as Hà Nội, Hồ Chi Minh Cities and other urban areas…
- Modernizing water management work. It is necessary to have immediately courses on water management for individual, community and organizations related to the exploitation and protection of groundwater;
- Processing pollutant and toxic waste sources which influence on water sources; Set more cooperation for develop projects assess water intrusion in Vietnam coastal central part.
- Cooperation for create projects of water resources Planning in the 9 biggest river basins of Vietnam.

7. Conclusion

Water Resources in Vietnam plays an important role in any sections of country's development. With reserves not rich and distributed very evenly in area and over time that lead happened there are more area lack water supply. Lack water can happen almost of the dry season or a few months and occurs not only in the northern part but also in the southern part and especially in the center areas. Water resource problems encountered in most of the periods, from management, lack of resources, pollution and salt water intrusion, over exploitation, lack of water resources planning and water resources protection. The issue must be identified and handing of international friends. For that reason urging develop more international cooperation not only in research but also for application and transfer technology. With the priority period planning (2016-2020) is to promote water investigation in the island and high mountains area, solving the problems of water pollution, groundwater intrusion as well as establishment of nationwide water resources planning.

8. References

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VIETNAM MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
NATIONAL CENTRE FOR WATER RESOURCES PLANNING AND INVESTIGATION

VIET NAM WATER RESOURCES, STATUS AND SOLUTIONS

The 2nd JPDC-KIGAM-CCOP Workshop on
'Solution for Groundwater Problems' in CCOP Region

MR. NGUYEN CHI NGHIA
Director of water resources monitoring Department
National Center for Water Resources Planning and Investigation (NAWAPI)

Jeju, 10/2014

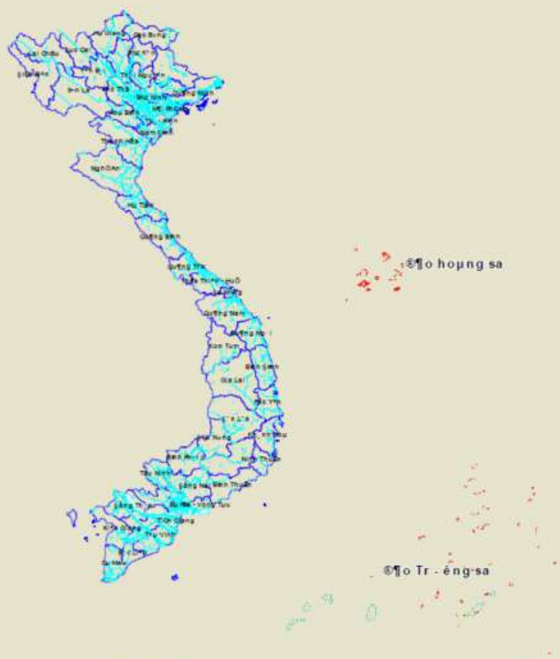
Content

1. Introduction
2. Vietnam Surface water status
3. Vietnam Groundwater status
4. Water Resources Management and Policy
5. Plans for Cooperation to Solve the Problems
6. Conclusion

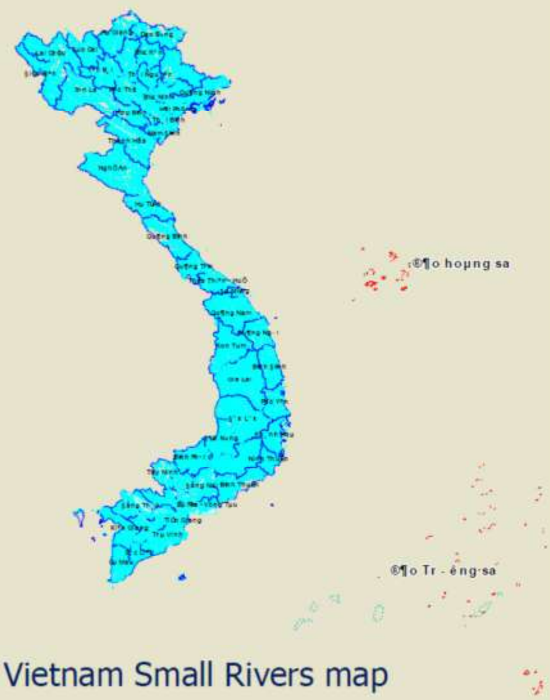
Introduction

In Vietnam, water resources are managed by Ministry of Natural resources and Environment (MONRE). Vietnam has over 3200 rivers, with 9 bigger river basins. Water resources has importance role for social develop in Vietnam. There are more regions facing water problems in the dry seasons. The groundwater is main water resources for domestic water supply in many cities and provinces. Up to now, we completed hydrogeological map scale 1: 200.000 for whole territory. In the key regions, we completed the hydrogeological map scale 1:100.000 and scale 1:50.000. Surface water is very importance sources in VN, we completed assessment surface water resources for nice bigger river basins. We are going to do water resources planning for 2 biggest river basin in Vietnam. Besides that, for water resources information, the water resources monitoring in the 5 regions was developed and observation of nearly 25 years (GW) and 50 years (SW).

Vietnam Surface water resources



Vietnam Big Rivers map



Vietnam Small Rivers map

Vietnam Surface water resources

In Vietnam, The total average annual of surface water in Vietnam has about 830 billion m^3. Nearly 57% of this flow contributed from the Mekong River basin, more than 16% in the Red River basin, and more than 4% in Dong Nai river basin, where most of the economic and social development. More than 60% of Vietnam's surface water is produced overseas, an average of only 309 billion m3 per year are produced in the territory of Vietnam. There are six basins depends on the flow coming from other countries. In the Mekong River basin, nearly 95% of the average annual surface flow is produced in the upper Mekong countries. Nearly 40% of the surface water in the Red River basin originates from China; 30% of the Ma River basin flow and 22% flow of it from the River Basin is come from from Laos; and nearly 17% flow of Dong Nai river basin is from Cambodia. The flow of the river basin Bang giang-Ky Cung flowing from China into Vietnam, and back to China. SrePok and Se San River flows contribute to Cambodia. Vietnam's surface water resources are unevenly distributed, not only in terms of space but also in time changes throughout the year. In the north, the dry season starts from October or November and in central and southern dry season starts later, usually in January 1st, dry season duration usually as 6 or 9 months.

Vietnam GW resources

In Vietnam, the hydrogeological national map scale of 1: 1.000.000 was created, which divided into 7 hydrogeological regions. 1) West Bắc Bộ HGR located in folded mountain structure in West Bắc Bộ. This is a complicated hydrogeological region (HGR). 2) East Bắc Bộ HGR belonging to formation of mountain ous area in East Bắc Bộ. 3) Bắc Bộ Delta HGR including the whole delta plains in North Việt Nam, which extends from Việt Trì City to the East Sea. This delta is built up by Red and Thai Binh River systems. 4) North Trung Bộ HGR including coastal plain provinces in the north of Central of Việt Nam such as Thanh Hóa, Nghệ An, Hà Tĩnh, Quảng Bình and Thừa Thiên – Huế. 5) South Trung Bộ HGR including coastal plain provinces in the south of Central of Việt Nam such as Tuy Hoà, Bình Thuận and Nha Trang – Khánh Hoà. 6) Central highlands region including Gialai, LamDong, Kontum, Daknong and Daklac provinces. 7) Nam Bộ Delta HGR including the whole delta plain belonging of Mekong and Đồng Nai River systems.

Vietnam Hydrogeology regions map

Vietnam GW resources

Natural dynamic reserves of groundwater in Vietnam territory

Water-bearing formation	Natural dynamic reserve (m^3/s)					
	East Bắc Bộ	West Bắc Bộ	Bắc Bộ Delta	North Nam Bộ	South Trung Bộ	Nam Bộ Delta
Loose sediments	2.25	9.095	88.865	83.17	48.535	158.25
Basalts	-	-	-	13.005	51.300	-
Carbonate	12.55	40.97	-	22.8	-	-
Terrigenous sediments	35.85	27.97	-	120.517	47.530	-
Metamorphic rocks	27.65	86.945	-	69.565	62.84	-
Intrusives	47.128	40.79	-	72.904	108.62	-
Mixed formations	114.165	47.742	-	85.032	-	-
Total	239.4	214.832	88.865	466.966	312.825	158.25

Vietnam GW resources

Forecasted water demand until 2014

No	Area	2010 (m^3/ng)			2014 (m^3/ng)		
		Urban area	Rural area	Total	Urban area	Rural area	Total
1	Bắc Bộ Plain	1004600	633170	1637770	1452860	1252700	2705560
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Water Resources Management and Policy

Surface water resources

Currently, Vietnam water demands of each year approximately 80.6 billion m^3, most of that volume comes from surface water. By 2020, this number is expected to rise to about 120 billion m^3, with an increase of 48%. In which irrigation water is expected to increase by 30%, an industrial water demands increase of nearly 190%, 150% for urban and 90% for aquaculture. By 2020, although the use of water for irrigation has increased significantly and is still the largest user of water, but this share will decrease from 82% to 72%. Note that, all of that demands not includes for hydro electricity because this use 'do not consume' water, although water use by this sector can significantly alter flow distributions and sometimes leads to transfer water from this river to other rivers. It is expected that the river basin is a large increase such as Tra Khuc, Kon River, three clusters eastern rivers such as Sre Pok and Se San River.

Water Resources Management and Policy

Groundwater resources

- *Management of quantity*

Natural dynamic reserve present shows great capacity of exploitable water (128,500,000 m^3), the real of economic and suitable exploitation is different from calculation. To manage the quantity of groundwater, there are many projects with different solutions, but in general, following problems should be concentrated:

- To assess the potential reserve of each area, each region and each locality for advising the management and exploitation. Professional monitoring data, good background investigation and suitable methodology can help in evaluating reserve by time believably and quickly. But in general all of thing still lack or limited.
- To investigate and assess the current status of exploitation and use of groundwater in the whole country; planning and exploiting reasonably in time and space.
- To plan the exploitation area on the basic of equilibratory and sustainable development.

Water Resources Management and Policy

Groundwater resources

- *Management of quantity*

At present, more water sources have been polluted by human activities, that makes the quality of water declined and then, cannot be used.

To manage and control the quality of water sources, we are perform the following works:

- Obeying strictly protective requirements for water sources during the time of exploitation and use;
- Establishing protective areas and belts to protect aquifers;
- Managing successfully and controlling strictly waste and pollutant sources that lead to the degradation of water quality...
- Developing monitoring network for whole territorial, specially for 7 hydrogeologycal as show above;
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- Developing groundwater resources investigation and assessment in large scale and step by step to complete the water resources planning at least for the regions with more water demands.

Problems Related to Water Resources

In Vietnam, there are a number of challenges issues across all disciplines of water, and the whole industry in general. What can be affected on not only water resources and water ecological systems but also on the whole of industry that leading to inefficient investment, unsustainable, and results can made not optimum of the economic and social.

In general, groundwater resources in Vietnam are not overexploited, but if we consider the concentrated water extraction, the situation is different. In Hanoi, the groundwater level has dropped more than 1m per year in some areas, and has reduced total 30m. Many places in Ho Chi Minh City, the underground water level is reduced to 30 m, and in many other places in the Mekong river basin, groundwater levels also decreased greatly. In Taynguyen Plateau areas where coffee plantations development, the groundwater levels there drawdown quickly because overexploited for irrigation. According to the investigation collection, the water levels here sometime decreases 2.5m per year.

Problems Related to Water Resources

Vietnam facing more challenges with shallow groundwater contamination what affected by over exploitation, industrial facilities, and due to the use of fertilizers and pesticides in agriculture, fisheries activities by mining, and waste. Currently there is no detailed scientific assessments, the areas "vulnerable" is before the impact of groundwater pollution are areas where aquifers are not limited to, a high concentration of activities potential pollutants and where communities and cities depend on ground water as drinking water supply activities. This particular issue also occurs on the coastal provinces beside water intrusion. As approved by many scientists that contaminated groundwater is very difficult to clean with very high cost. If not avoid that pollution or remedy the groundwater contamination groundwater pollution not only causes a major threat to public health, but also for operations and other industries requiring groundwater high quality.

The water resource information very necessary for decision making and water resources management. The national water resources monitoring network only concentrated in a few areas but with low density and measurement by hand. For water resources assessment, this lack needs to be resolved.

Plans for Cooperation to Solve the Problems

1. Urging perform law of water resources;
2. Strictly realizing guides, decrees and under-law documents. Managing successfully the works of drilling for groundwater exploitation. Listing water exploitation works to establish database for different works;
3. Propagandizing broadly to people the ways to exploit and use water effectively and economically. By late years of this decade, all people should have good sense in the protection of water resource;
4. Research for building protecting zones for water sources, especially in present exploiting areas such as Hà Nội, Hồ Chi Minh Cities and other urban areas…
5. Modernizing water management work. It is necessary to have immediately courses on water management for individual, community and organizations related to the exploitation and protection of groundwater;
6. Processing pollutant and toxic waste sources which influence on water sources; Set more cooperation for develop projects assess water intrusion in Vietnam coastal central part.
7. Cooperation for create projects of water resources Planning in the 9 biggest river basins of Vietnam.

Conclusion

1. Water Resources in Vietnam plays an important role in any sections of country's development. With reserves not rich and distributed very evenly in area and over time that lead happened there are more area lack water supply. Lack water can happen almost of the dry season or a few months and occurs not only in the northern part but also in the southern part and especially in the center areas.
2. Water resource problems in Vietnam are encountered in most of the periods, from management, lack of resources, pollution and salt water intrusion, over exploitation, lack of water resources planning and water resources protection.
3. We are welcome and urging develop more international cooperation not only in research but also for application and transfer technology. With the priority period planning (2016-2020) is to promote water investigation in the island and high mountains area, solving the problems of water pollution, groundwater intrusion as well as establishment of nationwide water resources planning.

Thanks for your attention!

Country Report

일본

< Japan >

Submitted by

Dr. Reo IKAWA

Geological Survey of Japan, AIST

Current Status and Issues related to Water Resources Management in Japan

1. Summary

Appropriate water resource management is a very important component of sustainable development in Asian countries. Indeed, this importance is reflected by the adoption of a variety of efforts related to water resource management by CCOP member countries. In Japan, the lack of a comprehensive understanding of the water cycle meant that issues related to the management of surface and groundwater resources were previously managed by different ministries and laws. However, a new law for the comprehensive management of water resources in Japan was enacted in March 2014 (Water Cycle Act). Based on the new law, groundwater will now be treated as a public resource, which is how surface water is currently treated. Consequently, knowledge of hydrology and hydrogeology and how they relate to water management will likely become increasingly important in the future. In addition, developing and improving catchment-scale hydrogeological map based on rigorous scientific methods is currently being undertaken by the Geological Survey of Japan.

2. Hydrogeological Setting

Diluvium and alluvium in Quaternary sediments constitute the main groundwater reservoirs in Japan. Additionally, A part of Neocene sediments and pyroclastic flow sediments derived from eruptions in the Tertiary to Quaternary periods also constitute important groundwater reservoirs in volcanic areas, such as Kyushu Island. Japan also has numerous plains and basins that vary in scale and which are underlain by thickly distributed unconsolidated clastic sediments and volcanic products from the Quaternary period. The coarse-grained parts of these sediments function as active aquifers (Agricultural Ground water Research Group, 1986).

2-1 Alluvium

Alluvium of the coastal plain consists of deltaic sediments deposited by transgression from the late Pleistocene to the Holocene inter-bedded with unconsolidated clay and silt. The alluvium of most plains is composed of a lower sandy layer (confined aquifer), a middle clay and silty layer (impermeable layer), and an upper sandy layer (unconfined aquifer). It is this soft impermeable layer that is responsible for land subsidence when the groundwater level falls.

2-2 Diluvium

Diluvium deposited from the middle to the late Pleistocene constitutes a large part of the groundwater reservoirs in Japanese plains. Geological layers consist of alternating fine and coarse sediments. Moreover, pyroclastic flow sediment and limestone from the middle to late Pleistocene constitute the major aquifers on the islands of Kyushu and Okinawa, respectively.

2-3. Neogene layer

The role of the Neogene layer as a groundwater reservoir is somewhat limited by the relatively high degree of consolidation associated with geological compaction. Consequently, this layer is typically treated as basement rock layer and not as an aquifer.

3. Status of Water Resources

3-1 Precipitation

Japan is located at the eastern end of the Asian monsoon region. Annual mean precipitation from 1981 to 2010 was 1690 mm, which is twice the world average (810 mm). Fig. 1 shows regional precipitation in Japan; precipitation in southern Japan is higher than that in the north. Annual precipitation for the period 1900 to 2010 is shown in Fig. 2. The data shows a decreasing trend in precipitation over time, particularly in recent decades, with a marked difference between wet and dry years.

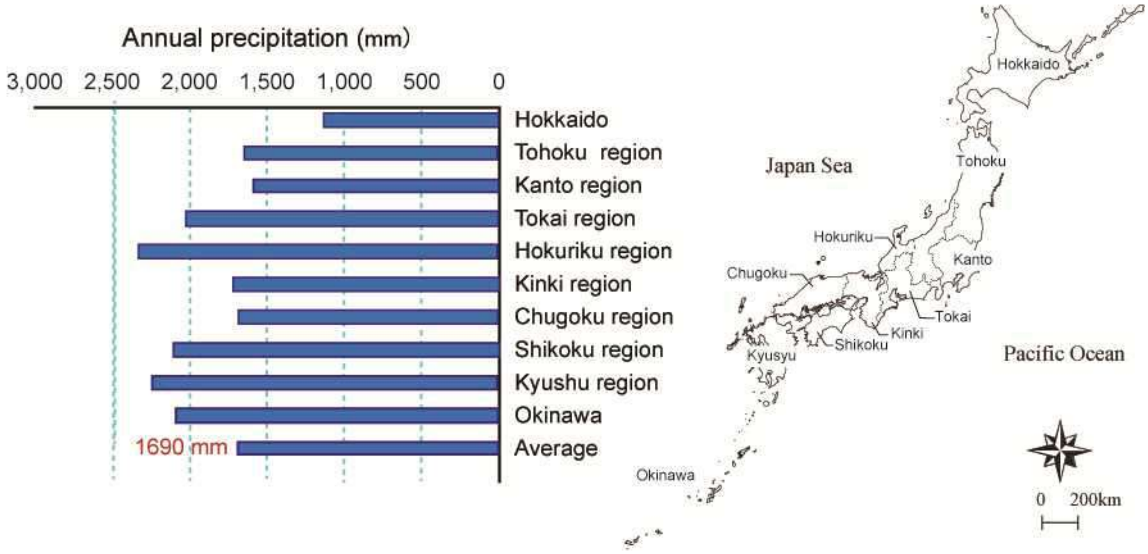


Fig. 1 Annual precipitation in different regions of Japan.

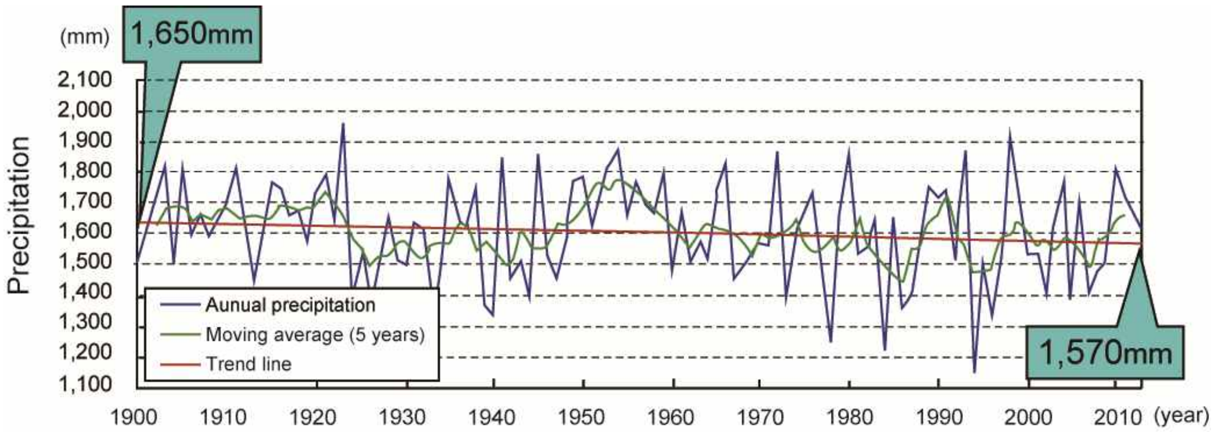


Fig.2 Trend in precipitation in Japan over time (MLIT, 2013).

3-2 Amount of available water resources

The amount of water resources per person (Q) was calculated by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) using the following equation (MLIT 2013):

$$Q = (P\text{-}ET) \times A \div TP$$

where P, ET, A, and TP refer to precipitation, evapotranspiration, total land area, and total population, respectively. In 2013, Q was estimated to be 3400 m^3/person, which is less than half the global average (8000 m^3/person). The relationship between amount of water resources and water consumption in Japan is shown in Fig 3. Annual water consumption (809×10^8 m^3) accounts for only 20% of the annual amount of available water resources (4100×10^8 m^3).

In Japan, the effective utilization of water resources is complicated by the unique hydro-topographical characteristics of the country, including precipitous mountains, short rivers, and high summer rainfall during the typhoon season. As a result, a large proportion of the annual precipitation is not utilized as it flows into the sea. Eighty-nine percent of the water that is used in Japan is river water, and dependence on groundwater is not large.

3-3. Actual state of water resource utilization

Fig. 4 shows the different uses of water consumption in Japan over time. The figure shows that water consumption has decreased gradually since the second half of the 1990s. Agricultural water utilization accounts for 70% of overall water consumption. The water used to irrigate paddy fields, which previously accounted for a large proportion of agricultural water usage, has decreased with the decline of rice cultivation area in recent years. Domestic and commercial water use has also decreased since the second half of the 1990s. The amount of freshwater from rivers and groundwater used for industrial purposes has also decreased since 1975 due to the implementation of water recycling measures.

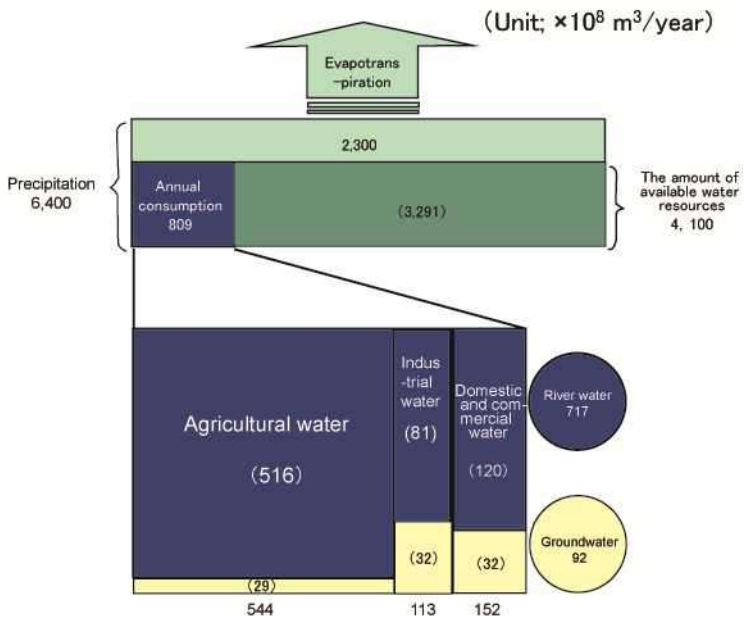


Fig. 3 Relationship between water resources and consumption in Japan (MLIT (2013)).

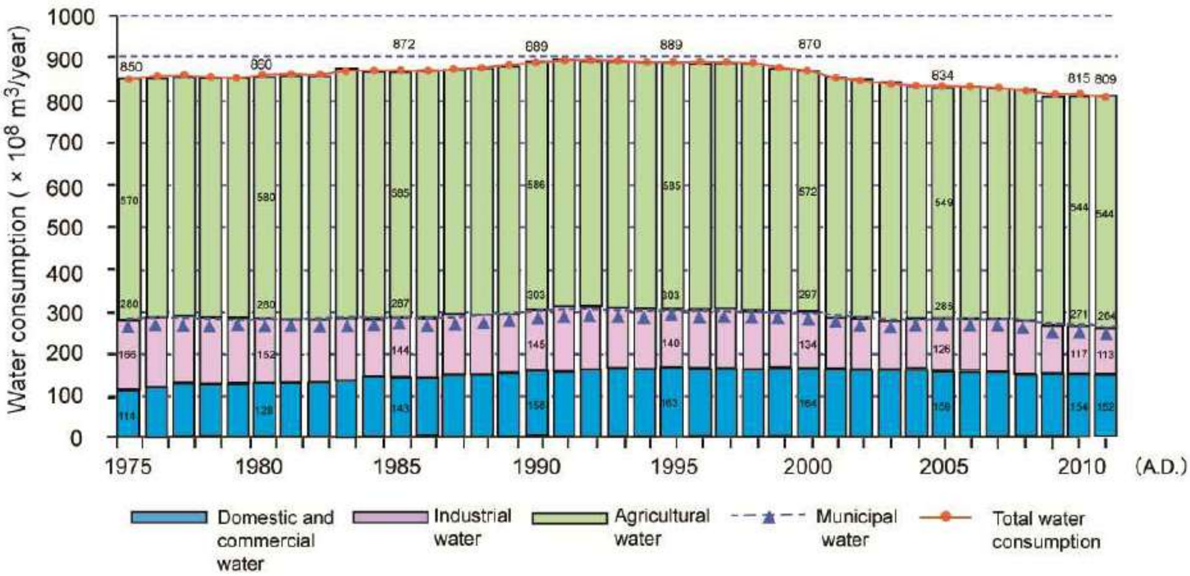


Fig. 4 Consumption and application of water resources from 1975 to 2011 (MLIT, 2013).

4. Water Resources Management and Policy

Japanese ministries and laws dealing with the management of water resources have changed as the focus and items being monitored have changed (Fig. 5). Water resource management was previously complicated by the involvement of many ministries. However, a new law for comprehensively managing water resources, the Water Cycle Act, was enacted in March 2014. Following promulgation of the law, considerable efforts have been made towards unifying water resource management in the country.

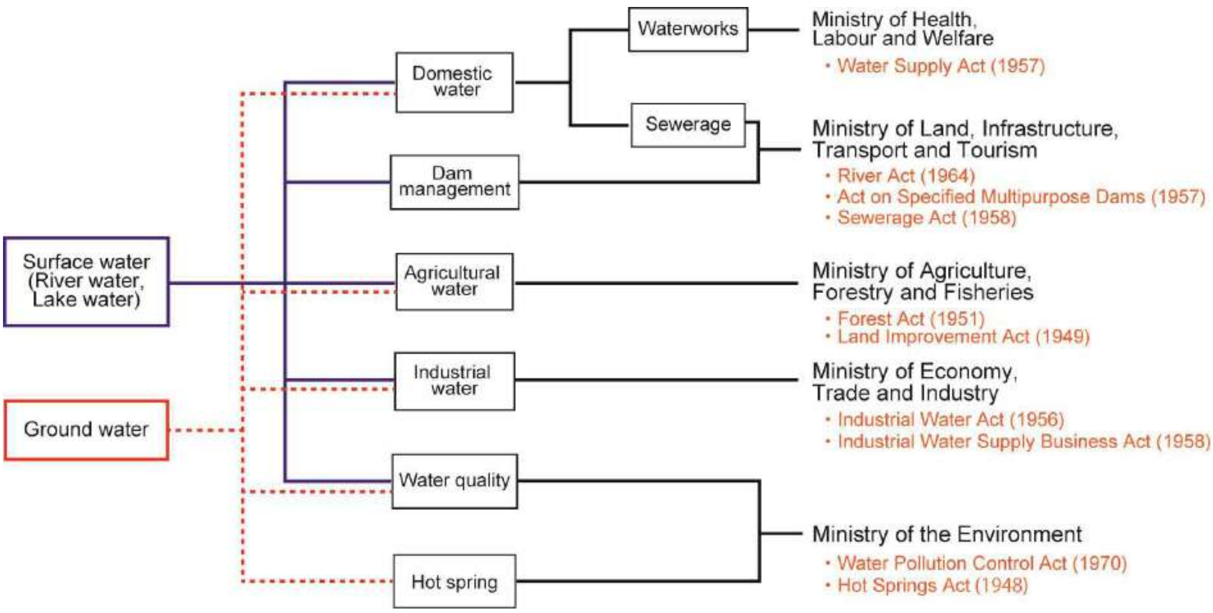


Fig. 5 Japanese ministries and laws related to water management.

5. Problems Related to Water Resources

As stated in section 3-2 above, river water accounts for 89% of water consumed in Japan. Groundwater accounts for 30% of industrial water, indicating the major role that groundwater plays in industry. Consequently, the problems related to surface and groundwater resources will be introduced separately in this report.

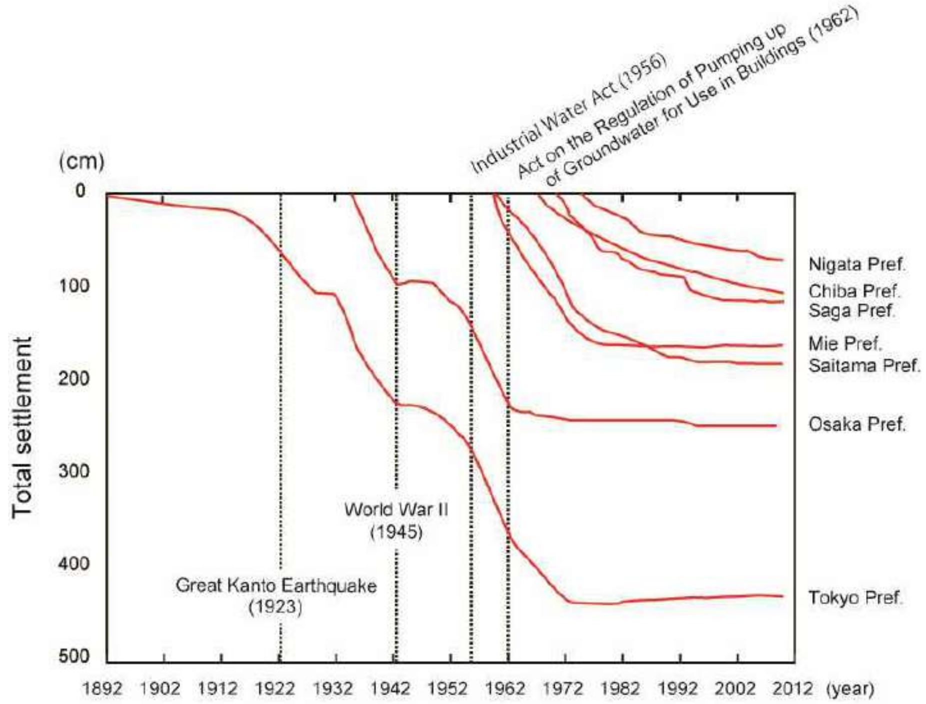
5-1. Surface water

Recently, the difference between precipitation in wet and dry years in Japan has increased (see Fig. 2). As stated in section 3-2 above, the steep gradient and relatively short length of most rivers in Japan means that a large proportion of precipitation flows directly into the sea. As a result, impounding rivers by constructing dams has historically been an important component of water resource management in Japan, and many impounding dams were constructed from 1940 to 1980.These dams have some serious problems for sustain able management, because dams are expensive to repair and maintain, resulting from superannuation now. Moreover, as the construction of hospitals and large commercial facilities in suburban areas has increased, with the spread of small high performance pumps and low cost filtration equipment, in these facilities, the groundwater extracted from the small-bore wells on site is mainly used as water supply. As a result, the income generated by the water services of local governments has decreased as groundwater utilization has increased. Consequently, the funds required to maintain the water supply infrastructure have also decreased, and water pollution caused by river and lake improvements has also become a problem.

5-2. Groundwater

Groundwater has been used for industrial purposes from the beginning of 1900. The utilization of groundwater has increased in large industrial facilities, and groundwater now accounts for 30% of industrial water. Consequently, serious land subsidence in some areas of Japan has resulted from this prolonged period of excessive groundwater pumping (Fig. 6). In addition, groundwater salination in coastal areas has also been reported (Murashita, 1982).

In order to prevent the extent of land subsidence, the Industrial Water Act, which regulates the groundwater pumping for industrial water, and the Act on the Regulation of Pumping up of Groundwater for Use in Buildings were enacted in 1956 and 1962, respectively. In response to the stipulations of these acts, most industrial factories have changed their water supply from groundwater to surface water. In response to this decrease in groundwater pumping, groundwater levels have gradually recovered and subsidence has been reduced since 1970 (Fig. 7). However, in recent decades, taking advantage of the thermostatic characteristics of groundwater, groundwater use has increased as the snow melting water in cold region. Consequently, significant decreases in groundwater levels and depletion of spring water during winter season have occurred in the urban areas of these regions (Photo 1 and 2). On the other hand, serious damages (i.e. water leakage) to und erground construction such as subway station and tunnels by the recovery of groundw ater level have been reported in areas where groundwater pumping is regulated.



Time variation of land subsidence in Japan (modified from MLIT (2013).

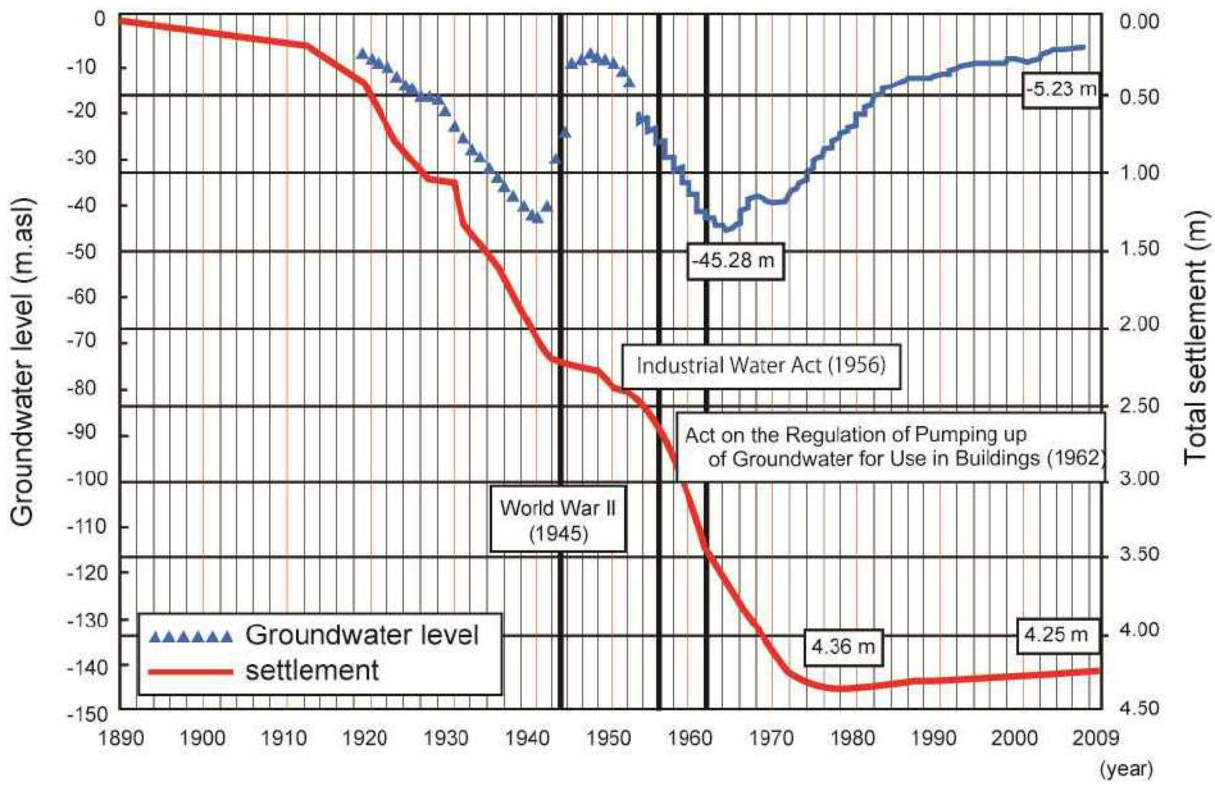


Fig. 7 Changes of groundwater level and total settlement in Tokyo (Kameido) over time (revised from Bureau of Environment, Tokyo Metropolitan Government (2011)).

Photo 1 Snow melting system using groundwater

Photo 2. Depletion of spring water

6. Plans for Cooperation to Solve the Problems

Based on the civil law (Article 207), surface water and groundwater are defined as being public and private resources, respectively in Japan. This separation of water resources into two separate entities has delayed the development and implementation of a comprehensive management plan for surface water and groundwater resources, even though the need for such a management plan was initially proposed more than 30 years ago by Nakanishi (1978). In recent years, the management approach regarding water resources in Japan has shifted from a development-type approach to a permanent management-type approach. In July 2013, the MLIT established a new water resource management department to orchestrate activities related to terrestrial conservation and water resource management at a national level. In addition, the Water Cycle Act, which deals with the management of groundwater and surface water resources, was enacted in 2014. The act clearly stipulates that all water resources, including groundwater and surface water, are the common property of the nation. On the other hand, local governments also exist that already have ordinances designating groundwater as public water. For example, Transboundary Groundwater Resource Management (Shimada, 2008) that was implemented among 11 local governments in the Kumamoto area of Kyushu Island, is a typical example of a groundwater management that targets transboundary aquifers in Japan. This management is an example of demand-side water management, in which groundwater users become administrators, and it is expected that such initiatives will expand to other regions in the future.

Additionally, in cold regions that use groundwater as snow melting water, artificial groundwater recharge by artificial recharge pond is promoted during the winter season (Photo 3). Citizen awareness of the need for groundwater protection is also high in these regions (Hida et al., 1999).

A Water Environment Map for the main groundwater basins in Japan has been compiled by the Geological Survey of Japan (see Fig. 8). It is expected that the demand for the hydrogeological map will increase as interest in groundwater resource management at a catchment-scale also increases.

Photo 3 Artificial recharge pond in Rokugo alluvium fan, Akita pref.

7. Conclusion

In Japanese water resource management, surface water and groundwater have historically been treated as separate entities. This problem has been compounded by the fact that separate ministries and laws were responsible for surface water and groundwater resources. Recently, however, the focus of water resource management in Japan has shifted from a development type approach to a permanent management type approach. In addition, in response to the need for a comprehensive water management framework for the country, the Water Cycle Act was enacted in 2014. The act is considered to represent a significant turning point in Japanese water resources management as

(a)

(b)

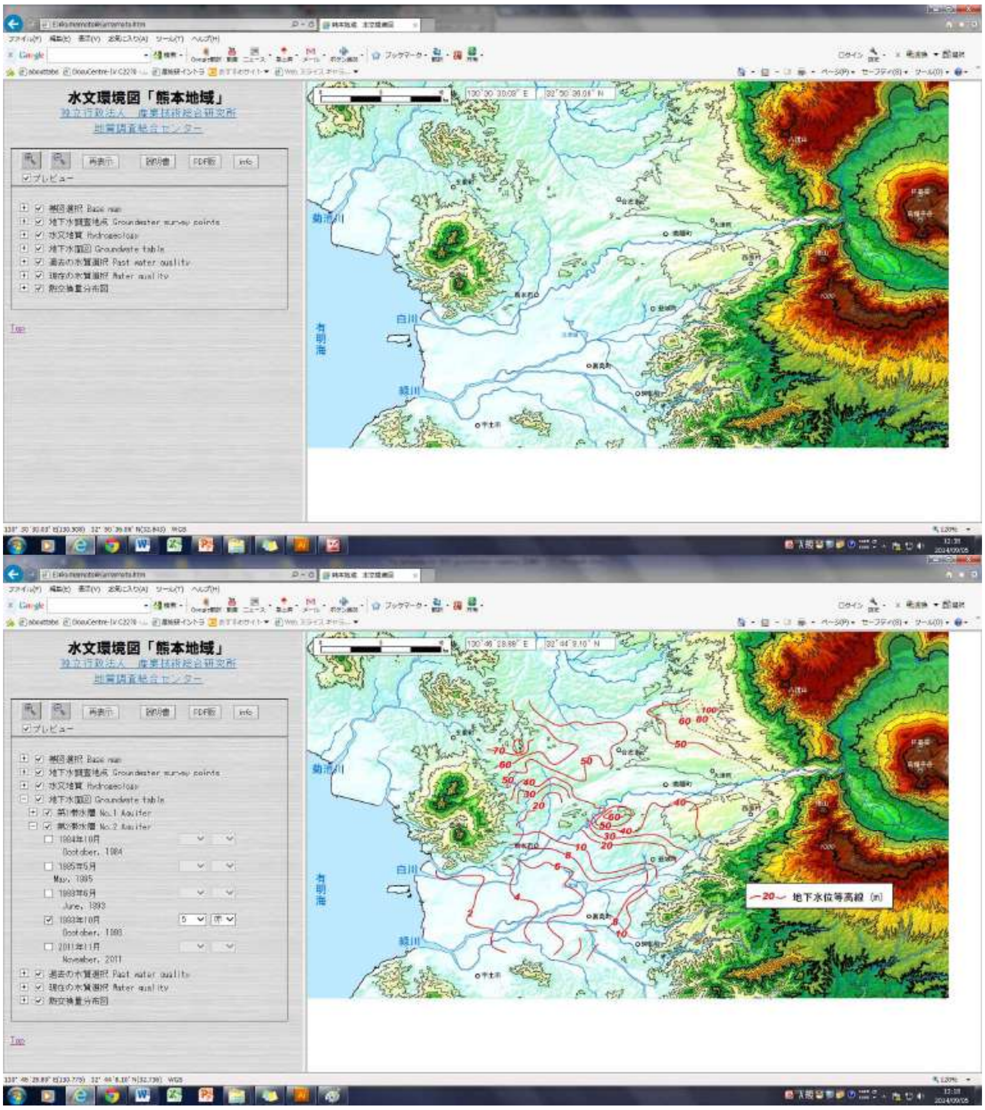


Fig. 8 Water environmental map "Kumamoto area" (Geological Survey of Japan, AIST (2014))

(a) Base topographical map. (b) Groundwater (hydraulic) potential map groundwater will henceforth be treated as “public resource”. Consequently catchment scale hydrogeological map compiled using rigorous scientific methods will also be required.

8. References

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Shimada J. (2008): Sustainable management of groundwater resources for over 700,000 residents in Kumamoto area, Japan. Proc. Of Symposium on Integrated Groundwater Science and Human Well-being, 36th IAH Cong., 104-111.

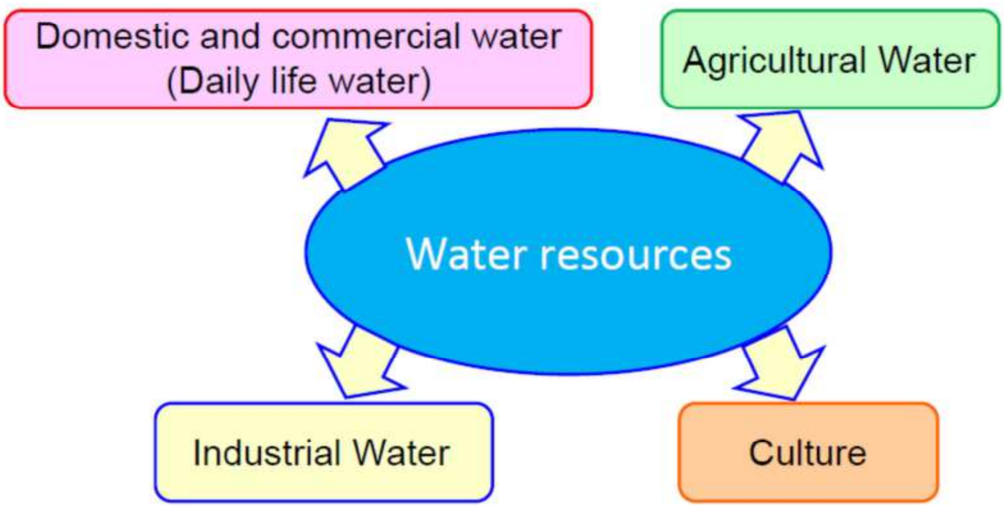
Current State and Issue related to Water Resources Management in Japan

(CCOP-KIGAM-JPDC 6th Jeju Water Forum)
6-8 October 2014

Reo IKAWA (Geological Survey of Japan, AIST)

Introduction

- Water resources management is key word for 21 century
  - ➡ It is essential to the development of country

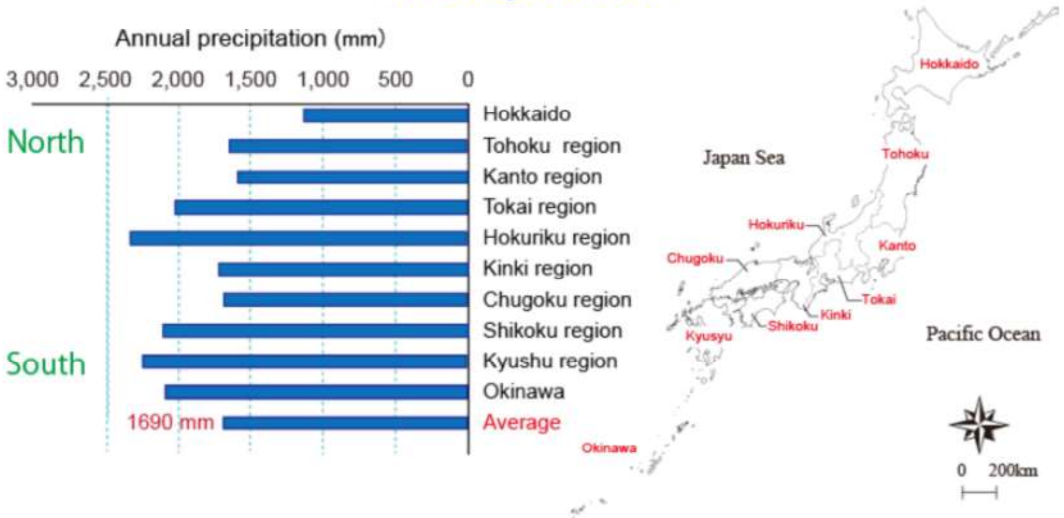


Introduce the current status of water resources in Japan.

1) Status of Water resources management and policy

Current state of water resources In Japan.

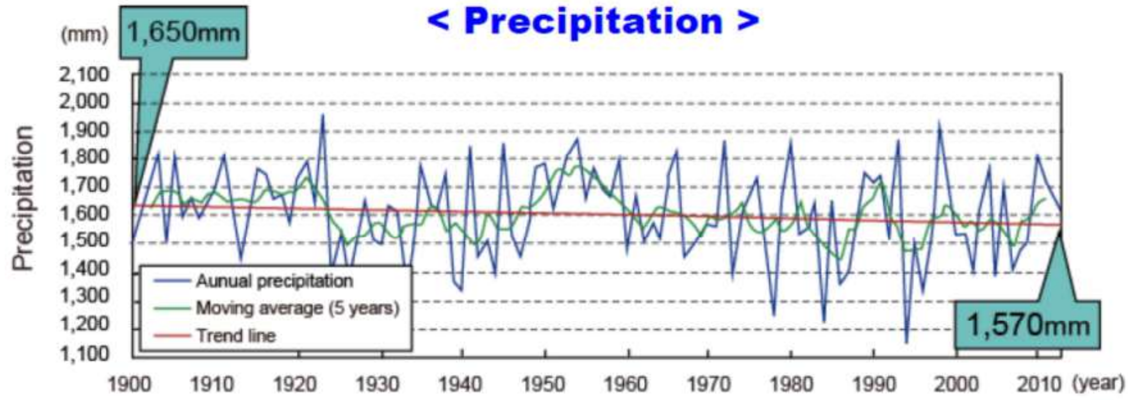
< Precipitation >



- Annual mean precipitation (1981-2010) : **1690 mm**
  (it is the twice the world average: 810mm)
- Precipitation: **South > North** (relatively)

Current state of water resources In Japan.

< Precipitation >



Annual precipitation trend in Japan

Precipitation (tend)		Range				
		Period	Min.	~	Max	Standard deviation
1900	1650 mm	1900 - 1909	-150	~	180	112.2
2013	1570 mm	2004 - 2013	-220	~	250	158.7

- Annual mean precipitation: 1900 (1650mm) > 2013 (1570mm)
- Standard deviation: 1900 (112.2) < 2013 (158.7)

⇨ **Effect of the Climate change ?**

Current state of water resources In Japan.

< Amount of available water resources >

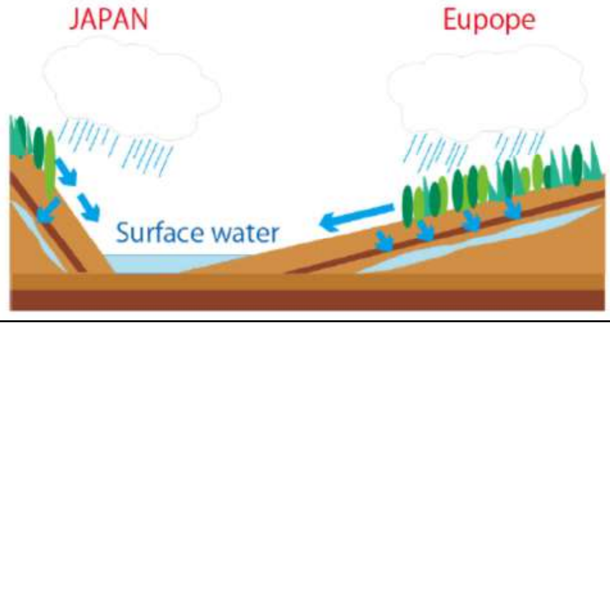
$$Q = \frac{(P - ET) \times A}{TP}$$

(MLIT, 2013)

Q: Amount of water resources (m^3/person)
P: Precipitation (mm)
ET: Evapotranspiration (mm)
A: Land area (m^2)
TP: Total population (person)

Q = 3400m^3/person (JAPAN) < 8000m^3/person (World average)

Because of high population (1276 million(2012)) and small land area (377,900 km^2)



Unique hydrological conditions In JAPAN

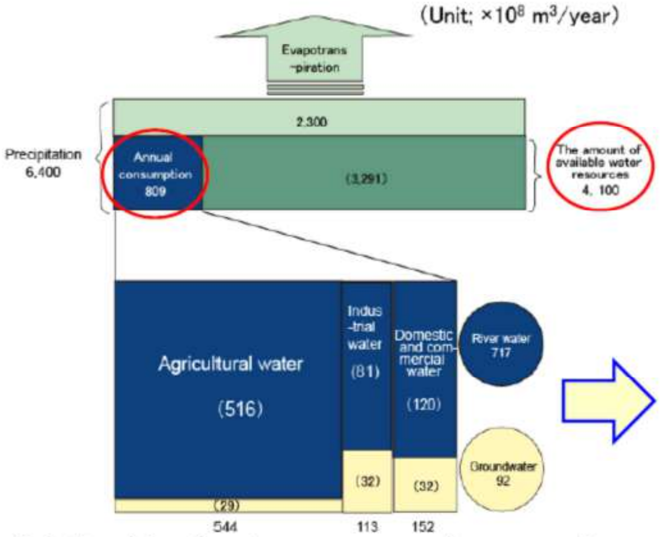
- Steep mountain
- Short-range river
- Large amount of rainfall in summer (i.e. Typhoon season)

➡ Rain water flow into the sea, directly!

Current state of water resources In Japan.

< Amount of available water resources >

As a result



Relationship of water resources and consumption in Japan

Actual consumption is only 20% of available water resources.

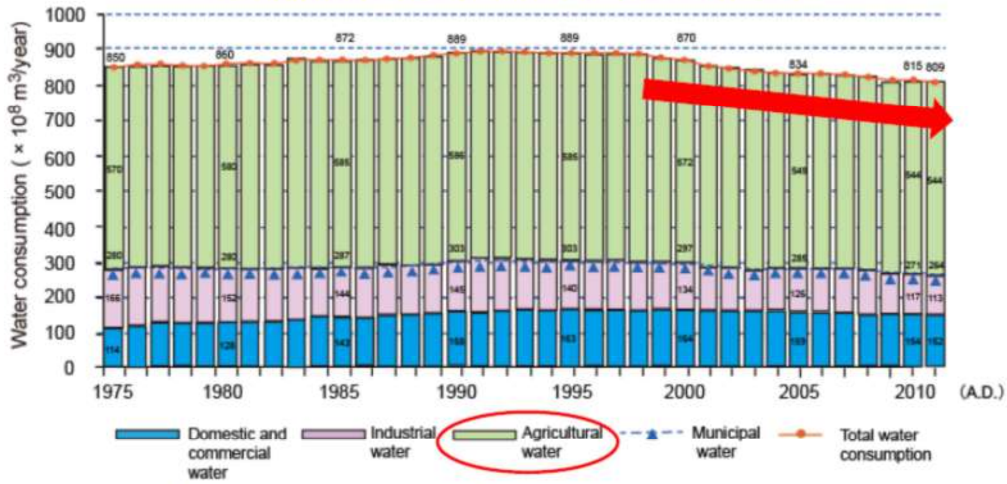
Moreover

River water account for 89% of water resources

Dependence of groundwater is very small.

Current state of water resources In Japan.

< Utilization of water resources>

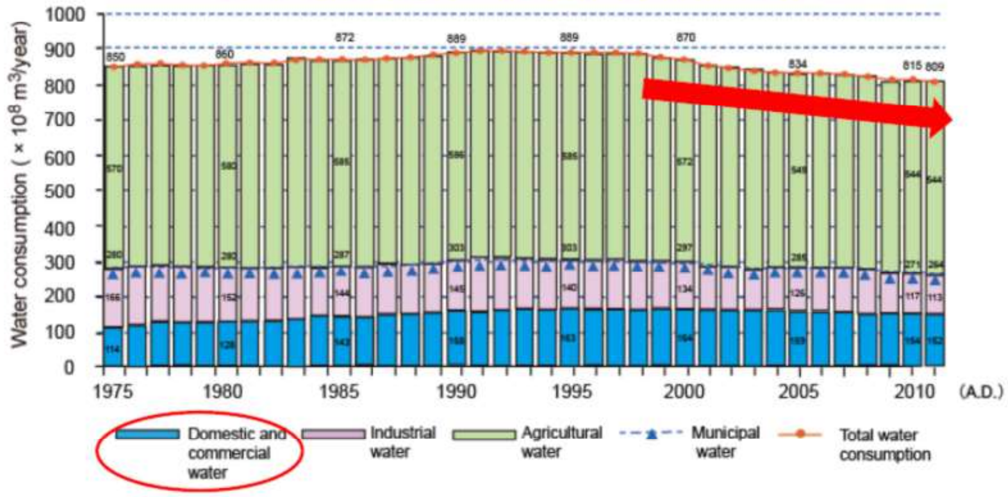


Use application of annual water consumption in Japan

- Agricultural water account for large part of water consumption.
- Agricultural water volume has been declined since 1999, because of reduction of the planted area.

Current state of water resources In Japan.

< Utilization of water resources>

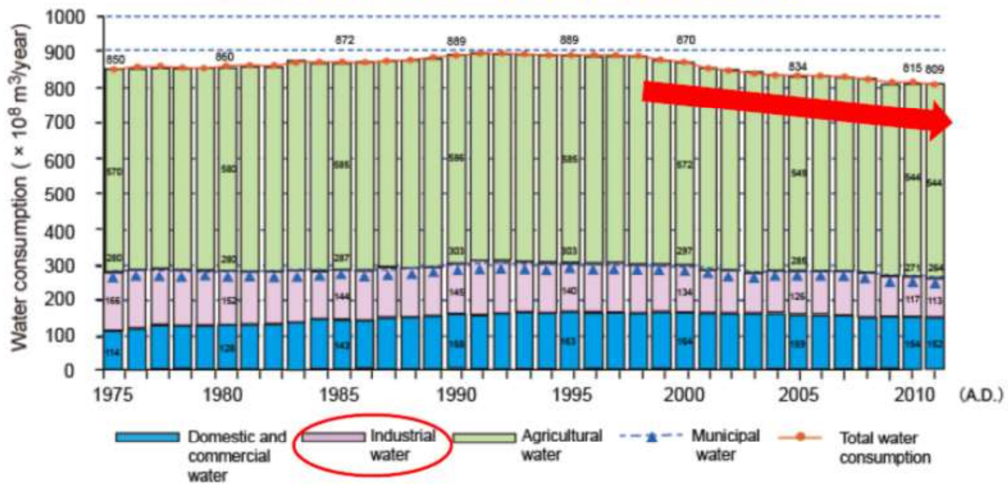


Amount of domestic and commercial water is also decrease, because of reduction of the daily personal water consumption with spread of energy-saving home electronics.

322 L/day (1995) → 289 L/day (2011)

Current state of water resources In Japan.

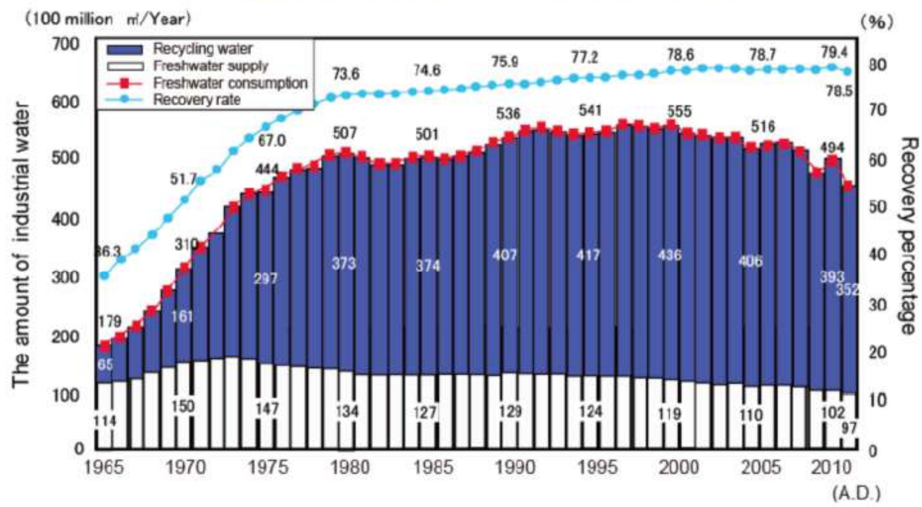
< Utilization of water resources>



Fresh water supply for the industrial water from river water and groundwater has been decreased since 1975.

Current state of water resources In Japan.

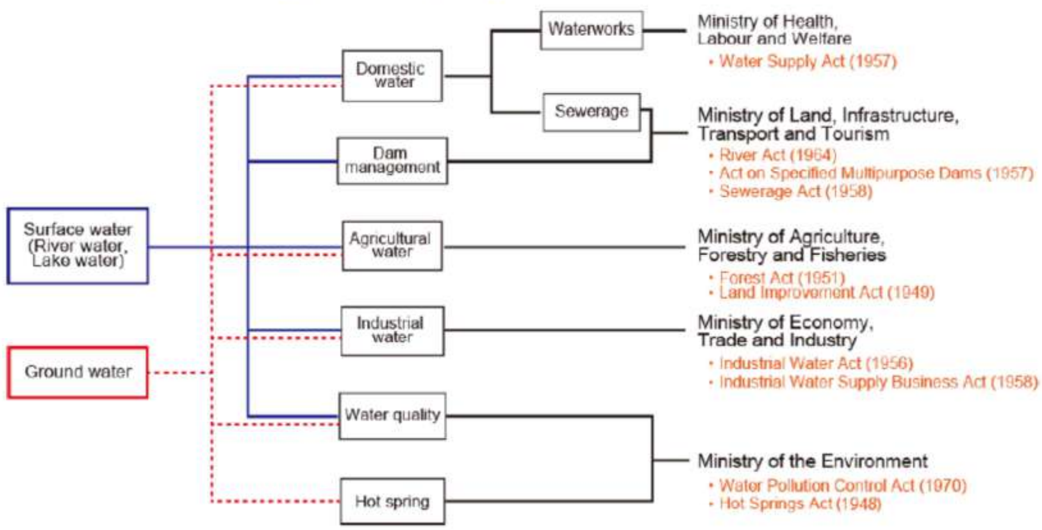
< Utilization of water resources>



Fresh water supply for the industrial water from river water and groundwater has been decreased since 1975.

⇨ Promotion of infrastructure equipment for recycling water.

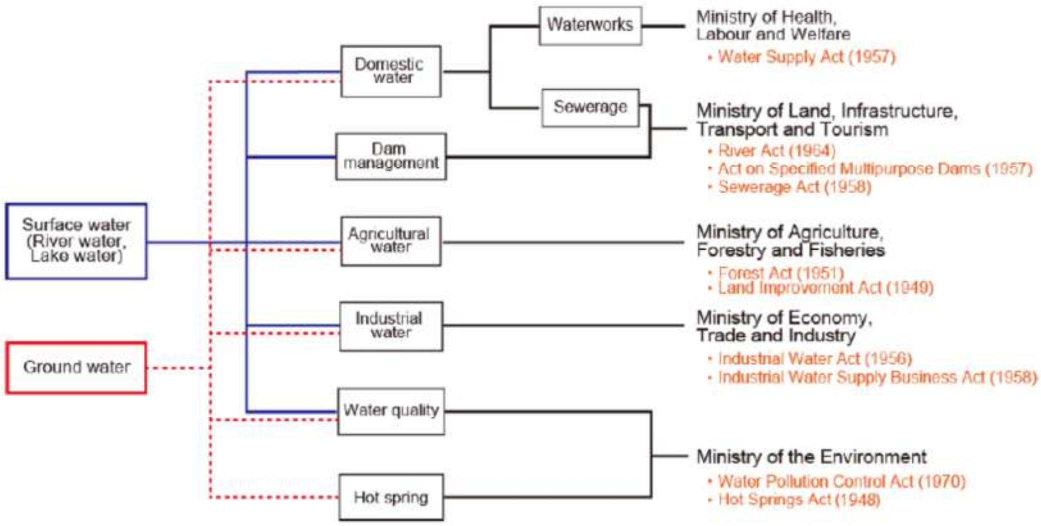
water resources management and policy



Water resources management is complicated by the existence of many relevant ministries and lows

The biggest problem is the lack of comprehensive management for surface water and groundwater

water resources management and policy



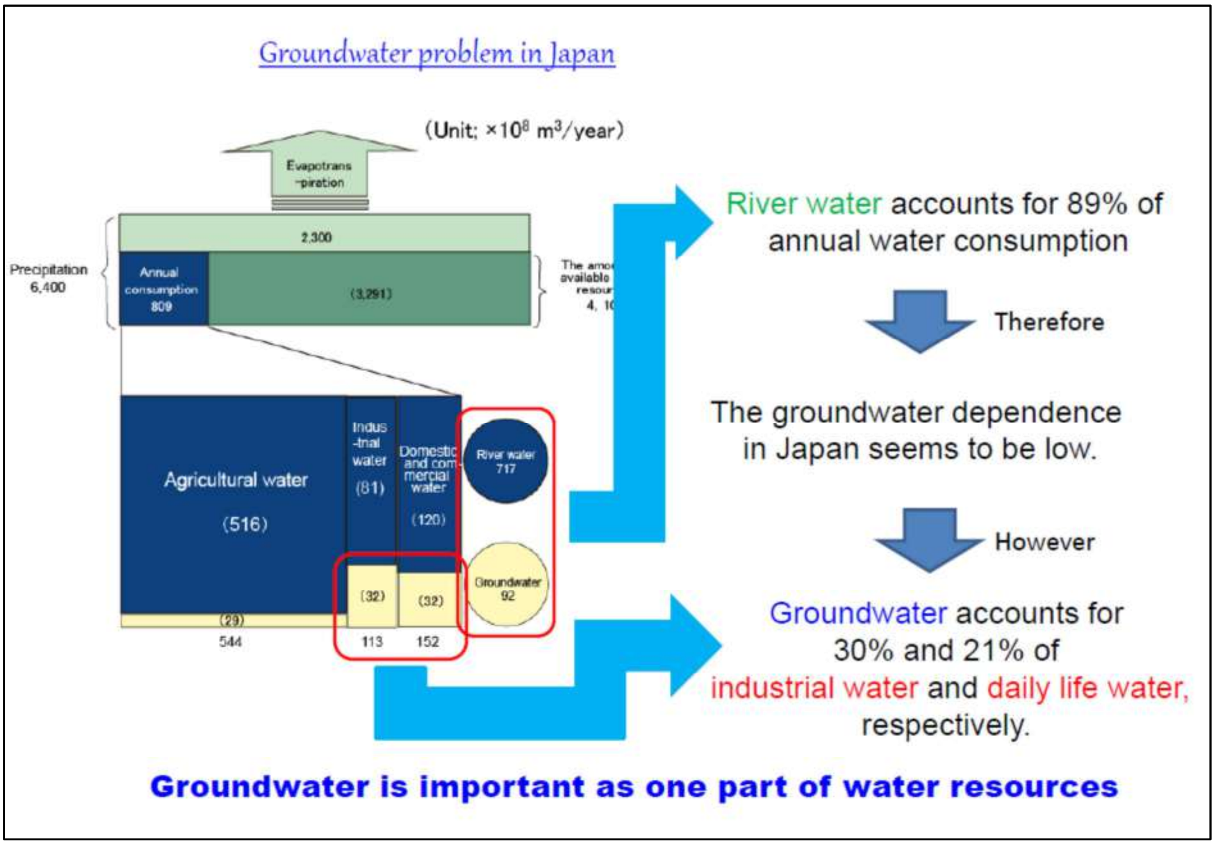
Water resources management is complicated by the existence of

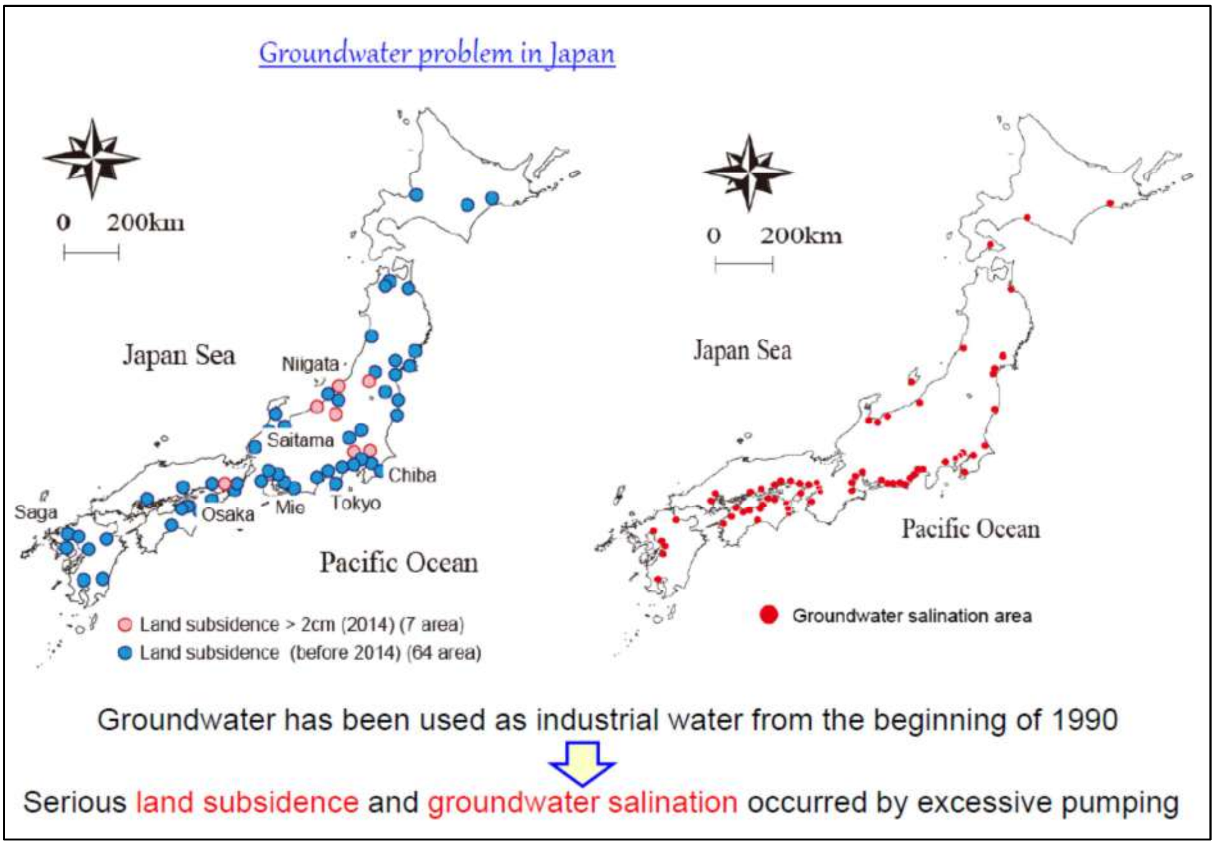
"Water Cycle Act" is enacted in March, 2014

(Law of the comprehensive management for water resources)

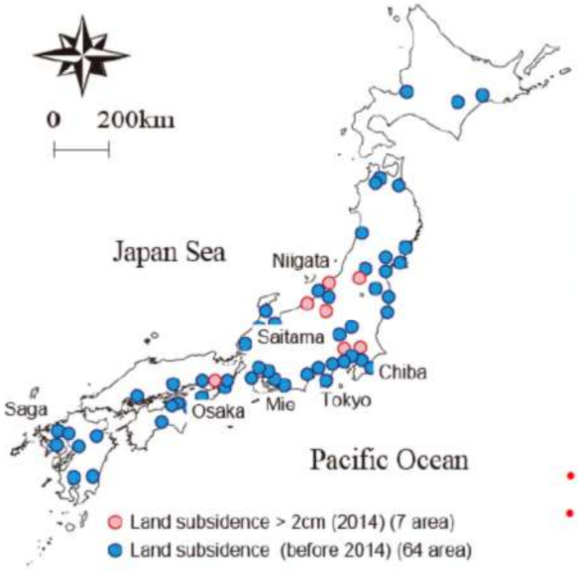
surface water and groundwater

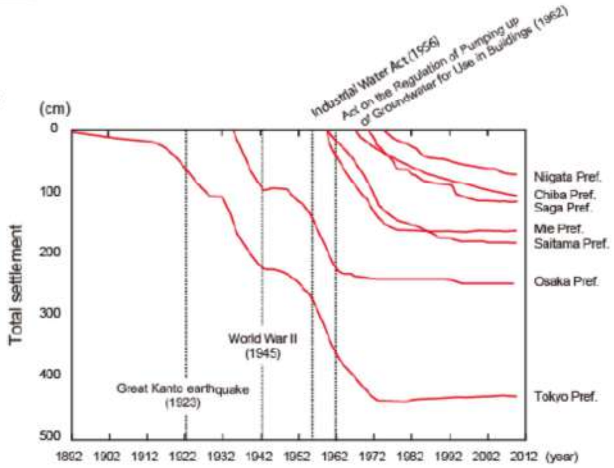
2) Groundwater-related problems and solutions for each country


Groundwater problem in Japan
(Unit; ×10⁸ m³/year)
Evapotrans -piration
2,300
Precipitation 6,400
Annual consumption 809
(3,291)
Agricultural water (516)
Indus -trial water (81)
Domestic and commercial water (120)
River water 717
Groundwater 92
(32)
(32)
(29)
544
113
152
River water accounts for 89% of annual water consumption
Therefore
The groundwater dependence in Japan seems to be low.
However
Groundwater accounts for 30% and 21% of industrial water and daily life water, respectively.
Groundwater is important as one part of water resources


Groundwater problem in Japan
0 200km
Japan Sea
Niigata
Saitama
Chiba
Tokyo
Mie
Osaka
Saga
Pacific Ocean
Land subsidence > 2cm (2014) (7 area)
Land subsidence (before 2014) (64 area)
0 200km
Japan Sea
Pacific Ocean
Groundwater salination area
Groundwater has been used as industrial water from the beginning of 1990
Serious land subsidence and groundwater salination occurred by excessive pumping

Groundwater problem in Japan

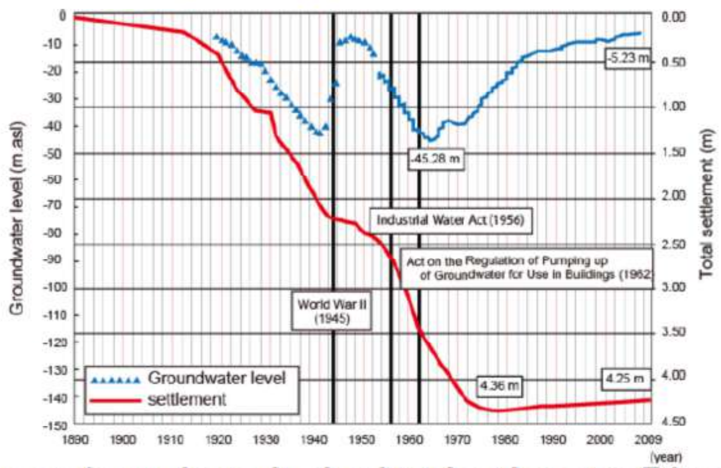




- Industrial water Act (1956)
- Act on the regulation of Pumping up of Groundwater for Use in Buildings (1962)

In order to prevent the extent of land subsidence and groundwater salination, two acts were enacted in 1956 and 1962.

Groundwater problem in Japan



Changes of groundwater level and total settlement in Tokyo (Kameido).

In response to the stipulations of these acts, most industrial factories have changed their water supply from groundwater to surface water.

Groundwater level has gradually recovered and land subsidence has been reduced since 1970

Groundwater problem in Japan

(Present problems)

Large commercial facilities

Hospital

Station building

These facilities use a groundwater as a private water supply

Two acts related for the groundwater have regulated a pumping with the diameter of a well.

⇩

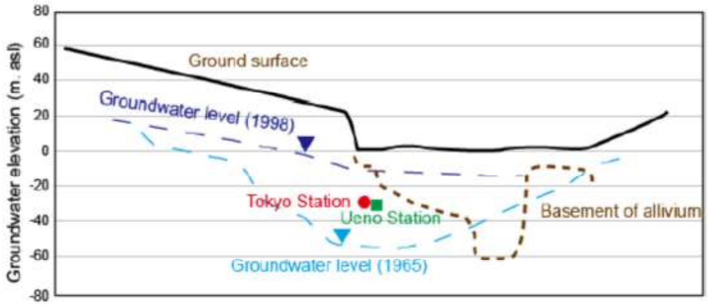
Recently, high-performance groundwater pumps and low-cost filtration equipment widely spread.

⇩

Groundwater pumping is not controlled by traditional(old) acts

Groundwater problem in Japan

(Present problems)



Tokyo Station (built in 1968-1972)
(located below -27m ground level)
Groundwater level
(-35m (1968) ⇨ -15m (1998))

Ueno Station (built in 1978-1985)
(located below -30m ground level)
Groundwater level
(-38m (1978) ⇨ -20m (1985))

Impact from groundwater level recovery to the subway (Groundwater leakage)

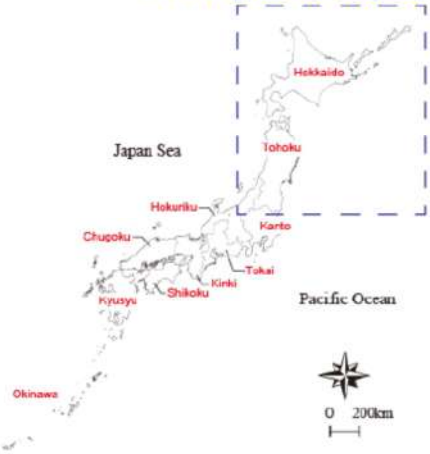
Groundwater problem in Japan

(Present problems)

Snow melting system using groundwater
(Utilization of thermostatic characteristics of groundwater)

Consequently

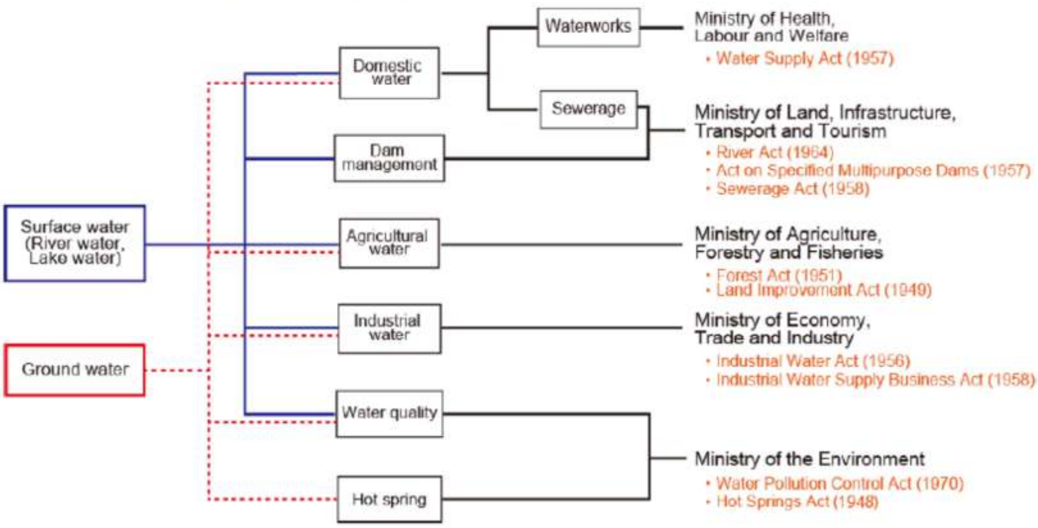
Cold regions in Japan



Decline of groundwater level

Depletion of spring and well

Solution of the problem

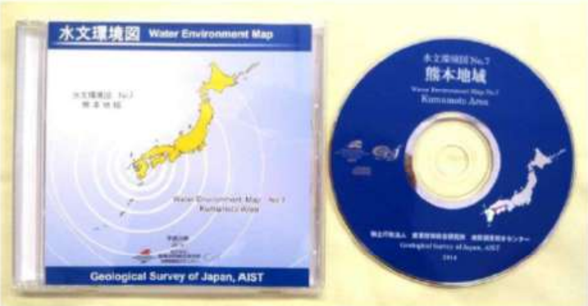


To solve any problem for groundwater,
we have to understand the water cycle in catchment scale

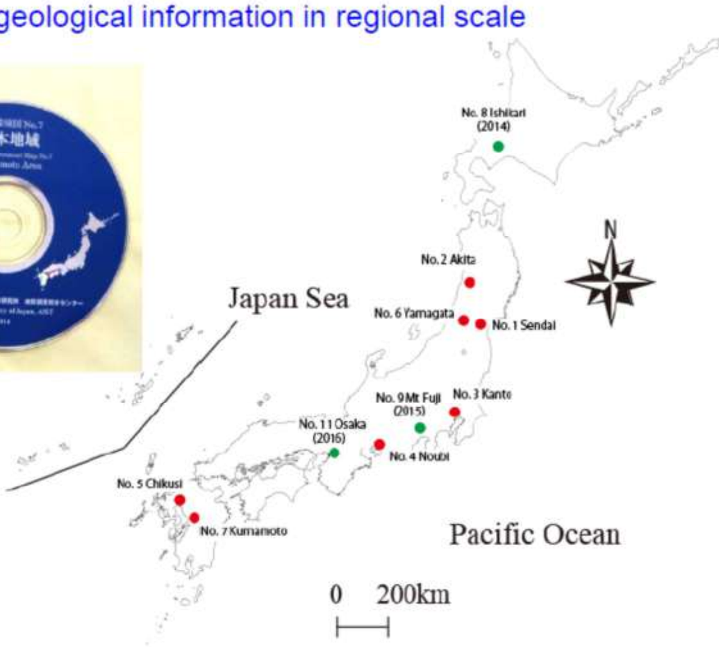
Based on the scientific knowledge ,
we should make a new law for the comprehensive water management.

Solution of the problem

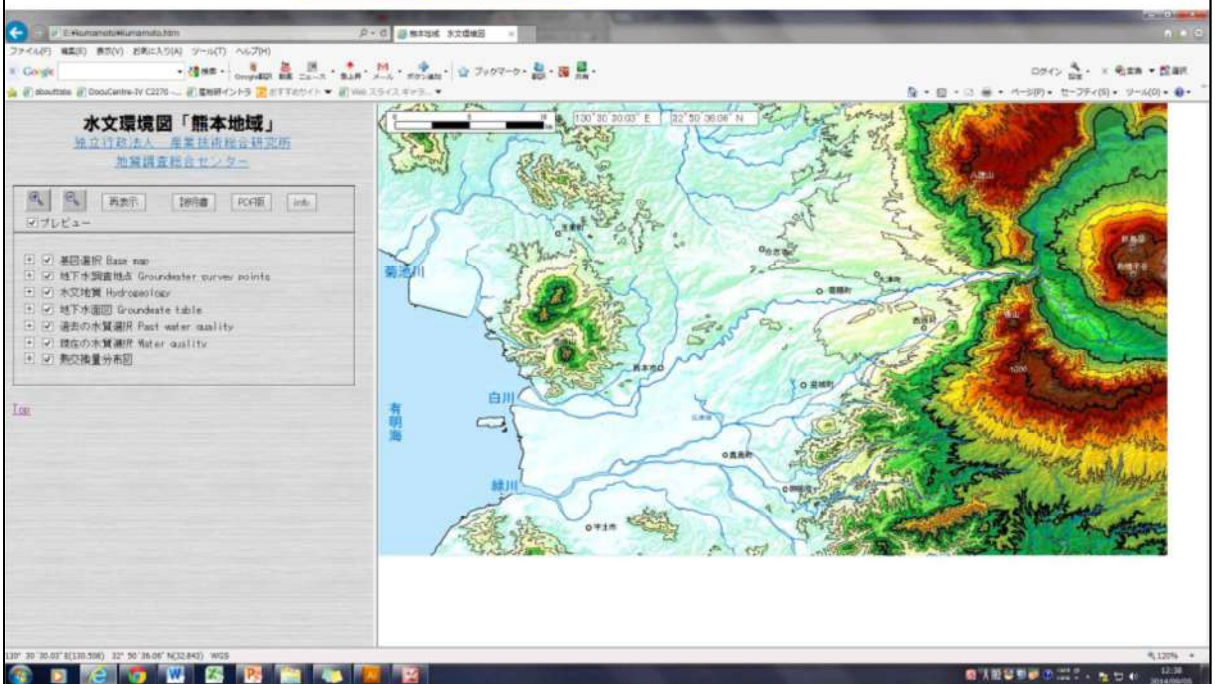
- Lack of correct hydrogeological information in regional scale



Water Environment Map
(Kumamoto area)
published by GSJ, AIST

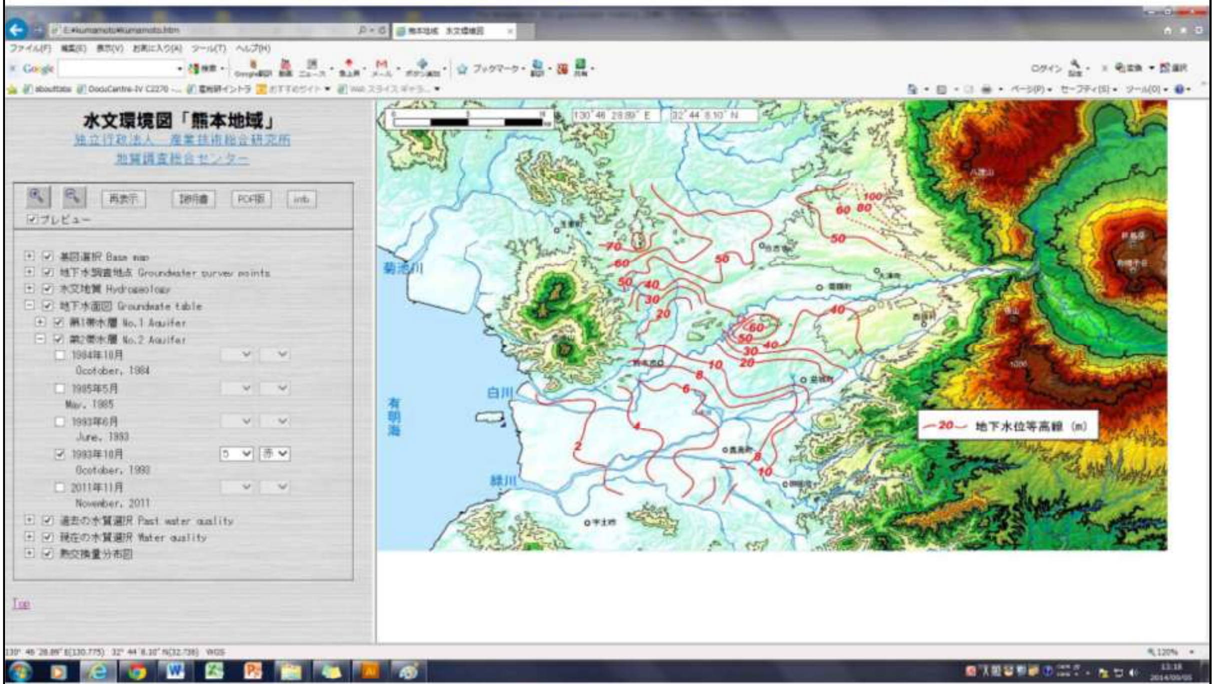


Solution of the problem



Water Environmental Map (Kumamoto area, GSJ 2014)

Solution of the problem

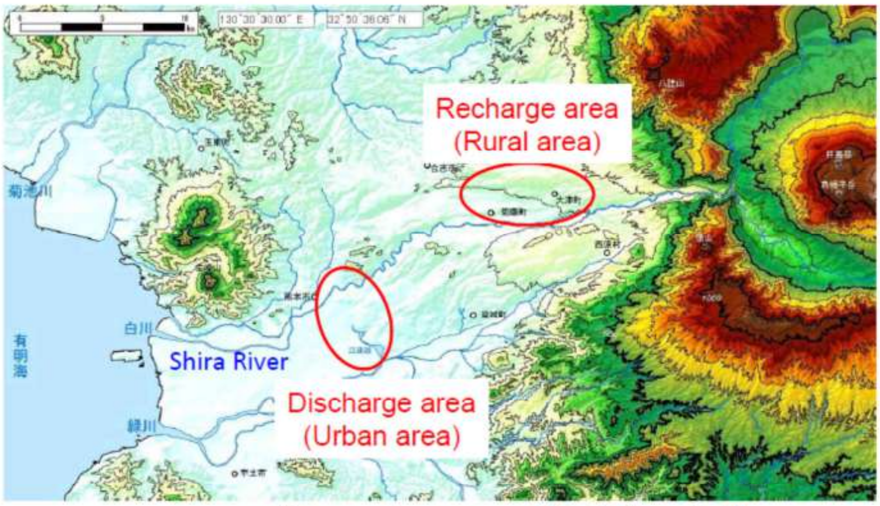


CCOP groundwater database (OPEN GIS) (Phase III)

Solution of the problem

- Change of citizen awareness to groundwater protection

Groundwater : private resource to public resource



Kumamoto area

Groundwater accounts for 97% of water consumption/

Groundwater is very important water resources

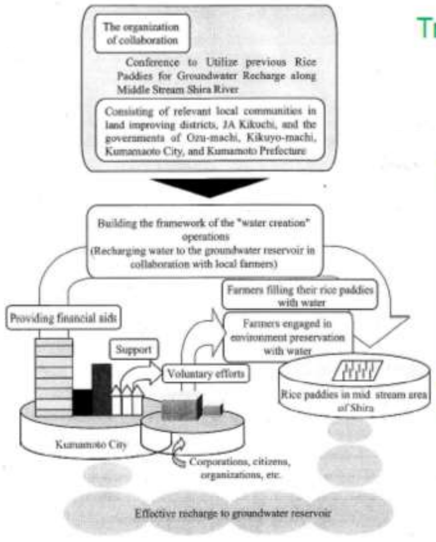
Kumamoto area consist of 11 local cities
(Discharge and recharge areas are located in different cities)

Needs for the new organization for the regional scale water management.

Solution of the problem

- Change of citizen awareness to groundwater protection

Groundwater : private resource to public resource



Schematic view of the creation of groundwater resources through rice paddies (Shimada, 2008)

Transboundary Groundwater Resource Management

Demand side water management

Groundwater users = administrators

Groundwater protection is conducted by groundwater users.

Groundwater = public resources

it is expected that such initiatives will expand to other regions in the future.

Solution of the problem

- Change of citizen awareness to groundwater protection

Rokugo alluvium fan
In Akita pref.

Groundwater has been used as a snow melting water

Spring is depleted during a winter season

Solution of the problem

- Change of citizen awareness to groundwater protection

Rokugo alluvium fan
in Akita pref.

Artificial groundwater recharge has been conducted during winter using an irrigation water and recharge pond

3) The bottled water markets and Industry

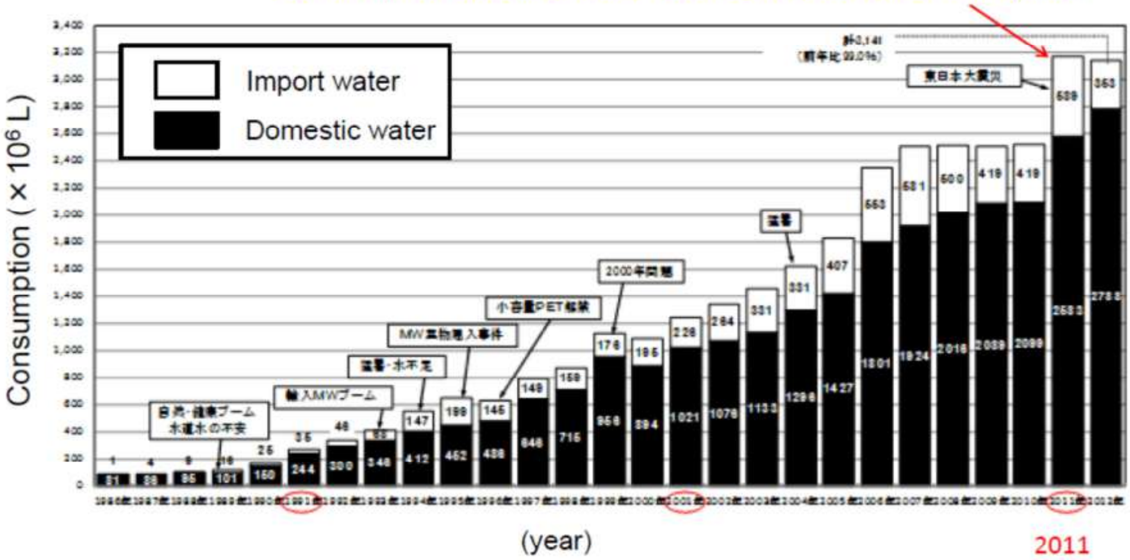
and

4) Consumption trend of bottled water

Bottled water Markets

The Great East Japan Earthquake

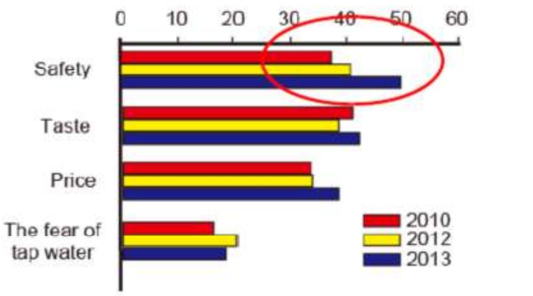
Consumption of bottled water had increased after the earthquake.



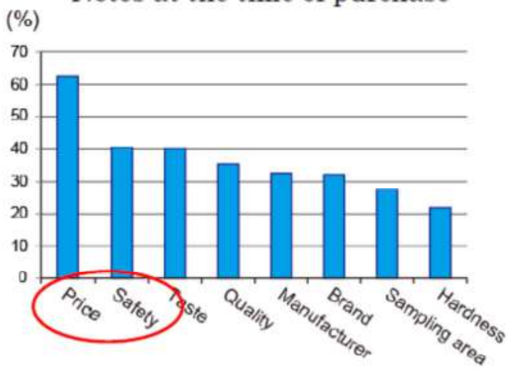
(Suntory: http://www.suntory.co.jp/softdrink/news/pr/d/sbf0024.html)

Bottled water Markets

Reason for the drinking of bottled water



Notes at the time of purchase



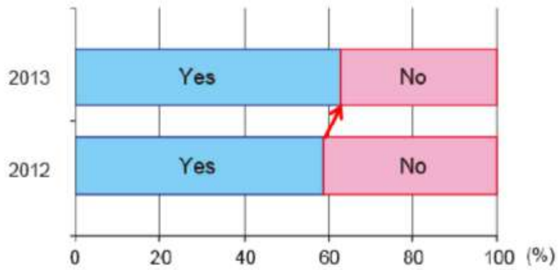
After the "The Great East Japan Earthquake", safety is "key word" in Japanese market.

because of

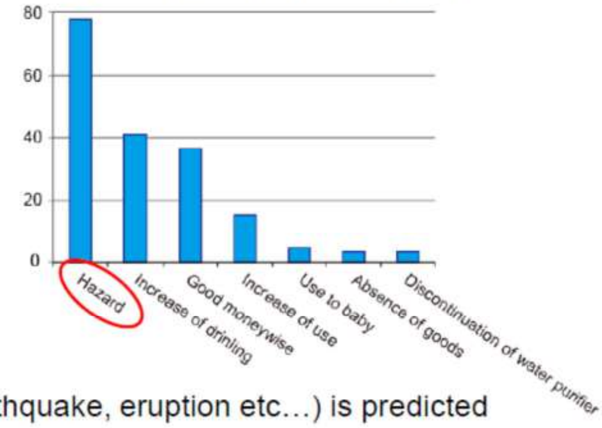
Effect of nuclear disaster of Fukushima reactor to drinking water

Bottled water Markets

Existence of the stockpile water in a house

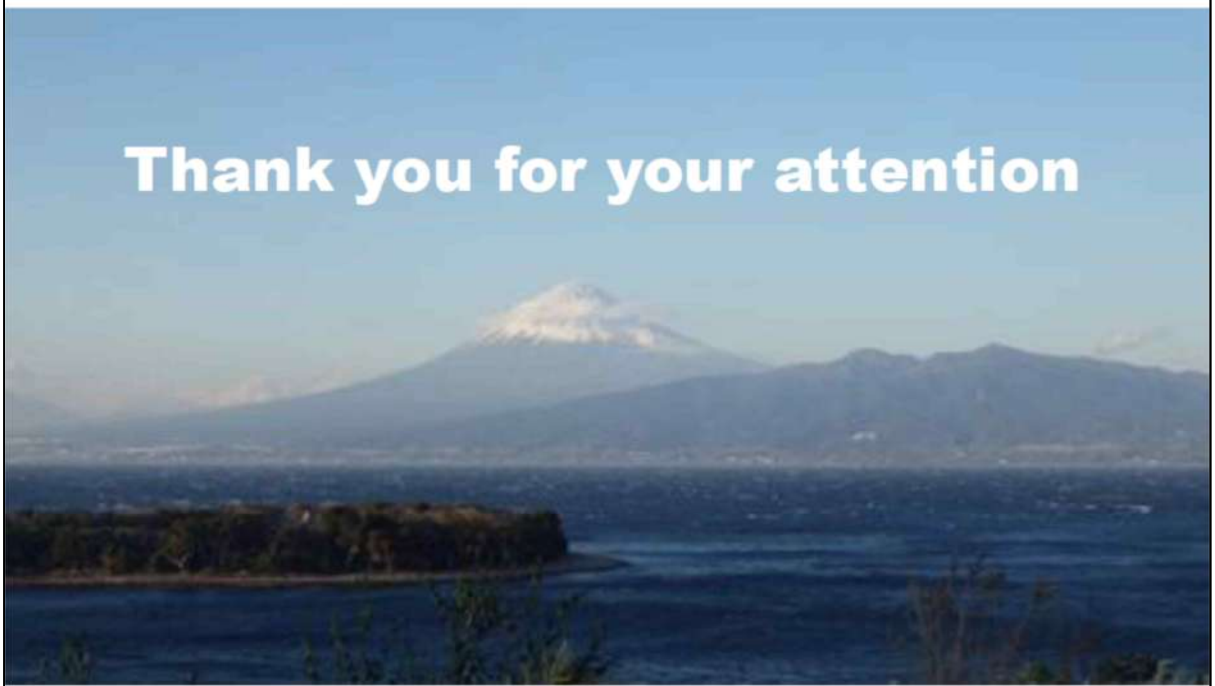


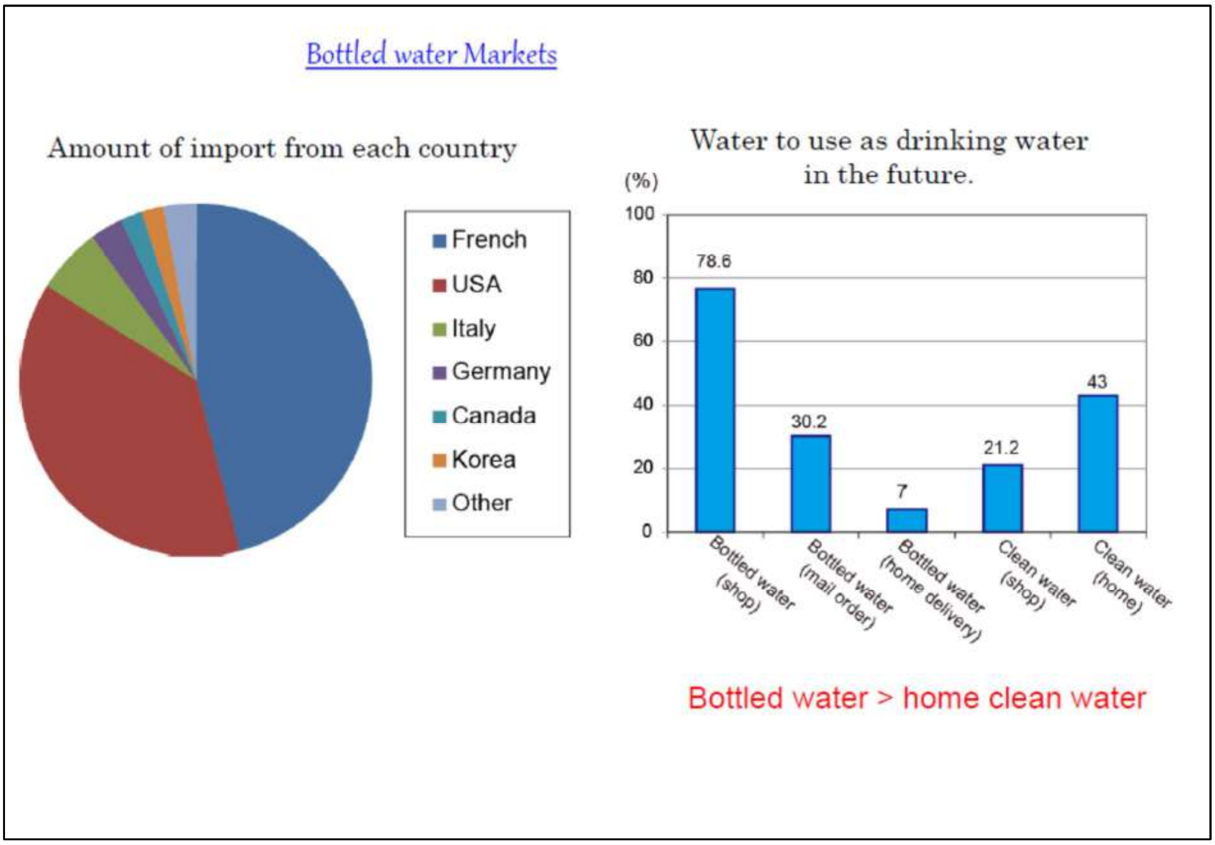
Reason for the increase of stock



Occurrence of some natural hazard (earthquake, eruption etc…) is predicted in Japan for the future.

In terms of "disaster prevention" and "safety", demand of bottled water will increase in Japan.





Bottled water Markets
Amount of import from each country
French
USA
Italy
Germany
Canada
Korea
Other
Water to use as drinking water in the future.
(%)
100
80
60
40
20
0
78.6
30.2
7
21.2
43
Bottled water (shop)
Bottled water (mail order)
Bottled water (home delivery)
Clean water (shop)
Clean water (home)
Bottled water > home clean water

Country Report

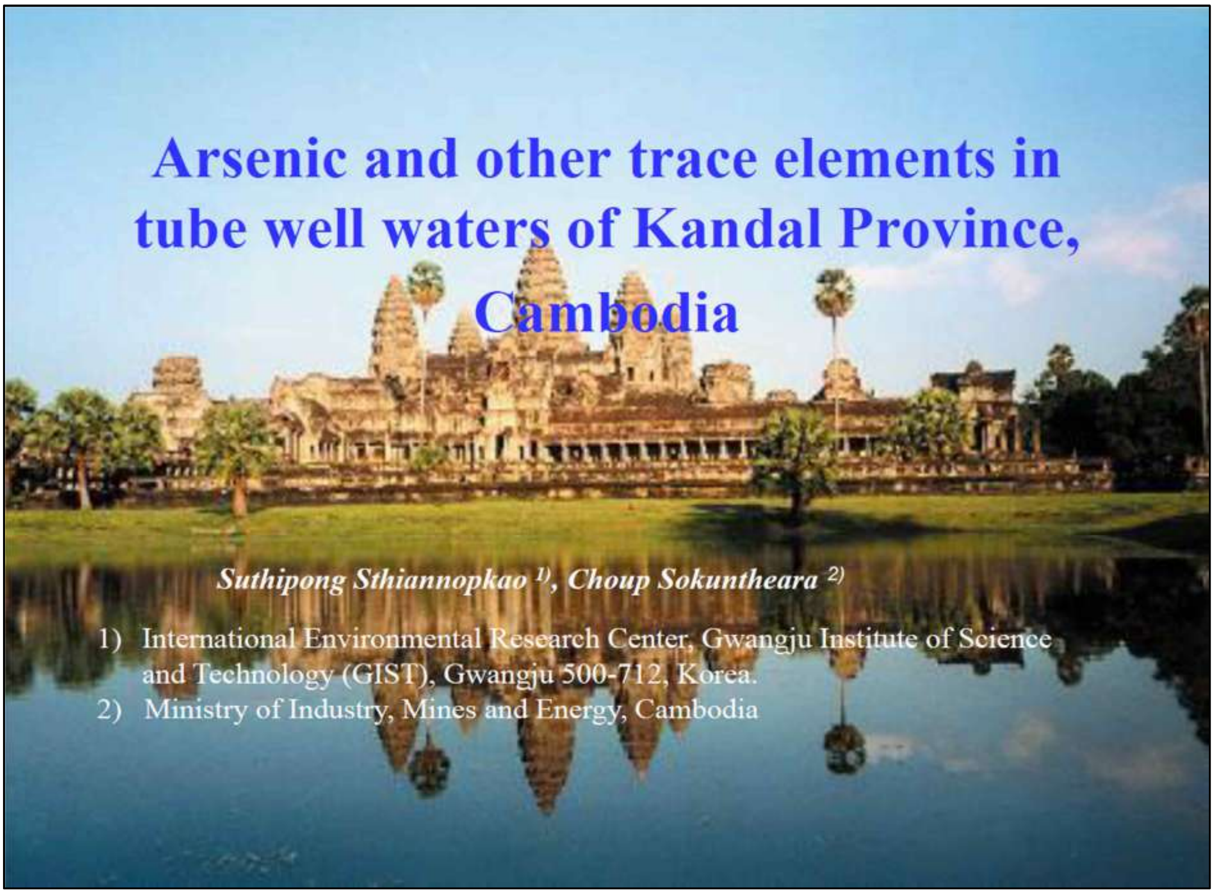
캄보디아

< Cambodia >

Submitted by

Mr. Choup Sokuntheara

Ministry of Industry, Mines and Energy



Outline

Objectives

Introduction

Materials and methods

- Sampling areas
- Sampling methods
- Samples analysis

Results and discussion

- Arsenic and trace elements contamination
- Exposure assessment

Conclusions

The objectives of this study

- To study arsenic and other trace elements geochemistry of groundwater in Kandal Province, Cambodia
- To reveal the As species existing in As contaminated groundwater
- To assess risk of cumulative- exposure to As by calculation.

Introduction

General arsenic information

- As: metalloid group
- Having many metallic properties
- Inorganic arsenic forms:
    - Arsenate-As(V): H_3AsO_4, $H_2AsO_4^{-1}$, $HAsO_4^{-2}$, AsO_4^{-3}
    - Arsenite-As(III): H_3AsO_3, $H_2AsO_3^{-}$

Impacts of As on human health

- Chronic arsenic exposure (5-20 years)
- Non-cancer diseases: weak digestion, tired, neurasthenia, vascular, skin disorders,…
- Relative cancer diseases : gangrene, skin, lung, bladder and liver cancer,…

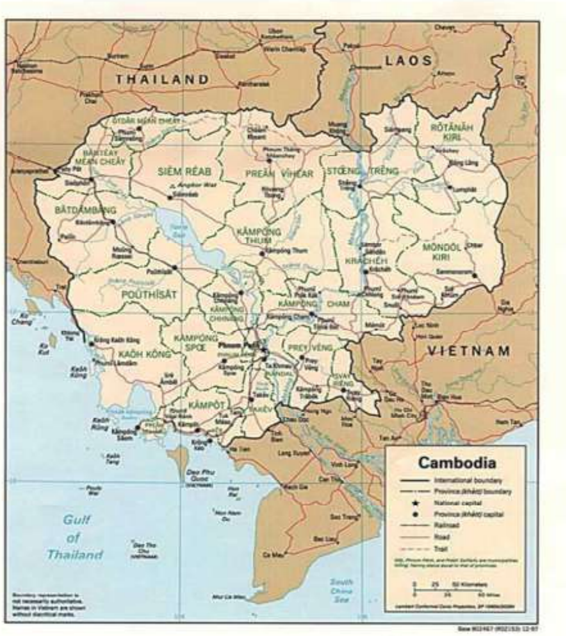
Background of Cambodia

Location: Cambodia borders on Thailand in the northeast and the west, the Lao PRD in the northeast, Vietnam in the southeast and the east and the Gulf of Thailand in the southeast.

Population:13,881,427 millions

Total area: 181,035 km^2

Approximately 84% of the total population lives in rural areas



Source: **SoNam, Tim Savuth, Naothuok**. 2000. Cambodia natural resources evaluation. Ministry of Agriculture and Fisheries

http://www.answers.com/topic/demographics-of-cambodia

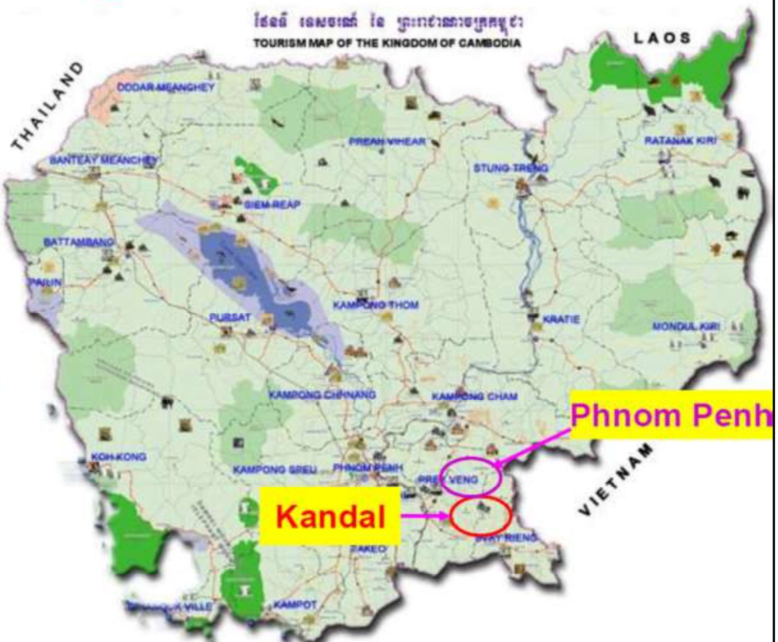
Arsenic contamination in Cambodia

- Groundwater tube-wells: Main source of drinking water in Cambodia, especially in the rural area.
- In 2000: Identified arsenic concentrations above 100 μg/L (WHO drinking water guideline: 10 μg/L) in Cambodia through a small-scale drinking water quality screening in hand-pumped tube-wells.

Source: Buschmann J., Berg M., Stengel, C., and Sampson, M. L. 2007. Arsenic and Manganese Contamination of Drinking Water Resources in Cambodia: Coincidence of Risk Areas with Low Relief Topography. Environ. Sci. Technol. 41 (7): 2146 -2152.

Groundwater usage in the Kandal Province

- About 1 million people have stopped using surface water or water from shallow dug wells due to bacterial diseases. Instead, it has become popular to pump groundwater using individual private tube-wells

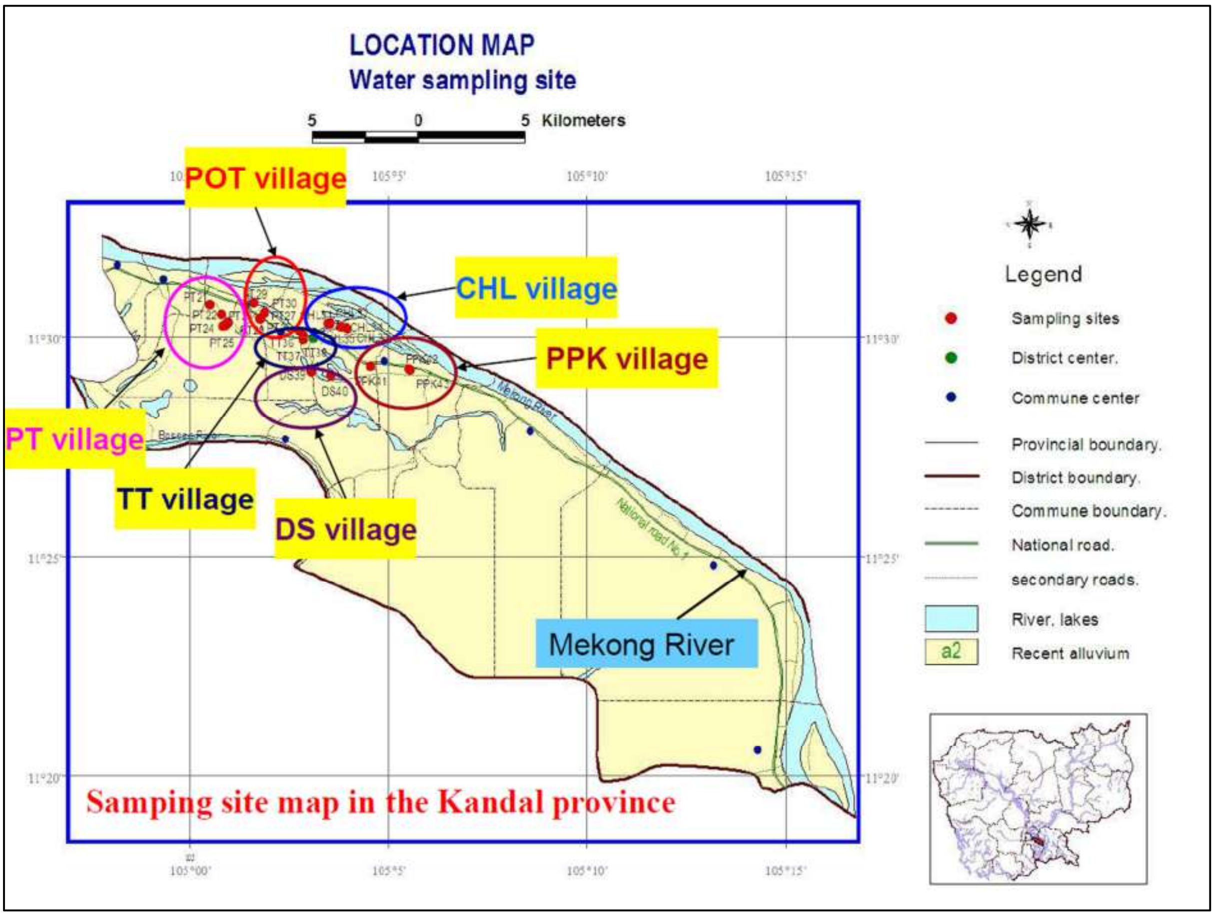


Source: **Buschmann J., Berg M., Stengel, C., and Sampson, M. L.** 2007. Arsenic and Manganese Contamination of Drinking Water Resources in Cambodia: Coincidence of Risk Areas with Low Relief Topography. Environ. Sci. Technol. 41 (7): 2146 -2152.
International Development Enterprises Cambodia. 2005. Final report: Strategic of groundwater resources in Prey Veng and Svay Rieng (phase-1).

Materials and methods

Groundwater sampling

Province	Sampling period	Number of groundwater samples	Number of control samples (water supply)	Parameters
Kandal	Feb, 2007	15 (PT, POT, CHL villages)	5 (Phnom Penh)	▪Arsenic & its speciation ▪Trace – elements (20) **(Ag, Al, B, Ba, Cd, Co, Cr, Cu, Fe, Ga, Mn, Mo, Ni, Pb, Rb, Se, Sr, Tl, U and Zn)**
	Aug, 2007	15 (TT, DS, PPK villages)		



Sampling Procedure

Water samples analysis

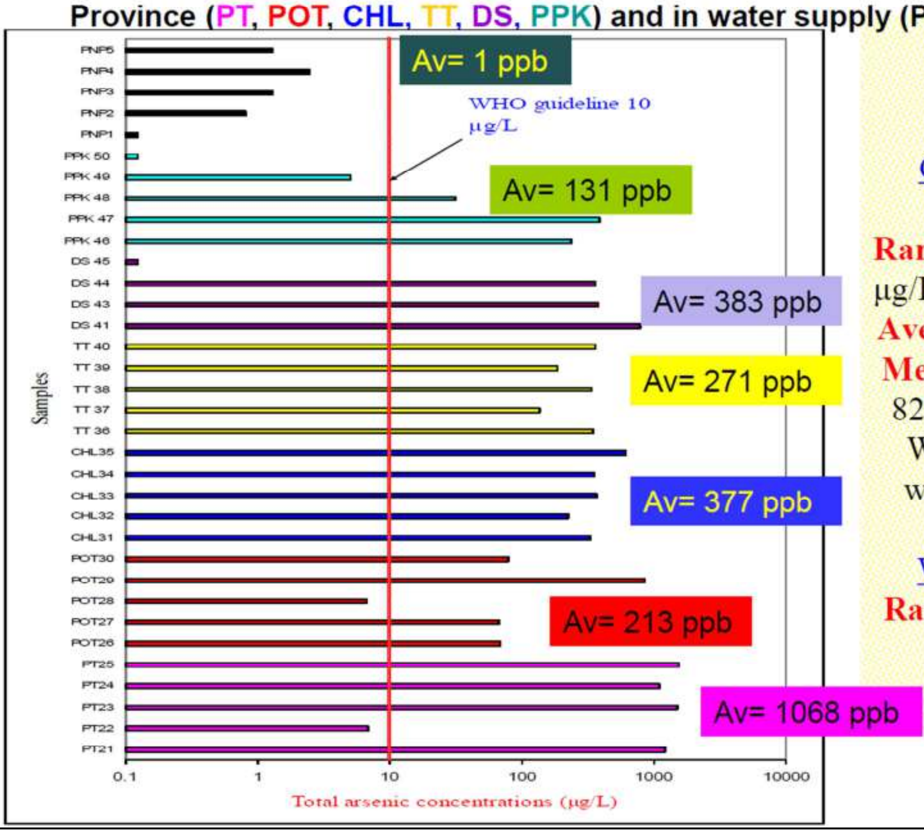
Arsenic and other trace elements concentrations were determined by GF-AAS; Perkin Elmer 5100 PC, USA and ICP-MS; Agilent 7500ce, USA, respectively

GF-AAS equipment

ICP-MS equipment

Results and discussion

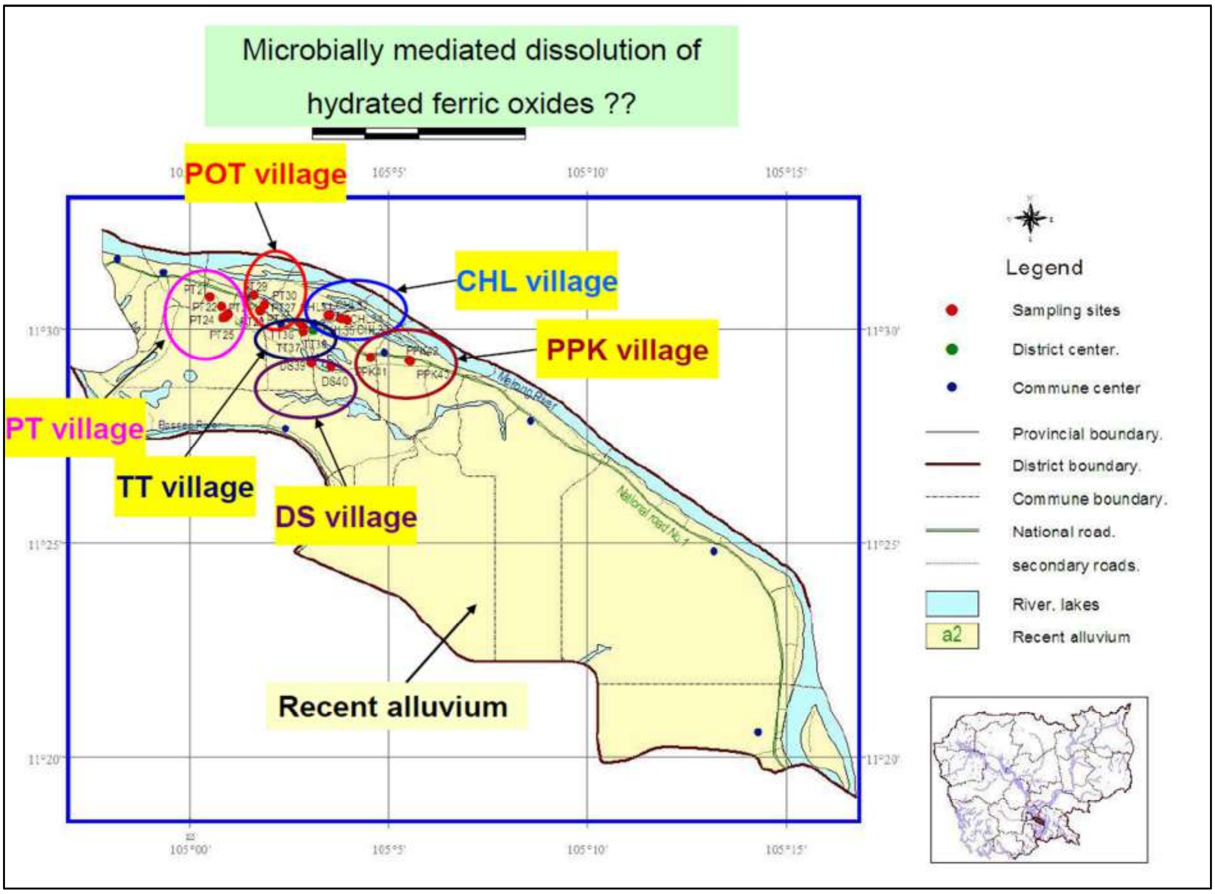
Total arsenic concentrations (µg/L) in groundwater in the Kandal Province (PT, POT, CHL, TT, DS, PPK) and in water supply (PNP)



Groundwater

Range: ND – 1,543 µg/L (in PT village)
Average: 408 µg/L
Median: 332 µg/L
82.7% exceeding WHO drinking water guideline

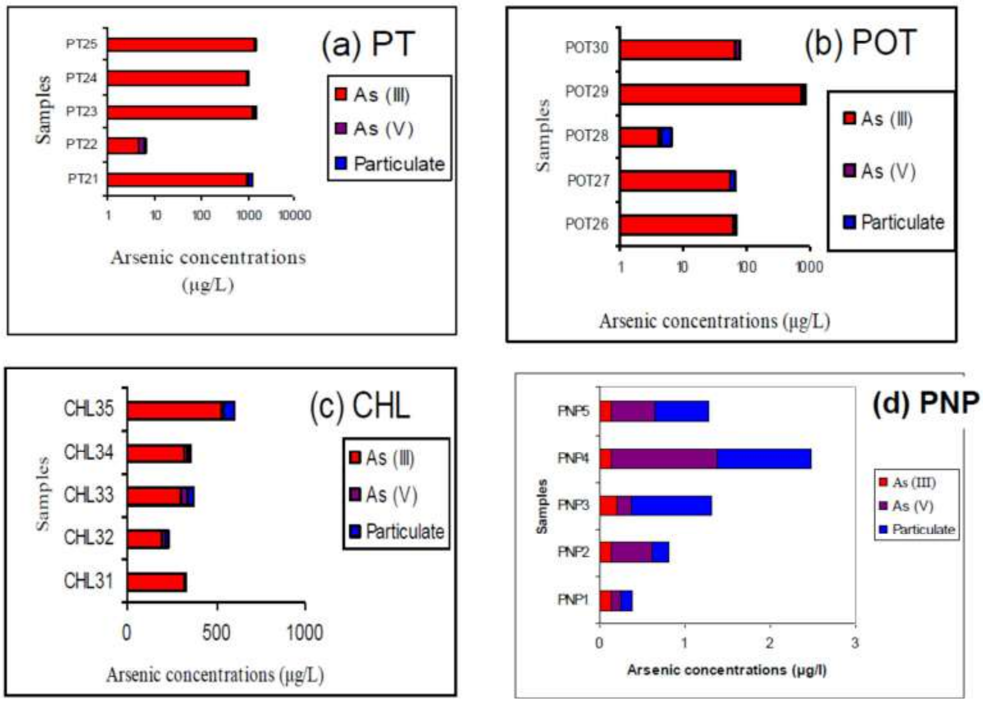
Water supply
Range: ND µg/L– 2.5 µg/L



Sample ID	PT village	POT village	CHL village
Parameters	Range (Average)	Range (Average)	Range (Average)
pH	6.8-7.5 (7.2)	7.2-7.6 (7.37)	7.05-7.4 (7.22)
TDS (gL^{-1})	0.23-0.64 (0.325)	0.32-0.6 (0.406)	0.28-0.41 (0.345)
Redox (mV)	-449- (-)18 (-140.1)	-73-122 (37.9)	25-89 (45.42)
Fe^{2+} (mg L^{-1})	<0.02-0.115 (0.07)	<0.02-0.475 (0.182)	0.35-1.43 (0.762)
NH_4^+ (mg L^{-1})	<0.025-15.55 (8.945)	4.85-23.75 (12.31)	9-20.6 (14.82)
NO_2^- (mg L^{-1})	0.005-0.026 (0.0115)	0.004-0.0155 (0.01)	0.0045-0.018 (0.0085)
NO_3^- (mg L^{-1})	1-4.45 (2.16)	0.25-3.15 (1.91)	2.25-3.9 (2.79)
Well depth (m)	6-54 (40)	40-65 (48.6)	28-65 (50.2)
Using periods (year)	1-7 (4.8)	2-10 (6.4)	7-10 (9)

Sample ID	TT village	DS village	PPK village
Parameters	Range (Average)	Range (Average)	Range (Average)
pH	7.00-7.3 (7.17)	7.25-7.4 (7.3)	6.85-7.45 (7.18)
TDS (gL^{-1})	0.3-0.43(0.339)	0.32-0.475 (0.376)	0.23-0.325 (0.265)
Redox (mV)	-126.5-79.5(-95.9)	-176.5 (-20.8)	-105.5-58 (-37.4)
Fe^{2+} (mg L^{-1})	4.1-13.4(8.47)	0.91-26.8 (14.73)	0.35-22.9 (10.47)
NH_4^+ (mg L^{-1})	1.55-5.7(3.64)	0.25-1.35 (0.863)	0.04-1.8 (0.788)
NO_2^- (mg L^{-1})	0.004-0.015(0.0073)	0.005-0.009 (0.006)	0.003-0.02 (0.0105)
NO_3^- (mg L^{-1})	1.1-2.05(1.57)	0.3-1.25 (0.825)	0.65-1.75 (1.07)
Well depth (m)	45-60(52.6)	36-53 (46.5)	48-53 (50.4)
Using periods (year)	0.08-8(3.416)	0.17-7 (2.293)	1-10 (5.8)

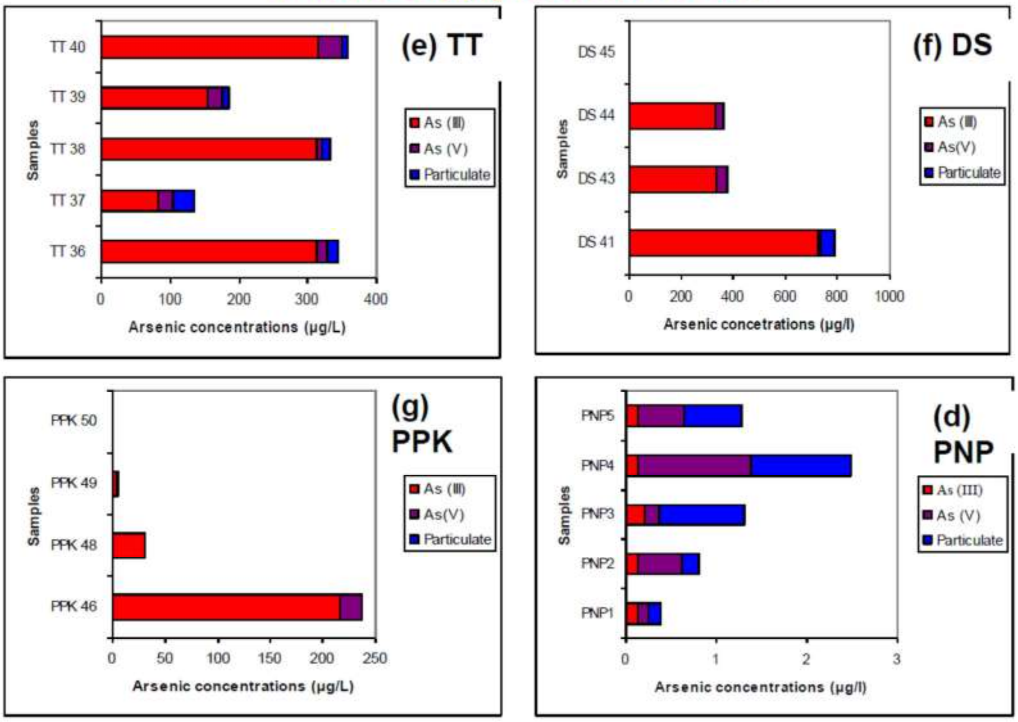
As speciation in groundwater in Kandal Province and in water supply in Phnom Penh



Samples	As (III)-µg/L	As (V)-µg/L	As (III)/ As (V)
PT21	928.8412	136.5739	6.801018204
PT22	4.605641	1.50457	3.061101178
PT23	1216.938	130.1965	9.346936208
PT24	991.0232	42.14131	23.51666809
PT25	1334.129	41.55277	32.10685882
POT26	61.02071	2.61311	23.3517571
POT27	54.19069	1.40295	38.6262447
POT28	3.918235	0.625127	6.267902362
POT29	719.3692	69.84954	10.29883991
POT30	64.6443	13.56377	4.765953713
CHL31	319.5706	2.76969	115.3813604
CHL32	192.3215	18.09397	10.6290394
CHL33	303.8793	34.74366	8.746324078
CHL34	317.8721	21.19108	15.00027936
CHL35	533.6187	6.18645	86.25604345
PNP 1	0.125	0.125	1
PNP2	0.125	0.486253	0.257067823
PNP3	0.203725	0.170607	1.194118647
PNP4	0.125	1.250631	0.099949537
PNP5	0.125	0.527326	0.237045016

Av=15 (PT) · Av= 17 (POT) · Av= 47 (CHL) · Av= 0.56 (PNP)

As speciation in groundwater in Kandal Province and in water supply in Phnom Penh



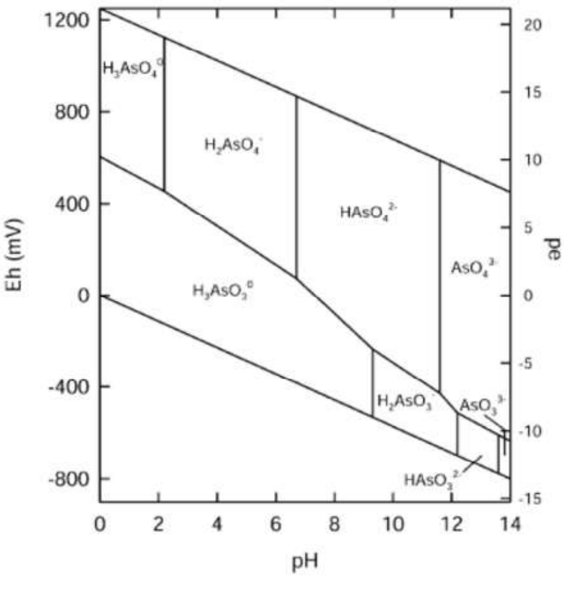
Samples	As (III)-μg/L	As (V)-μg/L	As (III)/ As (V)
TT 36	312.81	16.54	18.91233374
TT 37	83.495	21.105	3.956171523
TT 38	312.3	8.5	36.74117647
TT 39	153.635	22.905	6.707487448
TT 40	314.4	35.5	8.856338028
DS 41	726.04	11.09	65.46798918
DS 43	336.85	39.26	8.579979623
DS 44	330.69	28.92	11.4346473
DS 45	0.125	0.125	1
PPK 46	216.5	20	10.825
PPK 47	328.3	33.5	9.8
PPK 48	30.54	0.72	42.41666667
PPK 49	3.79	0.64	5.921875
PPK 50	0.125	0.125	1
PNP 1	0.125	0.125	1
PNP2	0.125	0.486253	0.257067823
PNP3	0.203725	0.170607	1.194118647
PNP4	0.125	1.250631	0.099949537
PNP5	0.125	0.527326	0.237045016

Av= 15

Av= 22

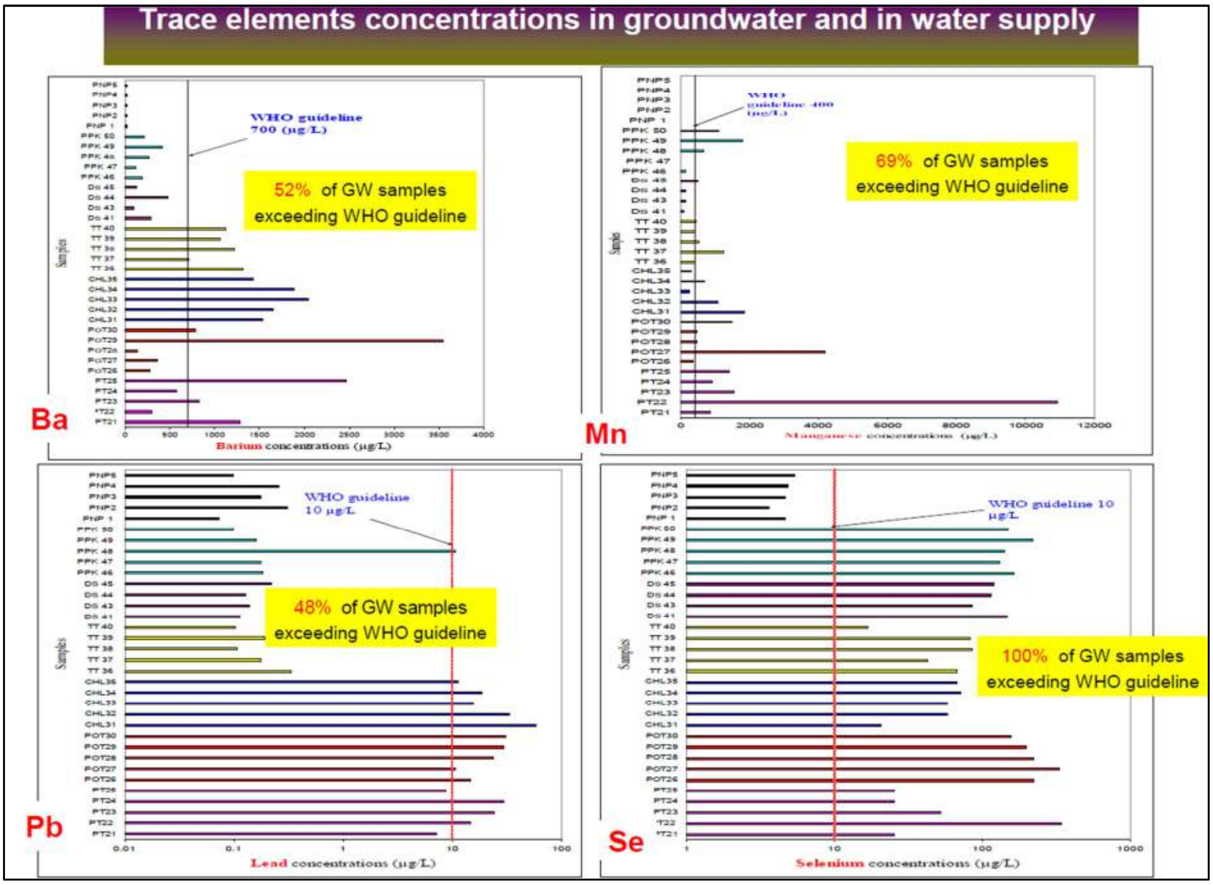
Av= 14

Av= 0.56



Eh-pH diagram for aqueous As species in the system As-O_2-H_2O

Sample ID	Range of pH	Range of Redox (mV)	Range of NH_4^+ (mg/L)	Range of NO_3^-(mg/L)
PT	6.8-7.5	(-)449 – (-)18	0.02-15.5	1- 4.5
POT	7.2-7.6	(-)73- (+)122	4.85-23.75	0.25-3.15
CHL	7.05-7.4	25-89	9-20.6	2.25-3.9
TT	7-7.3	(-)126.5 - (-)79.5	4.1-13.4	1.1-2.05
DS	7.3-7.4	-113 - 63.5	0.91-26.8	0.3-1.25
PPK	6.9-7.5	(-)105.5 – (+) 58	0.35 – 22.9	0.65 – 1.75



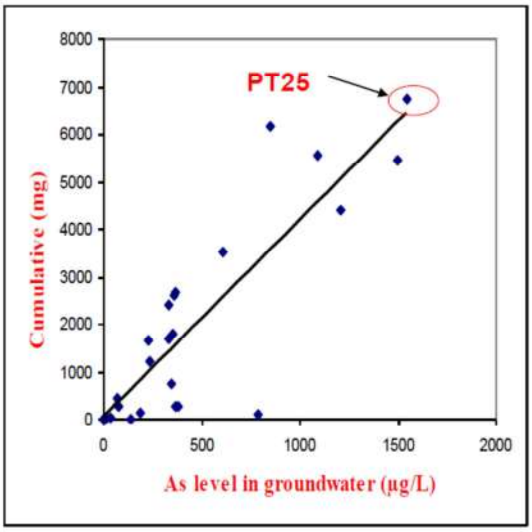
Exposure assessment

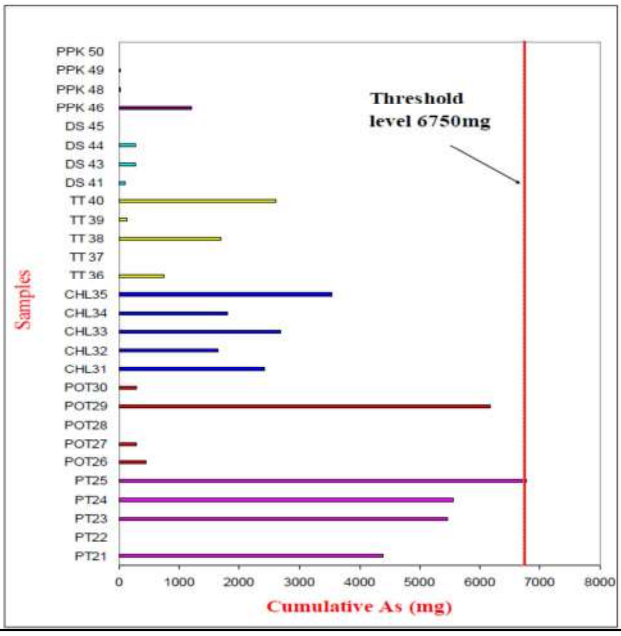
- [Cumulative As intake (mg)]= [As level in groundwater (mg/L)] X [Period of exposure (year)] X [Ingestion rate of groundwater (365 days/year) X [Water consumption (2L/day)]

- **Source**:**Agusa,T., Kunito, T., Fujihara J., Kubota, R., Minh, T. B. M., Trang, P. T. K., Iwata, H. Subramanian, A. Viet, P. H. Tanabe, S.** 2006. Contamination by arsenic and other trace elements in tube-well water and its risk assessment to humans in Hanoi, Vietnam. Environmental Pollution. 139: 95-106

As exposure assessment

Relationship between arsenic concentrations in groundwater and cumulative arsenic intake in residents in the Kandal Province





Conclusions

This study revealed that:

In the Kandal Province:

- Groundwater was considerably contaminated with As, Ba, Mn, Pb and Se. There were about 83%, 52%, 69%, 48% and 100% of groundwater exceeded WHO drinking water guidelines for As, Ba, Mn, Pb and Se, respectively.

- As (III) was found to be the dominant species in all of groundwater samples with high concentrations ranging from ND (in DS village) to 1,334 μg/L (in PT village).

This study revealed that:

In the Kandal Province:

High arsenic concentrations (> 100 μg/L) were found along the Mekong River with young alluvium sediments. This indicates the strong geological control of groundwater arsenic in Kandal Province.

For the health risk assessment, PT village had the highest cumulative As ingestion, followed by CHL, POT, TT, DS and PPK villages.


Acknowledgements
We wish to acknowledge the support of the International Environmental Research Center (IERC) Grant, Gwangju Institute of Science and Technology (GIST)
Associated Institution of
UNITED NATIONS UNIVERSITY


Thank you for your attention

Country Report

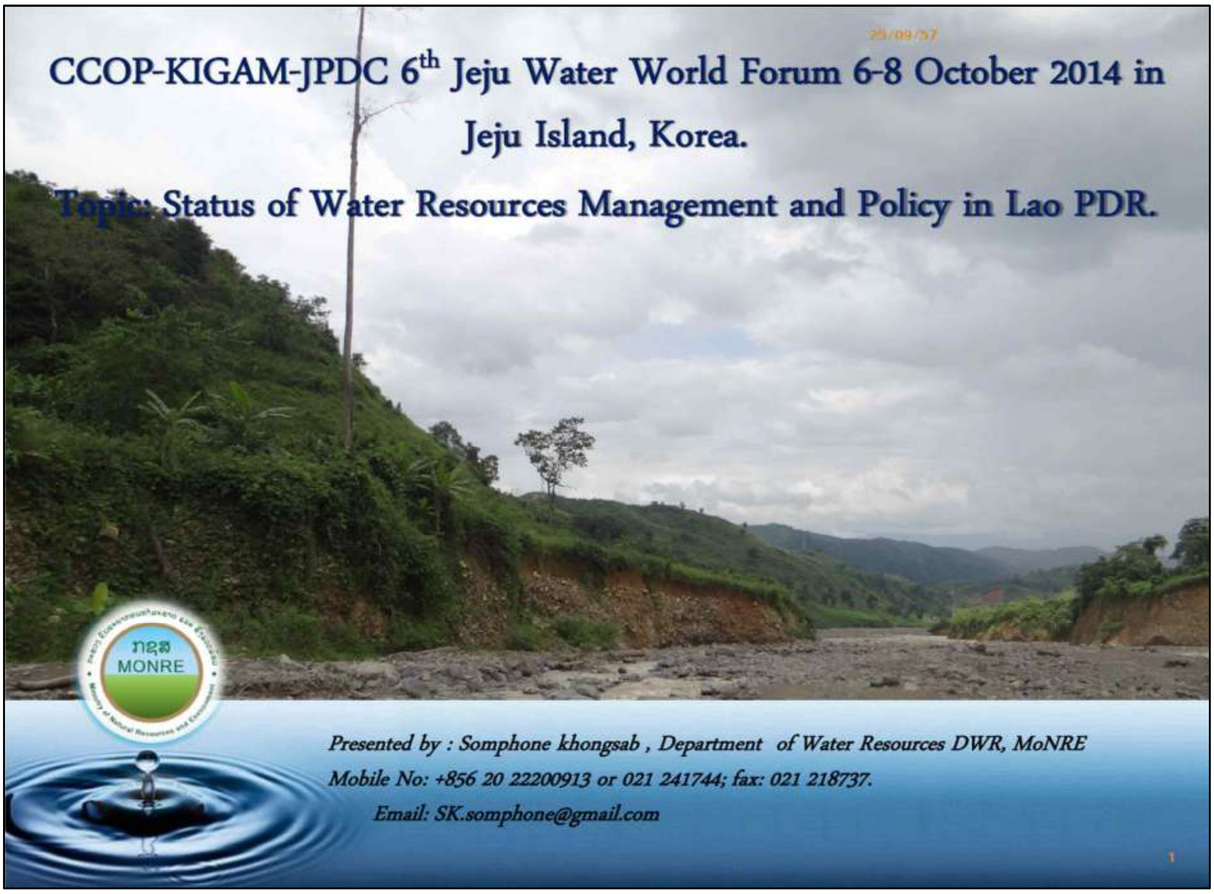
라오스

< Lao PDR >

Submitted by

Mr. Khongsab Somphone

Ministry of Natural Resources and Environment



CONTENTS

I. General Information
II. Status of Water Resources in Lao PDR
III. National Water Resources Policy and Strategy
IV. Problem Related to water resources
V. Plan for Cooperation to Solve the Problems
VI. Conclusion

I. GENERAL INFORMATION

- Location: South East Asian Region,
- Area: 236,800 km^2
- Population: 6,646 mil.(2012)
- The Capital: Vientiane City
- Number of Province: 17 Provinces
- Climate: Average Rainfall 1,850mm/y
  - Average temperature 20 ^{0}C in the Northern and 25-30 ^{0}C in the Southern of laos
- Elevation: Minimum 100 m with sea level and maximum 2,820 m with sea level
- Season: 2 Seasons dry season and raining season

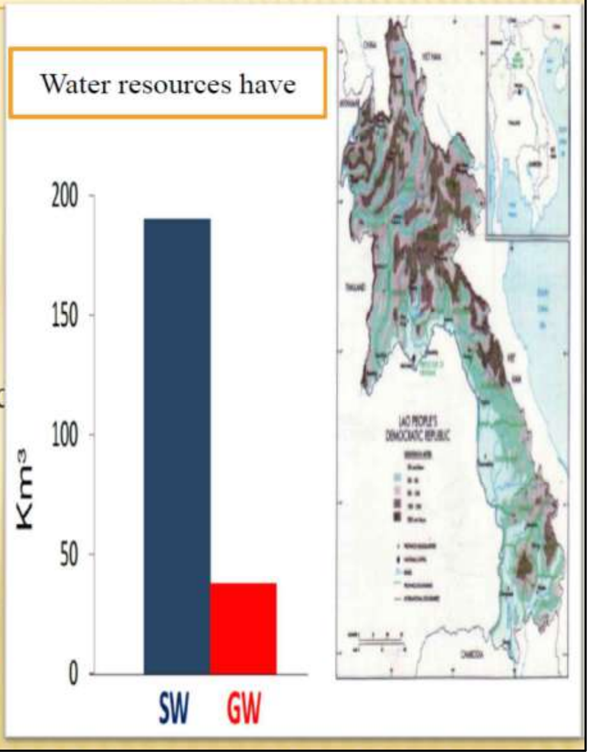
2. WATER RESOURCES STATUS IN LAOS

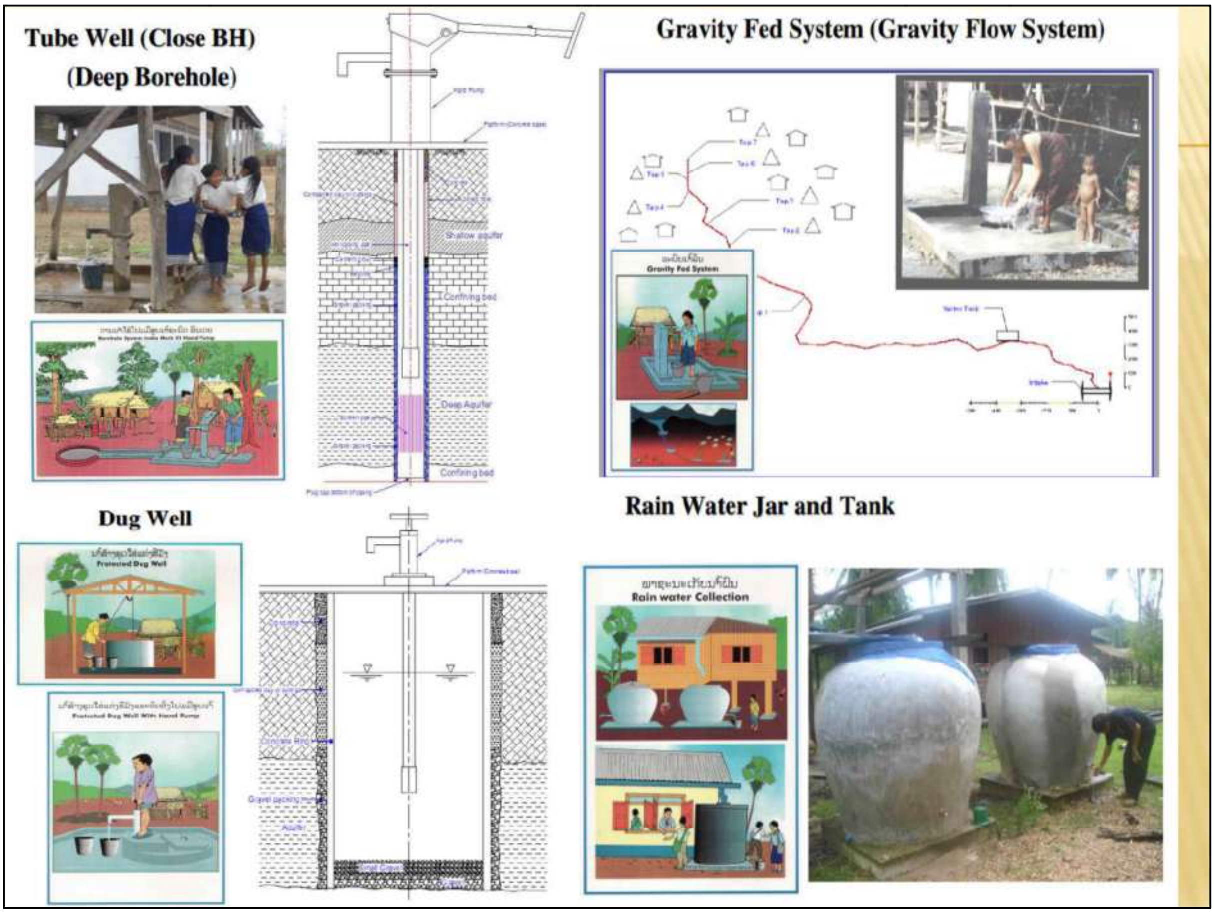
- The average annual rainfall is over 1,900 mm or 462 km^3 , among this 80% of surface water availability occurs in rainy season, while only 20% is availability in the dry season. About 35% of total Mekong runoff is contributed from Lao territory.
- Mekong river flows through 1,898 km of Lao PDR with 13 tributaries, and the average annual flow is approximately 8,500 km^3 per second.
- Groundwater information is limited in this country. Groundwater is an important sources of drinking water and use water for rural people and less in city,

2. STATUS OF WATER RESOURCES IN LAO PDR (CONT.)

2.1 Surface water and Groundwater surface:

- Most of the population in Lao PDR are using ground water surface for drinking and other daily usage
- 20% of water usage in urban get from well and dug well with hanc pump





2.2 IRRIGATION SCHEMES

Water usage for agriculture

Water usage for household

Sources: MOH, 2012

2.3 TYPE OF IRRIGATION FROM GROUNDWATER

ປະເພດຂອງຊົນລະປະທານນ້ຳໃຕ້ດິນ

Water usage within industry

ການສະໜອງນ້ຳໃຫ້ແກ່ອຸດສາຫະກຳ

Fresh groundwater usage for industry

Salt groundwater usage for industry

Sources: MOH, 2012

3. NEED FOR NATIONAL WATER RESOURCE POLICY AND STRATEGY IN LAO PDR

Survey, study and collecting baseline data

↓

Gap Analysis + Assessment

↓

Discuss to collect opinions → **Consultations (wider-stakeholders in the country by regions + national)**

↑

this is being finalized and will be adopted by government


ກຊສ MONRE
LAO WATER RESOURCES POLICY AND STRATEGY
Formation of National Policy, Strategy and 5-Year Action Plan 2011-2015 (by Department of Water Resources, MoNRE);
…this is being finalised and will be adopted by government
Vision
is coordinated, optimized and sustainable development and use of water resources, protection of the environment and improvement of social well-being.
11


ກຊສ MONRE
LAO WATER RESOURCES POLICY AND STRATEGY (CONT.)
Mission
ensure sustainable development and management of water resources and minimize water environment and social impacts
management and protection of water sources and systematic, comprehensive planning for water resources development and use, balancing socioeconomic outcomes and water ecosystems
strengthening ownership and participation of stakeholders on management of water resources development and use through capacity building and use of local knowledge
prioritization of water allocation for basic human needs, ensure equitable water uses and sharing the benefits of water availability and development
12

NATIONAL WATER RESOURCES POLICY (CONT.)

Objectives:

- **Define direction for development of a Coordinating mechanism for effective and efficient water resources management and development;**
- **Ensure sustainable water resources use and development, protection of water sources and minimizing social and ecosystem impacts;**
- **Equitable water and benefit sharing.**

LAO WR STRATEGY AND AP 2011 - 2015

- **Program 1. Institutional Strengthening & Coordination;**
- **Program 2. Legislation, Plans and Implementation;**
- **Program 3. River Basin and Sub-RBs WR Planning;**
- **Program 4. Groundwater Management;**
- Program 5. Data Collection and Analysis;
- Program 6. Water Allocation;
- **Program 7. Protection of Water Quality and Ecosystems;**

LAO WR STRATEGY AND AP 2011 – 2015 (CONT.)

Program 8. Wetland Management;

Program 9. Flood and Drought Management;

Program 10. Management of WR Risk & CC Adaptation;

Program 11. Financial Aspects of IWRM;

Program 12. Awareness, Participation & Capt. Building.

PROGRAM 4: GROUNDWATER MANAGEMENT

Action 1: formulation and implement regulations and groundwater management planning.

- Assess and develop report on groundwater status in priority river basin and sub-basin to use as basis informationfor further management and monitoring planning
- Initiate and implement groundwater management plan at national, river basin and sub-river basin level; groundwater registration, classification, groundwater quantity and quality management, identification of risk area, impact from climate change on groundwater sources.
- Initiate and implement regulations and legislations on the management and utilization of groundwater with involvement of local people and all relevant sectors.

- Establish and manage information system about quantity and quality of groundwater

Action2: Strengthen groundwater management capacity.

- Strengthen capacity in quantity and quality management of groundwater, groundwater data collection and analysis.
- Promote involvement of all relevant sectors in protection of groundwater sources, disseminate and promote community-based management approach.

4. PROBLEM RELATED TO WATER RESOURCES

- Weakness and gaps on the coordination and cooperation for water resources development;
- Poor knowledge and capacity building of water resources management;
- Long-term plan for water resources management and water usage;
- Understanding of social on the water resources management;
- Laws and regulations not clear yet

5. PLAN FOR COOPERATION TO SOLVE THE PROBLEMS

- Water resources management in Lao has been carried out in cooperation with the region for a long time. Such cooperation has several forms, specificatically: becoming a member of the South East Asian Nation or SEAN and Mekong sub-region cooperation
- Cooperation with international water resources management
- Cooperation with ASEAN countries in water resources management started since 2002 until now, with the vision "achieve sustainable water resources management to ensure sufficiency and acceptable water quality and quantity to assure and meet the needs of people in ASEAN countries in term of health, food, economy and environment"

- Mekong sub-region cooperation particularly under agreement in 1995 of four countries: Lao PDR, Vietnam, Cambodia and Thailand, have covered all aspects in sustainable development, utilization, management, protection of water and related resources in Mekong river basin including irrigation, hydropower, boat transportation, flood protection, fishery, river longing, recreation and tourism through optimal use of many models and for mutual benefits of the party countries and impact mitigation from natural phenomena and man-mad activities.

6. CONCLUSION

✓ REFERENCES


THANK YOU FOR ATTENTION

Country Report

미얀마

< Myanmar >

Submitted by

Mr. Win Myint

Department of Geological Survey and Mineral Exploration

Groundwater Resources of Myanmar

1. Summary

1.0 Introduction

Myanmar is situated in South-East Asia between latitudes 9 ° 32’ and 28 ° 31’ N and longitudes 92 °10‘ and 101°11’ E and has a total land area of 676,577 Sq.km (261,227 Sq mi). It extends 1931km (1200mi) north to south and 925km (575mi) east to west. It has a total coastline of 2,276km (1,414mi) and total international land borders of 5,858km (3,641mi) with five countries as follows: China (2,185km, 1357mi), Thailand (1799km, 1,118mi), India (1,403km, 872mi), Laos DPR (238km, 148mi) and Bangladesh (233km, 145mi). Most of the land frontiers are defined by mountains. A location map of Myanmar is shown in **Figure1.**

1.1 Population

The present population of Myanmar is estimated at 54.3 million and rural population about 70% of total. The projection for 2015 will become 63.4 million and it is expected to increase by around 50% by the year 2025. The present average population density of the country is nearly one person per hectare.

1.2 Country Economy

Myanmar is an agro-based country, and agricultural sector is the back bone of its economy. Agricultural sector contributes 43% of GDP, 15% of total export earnings, and employs 63% of the labour force.

1.3 Land Utilization

Twenty five percent of the total area of the country is culturable land. Presently, there are about 26.89 m acres (10.88 m ha) of net sown area in Myanmar. Expansion of new agricultural land, remaining 0.89 million acres (0.36 m ha) fallow land and 15.22 million acres (6.16 m ha) cultivable land is being encouraged. The following is some data for land utilization in Myanmar (2005-2006).

Land Utilization in Myanmar (2005-2006) (m ha)

Net sown area	10.88
Fallow land	0.36
Cultivable waste land	6.16
Reserved forests	16.72
Other forests	16.88
Others	16.65
Total	**67.65**

1.4 Administrative Regions

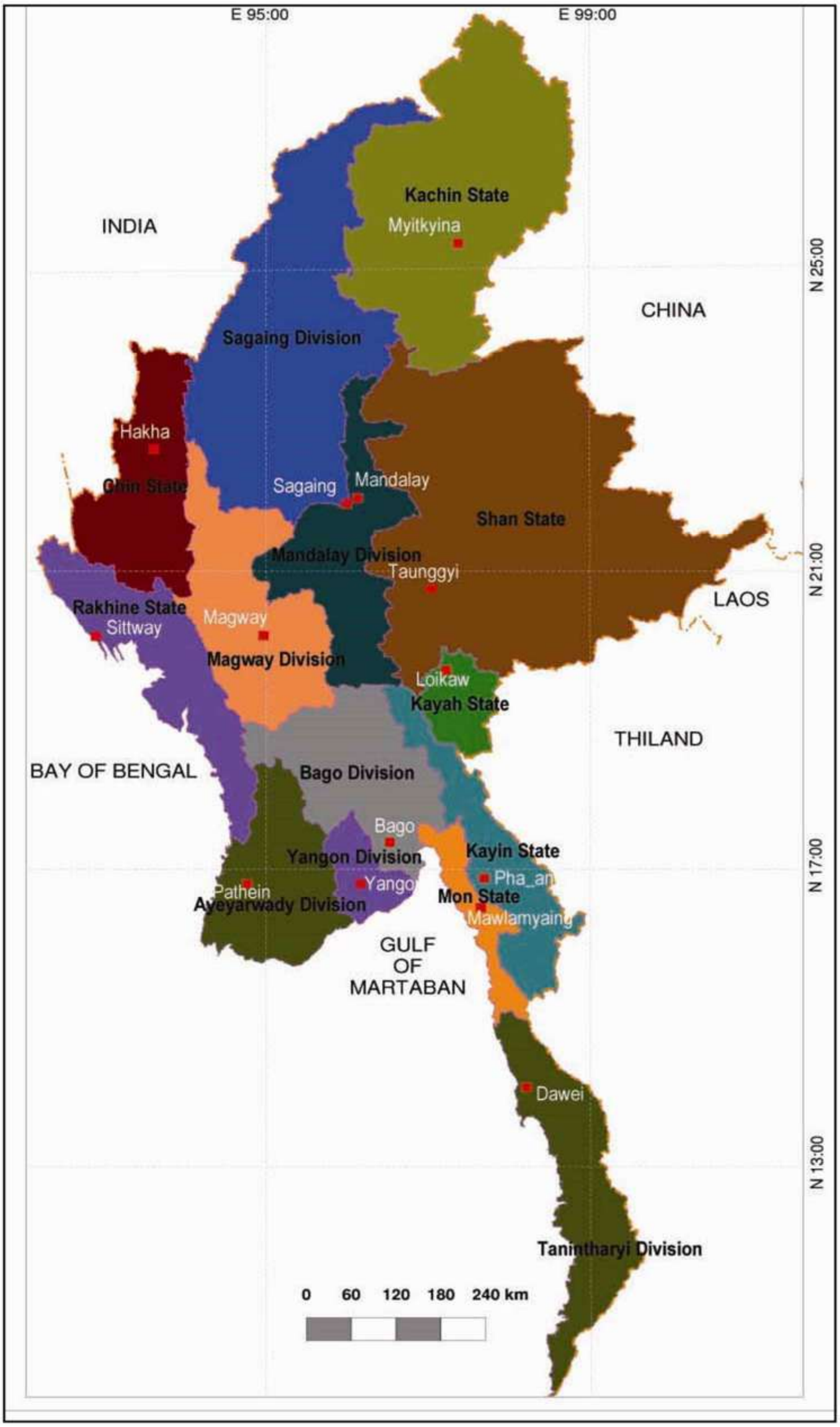
The administrative regions of the country consist of seven States and seven Divisions as follows:

1. Kachin State
2. Kayah State
3. Kayin State
4. Chin State
5. Sagaing Division
6. Tanintharyi Division
7. Bago Division
8. Magway Division
9. Mandalay Division
10. Mon State
11. Rakhine State
12. Yangon Division
13. Shan State
14. Ayeyarwady Division

The delineation of administrative boundaries is shown in **Figure 2**

Figure-1 **Location Map of Myanmar**

Figure-2 Map Showing States and Divisions of Myanmar



2. Hydrogeological Setting

2.0 General Geology

Myanmar relative to its size, possesses an impressive record of rocks representing practically as the standard periods of the geologic column. It is conveniently divisible into four geological regions each of which by its own right is a geotectonic belt possessing a separate stratigraphic succession and a deformational history. They are from east to west: the Eastern Highlands, the Central Belt, the Western Ranges, and the Rakhine Coastal Belt, as illustrated in **Figure 3**.

2.1 Eastern Highlands

The Eastern Highlands which include the northern and eastern mountainous tract of the Kachin State in the north, the Shan Plateau in the middle, and the Tanintharyi ranges in the south. The presence of Precambrian orthogneisses and low-grade meta-sedimentary rocks (Chaung Magyi Group),Paleozoic and Mesozoic carbonates, clastics, and igneous rocks enable this province to remain as a highland, locally with Karst topography in the limestone areas. The Chaung Magyi sediments were laid down probably in a eugeosyline, the Paleozoic carbonates and clastics in a shallow sea, and Mesozoic clastics and evaporates in enclosed and intermontane basins. The province had undergone at least four times of deformation before it was uplifted by the epirogenic movements at the end of Mesozoic. Since then, it has been a fairly stable block. Large linear granitoid plutons of mainly Upper Mesozoic and Lower Tertiary ages intruded along the western marginal zone of this province. These plutons were subduction-related igneous bodies that intruded along the weak junction zone between the tectonic provinces during late Mesozoic and Early Tertiary.

2.2 Central Lowlands or Central Cenozoic Belt

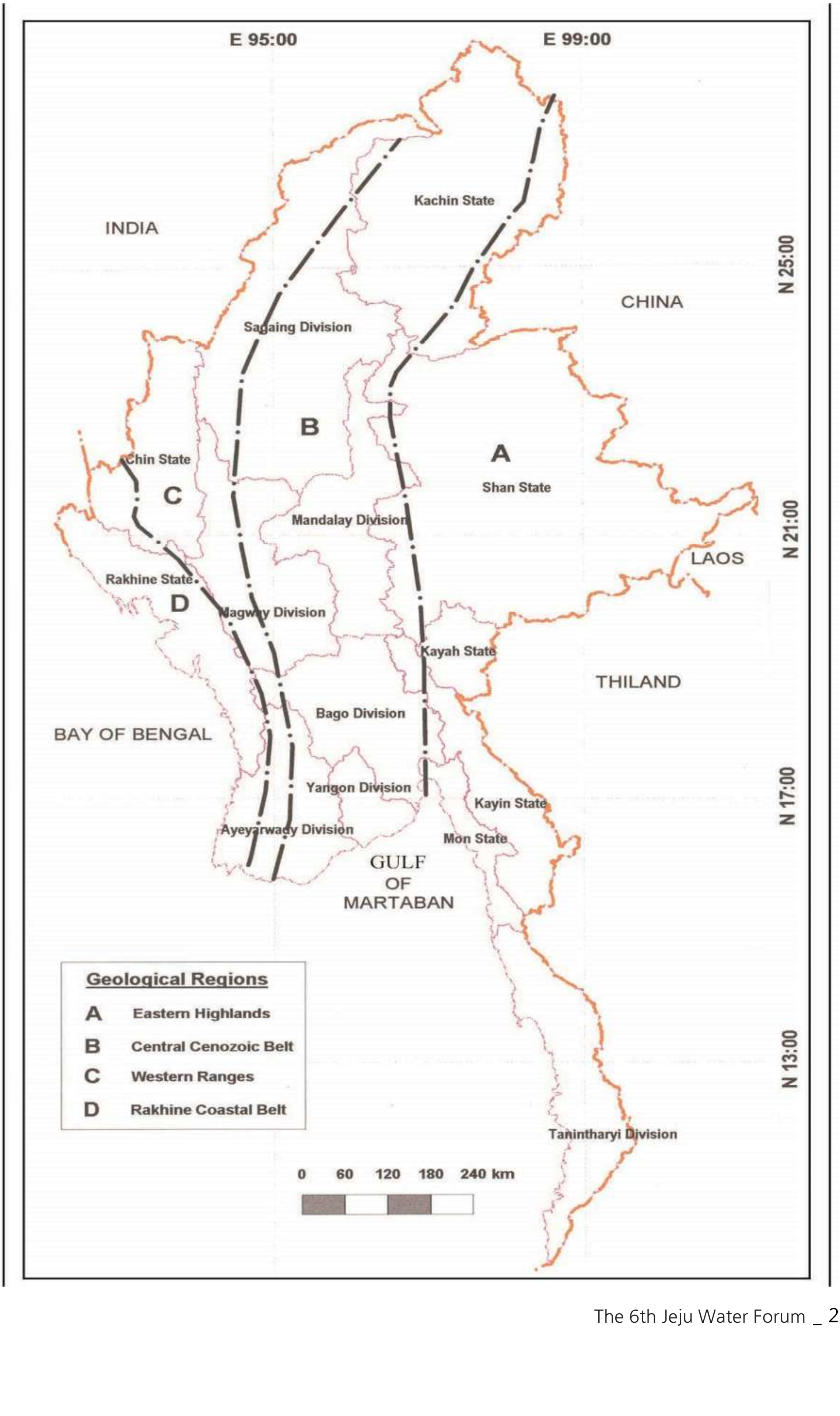
The Shan Plateau and Western Mountains were uplifted during late Cretaceous and Early Tertiary times. The Central Belt was then a subsiding trough which was gradually infilled with vest thickness of sediments possibly exceeding 75,000 feet. Fluviatile and deltaic sedimentation continually advanced to the south .In general , the northen portion of the Central Belt is characterized by continental sedimentation whereas the southern part is marine. In the late tertiary, tectonic movements resulted in broad folding and occasionally thrusting of the Tertiary sediments (general north-north-west strike for folds; north- north-west and north-east fault systems);the Bago Yoma hills were uplifted during this period and divided the southern part of the Central Belt into two alluvial valleys. Recently, the Ayeyarwaddy/Chidwin system has built up a huge alluvial delta to the Andaman Sea. Earth movements have continued and have affected the deposition of the Quaternary alluvium.

The General type area for the Tertiary sediments is the Minbu Basin in Central Myanmar. Here, the Eocenes, Peguan and Irrawaddian Series are separated from one another by unconformities. The Central Volcanic Line has divided this province into two halves since about Miocene. This igneous line starts from the Jade Mines area in the north, through the Wuntho igneous mass, Lower Chindwin Volcanoes, Salingyi, Shinmadaung,Mt.Popa,east of Zegon and Tharyarwady, to Myaungmya area in the south. The well-known Sagaing Fault, a right-lateral strike-slip fault, that runs north-south for a distance of nearly 600 miles is located near the eastern edge of the province.

2.3 Western Ranges or Indo-Burma Ranges

It comprises Naga Hills, Chin Hills and Rakhine Yoma.They are underlain by a thick, mildly deformed, tightly folded and weakly metamorphosed sequence of flysch type deposits, which apparently were deposited in a subduction trench that lay between the Eurasian plate and northeastward-subducting Indian plate. Exotic limestone ranging in size from tiny blocks to mappable units, ophiolites and metamorphic tectonites are locally present within the disrupted flysch deposits. The Western Ranges arose as the results of folding, over thrusting and uplifting during the Early Himalayan Orogeny at the close of Eocene.

Figure-3 Geological Regions of Myanmar



2.4 Rakhine Coastal Belt

The Rakhine Coastal lowland is underlain by Upper Cretaceous type deposits and lower Tertiary rocks in the south and by Upper Tertiary clastic sedimentary rocks of molassic character in the north. The strata are tightly folded and form chains of low hills. It is the southern continuation of the Assam Basin in northeastern India where a thick Tertiary succession is also present. The Minbu and Assam Basins are fairly similar not only stratigraphy and lithology , but also in the occurrance of oil and gas, especially in the Oligocene and Miocene formations.

3. Status of Water Resources

3.0 Water Resources Potential

The South-East Asia (SEA) has 15% of the total world's volume. Demand on water resources has increased due to rapid urbanization and industrialization of the region. It has also indicated that the deterioration in water quantity and quality low reliability of supply, high cost of water and more. Although SEA has the richest resources in the world but those resources and their potentials are being reduced at an alarming rate.

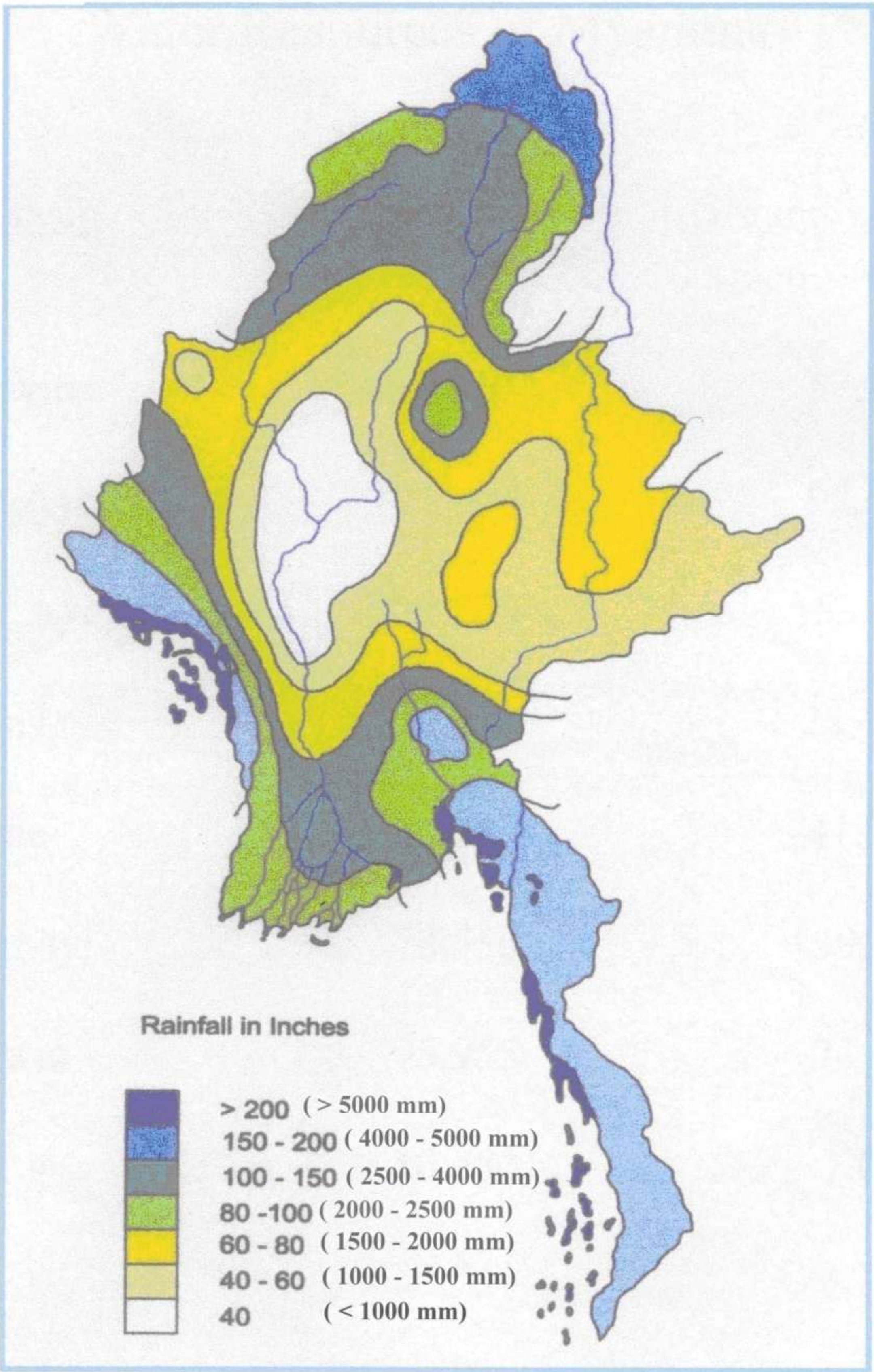
Among the water resources rich countries, Myanmar could still be classified as low water stress country. There are four major river systems, namely, the Ayeyarwaddy, the Thanlwin, the Chindwin and the Sittoung. Besides there are some river systems in Rakhine State and Thanintharyi Division. These river systems contribute for the surface water resources of the country. Due to favourable climatic condition and physiographic features, there are eight river basins those cover about 90% of the country's territory and shown in **Figure 5**.Total surface and groundwater potential of Myanmar are approximately 828 km^3 and 495km^3 per year respectively. Details are mentioned in **Table 1.** However, in many cases the usefulness of groundwater resources is limited due to their being non-renewable, saline or brackish, and hence not suitable for irrigation. If only renewable groundwater suitable for irrigation development is considered, the potential is reduced to 28.3 billion m^3.

Table 1.Myanmar's annual average water resources potential by river basin, 1980-1993.

Region / river basin	Surface water (mcm /Yr)	Groundwater (mcm /Yr)
Region 1. Chindwin	104720	57578
Region 2. Upper Ayeyawady	171969	92599
Region 3. Lower Ayeyawady	229873	153249
Region 4. Sittoung	52746	28402
Region 5. Rakhine	83547	41774
Region 6. Tanintharyi	78556	39278
Region 7.Thanlwin	95955	74779
Region 8.Mekong	10580	7054
Total	**827946**	**494713**

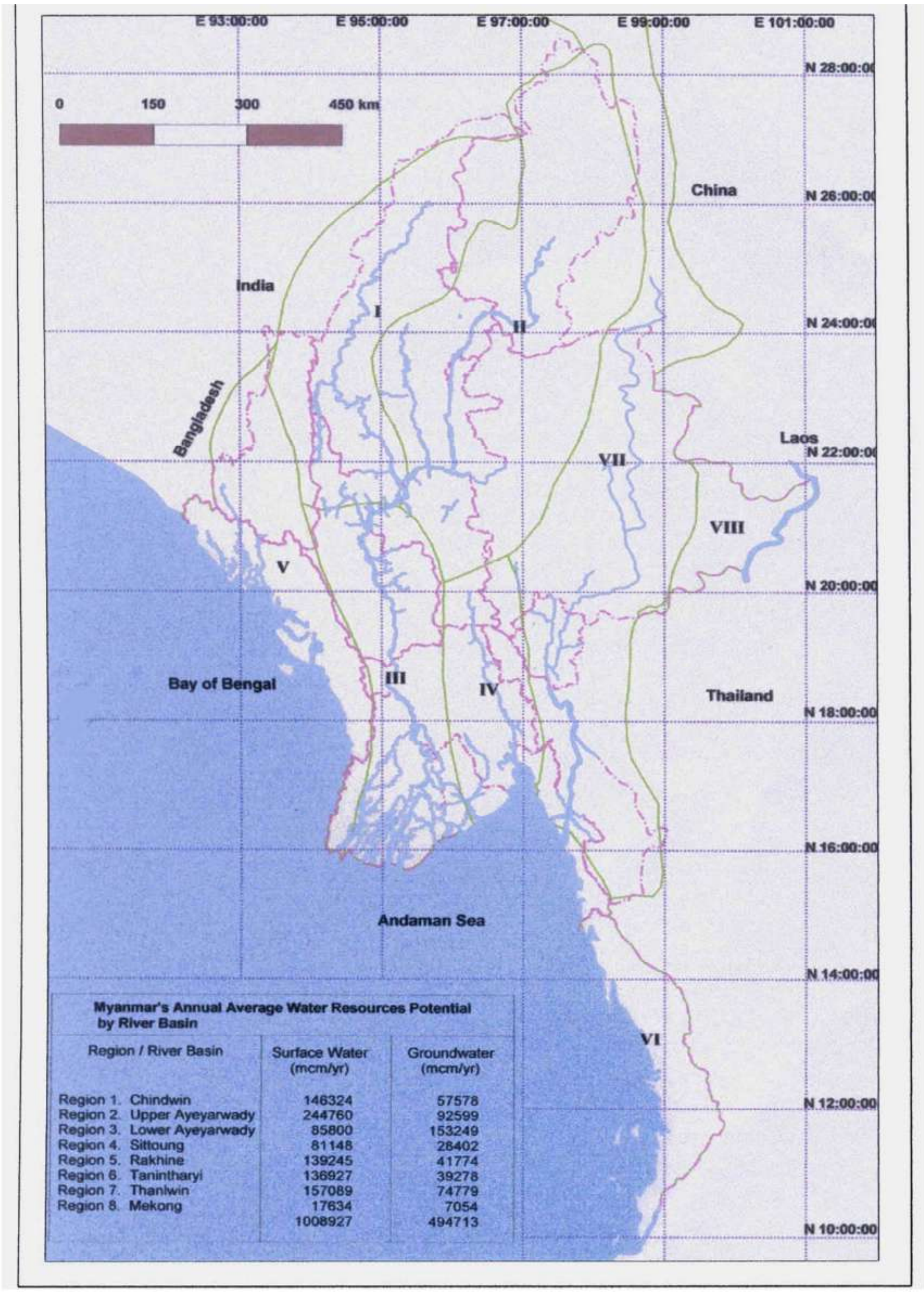
The assessment of water resources potential both for surface and groundwater is carried out on the basis of river basins. In terms of water resources, Myanmar stands the 14th position at global level and 5th position at Asia region.

Figure-4 Annual Rainfall Map of Union of Myanmar



Groundwater occurs mainly in limestones of the Carboniferous-Permian age. In the eastern part of the area, it lies in beds of Mesozoic and Precambrian ages. Groundwater in volcanic rocks is found in the southeastern part .Generally, it is fresh and mostly suitable for drinking and irrigation. To exploit economically, drilling method may be limited.

Figure-5 Drainage Basin Map of Myanmar



Myanmar's Annual Average Water Resources Potential by River Basin

Region / River Basin	Surface Water (mcm/yr)	Groundwater (mcm/yr)
Region 1. Chindwin	146324	57578
Region 2. Upper Ayeyarwady	244760	92599
Region 3. Lower Ayeyarwady	85800	153249
Region 4. Sittoung	81148	28402
Region 5. Rakhine	139245	41774
Region 6. Tanintharyi	136927	39278
Region 7. Thanlwin	157089	74779
Region 8. Mekong	17634	7054
	1008927	494713

3

On the basis of stratigraphy, there are eleven different types of aquifers in Myanmar (**See Table-2**). Depending on their lithologies and depositional environments, groundwater from those aquifers have disparities in quality and quantity. Of these, groundwater from Alluvial and Irrawaddian aquifers are more potable for both irrigation and domestic use. Groundwater are also extracted from Peguan, Eocene and Plateau limestone aquifers for domestic use in water scared areas, even though these are not totally suitable for drinking purposes. Different types of aquifers in Myanmar are shown in **Figure 6**.

The groundwater resources of Myanmar by administrative region can be summarized as follows.

3.2 Kachin State (northern areas)

Groundwater is found mainly in Oligocene- mid- Miocene and Eocene rocks. It is mainly brackish and rarely fresh. In the valley areas, groundwater from alluvial deposits is fresh and yield may be high, but it is found only in localized areas.

3.3 Sagaing Division (north-western area)

In the northern part of the Division, groundwater is situated in Oligocene to mid- Miocene rocks and is brackish in quality. Groundwater in the Chindwin Basin is of mid-pliocene age and occurs in a contained area. The water is suitable for drinking and irrigation purposes. Groundwater in the southern part of the Division is suitable mostly in alluvial beds of Quaternary age, mainly fresh water, and has a good yield. The water is also suitable for drinking and irrigation purposes.

3.4 Shan, Kayah, Kayin and Mon States and Tanintharyi Division (East and South-eastern area)

Groundwater occurs mainly in limestones of the Carboniferous-Permian age. In the eastern part of the area, it lies in beds of Mesozoic and Precambrian ages. Groundwater in volcanic rocks is found in the southeastern part .Generally, it is fresh and mostly suitable for drinking and irrigation. To exploit economically, drilling method may be limited.

3.5 Rakhine and Chin States (western area)

In the eastern part of the states, groundwater occurs in Eocene rocks. The groundwater is mainly brackish and fresh water is rarely encountered in this area. On the Western side groundwater is of Oligo-mid-Miocene and is brackish in quality. Natural reserves of fresh water are limited and seawater intrusion may be encountered.

3.6 The Central Area (Mandalay and Magway Divisions)

Fresh groundwater is found in Quaternary and Mio-Pliocene rocks. But salinity of groundwater in Mio-Pliocene beds increases with depth. It is suitable for drinking and irrigation purpose. Small supplies of groundwater have been achieved from boreholes tapped in Upper and Lower Peguan in some areas. They are of Miocene and Oligocene ages. Groundwater in these sediments is mostly saline and rarely fresh.

3.7 The Delta Area (Yangon and Ayeyarwady Division)

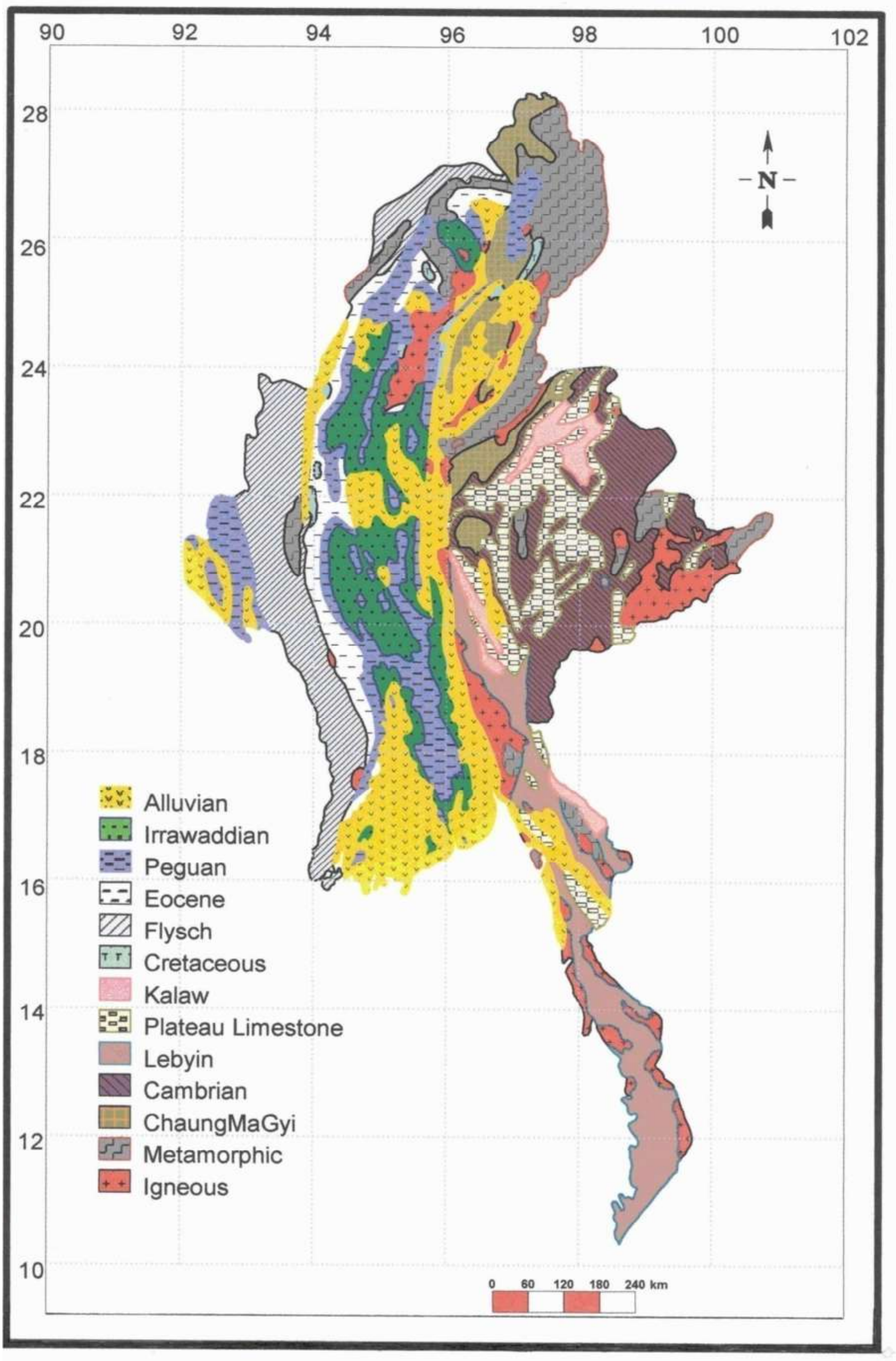
Groundwater occurs in alluvial beds of Quaternary age. It is mostly fresh and in some parts brackish and suitable for drinking and irrigation purposes. In coastal area the water quality may be saline.

3.8 Bago Division (southern area) the central area of the Division is Bago Yoma and it has the rocks of Oligo- Miocene age bearing mainly brackish water. Natural reserves of fresh water are limited. In the eastern and western parts of the Division, groundwater of alluvial beds is exploited. Groundwater reserves are considerable and suitable for drinking and irrigation purposes.

Table-2 The Major Aquifers in Myanmar

Sr.No	Name of Aquifer	Major rock units	Area of occurrences	Remark
	Chaung Magyi Aquifer	Low grade metamorphic rocks	Eastern Highland	To be study in detail
2	Cambrain- Silurain Aquifer	Molohein Group Pindaya Group Mibayataung Group	Eastern Highland	To be study in detail
3	Lebyin- Mergui Aquifer	Graywecke , quartzite, argillite, slate, mudstone, gravel etc;	Western boundary of Eastern Highland and Taninthari ranges	To be study in detail
4	Plateau Limestone Aquifer	Limestone & dolomite	Eastern Highland	GW is being extracted in some places
5	Kalaw- Pinlaung- Lashio Aquifer	Loi- an Group & Kalaw Red Beds	Western boundary of Eastern Highland and Tanintharyi ranges	To be study in detail
6	Cretaceous Aquifer	Flysch units and limestone units	Western Ranges Northern Kachin	To be study in detail
7	Flysch Aquifer	Interbedded units of sand, siltstones, shale and mudstone	Western Ranges	Probable GW source area
8	Eocene Aquifer	Sandstones, siltstones and shales	Perriphery of Central Lowland	Probable GW source area
9	Pegu Group Aquifer	Sandstone, siltstones and shales	Central Lowland and Rakhine Coastal Plain	Mostly saline & brackish water, some fresh water in recharged areas
10	Irrawaddian Aquifer	Mainly sands, sandstones with gravels, grits, siltstones and mudstones	Central Lowland and Rakhine Coastal Plain	Thick aquifer fresh GW with high iron content
11	Alluvial Aquifer	Sands, gravels and muds	Major river basins and its tributaries, base of mountains and ranges	Fresh GW, seasonal water table changes

Figure-6 **Aquifer Map of Myanmar**



3.9 Groundwater Resources Development in Myanmar

Currently, several government agencies and departments under different Ministries are engaged independently both in surface and groundwater use but the extent and type of use are different from one another. (**See Table-3**)

The major government organizations concerned with groundwater development are the Water Resources Utilization Department (WRUD) of the Ministry of Agriculture and Irrigation (MOAI) and the Department of Development Affairs (DDA) of the Ministry of Progress of Border Areas and National Races and Development Affairs. WRUD was established in 1995, by merging the Rural Water Supply Division (RWSD) of Agricultural Mechanization Department (AMD) and Groundwater Division of Irrigation Department (ID), under MOAI.

Table-3 Various agencies and departments engaged in water use sector

Agency/Department	Ministry/City/Other	Duty and function
Irrigation Department	Agriculture & Irrigation	Provision of irrigation water to farmland
Water Resources Utilization Department	Agriculture & Irrigation	Pump irrigation and rural water supply
Directorate of Water Resources and Improvement of River System	Transport	River training and navigation
Myanmar Electric Power Enterprise	Electric Power	Electric Power generation
Department of Hydroelectric Power	Electric Power	Hydro Power generation
Factories under the Ministry of Industry	Industry(1) and Industry (2)	Industrial
Myanmar Fishery Enterprise	Livestock, breeding & Fishery	Fishery works
City Development Committee	Yangon/Mandalay	City water supply and sanitation
Department of Development Affairs	Progress of Border Areas & national Races and Development Affairs	Domestic and rural water supply and sanitation

Agency/Department	Ministry/City/Other	Duty and function
Private users	UN agencies, NGOs & private entrepreneurs	Domestic water supply navigation & fisheries
Department of Meteorology and Hydrology	Transport	Water assessment of main rivers
Forest Department	Forestry	Reforestation and conservation of forest
Public Works	Construction	Domestic & industrial water supply and sanitation
Department of Human Settlement and Housing Development	Construction	Domestic water supply
Department of Health	Health	Environmental health, water quality assessment and control
Central Health Education Bureau Dept. of Health Planning	Health	Social mobilization , health promotion, behaviour research
Yangon Technological University	Science and Technology	Training and research

4. Water Resources Management and Policy

4.0 Even there are many laws, acts, legislations and regulations related to water sectors, most of the laws and acts of relevant water sectors are still needed to modify and should be reviewed with a view to enacting unified water resources law so as to promote a more effective legal framework for coordination and management of water resources. Some acts (such as Burma groundwater act developed in 1930) have weakness as jurisdiction are very much limited and no attempts have been made to amend it and some acts are no more applicable and suitable with the present changing situation. The water laws or other provisions are shown in **Annex IX**.

Annex IX

Water Laws in Myanmar

(a) For urban water utilization

The Rangoon Water Works Act(1885)

The Burma Municipal Act(1898)

The Burma Canal Act,1905,as amended by the Burma Act of 1914,1924,1928 and 1934

The Burma Embankment Act,1909,as amended by the Burma Act of 1923 and 1931

The City of Rangoon Municipal Act(1922)

The Underground Water Act (1930),(Burma Act IV 1930)21 June 1930

The Burma Water Power Rules (1932)

The Rangoon Municipal Act(1941)

Section 114:	Water supply
Section 115:	General powers for suppling the city with water
Section 116:	Power of access to municipal waterworks
Section 117:	Prohibition of erection of any building which damages sources of water supply
Section 118:	Prohibition of bathing in or polluting water
Section 119:	Occupiers of premises to be primarily liable for certain offences against the Act

The City of Yangon Development Law,14 May 1990(Law No.11/90)

The City of Yangon Development Law,17 December 1999(Law No. 6/99)

Most of the above laws are related to urban water supply. For groundwater use, the laws are still being processed , and some may introduce new concepts.

(b) For water supply for irrigation

Canal Act, 1905(Amendment Canal Act in 1998)

Myanmar Embankment Act, 1909(Amendment Embakment Act in 1998)

Myanmar Irrigation Manual, 1945(Revised : Edit)

4.1 In Myanmar up to present water resources management and policy is following "Burma ground water act" developed in 1930 and "the City of Yangon Development Law" enact in on 17.12.1999.

4.2 To fulfill the present situation now new "Myanmar ground water act" is promulgated and already submitted to the Parliament for the approval.

5. Problems Related to Water Resources

5.0 Arsenic content is 50 ppb to 100 ppb level from 0 to depth 300 ft within the Aquifer.

6. Plans for Cooperation to Solve the Problems

6.0 Below 300 ft Arsenic content is decreased so it is needed to drill below 300 ft level to pump out the ground water.

6.1 Arsenic content can be reduced by passing charcoal filter at the water tank or water storage.

7. Conclusion

7.0 Conclusion

Although Myanmar has abundant water resources for sufficiency of her nation, parts of the country, especially in larger cities, has suffered shortage of fresh water. In the near future Myanmar may reach the stage in which water becomes the scarce resource due to the increase of water demand brought about by rapid population growth, expansion of irrigation and industrial production. Given the finite amount of renewable fresh water resources available, shortage of fresh water supply would become a major constraint for development and social well being, unless due attention for equitable and economically efficient utilization and conservation policies could be developed to satisfy the water demand of various competing water use sectors.

Conflict of interest will become more among such competing users as urban water supply, power generation, flood control and inland navigation. As the competition of water could only become more intense in the future, it would be useful to country to address efficient water use technologies and water conservation measures for the sustainability of its resources. Effect of population on fresh water, both surface and underground, results in reduction of water availability for various uses.

It is the national concern, regarding the depth of monitoring systems on law enforcement on protecting water resources from industrial and' agricultural effluents to keep the extent resources intact. Frugal consumption using efficient utilization of water is a prudent technology that should apply extensively in the country. Insufficient facilities for treatment of industrial effluents, particularly toxic chemicals, pose a threat to the nation's health, environment including eco-systems.

Despite the government encouragement on utilizing bio-fertilizers, availability of such less hazardous are limited and chemical fertilizers are unavoidably used extensively for boosting crop production. Stringent laws and regulation should be imposed to handle the risk of industrial effluents and wastewater. The government and incumbent agencies should realize the essences of efficient water utilization and water conservation comprehensively and impart that knowledge to the users or consumers. Accordingly to instill them impart this consensus to safeguarding national resources. Currently, national practices on efficient utilization and water conservation measures are inadequate and thus it is the national cause to harness the danger of deteriorating of water resources through collective efforts of suppliers, users, the policy makers and international co-operation as a whole.

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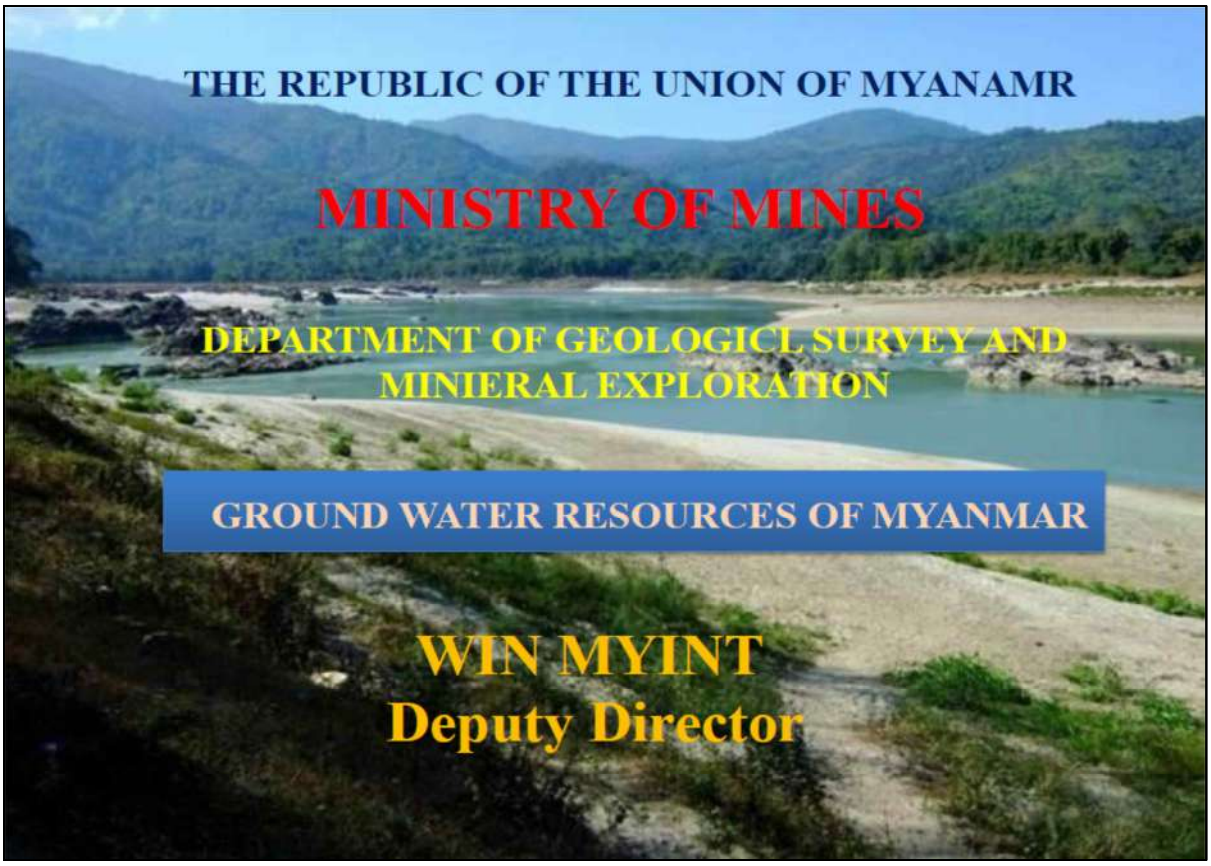


1.Introduction

Myanmar is endowed with resources of arable land, water resources, natural gas, mineral deposits, fisheries, forestry and manpower.

1. INTRODUCTION

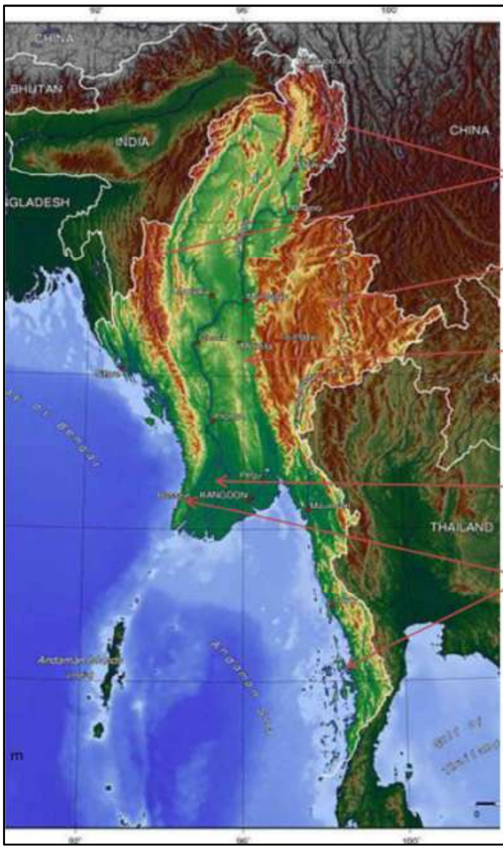
Area	**:**	**678528 sq.km**
Coast Line	**:**	**2100 km**
Border :		**4000 km**
NS Extend	**:**	**2200 km**
EW Extend	**:**	**950 km**
Population	**:**	**60millions(appx.)**
Region :		**7**
State:	**:**	**7**
Location :		**10° N to 28° 30'** **92° 30' E to 101° 30**

1.1.1 Location

Myanmar is the largest country in South-East Asia and is situated between 10º 32' and 28º30' N Latitude and 92º 30' and 101º 30' E Longitude. It has common international borders with China in the North, Thailand and Laos in the East, India and Bangladesh in the West and again with Thailand in the South.

1.1.2 Topography

Myanmar has mountain ranges in the North, East and West. Lengthwise, it stretches about 2200 Km North to South and approximately 950 Km East to West. Myanmar also has a long coastal line of 2200 Km in the South. Sea frontier comprises Rakhine coast line 710 Km, Delta coast line 430 Km and Tanintharyi coast line 1070 Km. The highest lands are at the North of the country and it inclines towards the South, resulting in most of the rivers flowing from the North to the South.



TOPOGRAPHIC REGIONS

I. The Western and Northern hilly regions

II. Shan plateau (Eastern part),

III. The central dry zone or central semi-arid regions,

V. The deltaic zone

IV. The Rakhine and Tanintharyi coastal strips and mountainous regions.

Groundwater Resources in Myanmar

On the basis of stratigraphy, there are eleven different types of aquifers in Myanmar . Depending on their lithologies and depositional environments, groundwater from those aquifers have disparities in quality and quantity. Of these, groundwater from Alluvial and Irrawaddian aquifers are more potable for both irrigation and domestic use. Groundwater are also extracted from Peguan, Eocene and Plateau limestone aquifers for domestic use in water scared areas, even though these are not totally suitable for drinking purposes.

The groundwater resources of Myanmar by administrative region can be summarized as follows.

Kachin State (northern areas)
Groundwater is found mainly in Oligocene- mid- Miocene and Eocene rocks.

Sagaing Region (north-western area)
In the northern part of the Division, groundwater is situated in Oligocene to mid- Miocene rocks and is brackish in quality

Shan, Kayah, Kayin and Mon States and Tanintharyi Region(East and South-eastern area)
Groundwater occurs mainly in limestones of the Carboniferous-Permian age. In the eastern part of the area, it lies in beds of Mesozoic and Precambrian age.

Rakhine and Chin States (western area)
In the eastern part of the states, groundwater occurs in Eocene rocks. The groundwater is mainly brackish and fresh water is rarely encountered in this area.

The Central Area (Mandalay and Magway Regions)
Fresh groundwater is found in Quaternary and Mio-Pliocene rocks. But salinity of groundwater in Mio-Pliocene beds increases with depth.

The Delta Area (Yangon and Ayeyarwady Region)
Groundwater occurs in alluvial beds of Quaternary age. It is mostly fresh and in some parts brackish and suitable for drinking and irrigation purposes.

Bago Region (southern area)

the central area of the Division is Bago Yoma and it has the rocks of Oligo- Miocene age bearing mainly brackish water. Natural reserves of fresh water are limited. In the eastern and western parts of the Division, groundwater of alluvial

GROUNDWATER RESOURCES IN MYANMAR

- On the basis of the stratigraphy , there are 11 different types of aquifer in Myanmar.

Sr.	Name of Aquifer	Major Rock Unit	Area	Remark
1	Chaungmagyi Aquifer (Precambrian)	Low grade metamorphic rocks,	Eastern Highland	To be study in detail
2	Cambrian Silurian Aquifer	Mainly Quartzose Sst. Lst, Siltstones, Shale	Western boundary of Eastern Highlands and Taninthayi region	To be study in detail
3	Lebyin Mergui Aquifer	Greywecke, Quartzite, argillite, slate, mudstone, gravel etc.	Western boundary of Eastern Highlands and Taninthayi region	To be study in detail
4	Plateau Limestone Aquifer	Limestone and Dolomite	Eastern Highland	GW is being extracted in some place
5	Kalaw- Pinlaung –Lashio Aquifer	Conglomerates and Siltstones	Western boundary of Eastern Highlands and Taninthayi region	To be study in detail
6	Cretaceous Aquifer	Flysch units and Lst units	Western ranges Northern Kachin	To be study in detail
7	Flysch Aquifer	Interbedded units of Sst., Siltstones, Shale and mudstones	Western ranges	Possible GW source area

Sr.	Name of Aquifer	Major Rock Unit	Area	Remark
8	Eocene Aquifer	Sst,, Siltstones, Shale	Perriphery of central lowland	Probable GW source area
9	Pegu Group Aquifer	Sst,, Siltstones, Shale	Central lowland and Rakhine coastal plain	Mostly saline and brackish water
10	Irrawaddian Aquifer	Mainly Sands, Sst with gravels, grits and Siltstone and mudstones	Central lowland and western coastal plain	Thick aquifer, Fresh ground water with high iron content.
11	Alluvial Aquifer	Sands, Gravels and muds	Major river basins and its tributaries, base of the mountain ranges	Fresh ground water, Seasonal WT change.

GROUNDWATER RESOURCES IN MYANMAR

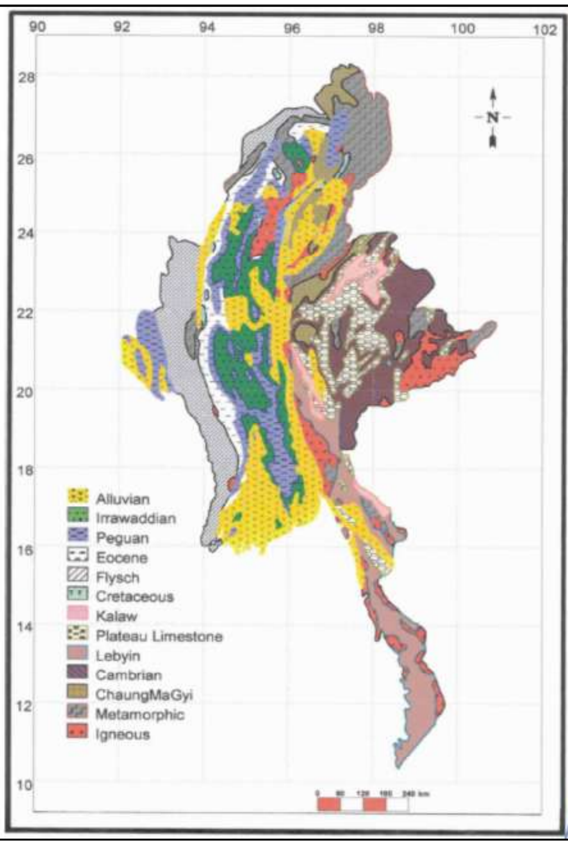
•The GW resources of Myanmar by administrative region can be summarize as follow

Sr.	Region/ State	Major Rock Unit	Remark
1	Kachin (Northern area)	Oligocene, mid Miocene and Eocene rocks Alluvial deposit	Mainly brackish and rarely fresh Fresh , localize
2	Sagaing (NW area)	Oligocene, mid Miocene Mid Pliocene and Quaternary	Brackish Fresh suitable for drinking and irrigation
3	Shan, Kayah, Kayin, Mon and Tanintharyi	Carboniferous – Permian age Lst, Mezosoic and Precambrian at the Eastern	Generally fresh and suitable for drinking and irrigation
4	Rakhine and Chin	Eocene rocks, Oligo- Mid Miocene on western side	Mainly brackish and rarely fresh Brackish
5	Mandalay and Magwe (Central area)	Quaternary and Mid Pliocene Upper and Lower Pegu beds of Miocene and Oligocene in some area	Salinity on Mid Pliocene beds increase at depth, suitable for drinking and irrigation
6	Yangon and Ayeyarwadi Delta area	Alluvial beds of Quaternary age	Mostly fresh and in some parts brackis suitable for drinking and irrigation

Sr.	Region/ State	Major Rock Unit	Remark
7	Bago (Southern area)	Oligocene, Miocene rocks Alluvial deposit	Mainly brackish and rarely fresh Fresh , localize suitable for drinking and irrigation

Major Aquifer and Groundwater Potential

Sr. No.	Name of Aquifer	Major Rock Unit	Area	Remark
1	Alluvial Aquifer	Sands, Gravels and Silts	Major river basins and its tributaries, base of the mountain ranges	Fresh ground water, Seasonal WT change.
2	Irrawaddian Aquifer	Mainly Sands, Sst with gravels, grits and Siltstone	Central lowland and western coastal area	Fresh ground water with high iron content.
3	Peguan Aquifer	Marine Sst, Shales and Siltstones	Central lowland and western coastal plain	Mostly saline and brackish water
4	Limestone Aquifer (Plateau Lst, Mawlamyein Lst and its equivalents)	Mainly Carbonate Rocks and Dolomite	Mainly occur along the Eastern Highland and Tanintharyi area	Groundwater quality is generally fresh but hard
5	Igneous Aquifer	Mainly granite, andesite, rhyolite, basic and ultra basic rocks	Natural reserve are fairly limited	To be study in detail
6	Other minor Aquifer	Mainly low grade metamorphic rocks, metasedimentary rocks and marine clastic rocks	Eastern Highland, Tanintharyi, Western Ranges	To be study in detail



Aquifer Map of Myanmar

Law and Administration

Even there are many laws, acts, legislations and regulations related to water sectors, most of the laws and acts of relevant water sectors are still needed to modify and should be reviewed with a view to enacting unified water resources law so as to promote a more effective legal framework for coordination and management of water resources. Some acts (such as Burma groundwater act developed in 1930) have weakness as jurisdiction are very much limited and no attempts have been made to amend it and some acts are no more applicable and suitable with the present changing situation.

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(b) For water supply for irrigation

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Myanmar Irrigation Manual, 1945(Revised : Edit)

2.0 General Geology

Myanmar relative to its size, possesses an impressive record of rocks representing practically as the standard periods of the geologic column. It is conveniently divisible into four geological regions each of which by its own right is a geotectonic belt possessing a separate stratigraphic succession and a deformational history. They are from east to west: the Eastern Highlands, the Central Belt, the Western Ranges, and the Rakhine Coastal Belt, as illustrated in **Figure 3**.

2.1 Eastern Highlands

The Eastern Highlands which include the northern and eastern mountainous tract of the Kachin State in the north, the Shan Plateau in the middle, and the Tanintharyi ranges in the south. The presence of Precambrian orthogneisses and low-grade meta-sedimentary rocks (Chaung Magyi Group),Paleozoic and Mesozoic carbonates, clastics, and igneous rocks enable this province to remain as a highland, locally with Karst topography in the limestone areas. The Chaung Magyi sediments were laid down probably in a eugeosyline, the Paleozoic carbonates and clastics in a shallow sea, and Mesozoic clastics and evaporates in enclosed and intermontane basins. The province had undergone at least four times of deformation before it was uplifted by the epirogenic movements at the end of Mesozoic. Since then, it has been a fairly stable block. Large linear granitoid plutons of mainly Upper Mesozoic and Lower Tertiary ages intruded along the western marginal zone of this province. These plutons were subduction-related igneous bodies that intruded along the weak junction zone between the tectonic provinces during late Mesozoic nd Early Tertiary.

2.2 **Central Lowlands or Central Cenozoic Belt**

The Shan Plateau and Western Mountains were uplifted during late Cretaceous and Early 'ertiary times. The Central Belt was then a subsiding trough which was gradually infilled with est thickness of sediments possibly exceeding 75,000 feet. Fluviatile and deltaic sedimentation ontinually advanced to the south .In general , the northen portion of the Central Belt is haracterized by continental sedimentation whereas the southern part is marine. In the late rtiary , tectonic movements resulted in broad folding and occasionally thrusting of the Tertiary ediments (general north-north-west strike for folds; north- north-west and north-east fault ystems);the Bago Yoma hills were uplifted during this period and divided the southern part of the entral Belt into two alluvial valleys. Recently, the Ayeyarwaddy/Chidwin system has built up a uge alluvial delta to the Andaman Sea. Earth movements have continued and have affected the eposition of the Quaternary alluvium.

The General type area for the Tertiary sediments is the Minbu Basin in Central Myanmar. lere, the Eocenes, Peguan and Irrawaddian Series are separated from one another by nconformities. The Central Volcanic Line has divided this province into two halves since about liocene. This igneous line starts from the Jade Mines area in the north, through the Wuntho gneous mass, Lower Chindwin Volcanoes, Salingyi, Shinmadaung,Mt Popa,east of Zegon and 'haryarwady, to Myaungmya area in the south. The well-known Sagaing Fault, a right-lateral trike-slip fault, that runs north-south for a distance of nearly 600 miles is located near the eastern dge of the province.

2.3 **Western Ranges or Indo-Burma Ranges**

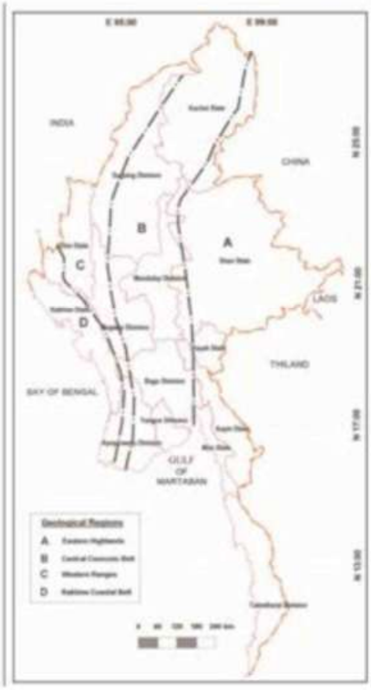
It comprises Naga Hills, Chin Hills and Rakhine Yoma.They are underlain by a thick nildly deformed, tightly folded and weakly metamorphosed sequence of flysch type deposits hich apparently were deposited in a subduction trench that lay between the Eurasian plate an ortheastward-subducting Indian plate. Exotic limestone ranging in size from tiny blocks t nappable units, ophiolites and metamorphic tectonites are locally present within the disrupte lysch deposits. The Western Ranges arose as the results of folding, over thrusting and upliftin uring the Early Himalayan Orogeny at the close of Eocene.

.4 **Rakhine Coastal Belt**

The Rakhine Coastal lowland is underlain by Upper Cretaceous type deposits and lowe 'ertiary rocks in the south and by Upper Tertiary clastic sedimentary rocks of molassic characte n the north. The strata are tightly folded and form chains of low hills. It is the souther ontinuation of the Assam Basin in northeastern India where a thick Tertiary succession is als resent. The Minbu and Assam Basins are fairly similar not only stratigraphy and lithology , bu lso in the occurrance of oil and gas, especially in the Oligocene and Miocene formations.

-5-

Figure-3 Geological Regions of Myanmar



5.0 Water Resources Potential

The South-East Asia (SEA) has 15% of the total world's volume. Demand on water resources has increased due to rapid urbanization and industrialization of the region. It has also indicated that the deterioration in water quantity and quality low reliability of supply, high cost of water and more. Although SEA has the richest resources in the world but those resources and their potentials are being reduced at an alarming rate.

Among the water resources rich countries, Myanmar could still be classified as low water stress country. There are four major river systems, namely, the Ayeyarwaddy, the Thanlwin, the Chindwin and the Sittoung. Besides there are some river systems in Rakhine State and Thanintharyi Division. These river systems contribute for the surface water resources of the country. Due to favourable climatic condition and physiographic features, there are eight river basins those cover about 90% of the country's territory and shown in **Figure 5**.Total surface and groundwater potential of Myanmar are approximately 828 km^3 and 495km^3 per year respectively. Details are mentioned in **Table 1.** However, in many cases the usefulness of groundwater resources is limited due to their being non-renewable, saline or brackish, and hence not suitable for irrigation. If only renewable groundwater suitable for irrigation development is considered, the potential is reduced to 28.3 billion m^3.

Table 1.Myanmar's annual average water resources potential by river basin, 1980-1993.

Region / river basin	Surface water (mcm /Yr)	Groundwater (mcm /Yr)
Region 1. Chindwin	104720	57578
Region 2. Upper Ayeyawady	171969	92599
Region 3. Lower Ayeyawady	229873	153249
Region 4. Sittoung	52746	28402
Region 5. Rakhine	83547	41774
Region 6. Tanintharyi	78556	39278
Region 7.Thanlwin	95955	74779
Region 8.Mekong	10580	7054
Total	**827946**	**494713**

The assessment of water resources potential both for surface and groundwater is carried out on the basis of river basins. In terms of water resources, Myanmar stands the 14th position at global level and 5th position at Asia region.

Figure-4 Annual Rainfall Map of Union of Myanmar

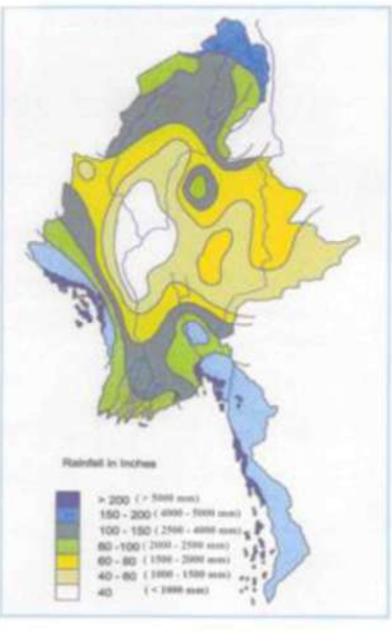
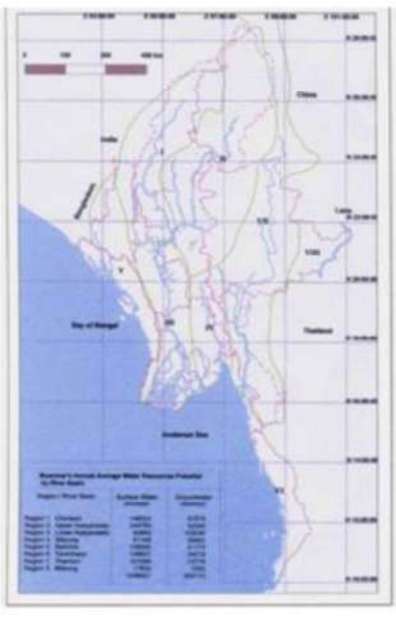


Figure-5 Drainage Basin Map of Myanmar



6.0 Groundwater Resources in Myanmar

On the basis of stratigraphy, there are eleven different types of aquifers in Myanmar (**See Table -2**). Depending on their lithologies and depositional environments, groundwater from those aquifers have disparities in quality and quantity. Of these, groundwater from Alluvial and Irrawaddian aquifers are more potable for both irrigation and domestic use. Groundwater are also extracted from Peguan, Eocene and Plateau limestone aquifers for domestic use in water scared areas, even though these are not totally suitable for drinking purposes. Different types of aquifers in Myanmar are shown in **Figure 6**.

The groundwater resources of Myanmar by administrative region can be summarized as follows.

6.1 Kachin State (northern areas)

Groundwater is found mainly in Oligocene- mid- Miocene and Eocene rocks. It is mainly brackish and rarely fresh. In the valley areas, groundwater from alluvial deposits is fresh and yield may be high, but it is found only in localized areas.

6.2 Sagaing Division (north-western area)

In the northern part of the Division, groundwater is situated in Oligocene to mid- Miocene rocks and is brackish in quality. Groundwater in the Chindwin Basin is of mid-pliocene age and occurs in a contained area. The water is suitable for drinking and irrigation purposes. Groundwater in the southern part of the Division is suitable mostly in alluvial beds of Quaternary age, mainly fresh water, and has a good yield. The water is also suitable for drinking and irrigation purposes.

6.3 Shan, Kayah, Kayin and Mon States and Tanintharyi Division (East and South-eastern area)

Groundwater occurs mainly in limestones of the Carboniferous-Permian age. In the eastern part of the area, it lies in beds of Mesozoic and Precambrian ages. Groundwater in volcanic rocks is found in the southeastern part .Generally, it is fresh and mostly suitable for drinking and irrigation. To exploit economically, drilling method may be limited.

6.4 Rakhine and Chin States (western area)

In the eastern part of the states, groundwater occurs in Eocene rocks. The groundwater is mainly brackish and fresh water is rarely encountered in this area. On the Western side groundwater is of Oligo-mid-Miocene and is brackish in quality. Natural reserves of fresh water are limited and seawater intrusion may be encountered.

6.5 The Central Area (Mandalay and Magway Divisions)

Fresh groundwater is found in Quaternary and Mio-Pliocene rocks. But salinity of groundwater in Mio-Pliocene beds increases with depth. It is suitable for drinking and irrigation purpose. Small supplies of groundwater have been achieved from boreholes tapped in Upper and Lower Peguan in some areas. They are of Miocene and Oligocene ages. Groundwater in these sediments is mostly saline and rarely fresh.

6.6 The Delta Area (Yangon and Ayeyarwady Division)

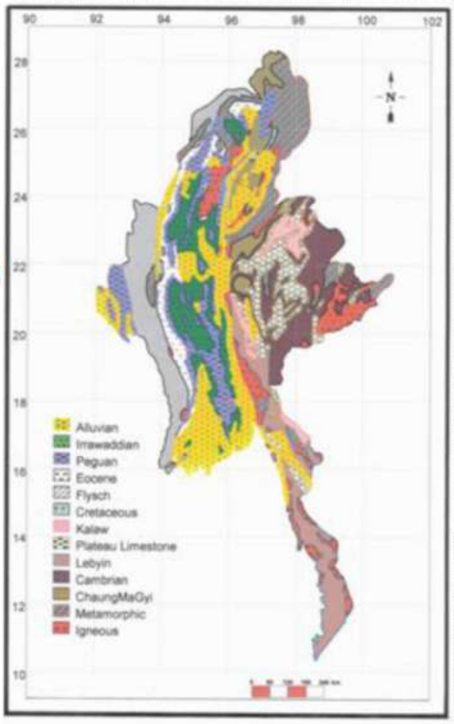
Groundwater occurs in alluvial beds of Quaternary age. It is mostly fresh and in some parts brackish and suitable for drinking and irrigation purposes. In coastal area the water quality may be saline.

6.7 Bago Division (southern area) the central area of the Division is Bago Yoma and it has the rocks of Oligo- Miocene age bearing mainly brackish water. Natural reserves of fresh water are limited. In the eastern and western parts of the Division, groundwater of alluvial beds is exploited. Groundwater reserves are considerable and suitable for drinking and irrigation purposes

Table-2 The Major Aquifers in Myanmar

Sr.No	Name of Aquifer	Major rock units	Area of occurrences	Remark
1	Chaung Magyi Aquifer	Low grade metamorphic rocks	Eastern Highland	To be study in detail
2	Cambrian- Silurian Aquifer	Molohein Group Pindaya Group Mibayataung Group	Eastern Highland	To be study in detail
3	Lebyin- Mergui Aquifer	Graywacke , quartzite, argillite, slate, mudstone, gravel etc;	Western boundary of Eastern Highland and Tanintharyi ranges	To be study in detail
4	Plateau Limestone Aquifer	Limestone & dolomite	Eastern Highland	GW is being extracted in some places
5	Kalaw- Pinlaung- Lashio Aquifer	Loi- an Group & Kalaw Red Bed	Western boundary of Eastern Highland and Tanintharyi ranges	To be study in detail
6	Cretaceous Aquifer	Flysch units and limestone units	Western Ranges Northern Kachin	To be study in detail
7	Flysch Aquifer	Interbedded units of sand, siltstones, shale and mudstone	Western Ranges	Probable GW source area
8	Eocene Aquifer	Sandstones, siltstones and shales	Periphery of Central Lowland	Probable GW source area
9	Pegu Group Aquifer	Sandstone, siltstones and shales	Central Lowland and Rakhine Coastal Plain	Mostly saline & brackish water, some fresh water in recharged areas
10	Irrawaddian Aquifer	Mainly sands, sandstones with gravels, grits, siltstones and mudstones	Central Lowland and Rakhine Coastal Plain	Thick aquifer fresh GW with high iron content
11	Alluvial Aquifer	Sands, gravels and muds	Major river basins and its tributaries, base of mountains and ranges	Fresh GW, seasonal water table changes

Figure-6 Aquifer Map of Myanmar



4. Water Resources Management and Policy

Even there are many laws, acts, legislations and regulations related to water sectors, most of the laws and acts of relevant water sectors are still needed to modify and should be reviewed with a view to enacting unified water resources law so as to promote a more effective legal framework for coordination and management of water resources. Some acts (such as Burma groundwater act developed in 1930) have weakness as jurisdiction are very much limited and no attempts have been made to amend it and some acts are no more applicable and suitable with the present changing situation.

Water Laws in Myanmar

(a) For urban water utilization

The Rangoon Water Works Act(1885)
The Burma Municipal Act(1898)
The Burma Canal Act,1905,as amended by the Burma Act of 1914,1924,1928 and 1934
The Burma Embankment Act,1909,as amended by the Burma Act of 1923 and 1931

The City of Rangoon Municipal Act(1922)
The Underground Water Act (1930),(Burma Act IV 1930)21 June 1930
The Burma Water Power Rules (1932)
The Rangoon Municipal Act(1941)

Section 114: Water supply
Section 115: General powers for suppling the city with water
Section 116: Power of access to municipal waterworks
Section 117: Prohibition of erection of any building which damages sources of water supply
Section 118: Prohibition of bathing in or polluting water
Section 119: Occupiers of premises to be primarily liable for certain offences against the Act

The City of Yangon Development Law,14 May 1990(Law No.11/90)
The City of Yangon Development Law,17 December 1999(Law No. 6/99)

Most of the above laws are related to urban water supply.For groundwater use,the laws are still being processed , and some may introduce new concepts.

For water supply for irrigation

Canal Act, 1905(Amendment Canal Act in 1998)

Myanmar Embankment Act, 1909(Amendment Embakment Act in 1998)

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In Myanmar up to present water resources management and policy is following "Burma ground water act" developed in 1930 and "the City of Yangon Development Law" enact in on 17.12.1999.

To fulfill the present situation now new "Myanmar ground water act" is promulgated and already submitted to the Parliament for the approval.

Problems Related to Water Resources

Arsenic content is 50 ppb to 100 ppb level from 0 to depth 300 ft within the Aquifer at Ayeyarwaddy Region

Plans for Cooperation to Solve the Problems

Below 300 ft Arsenic content is decreased so it is needed to drill below 300 ft level to pump out the ground water.

Arsenic content can be reduced by passing charcoal filter at the water tank or water storage.

Country Report

동티모르

<Democratic Republic of Timor Leste>

Submitted by

Mr. Cipriano Fernandes

Institute of Petroleum and Geology(IPG)

Status of Water Resources Management and Policy

1. Summary

Democratic Republic of Timor Leste is located between Australia and Indonesia (figure.1) Timor-Leste forms the eastern half of the island of Timor, sitting adjacent to Indonesia and separated from Australia by the Timor Sea. The country is about 14,922 km and includes the island of Atauro and the enclave of Oecussi (latitude 8° 00' to 9° 30' south and longitude 124° 00' to 127° 30' east Timor Leste has 1.25 million population with population growth 3.2% /year. Increasing in amount of population Timor Leste has conveyed towards the increasing of the water demanding for daily life, such as drinking water and irrigation water for agriculture. To meet the high demand of Water resources in the country, mostly people are getting water from surface water and only few people are getting water from groundwater. Due to unfriendly of climate and geological setting, the amount of groundwater is low.

Figure 1. Location of Timor-Leste (after Asian Development Bank, 2004)

The topography of the country is generally mountainous, characterised by rugged terrain and small narrow valleys (Figure 3). It has been t has been suggested that as much as 44% of the country may have a slope of >40%. Many of these mountains are above 2,000 m elevation, Mount Ramelau the highest at 2,963 m. Timor-Leste ranges between 75 km and 100 km in width. In the north-east, uplifted coral reef stretches along the coast, and is characterized by typical karst topography.

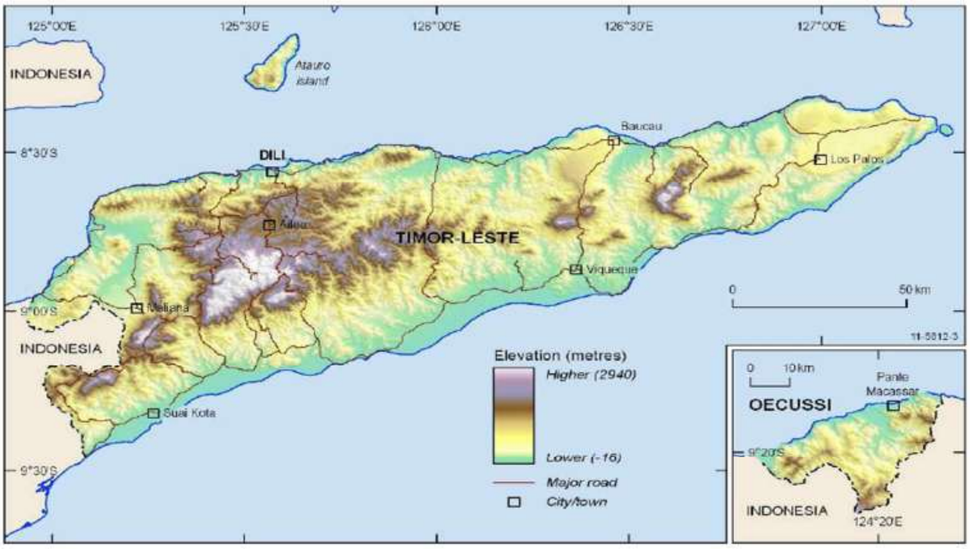

Figure 2. Topography of Timor-Leste (Adapted from Geosciences Australia, 2012)

2. Hydrogeological Setting

2.1 Geological Setting

Geologically, Timor Island is a part of the Banda Arc (figure .7). The tectonic history of Timor is complex and has been the subject of considerable attention. According to one theory, the Banda arc marks the zone of collision between the northwestern edge of the Australian continent and a former oceanic subduction zone. The outer arc, including the island of Timor, is structurally a fold and thrust belt, consisting of the imbricated outer edge of the Australian continental margin, overlain at high structural levels by remnants of the pre-collisional oceanic fore-arc complex (Charlton, 2002).

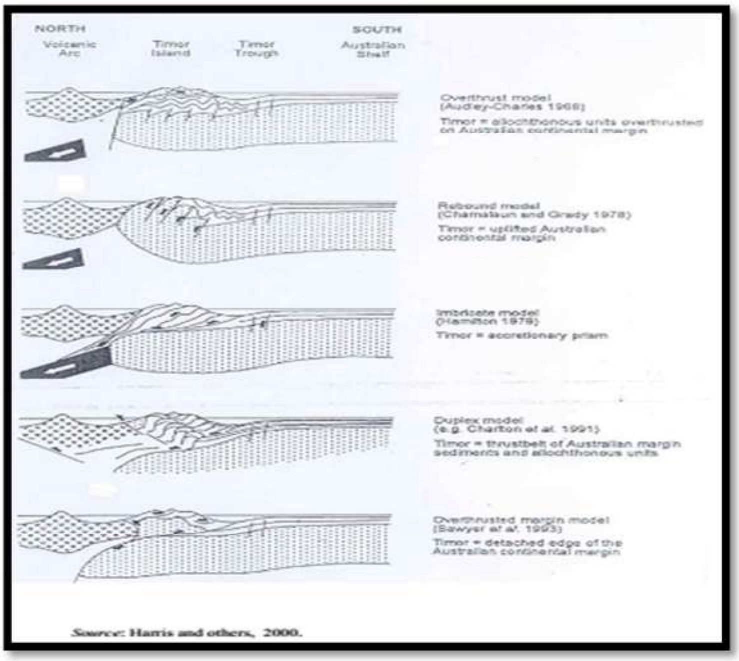

Figure.3. The geological setting of Timor Leste

The geology of Timor-Leste is complex both compositionally and tectonically as shown in Figure 4. Compositionally, Timor-Leste contains a wide variety of rock types (igneous, metamorphic and sedimentary) with a range of textural (fine-grained and well sorted to large boulder conglomerates) and chemical (felsic to ultra-mafic) compositions. It is important to note, however, that volcanism is not a key feature of the geology in mainland Timor-Leste, in contrast to the surrounding islands. The tectonic history of Timor-Leste, which sits at the interface of the Eurasian and Australian Tectonic Plate boundaries, has received much attention and several tectonic evolution models exist. Geological work has been undertaken pre-1975 before Indonesian occupation with foreign access (Audley-Charles, 1965); 1975-1999 during Indonesian occupation with limited foreign access; and post-1999 with independence of Timor-Leste and foreign access once again possible.

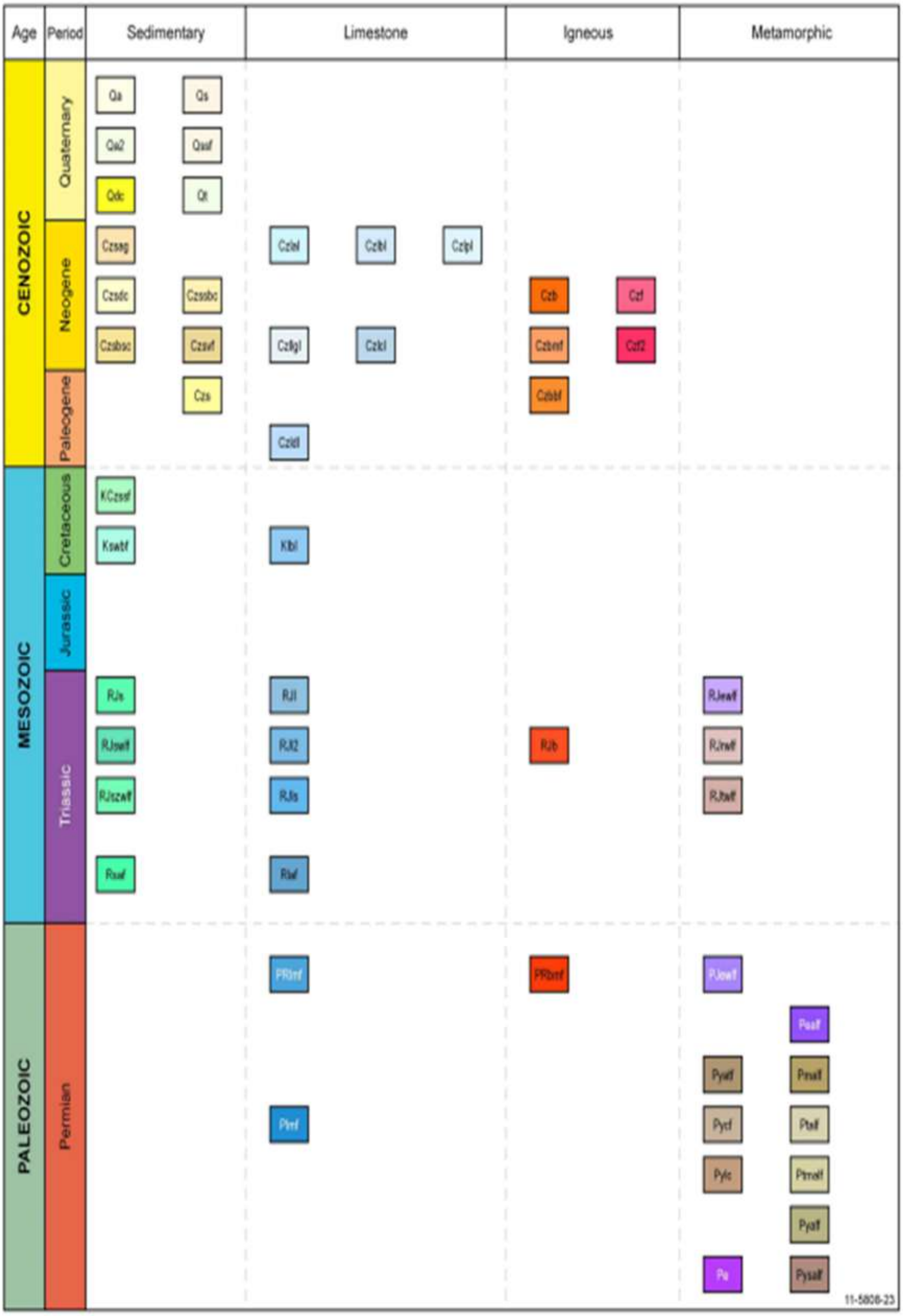

Figure 4 legend, Geology of Timor-Leste (Wallace et al., 2012).

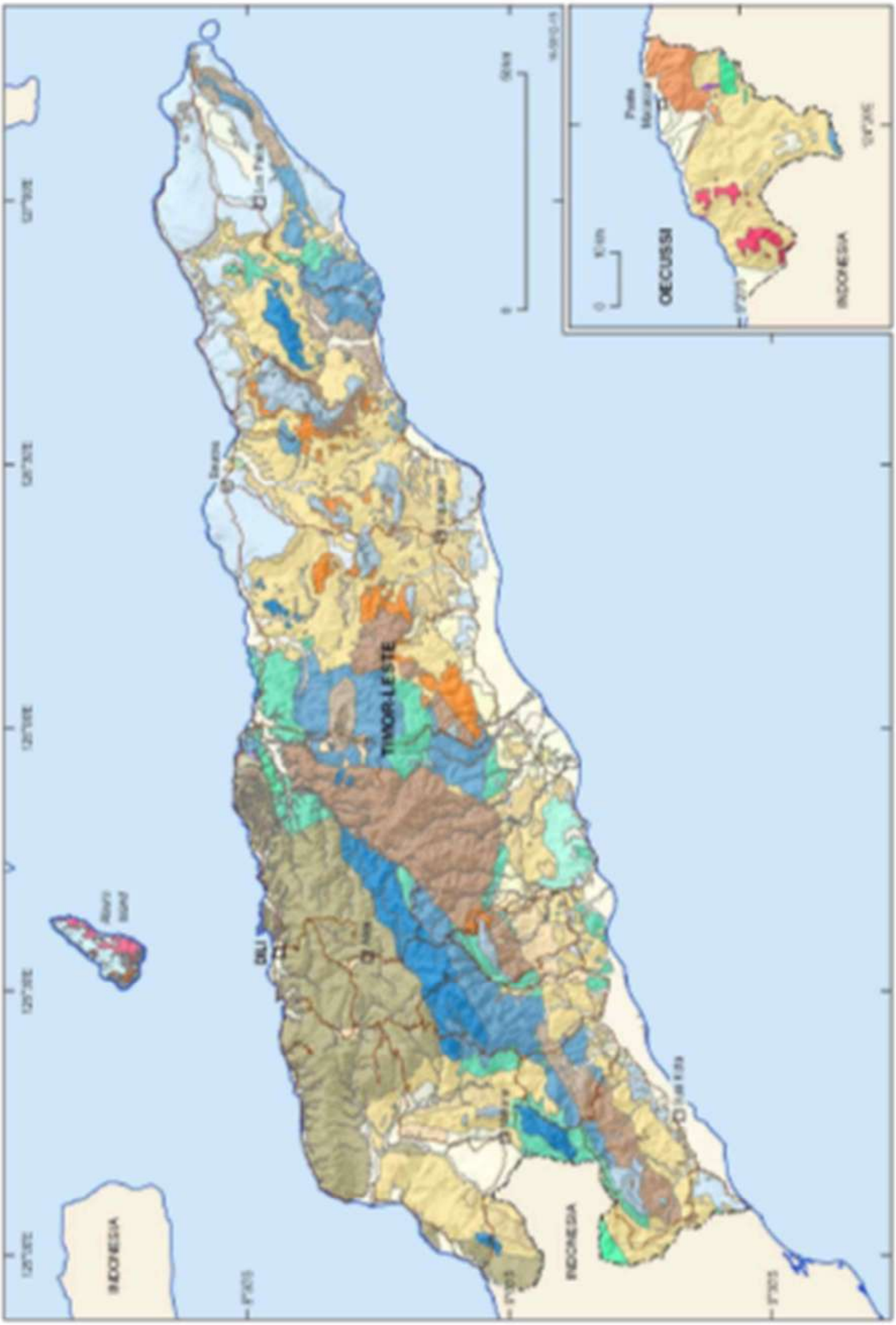

Figure 5. Geological Map of Timor Leste

2.2 Soils

There are four distinct soil types that occur in Timor-Leste, reflecting the regional geology. In general the soils of Timor-Leste are not very fertile, do not store water well, and are easily eroded (Figure 6). The soils located at the mouth of the River Loes, to the south of Manatuto, and to the east of Baucau, are of recent alluvial formations and are not suitable for agriculture. The soils found in the eastern regions such as in Maliana, Ainaro, and Maubisse, and to a lesser extend in Baucau, Lauten and in Los Palos are the most fertile and are suitable for agriculture. The soils of alluvial origin are confined to the coastal regions around Dili, Suai and Manatuto and are poorly drained soils. The soils present in the highlands around Ermera are rich in organic matter and suitable for agriculture.

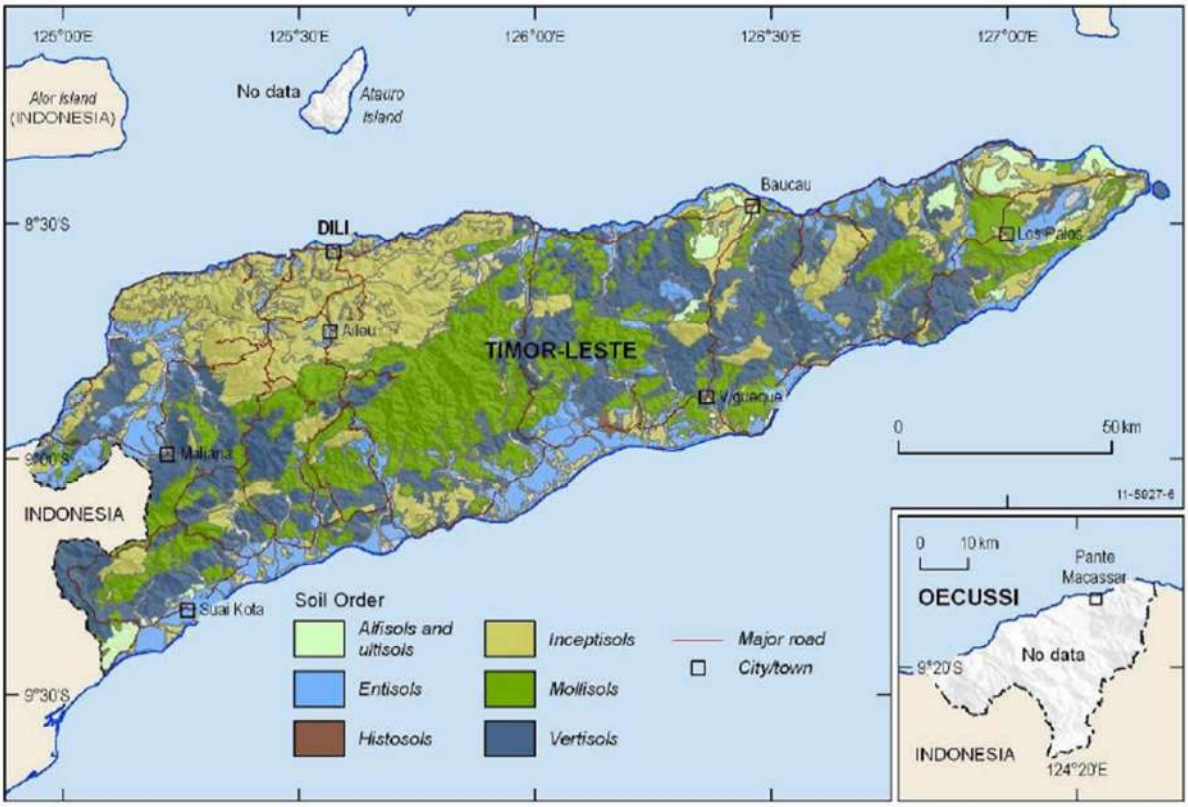

Figure 6. Soil types of Timor Leste

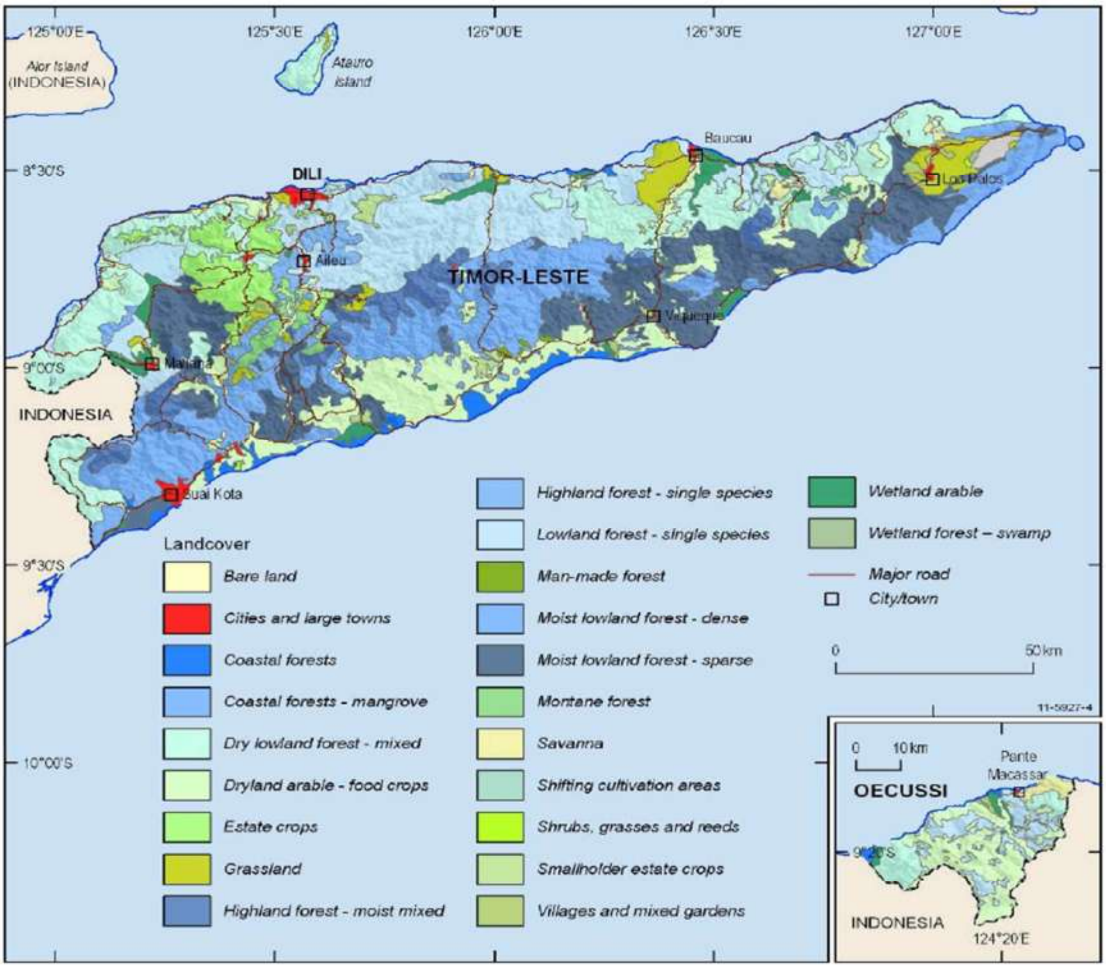

Figure 7. Landuse map of Timor-Leste (Adapted from Geosciences Australia, 2012)

2.3 Climate

The climate of Timor-Leste is characterized by the Asian tropical monsoonal system due to its topographic relief and geographical location. The climate of Timor-Leste can largely be divided in to two distinct seasons: the ‘Wet season’ (December to May) with the wettest month January, February or May depending on the region; and the ‘dry season’ (June to November) with September-October generally the driest months, also depending on the region.

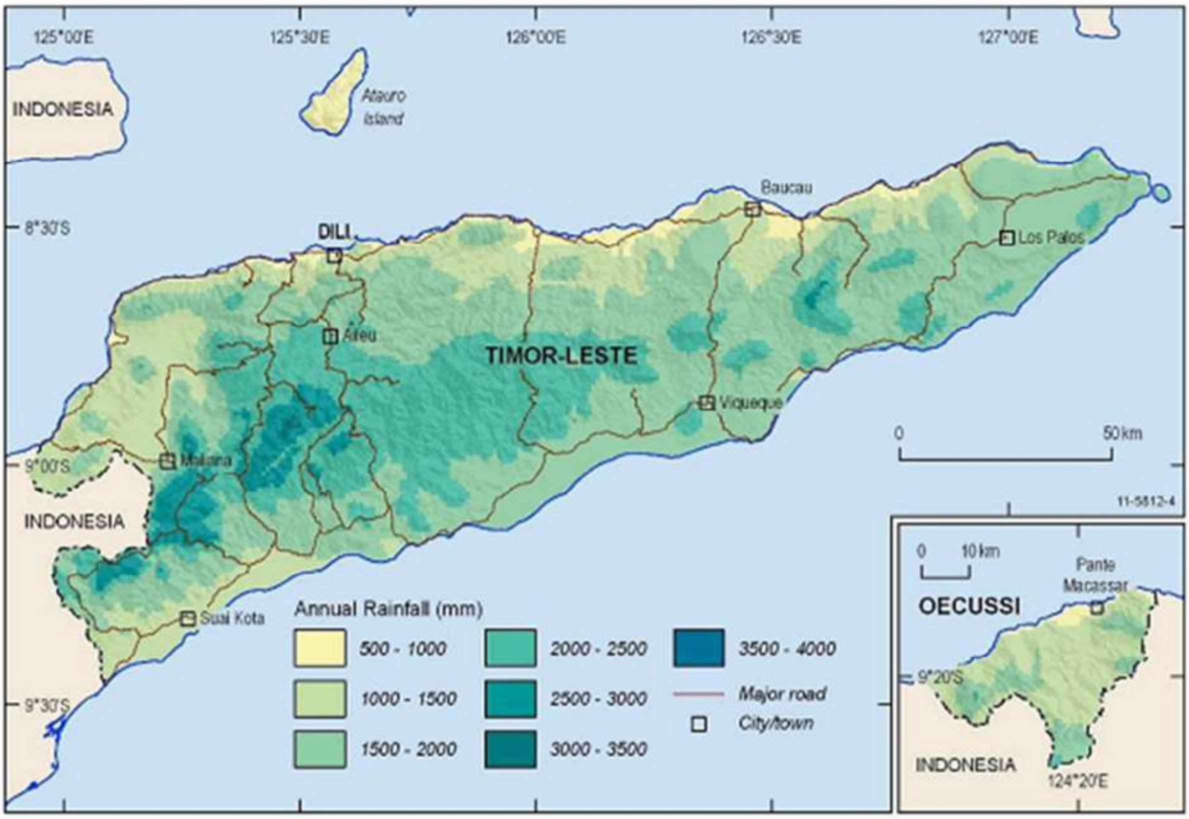

Figure 8. Mean annual Rainfall of Timor Leste

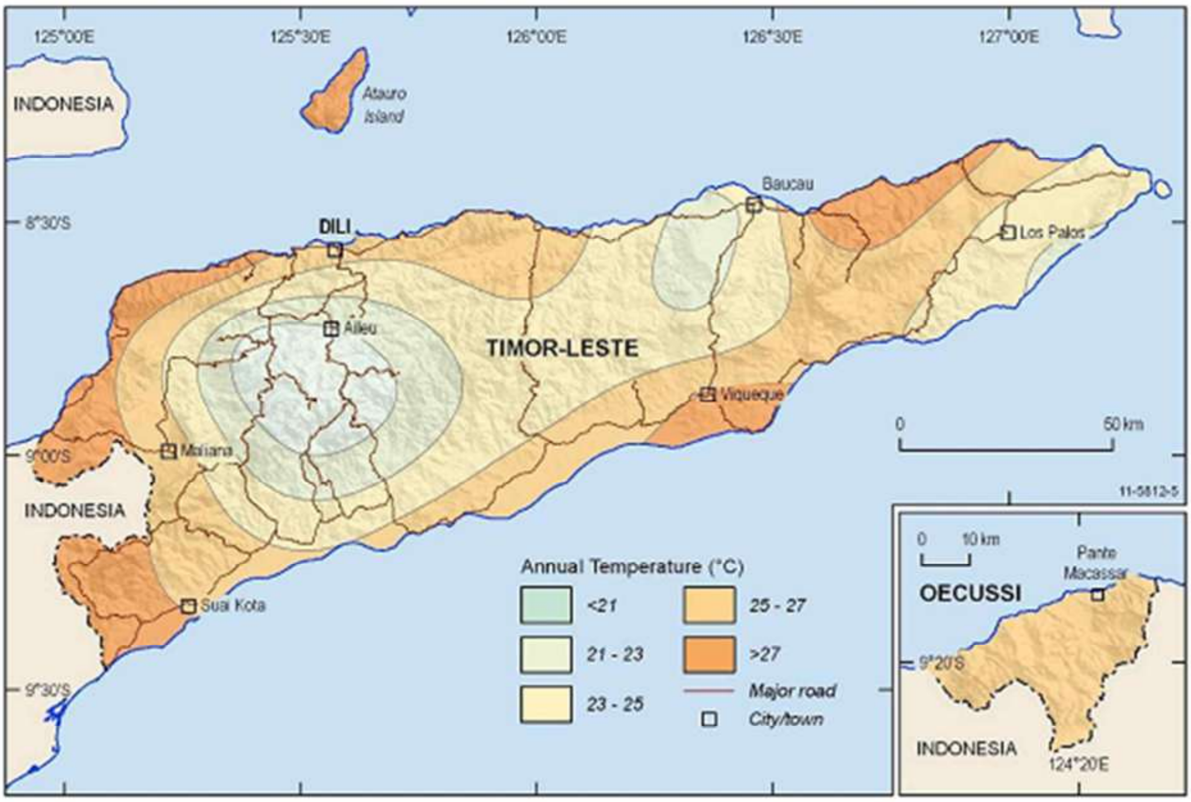

Figure 9. Mean annual Temperature of Timor Leste

2.4 Groundwater and Aquifer Systems in Timor Leste

Groundwater is water stored below the ground in spaces and cracks in the rocks and sediments. These are called pores, fractures or fissures. Groundwater is a vast resource which greatly exceeds the amount of water in rivers and lakes, both around the world and in Timor-Leste. The porous rocks and fissured/fractured rocks in which groundwater is stored and flows are called aquifers. These aquifers typically consist of sediments, limestone or fractured igneous/metamorphic rocks. Groundwater may flow relatively homogenously through an aquifer or may flow along localized preferential flow paths. The amount of homogenous flow relative to preferential flow within an aquifer will depend on the rock type. Some of the general properties of the typical aquifer types made of different types of rock are discussed in the following sections.

There is no detailed national groundwater studies were available and few measurements has been made. Groundwater is likely to be found beneath all land in Timor-Leste, however the groundwater resources are likely to be unevenly distributed and vary in quality and quantity.

Groundwater is a critical resource in Timor-Leste. Most of People of Timor-Leste rely on groundwater during the dry season when most surface water dries up. Groundwater is used as a source of drinking water for urban and rural communities and for industrial and agricultural activities. Rural villages may have one or two groundwater wells which service the entire community, while many others get their water solely from natural groundwater springs. Intensive groundwater pumping occurs in the major centers for the purposes of general consumptive, industrial and agricultural use.

Groundwater in Timor-Leste is recharged by rainfall during the wet season to maintain enough storage for use during the dry season. Without regular recharge, the stored groundwater decreases. Increased demand caused by growth in population, industry and agriculture also has the potential to reduce the amount of stored groundwater. Both groundwater recharge and pumping need to be understood and, in the case of pumping, managed in Timor-Leste to ensure enough groundwater is available when needed.

A hydrogeology framework has been developed to allow Timor-Leste to manage groundwater resources into the future. The framework outlines the steps needed to develop understanding groundwater resources.

Types and the occurrence of aquifer is defined base on, geology (lithology type) rock texture, fracture, extend and thickness. Three principal types of aquifer have been identifying for the national map such as, intergranular porosity, fissure porosity, localized flow, fractured localized porosity.

The intergranular porosity hydrogeology sub-division (blue) includes sedimentary rocks of ages from the Triassic-Jurassic, Cretaceous and Cenozoic, and are present throughout Timor-Leste. Extensive deposits of sedimentary rocks and unconsolidated sediments are concentrated along the coast of Timor-Leste, forming sedimentary plains, but these deposits are also present within several inland depressions. Smaller sediment deposits are present throughout Timor-Leste within drainage lines which become larger towards the coast. To reflect the potential hydrological difference in these sedimentary environments, the intergranular porosity sub-division has been further separated into higher potential yield (sedimentary plains) and lower potential yield (drainage line river valley sediments).

The fissured porosity (karst) hydrogeology sub-division (green) largely consists of the limestone rocks with karstic textures, which range in age from Permian to Cenozoic, and occur throughout Timor-Leste. The older limestone (Permian to Cretaceous) is particularly prevalent in the central mountains that run the length of the country from east to west. The younger limestone (Cenozoic) predominantly occurs closer to the coast, particularly prominent in the eastern half of the country. These rocks are known to produce substantial groundwater resources. Within the fissured porosity sub-division, the younger limestone has been given a higher potential yield, to reflect the known high karst features and volumes of groundwater flow, and the older limestone a lower potential yield due to the metamorphism and more fractured nature of these rocks.

The localized flow hydrogeology sub-division combines two principal and very different rock types of fractured rocks (buff) and confining units (brown). Both these classifications may produce localized flow, but will do so for different reasons. The groundwater flow within fractured rocks will be focused along fractures, with the rock itself having little primary porosity. The clay-rich confining units will focus groundwater along courser sedimentary horizons where, locally, groundwater will flow through sand and gravel beds. As the localized porosity units do not have consistent flow throughout, the prospectively is lower in these areas. That is, just because groundwater flow is high in one area there is no guarantee that groundwater flow will be high in an adjacent location.

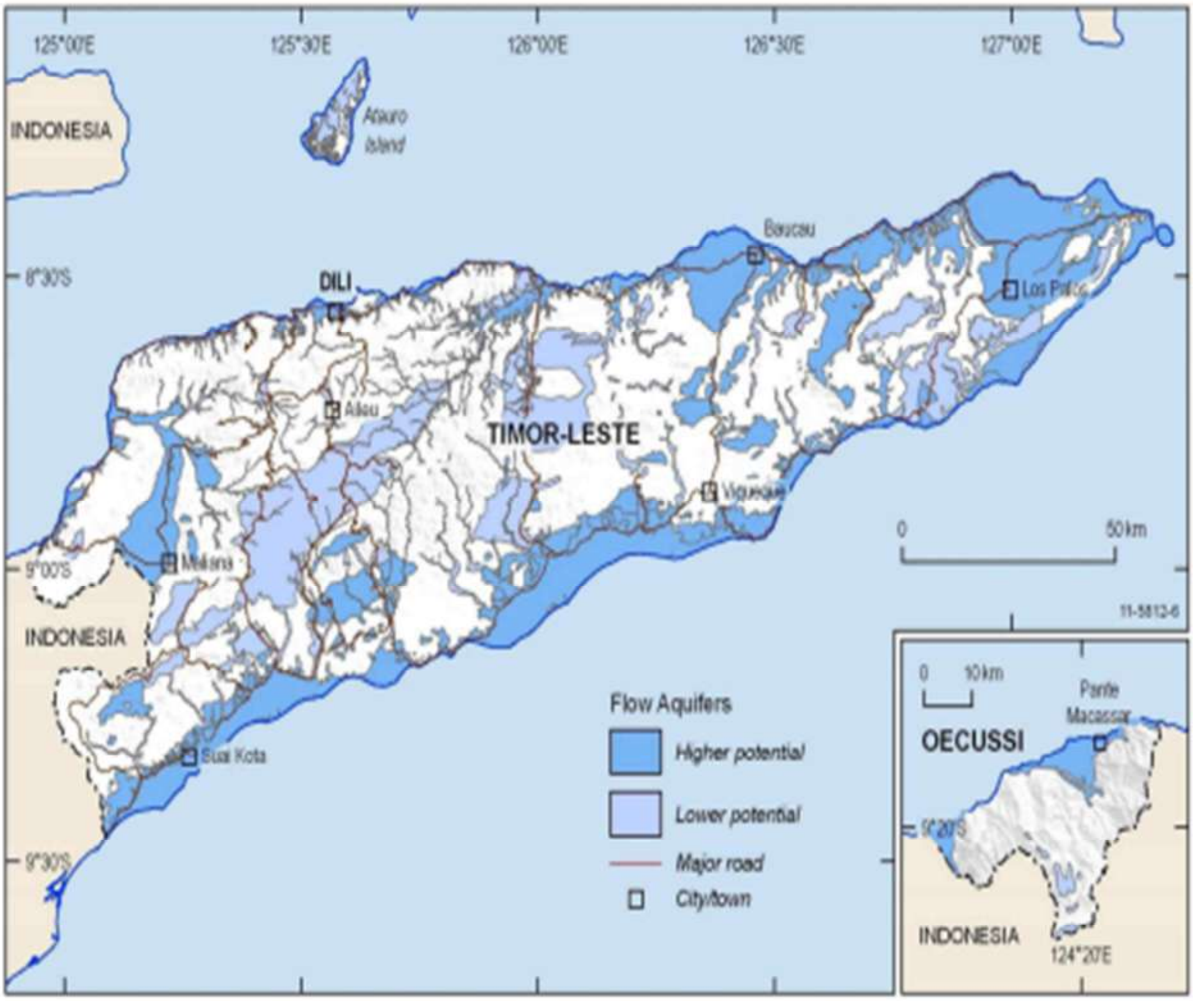

Figure 10. Hydrogeological map in Timor Leste, (Adapted from Geosciences Australia, 2012)

3. Status of Water Resources

3.1 Water Resources in Timor Leste

Water resources status base on water resources management policy (Draft) article 4 "Ownership" state that "all water resources are owned by state, unless otherwise is determined under customary law is not exempted by the Ministry.

Water resources management is under the Ministry of Infrastructure and controlled by Secretary Estate of Water Resources and Urbanization and its' Directorates with their variation of responsibilities.

3.2 Water Resources and IPG.IP

Institute of Petroleum and Geology-Public Institution (IPG.IP) which is established base on a decree law in order to do research on Petroleum and Geology as well as geohidrology research. IPG.IP as a Research institution has responsibility to define the water resources (quality and quantity).

4. Water Resources Management And Policy

Groundwater has an important role to the lives and livelihoods of the people of Timor Leste, given its function as one of the basic necessities of life.

Commonly, groundwater management based on groundwater basin, while in Timor Leste has been no detailed study to identify groundwater basin.

At this moment, groundwater management policy in Timor Leste is in draft and will be discussed further at Council Ministry during October 2014. Therefore groundwater must be managed wisely, comprehensive, integrated, sustainable, and environmentally friendly.

Service water supply and sanitation must issue a permit for the use of industrial and commercial (other than irrigation). A permit valid up to three years.

5. Problems Related to Water Resources

5.1 Problem related water resources shortage

There are several problems have been identifying related to shortage water such as population growth increase the demanding of water, change in amount of rainfall and increase in development which lead to change in landuse are decreased the amount of the groundwater. Moreover the quality of the groundwater in the coastline area is low, due to intrusion of sea water. Despite of that, no detail hydrogeological mapping has been conducting in order to collect detail information on water resources (groundwater).

5.2 Water Management Policy

There is no especial policy at the moment to regulate the investor on water resources in terms of the quantity of daily production by the company.

6. Plans for Cooperation to Solve the Problems

6.1. Research Institution

IPG.IP is planning to establish more Memorandum of Understanding (MoU) with the Geological researches institution and strength the established MoU that IPG.IP has with the other researches institution.

6.2. International Company

As a State, Timor Leste is very welcome to international companies which interest to invest on exploration and exploitation water resources in Timor Leste.

7. Conclusion

Timor-Leste situated in Maritime Southeast Asia, it comprises the eastern half of the island of Timor, the nearby island of Atauro and Jaco, and Oecusse, enclave on the northwestern side of the island, within Indonesia West Timor, the country size is about 15,410 KM^2, composed by 13 administrative divisions named “districts” with total population 1.25 million based on statistics data 2013.

Timor-Leste topographically mountainous in generally, characterized by rugged terrain and small narrow valleys, it has been suggested that as much as 44% of the country may have a slope of >40%.

The geology of Timor-Leste is complex both compositionally and tectonically and compositionally, and in general the soils of Timor-Leste are not very fertile, do not store water well, and are easily eroded

The climate of Timor-Leste is characterized by the Asian tropical monsoonal system due to its topographic relief and geographical location. The climate of Timor-Leste can largely be divided in to two distinct seasons: the ‘Wet season’ (December to May) and the ‘dry season’ (June to November) with September-October.

Groundwater in Timor-Leste is recharged by rainfall during the wet season to maintain enough storage for use during the dry season. Without regular recharge, the stored groundwater decreases. Increased demand caused by growth in populations, industry and agriculture also has the potential to reduce the amount of stored groundwater. Both groundwater recharge and pumping need to be understood and, in the case of pumping, managed in Timor-Leste to ensure enough groundwater is available when needed.

A hydrogeology framework has been developed to allow Timor-Leste to manage groundwater resources into the future. The framework outlines the steps needed to develop understanding groundwater resources.

Types and the occurrence of aquifer is defined base on geology (lithology type) rock texture, fracture, extend and thickness. Three principal types of aquifer have been identifying for the national map such as, inter-granular porosity, fissure porosity, localized flow, fractured localized porosity.

There are several problems have been identifying related to shortage water such as populations growth increase the demanding of water, change in amount of rainfall and increase in development which lead to change in land-use are decreased the amount of the groundwater.

Institute of Petroleum and Geology-Public Institution (IPG.IP) which is established base on a decree law in order to do research on Petroleum and Geology as well as geo-hydrology research. IPG.IP as a Research institution has responsibility to define the water resources (quality and quantity). Planning to establish more Memorandum of Understanding (MoU) with the Geological researches institution and strength the established MoU that IPG.IP has with the other researches institution.

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STATUS OF WATER RESOURCES MANAGEMENT AND POLICY

POSITION OF TIMOR LESTE

Figure 1. Location of Timor-Leste (after Asian Development Bank, 2004)

TOPGRAPHY OF TIMOR LESTE

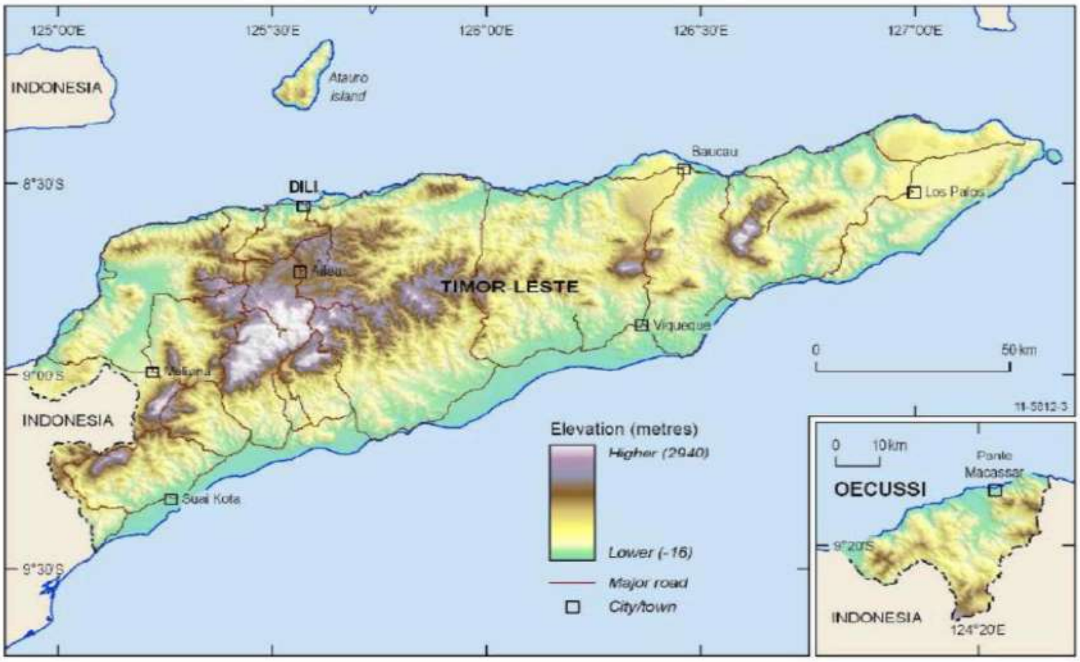

Figure 2. Topography of Timor-Leste (Adapted from Geosciences Australia, 2012)

CLIMATE OF TIMOR LESTE

- The climate of Timor-Leste is characterised by the Asian tropical monsoonal system due to its topographic relief and geographical location.
- The climate of Timor-Leste can largely be divided in to two distinct seasons:
  - the 'Wet season' (December to May)
  - and the 'dry season' (June to November)

GEOLOGY OF TIMOR LESTE

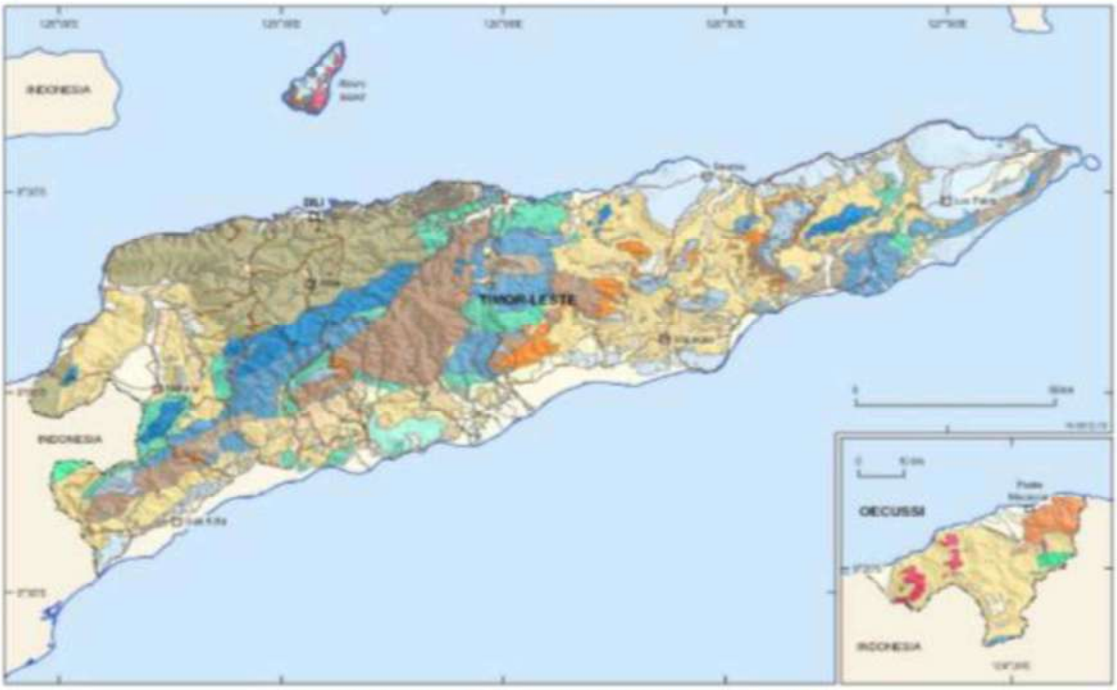

Figure 3. Geology of Timor-Leste (Wallace et al., 2012)..

SOILS IN TIMOR LESTE

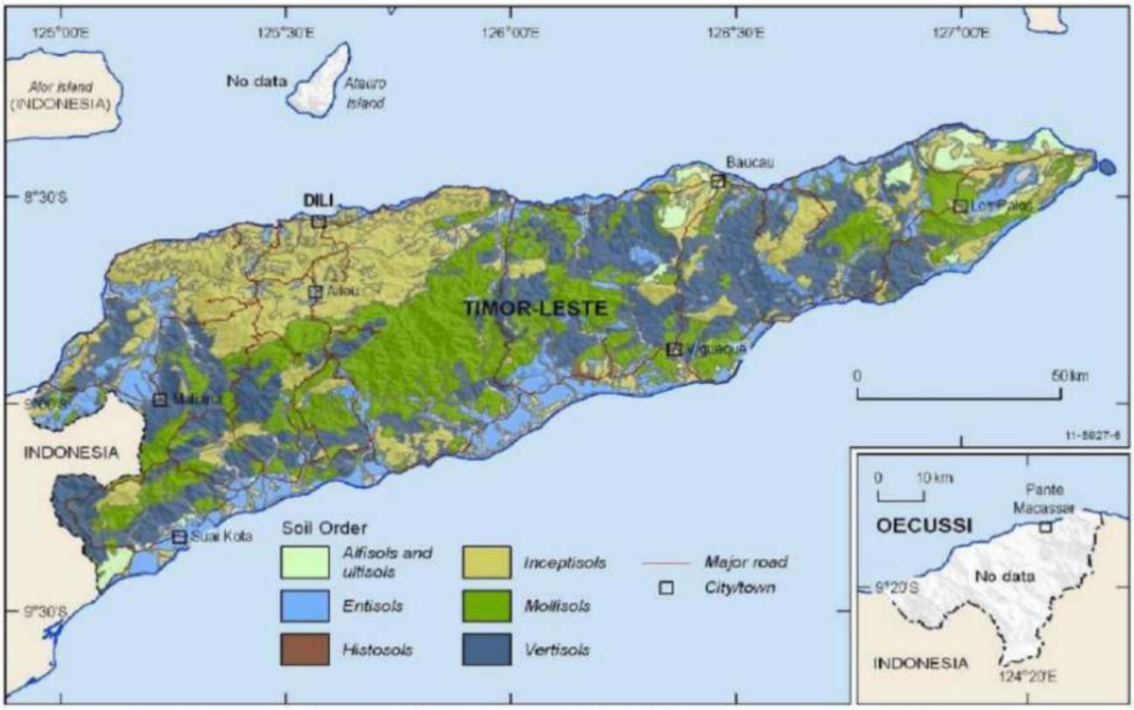

Figure 4. Soil Order map of Timor-Leste (Adapted from Geosciences Australia, 2012)

LAND USE

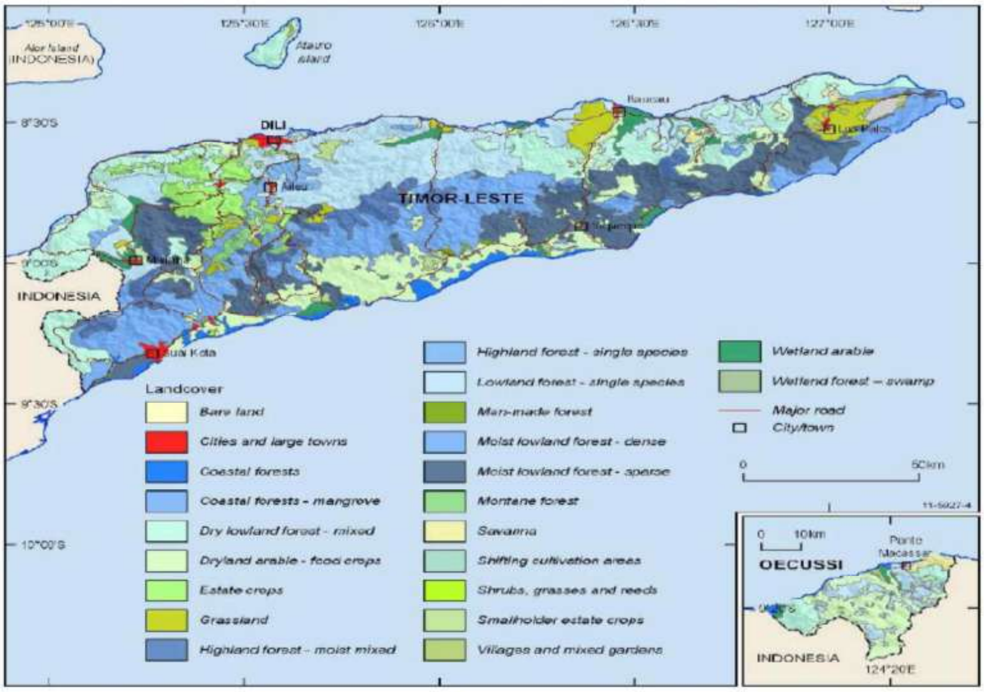

Figure 5. Landuse map of Timor-Leste (Adapted from Geosciences Australia, 2012)

POTENTIAL AQUIFER IN TIMOR LESTE

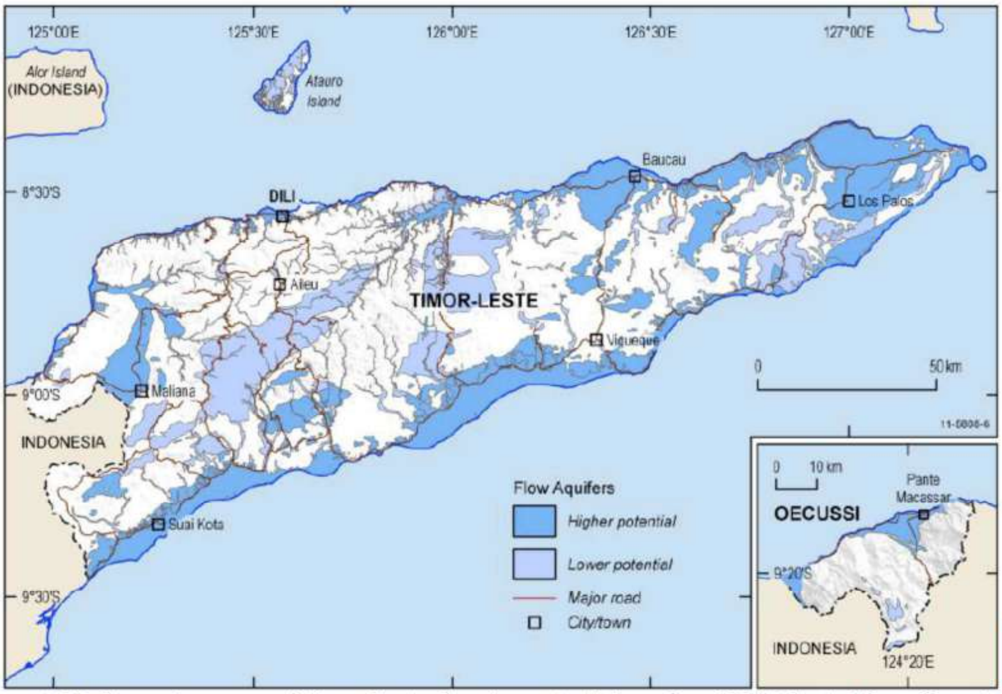

Figure 6: Hydrogeology map of Timor-Leste showing potential aqufer yield (Adapted from Geosciences Australia, 2012)

- **Status of Water Resources**
  - Water Resources status in Timor Leste
  - IPG-IP roles an responsabilities to manage water resources in Timor - Leste
- **Water Resources Management And Policy**
- **Problems Related to Water Resources**
  - Problem related water resources shortage
  - Water Management Policy
- **Plans for Cooperation to Solve the Problems**
  - Research Institution
  - International Competitions in exploration water resources

THANK YOU

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Country Report

대한민국

< Republic of Korea >

Submitted by

Yongcheol Kim, Heesung Yoon, Gipyo Kim, Yongje Kim

Korea Institute of Geoscience and Mineral Resources

Technical advance in salt-water intrusion monitoring; Preliminary application results in Jeju Island

1. Summary

Jeju is volcanic island where groundwater is a primary source for water. Although higher recharge rate and aquifer productivity of groundwater compared to the other area in Korea, groundwater resources should be properly maintained by well-organized monitoring networks to protect from over extraction for agricultural use and saltwater intrusion. Jeju special self-governing province operates 53 monitoring wells for saltwater intrusion and has collected data for more than decades using a single sensor at a specific depth. Cause of the limits of single sensor method in monitoring dynamically-changing coastal aquifer, a novel method which is called 'interface egg', which is floating between freshwater and saltwater in monitoring well following a specific density, is applied to the Handong-1 monitoring station. The data obtained from the interface egg succeeds to show time series changes of the interface and freshwater thickness. Further, with an aid of an existing or developing forecasting model such as artificial neural network model, the new method could be promising in salt water intrusion early warning system which can give a measuring time for local government to protect saltwater intrusion.

2. Hydrogeological Setting

2-1 Geography and Geology

Jeju Province is the largest island in the Republic of Korea (Korea from here on), located off the south-west coast of the Korean peninsula in the South Korea Strait. Jeju is a Quaternary volcanic island 73 km wide and 41 km long with a total area of 1,848 km^2. Numerous tuff rings and tuff cones occur scattered prominently on the surface in addition to lava flows and scoria cones produced on the island approximately 1.8 Ma ago. Volcanic rocks from flows and pyroclastic dominate on the island, but sedimentary rocks also occur interbedded with volcanics at depth. Underlying the volcanics are the Seogwipo sedimentary formation and unconsolidated sediments, with Cretaceous granite and welded tuffs stratigraphically below these (Fig. 1).

2-2 Hydrogeology

Jeju Province has a mean annual rainfall of 1,975 mm of which about 60% of annual precipitation occurs during the summer monsoon between June and September. A low evapotranspiration rate and high permeability of geologic formations allow year-round recharge of groundwater, as approximately half of the annual rainfall (1.58 billion m^3/year) permeates into the ground (KIGAM, 2012).

Although about 143 streams are designated by Jeju Government, most streams are ephemeral except for some streams and only during the monsoon season do waters run in the most streams which is the reason why groundwater is major source for water works in Jeju. Groundwater occurs and migrates through permeable layers such as clinker, hyaloclastite breccia, scoria, lava tube, rock joint. Seogwipo formation acts as lower impermeable boundary.

Saltwater intrudes naturally more at eastern part rather than the other parts because of low hydraulic gradient and subsurface geological features in this area. However, western part is intruded by saltwater by over-pumping for agricultural use.

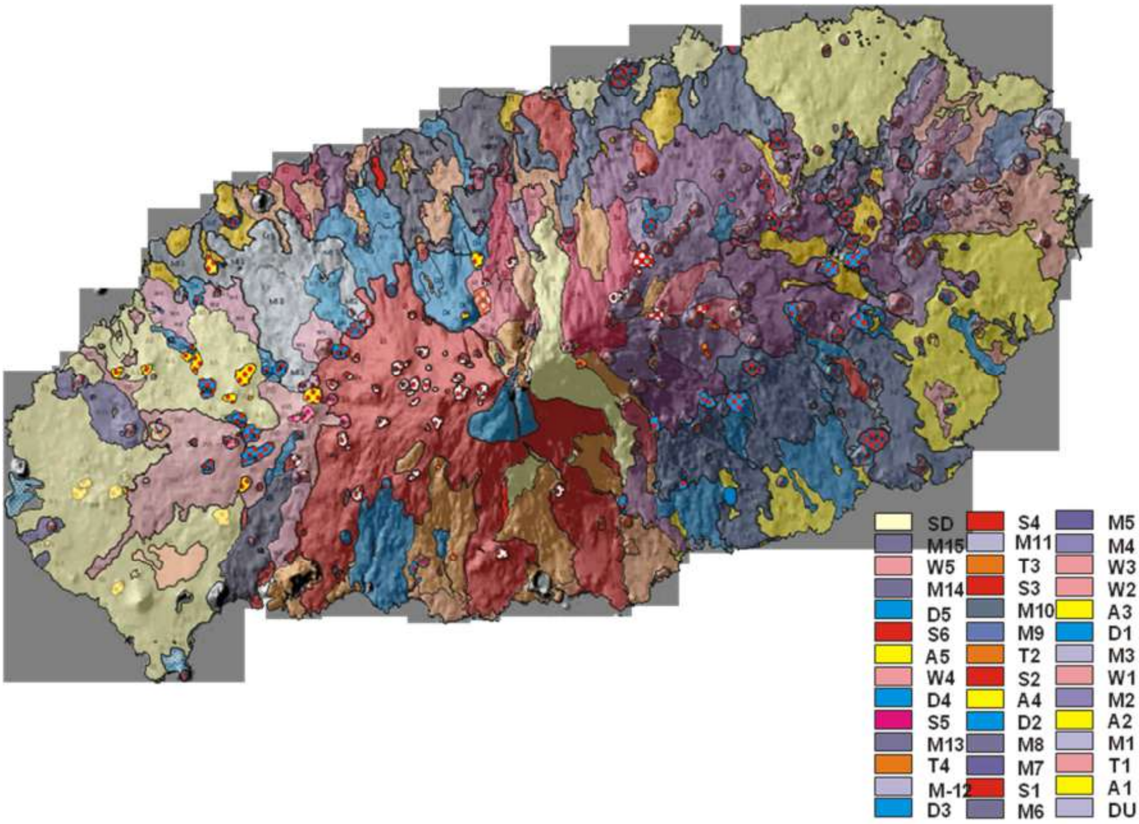

Fig. 1. Geological map of Jeju Island (KIGAM, 2012).

3. Status of Water Resources

3-1 Water resources availability and use

While there is potential surface water of 260 million m^3, it is ephemeral in character. Therefore, groundwater is the primary source of water on the island, and it is heavily drawn on. In fact, in 2010, annual abstraction corresponded to 20% of estimated safe yield (Table 1).

Table 1 Groundwater development and usage in Jeju Island

Consumption	Amount (m^3/d)	%
Domestic	202,000	57.1
Agriculture	144,000	40.7
Industry and others*	8,000	2.2
Total+	354,000	100.0

* Food processing, etc. +Estimated safe yield: 1,768,000 m^3/d

Agriculture is practiced over 31% of the island. The most important agricultural products are oranges and mandarins, followed by other crops such as beans, radishes, garlic and potatoes. Between 1970 and 2002, the size of the agricultural area increased at a rate of 0.5% per year. However, since then there has been a declining trend, which is expected to continue.

The area of irrigated land is 38,392 ha, which corresponds to 71% of the total cultivated area as of 2003. Although more agricultural land can be irrigated, the availability of water is the limiting factor. While drip irrigation and sprinklers are used, there is still the possibility of improving efficiency. Overall, 98.8% of irrigation water is drawn from aquifers.

4. Water Resources Management and Policy

4-1 Water resources management

All aspects of water management, from resource development to policy making and implementation, are the direct responsibility of the water and sewage administration of the provincial government. Growing concerns about how to protect groundwater resources from over-pumping and potential seawater intrusion prompted the development of a special Act in 1991, which laid the framework for groundwater management and regulated the drilling of wells. Other administrative measures included regular water-quality inspections across the island, and a tax increase for groundwater use. Given the importance of groundwater resources, in 2004 the provincial government put a specific management plan in place to promote the improved maintenance of wells, more efficient use of water in agriculture, and the diversification of water resources development. Following structural reforms in 2006, a heavily fragmented city and county approach to water-resources management was abandoned and replaced by the consolidation of all functions in the Jeju Water Supply and Drainage Management Headquarter. This, in addition to better management of water supply, helped in the standardization of environmental practices through the adoption of ISO 14001. Within this context, sewage-related operations, previously administered by cities, were integrated into regional systems in 2008, to ensure a more environmentally conscious overall approach.

Water pricing is also geared towards discouraging the misuse of scarce water resources. In line with guidelines set by central government, those water rates have been increasing gradually, with the eventual aim of reaching full cost recovery. As of 2006, the unit price of water corresponded to 62.5% of its estimated cost.

The provincial government has plans to invest over US$780 million over a time span of twenty years (2004–2025) on water supply and infrastructure improvement. A limited portion of these funds will come from the private sector. In fact, public private partnerships and privatization of certain services, such as the operation of sewage processing plants, are becoming more and more common. As a result, a range of strategies is currently under development to promote greater involvement by the private sector.

4-2 Groundwater monitoring system

The Province maintains various monitoring programs, designed to acquire a consistent set of high quality measurements, to identify present-day problems related to water resources, to provide a basis for integrated water resources management (IWRM) and for future planning. Automatic or semi-automatic monitoring systems measure atmospheric conditions, rainfall amounts and hydrochemistry, stream discharge, spring discharge, groundwater levels and water quality, and seawater intrusion. These measured data are synthesized, processed, stored in GIS systems, analysed, interpreted, and reported by research institutes, administrative, corporations and universities.

Groundwater monitoring wells in Jeju Island can be categorized into five types, according to their predominant uses: monitoring of groundwater levels, assessment of seawater intrusion, and monitoring of groundwater quality and groundwater usage. As of December 2007, 441 groundwater wells were in operation, with 50 used for groundwater level monitoring, 41 for seawater intrusion (53 as of 2014), 150 for groundwater usage, and 100 for monitoring groundwater quality.

5. Problems Related to Water Resources

5-1 Salt water intrusion in Jeju

Eastern Jeju is naturally vulnerable to salt water intrusion compared to the other part of Jeju because of gentle topographic and hydraulic gradient, abundance of highly permeable subsurface structures such as hyaloclastite and lava tube, and lack of low permeable layer like Seogwipo formation. Based on the fact that the groundwater usage in eastern Jeju is lowest in Jeju, the salt water intrusion phenomenon in this area is considered to be naturally occurred. Western Jeju has similar topographic gradient with eastern Jeju but steeper hydraulic gradient than east Jeju. The aquifer in west area is more confined rather than east cause of subsurface geological features. The salt water intrusion in this area, if happened, could be said that it is a man-maid result from over-exploitation of groundwater. Western Jeju has lowest annual precipitation and consumed much more groundwater for agricultural use especially in

September to November.

Salt water intrusion issue has been rose occasionally, especially in western Jeju such as Hangyeong, Hallim, Daejeong in autumn drought season, in 2005, 2009, 2011, 2013. When there was drought in October 2011, several agricultural wells in Daejeong and Hangyeong area have contaminated by salt water intrusion and are not recovered yet by present 2014.

5-2 Salt water intrusion monitoring system and its limits

Jeju province has been install salt water intrusion monitoring wells since 2001 and the number of it has been increased to be 53 as of 2014 (Fig. 2). According to Jeju Water Resources Headquarter, a salt water intrusion warning system is operating with three step alarm comparing the pre-set water level criteria and the groundwater table level which is transmitted remotely. First step is reporting and campaign, hardening monitoring surroundings, second step is 10% reduction and third step is 30% reduction in heavy groundwater abstracting users.

However, the groundwater level is not direct representative information for the salt water intrusion whereas upper boundary location of freshwater-salt water interface could be a direct signal for the intrusion. Although the boundary location can be estimated by groundwater level using the Gyben-Herzberg theory, the interface generally occurs in transition type from dense salt water to light freshwater and it location is influenced by subsurface geological heterogeneity. Single sensor method installed at a specific depth cannot gives information on the actual interface boundary.

Multi-level sensing method can reduce the limit of single sensing method but still have blind zone between sensors and cost can be a problem for more precise resolution. Geophysical logging can be another method to monitor, but it is time and efforts consuming work and it can hardly give time series data of the interface.

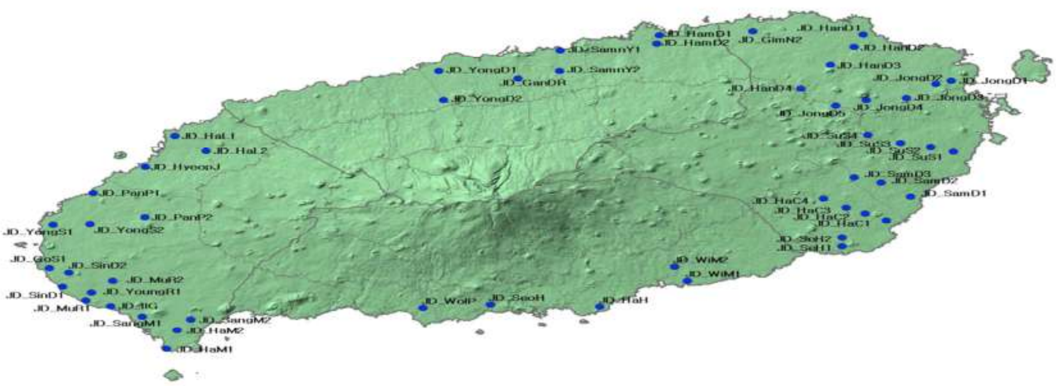

Fig. 2. Location of salt water intrusion monitoring stations

6. Plans for Cooperation to Solve the Problems

6-1 new method for salt water intrusion monitoring

A new method using an interface-floating device, named 'interface egg' to monitor the time series change of the freshwater-saltwater interface is developed and has been applied Handong-1, a sea water intrusion monitoring station of Jeju island (Kim and Yoon, 2013; Kim et al., 2014). The floating device can move up and down along with movement of the interface because it has intermediate density between freshwater and saltwater (Fig. 3). Although in case that there is more or less wide transition zone, it can give us a real time location of the upper or lower boundary or a certain density within the transition zone. It has been applied to Handong-1, a sea water intrusion monitoring station of Jeju Island, South Korea with a depth-fixed pressure sensor. Fig. 4 shows the location of Handong-1, tide level monitoring station and weather station.

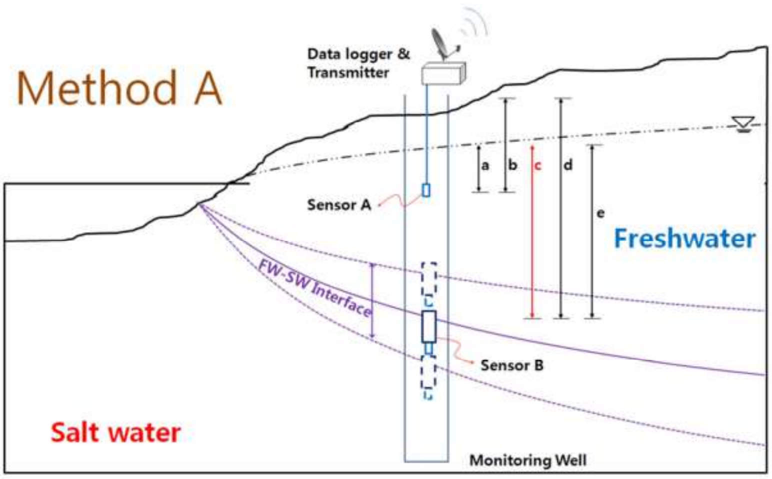

Fig. 3. Schematic description to get a time series data of the freshwater-saltwater interface location and thickness of the freshwater by using a floating device (B) and a fixed sensor (A).

The device was a success in obtaining time series data of the groundwater and interface levels (Fig. 5). Based on the 21-day time series data in August, 2013, it is found out that maximum amplitude of the freshwater level and the interface are damped down to 1.1m and 0.14m, respectively, compared to tide of which maximum amplitude was 2.6m. The lag times of the freshwater level and the interface compared to tide were calculated to be 80 minutes and 195 minutes, respectively. According to vertical EC profiles obtained from 32 times well logging from April 2001 to August 2011, the average depth of the upper and lower boundary is -34.6m and -44.8m from the mean sea level, respectively. The upper and lower boundary of the transition zone has EC values of about 2,000μS/cm and ranging 47,000 to 51,000μS/cm, respectively. The device was estimated to move up and down following the brackish water of about 8,000μS/cm in this site.

Monitoring data from September to November indicates that the groundwater and interface level fluctuations are highly affected by the tide level (Fig.5). The interface level shows the rising tendency reducing the size of the freshwater lens. A long-term data will be obtained and analyzed to find out the effect of rainfall on interface fluctuations and the cause of upward trend of the interface level.

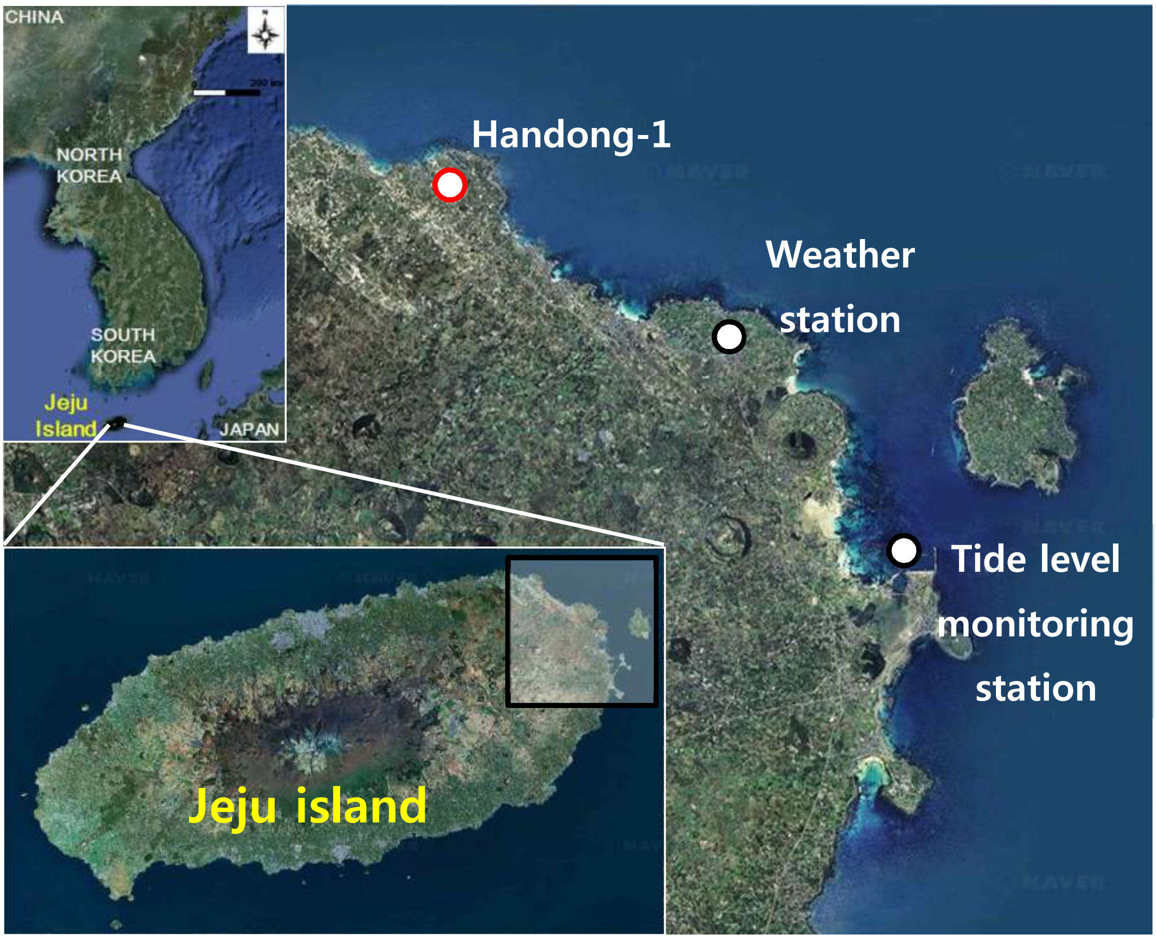

Fig. 4. Location of the application area, Handong-1 salt water intrusion monitoring station (Kim and Yoon, 2013)

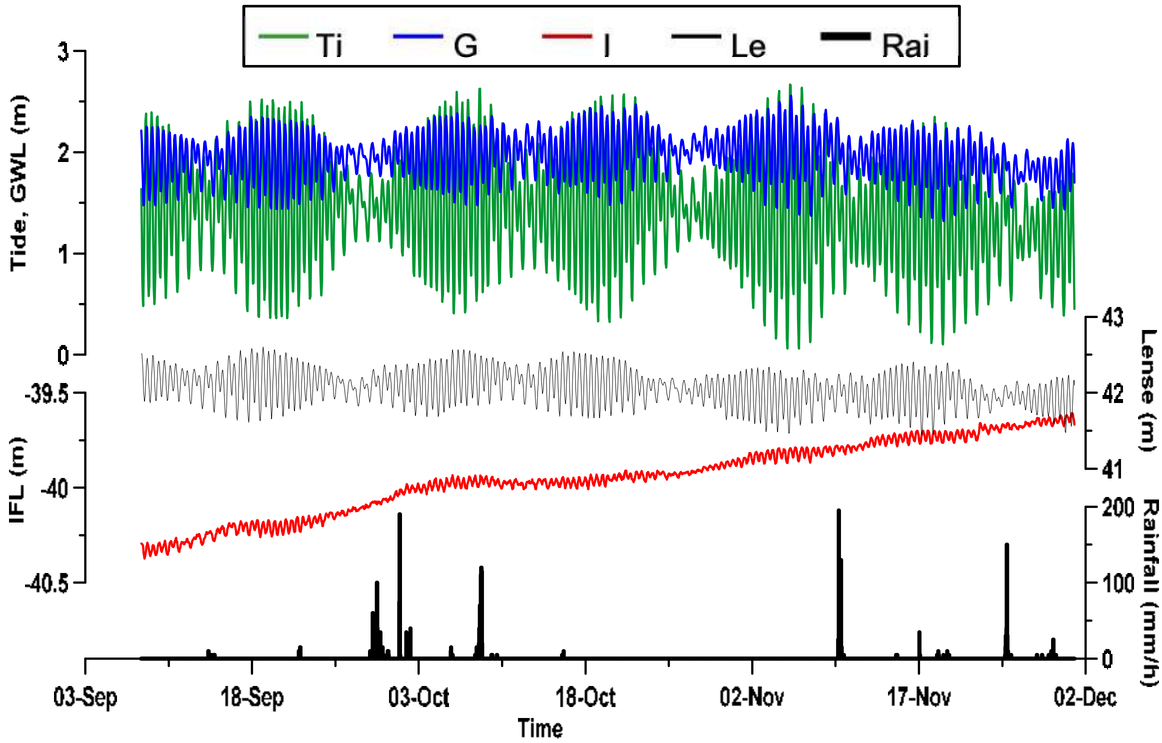

Fig. 5. Time series data of groundwater and interface levels (Kim et al, 2014)

The floating device can be applied to sea water intrusion warning system if it is combined with a proper prospecting model and remote communication technology (Fig. 6).

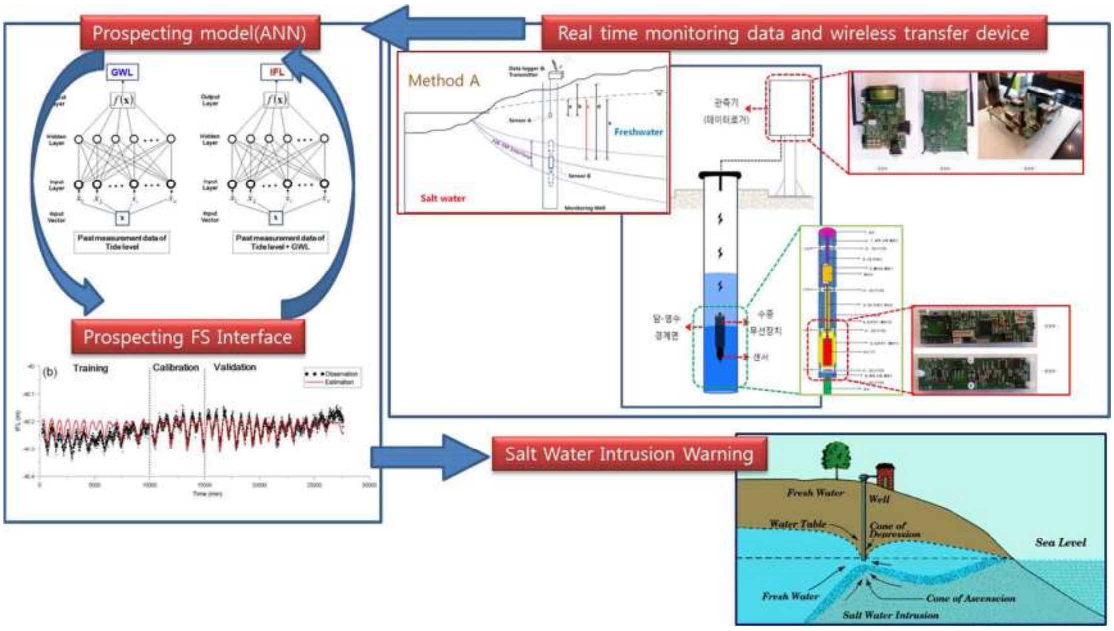

Fig. 6. Conceptual model for real time early warning system for salt water intrusion (Kim et al., 2014).

7. Conclusion

The importance of monitoring the coastal aquifer is increasing under changing circumstance of global climate. Sea level has been rising due to global warming and expected to increase up to 25-50cm by 2100. Excessive pumping at coastal aquifer results in salt water intrusion and salt water up-coning at many places. Therefore, many places including Jeju Island have installed monitoring wells along coastal line to protect groundwater resources. The new method using interface floating tracker showed a successful application in eastern Jeju overcoming the deficits of various existing monitoring methods. Further, with an aid of an existing or developing forecasting model such as artificial neural network model, the new method could be promising in salt water intrusion early warning system which can give a measuring time for local government to protect saltwater intrusion.

8. References

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Kim, Yongcheol, Heesung Yoon and Gipyo Kim. 2014. Characteristics of real time variations of freshwater-saltwater interface using a new monitoring method at Jeju Island, South Korea. 23rd Salt Water Intrusion Meeting, Husum, German.

Technical advance in salt-water intrusion monitoring; Preliminary application results in Jeju island

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[2]Jeju Water Resources Headquarter

7 October 2014
CCOP-KIGAM-JPDC joint 6th Jeju Water Forum

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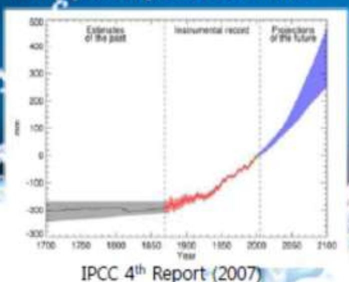
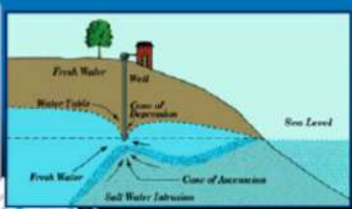
Dynamics of FW-SW Interface

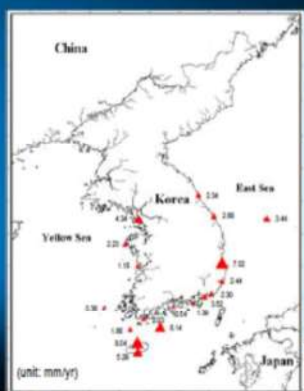
- Sea level rise by global warming
- Salt water intrusion by sea level rise and over extraction of coastal groundwater
- Necessity for monitoring of coastal aquifer, especially, freshwater/salt water interface to protect salt water intrusion

Prospection of global sea level rise



IPCC 4th Report (2007)



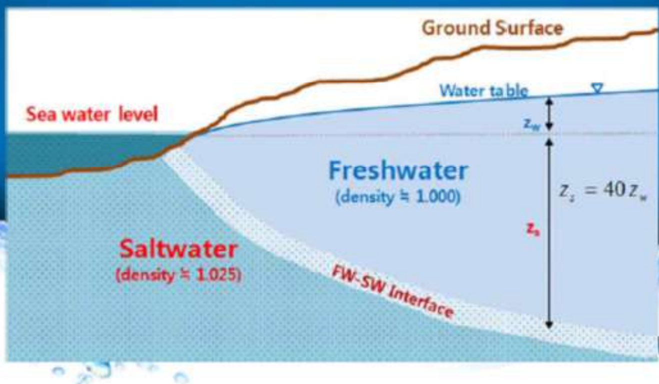


- Recent 20 years (1988~2007)
- Avg. of 18 stations = 3.20±2.17 mm/yr (Kim & Lee, 2011)

Dynamics of FW-SW Interface

- Interface formed by density difference (sharp or gradual)
- Drag forces for the dynamics : Tide (daily), spring-neap(semi-monthly) Pumping (days~years), Precipitation(seasonal), Sea level rise (global, years or decades)

Necessity for time series monitoring for SWI by central and local government



Korea Institute of Geoscience and Mineral Resources

How has the SW/FW interface been observed up to now?

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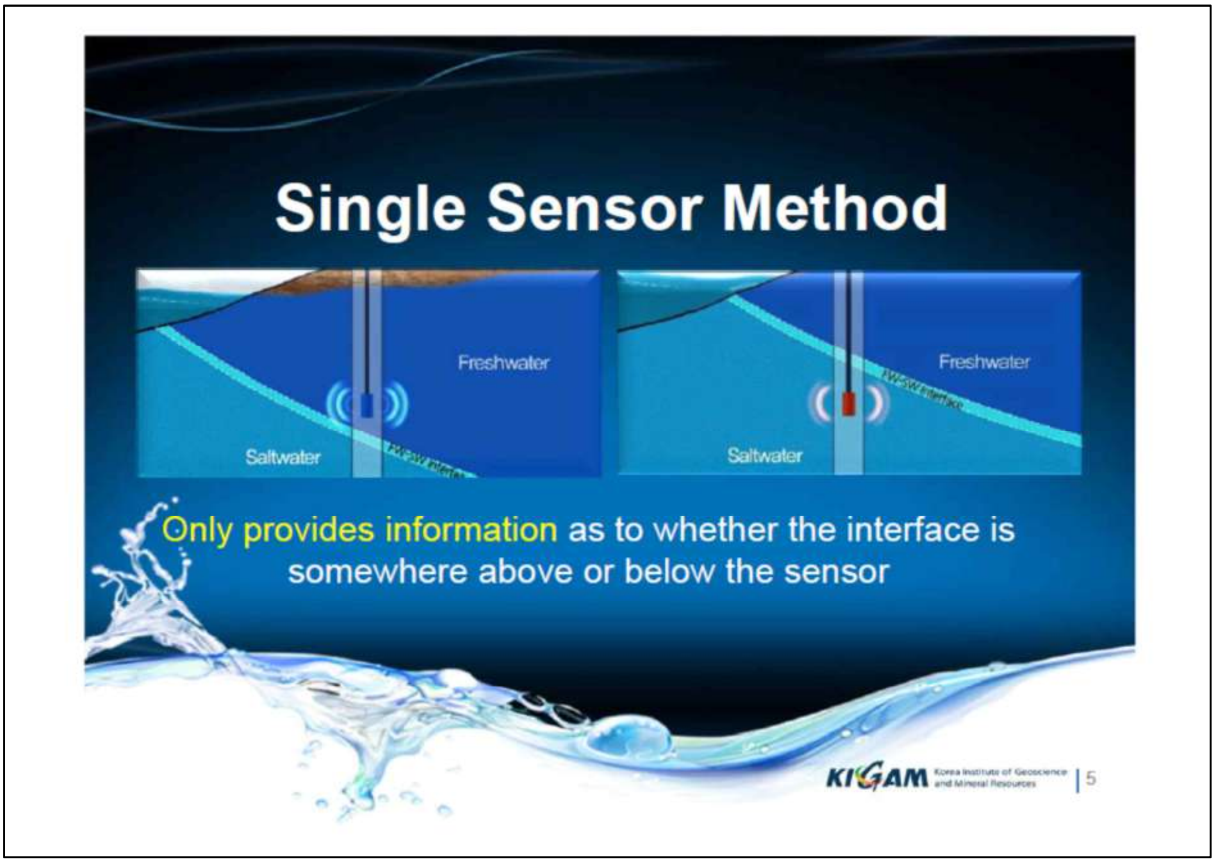
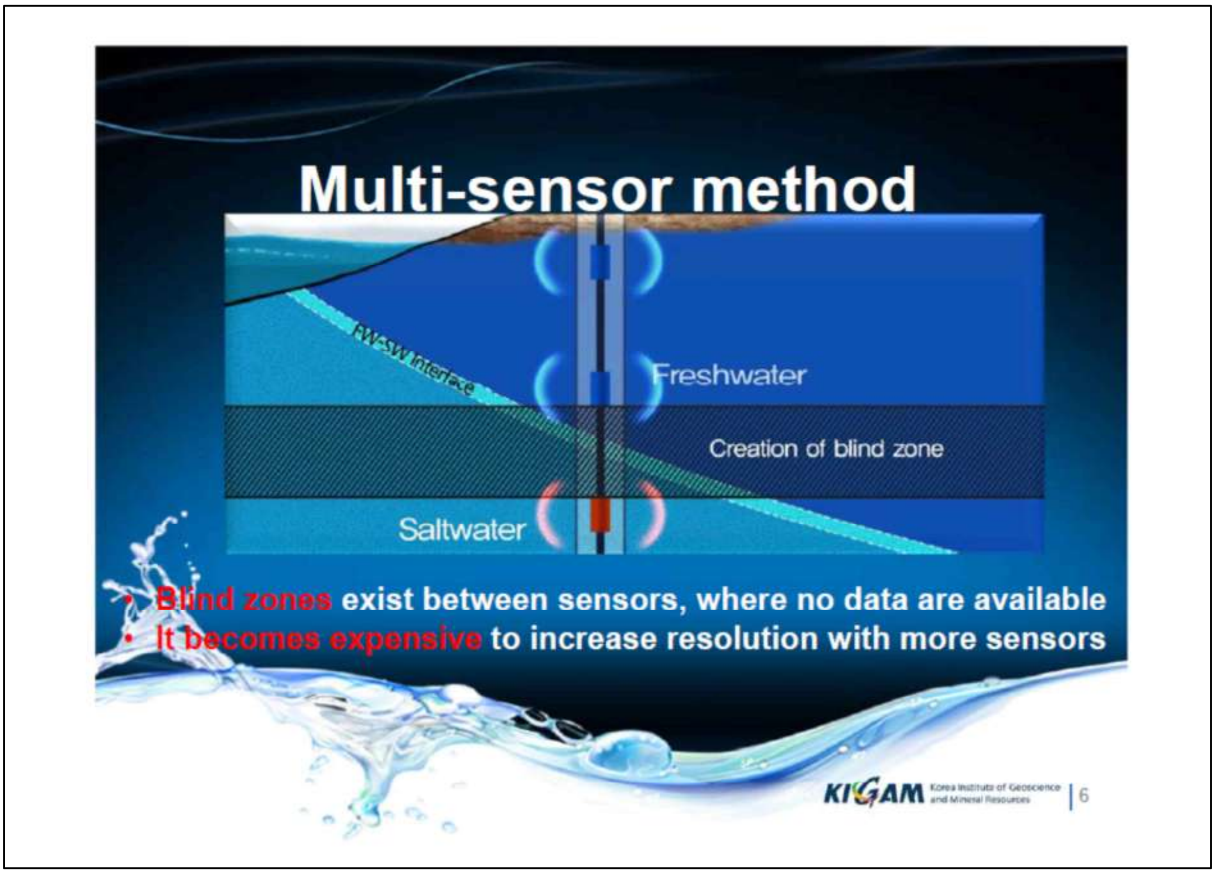
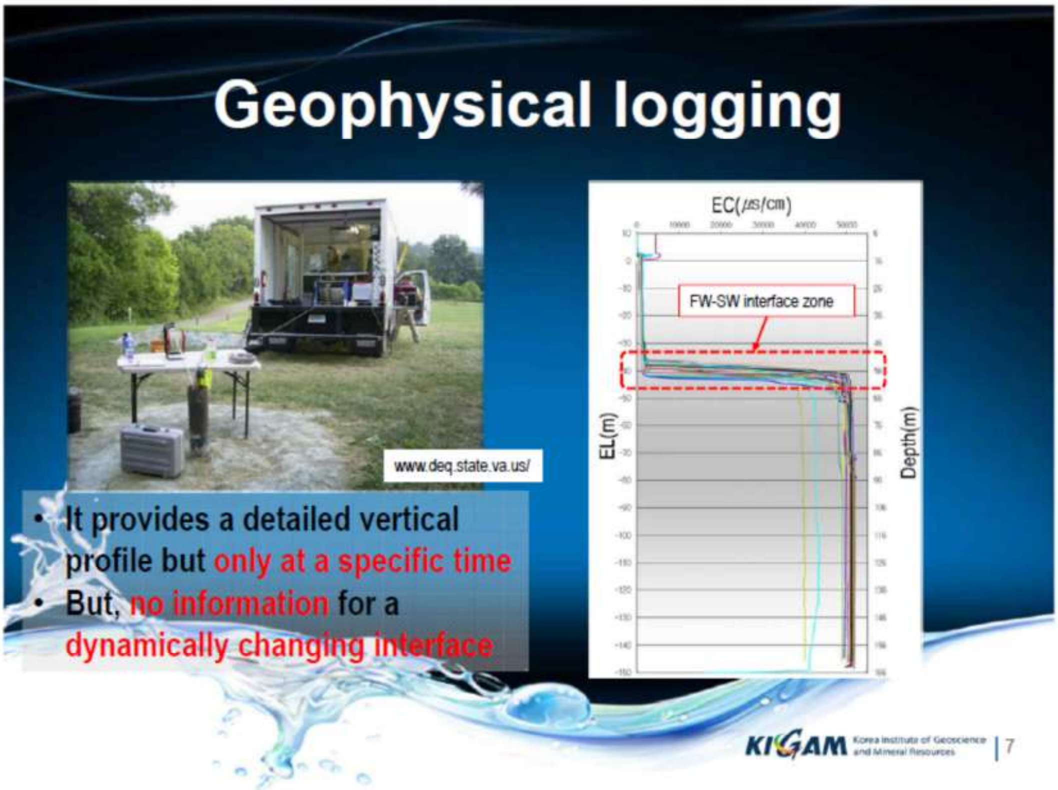
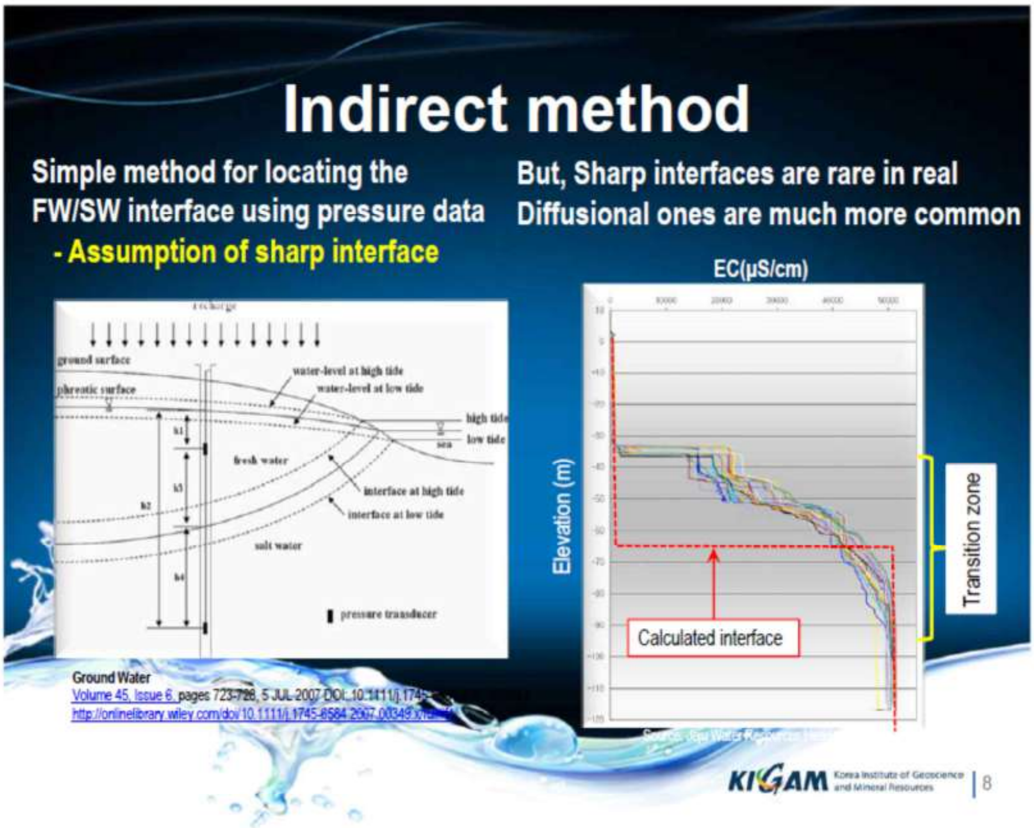
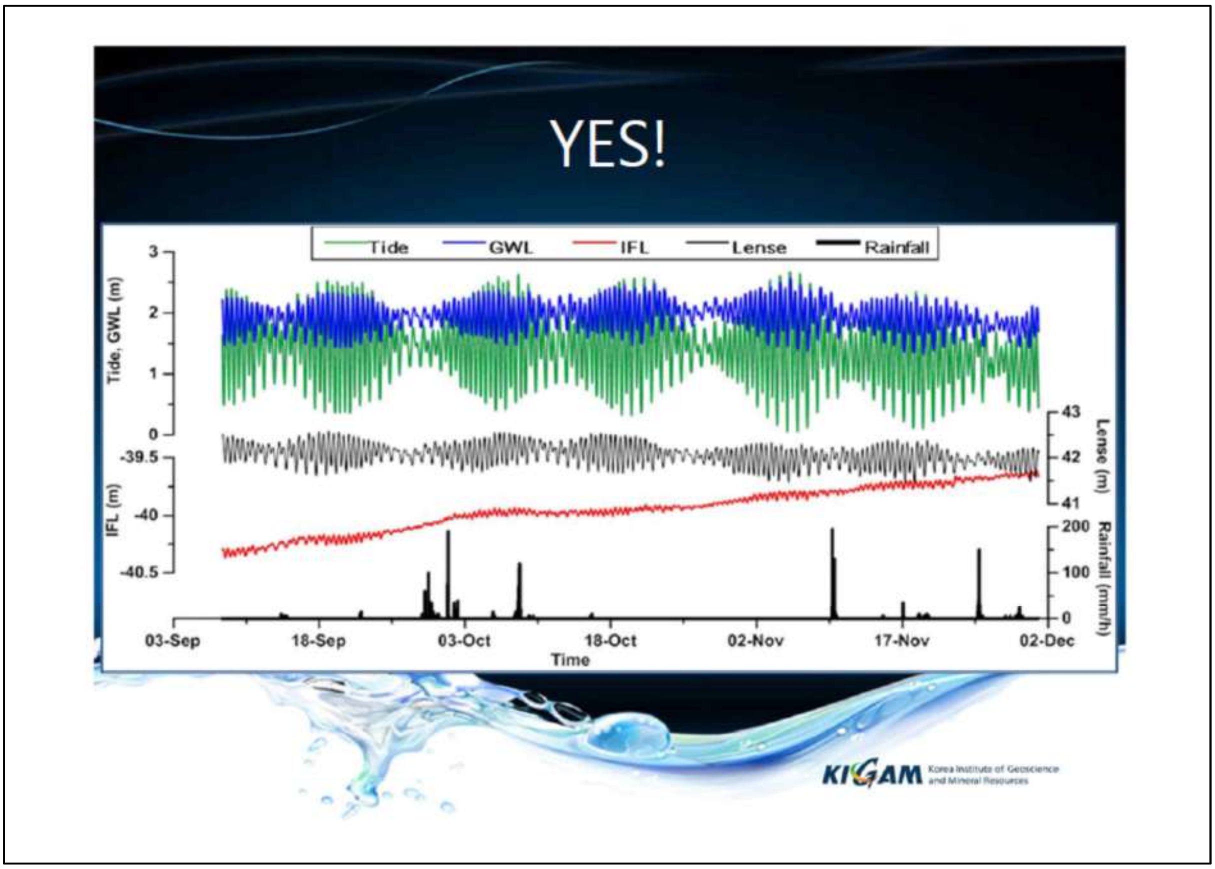

Single Sensor Method
Freshwater
Saltwater
Freshwater
Saltwater
Only provides information as to whether the interface is somewhere above or below the sensor
KIGAM
5


Multi-sensor method
FW-SW interface
Freshwater
Creation of blind zone
Saltwater
• Blind zones exist between sensors, where no data are available
• It becomes expensive to increase resolution with more sensors
KIGAM
6


Geophysical logging
EC(㎲/cm)
FW-SW interface zone
EL(m)
Depth(m)
www.deq.state.va.us/
It provides a detailed vertical profile but only at a specific time
But, no information for a dynamically changing interface
KIGAM Korea Institute of Geoscience and Mineral Resources
7


Indirect method
Simple method for locating the FW/SW interface using pressure data
- Assumption of sharp interface
But, Sharp interfaces are rare in real
Diffusional ones are much more common
EC(μS/cm)
ground surface
phreatic surface
water-level at high tide
water-level at low tide
high tide
low tide
sea
fresh water
interface at high tide
interface at low tide
salt water
pressure transducer
Elevation (m)
Calculated interface
Transition zone
Ground Water
KIGAM Korea Institute of Geoscience and Mineral Resources
8


CAN WE GET A TIME SERIES DATA OF
A REAL FW-SW INTERFACE AND
THE THICKNESS OF THE FRESHWATER LENS?
KIGAM Korea Institute of Geoscience and Mineral Resources


YES!
Tide
GWL
IFL
Lense
Rainfall
Tide, GWL (m)
IFL (m)
Lense (m)
Rainfall (mm/h)
03-Sep
18-Sep
03-Oct
18-Oct
02-Nov
17-Nov
02-Dec
Time
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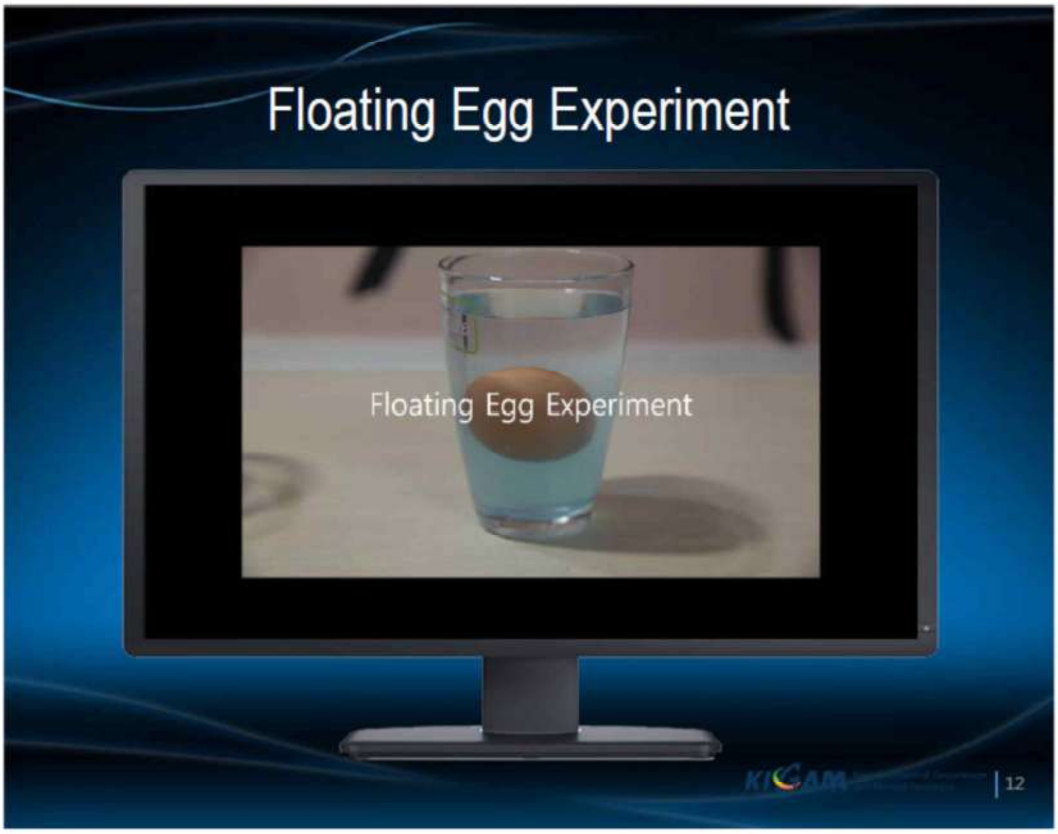
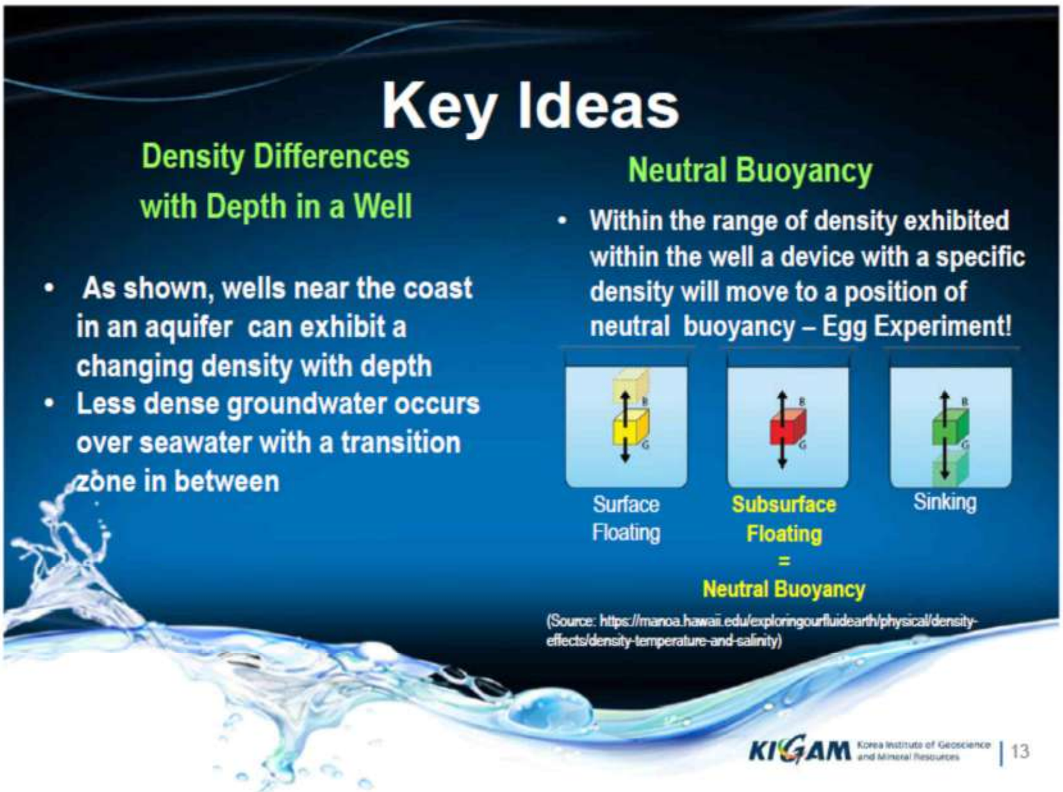
A New System for Real Time
Monitoring of the Freshwater -
Saltwater Interface
KIGAM


Floating Egg Experiment
Floating Egg Experiment
12


Key Ideas
Density Differences
with Depth in a Well
• As shown, wells near the coast in an aquifer can exhibit a changing density with depth
• Less dense groundwater occurs over seawater with a transition zone in between
Neutral Buoyancy
• Within the range of density exhibited within the well a device with a specific density will move to a position of neutral buoyancy – Egg Experiment!
Surface Floating
Subsurface Floating
=
Neutral Buoyancy
Sinking
(Source: https://manoa.hawaii.edu/exploringourfluidearth/physical/density-effects/density-temperature-and-salinity)
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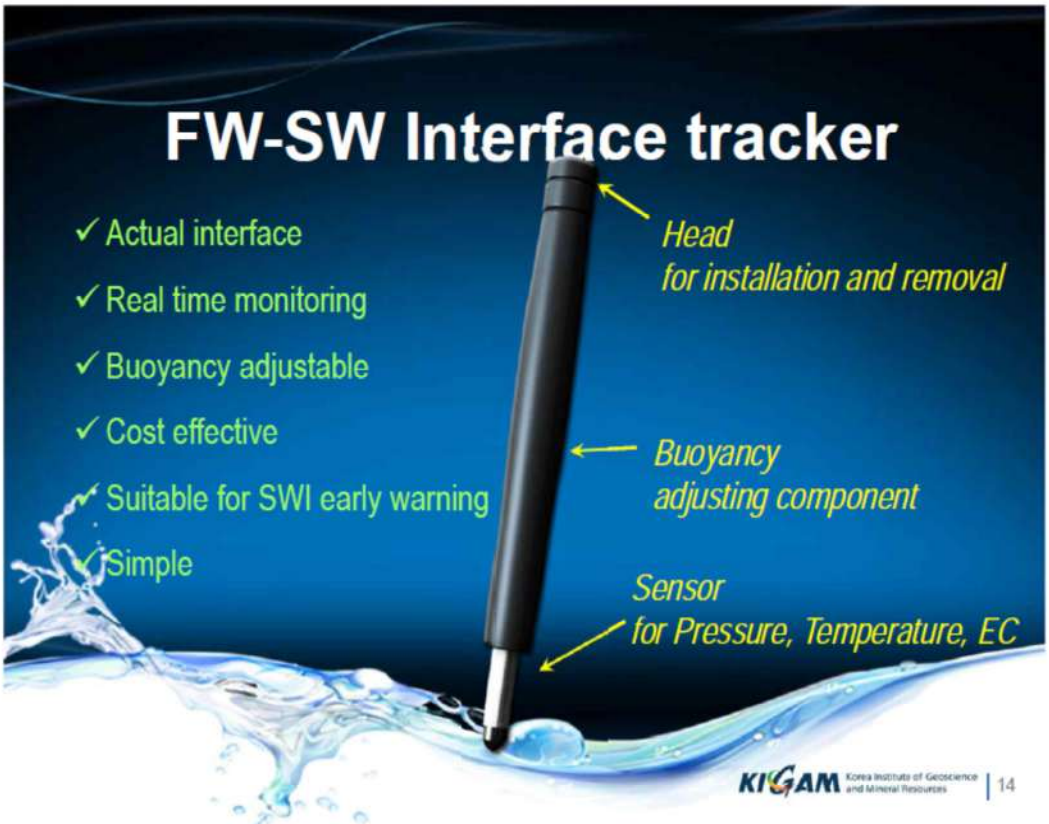
FW-SW Interface tracker
✓ Actual interface
✓ Real time monitoring
✓ Buoyancy adjustable
✓ Cost effective
✓ Suitable for SWI early warning
✓ Simple
Head
for installation and removal
Buoyancy
adjusting component
Sensor
for Pressure, Temperature, EC
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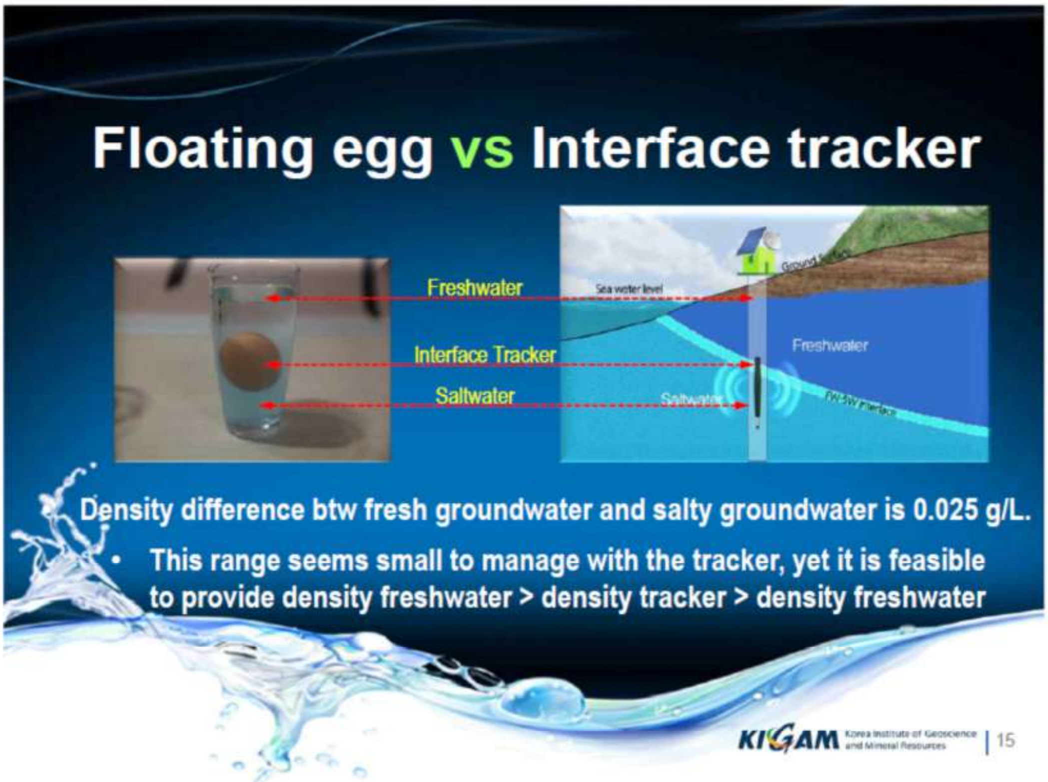
Floating egg vs Interface tracker
Freshwater
Interface Tracker
Saltwater
Sea water level
Freshwater
Saltwater
Density difference btw fresh groundwater and salty groundwater is 0.025 g/L.
• This range seems small to manage with the tracker, yet it is feasible to provide density freshwater > density tracker > density freshwater
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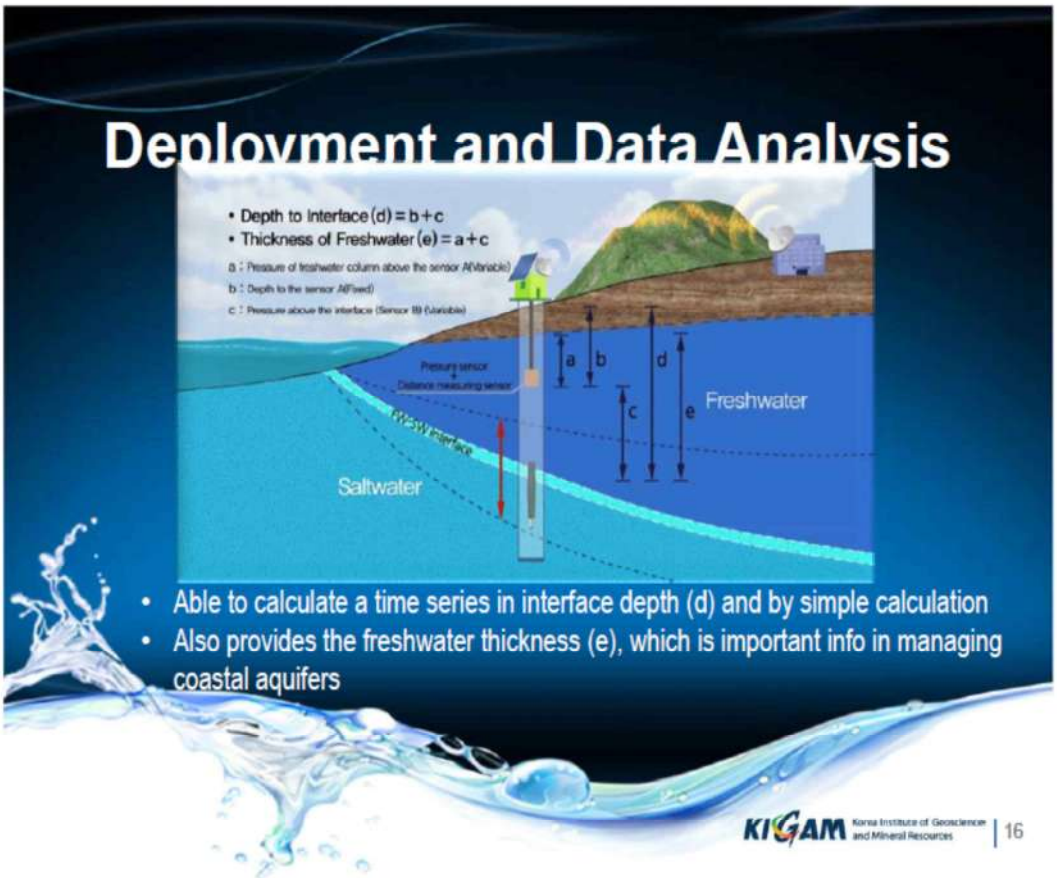
Deployment and Data Analysis
• Depth to Interface (d) = b + c
• Thickness of Freshwater (e) = a + c
a b d c e
Freshwater
Saltwater
• Able to calculate a time series in interface depth (d) and by simple calculation
• Also provides the freshwater thickness (e), which is important info in managing coastal aquifers
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CASE STUDY
- JEJU ISLAND, KOREA

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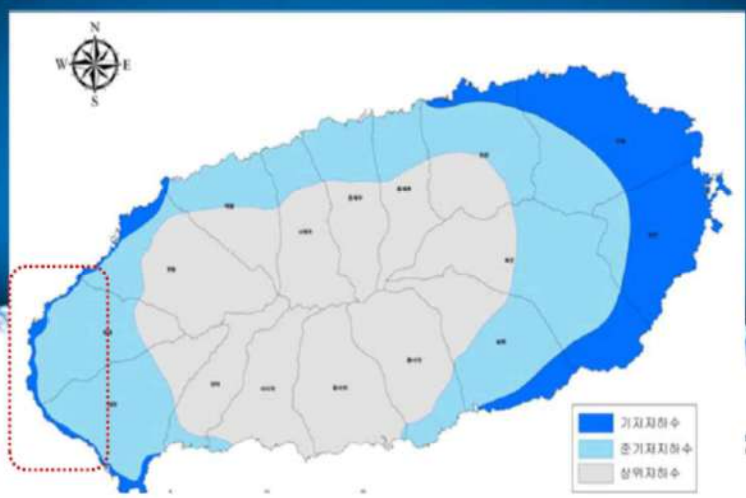
Salt Water Intrusion Issues in Jeju

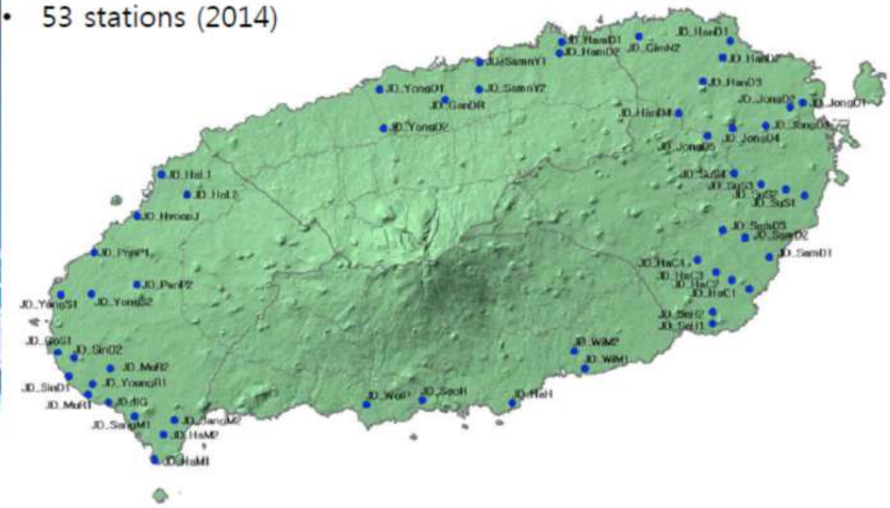
- East: Naturally occurred by permeable subsurface geological property, gentle hydraulic/topographic gradient
- West: Man-made occurrence when groundwater over-exploitation in drought season. Lowest annual precipitation area in Jeju

❖ Several wells of western area (Hangyeong and Daejeong) contaminated by SWI in 2011 Fall



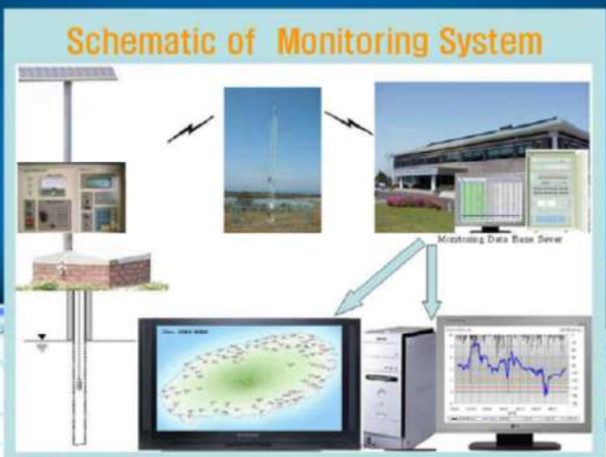
Saltwater intrusion monitoring network of Jeju Island

- Start to build 2001
- 53 stations (2014)



Saltwater intrusion monitoring network of Jeju Island

- Three step warning system based on groundwater level comparing with preset criteria
  - 1st step: reporting and intense monitoring
  - 2nd step: 10% reduction for heavy user
  - 3rd step: 30% reduction for heavy user



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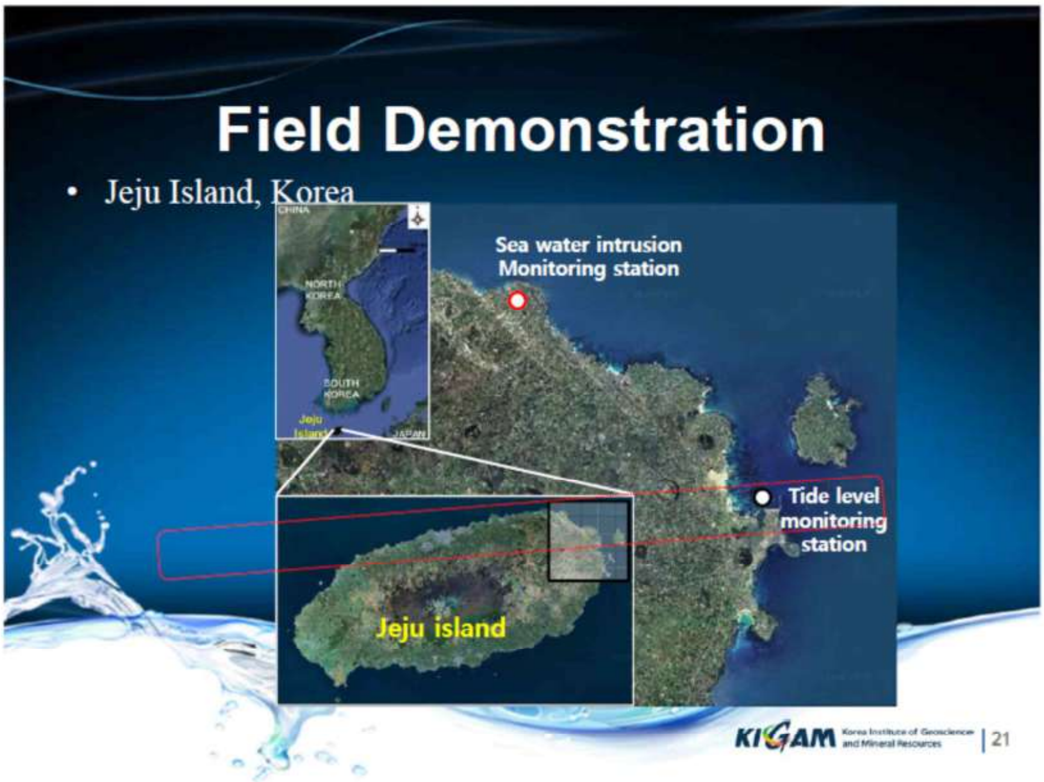
Field Demonstration
• Jeju Island, Korea
Sea water intrusion
Monitoring station
Tide level
monitoring
station
Jeju island
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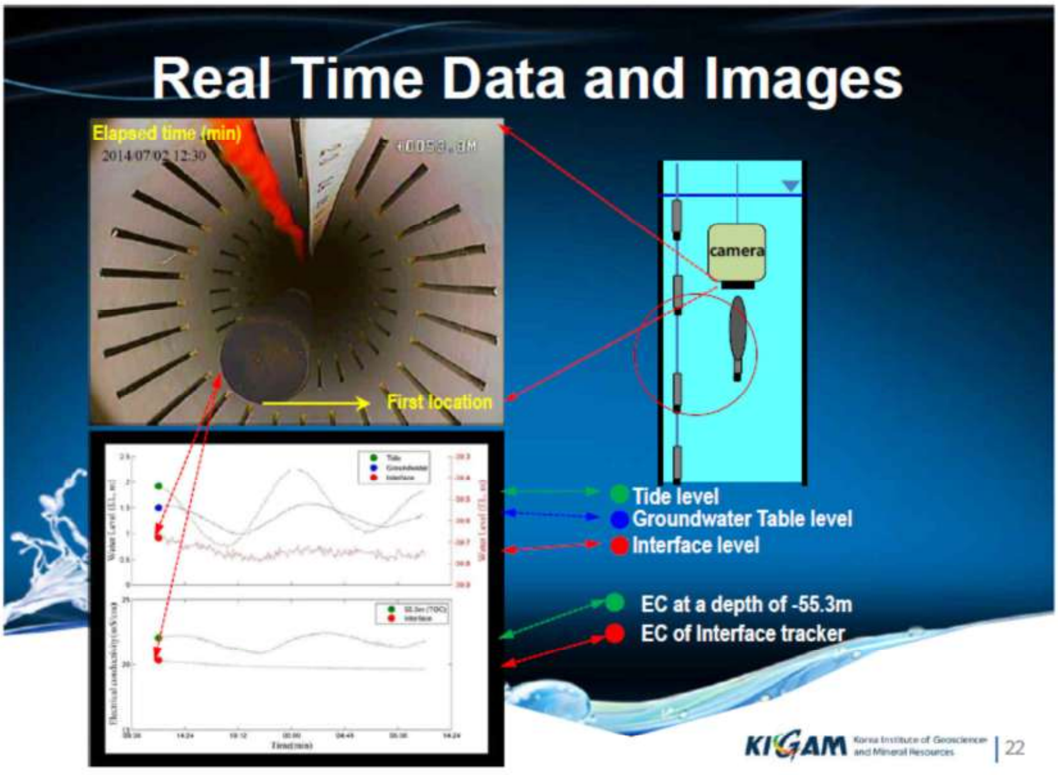
Real Time Data and Images
Elapsed time (min)
2014/07/02 12:30
First location
camera
Tide level
Groundwater Table level
Interface level
EC at a depth of -55.3m
EC of Interface tracker
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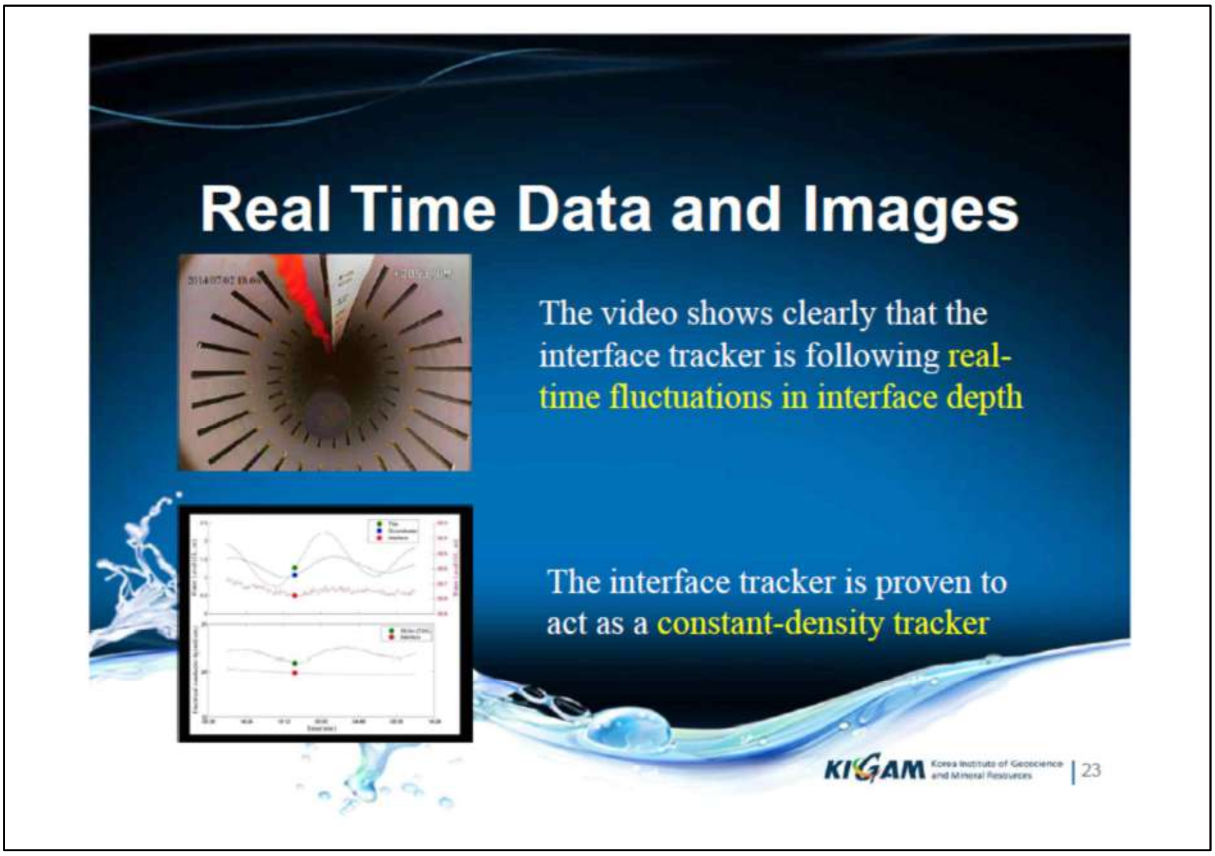
Real Time Data and Images
The video shows clearly that the interface tracker is following real-time fluctuations in interface depth
The interface tracker is proven to act as a constant-density tracker
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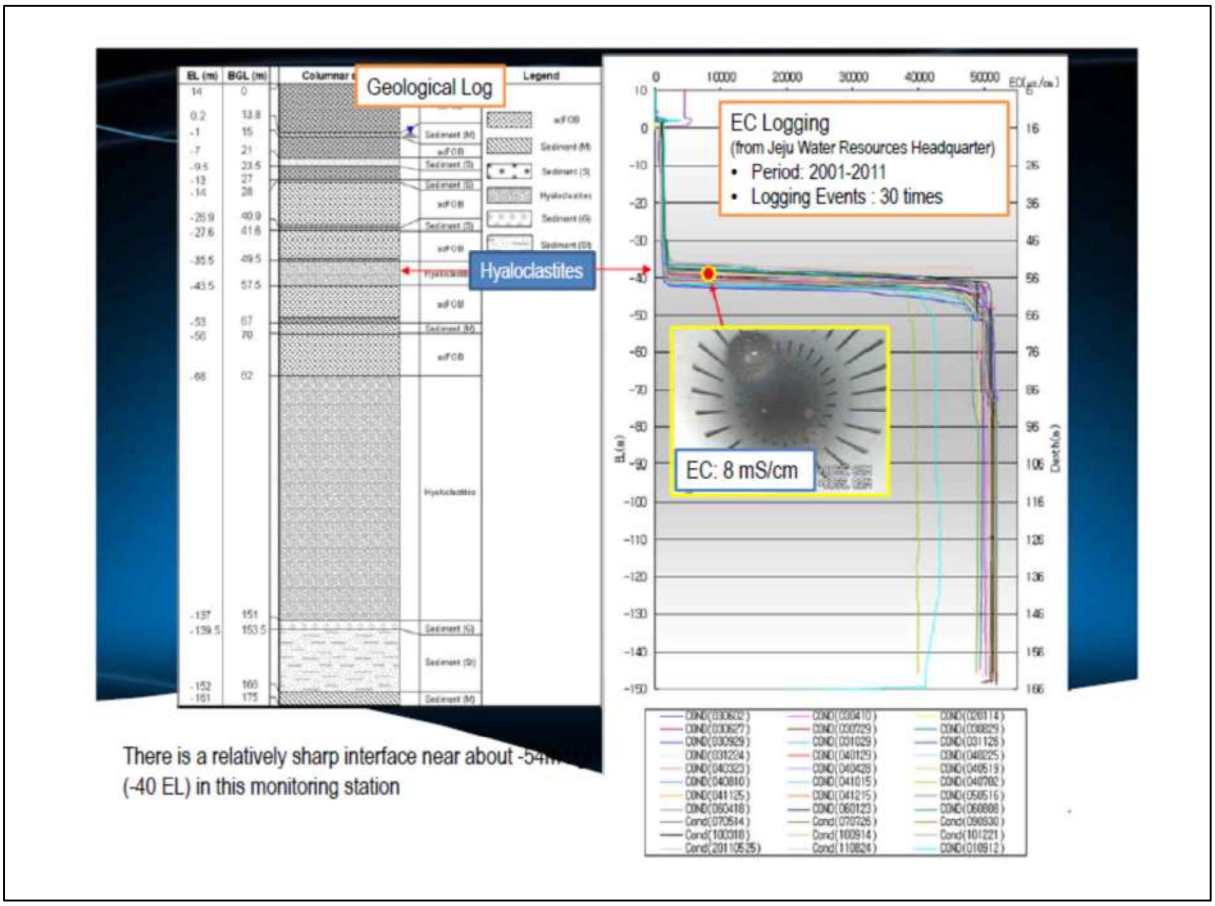
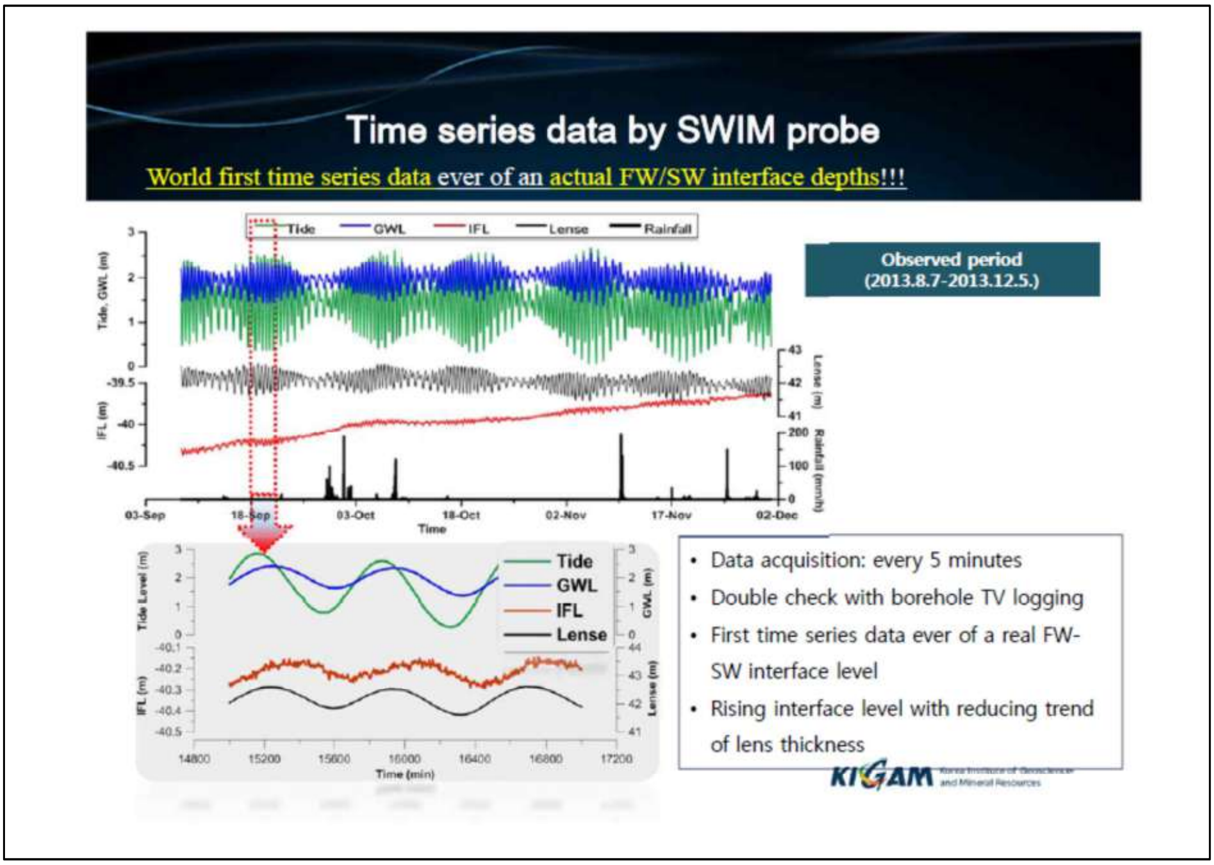
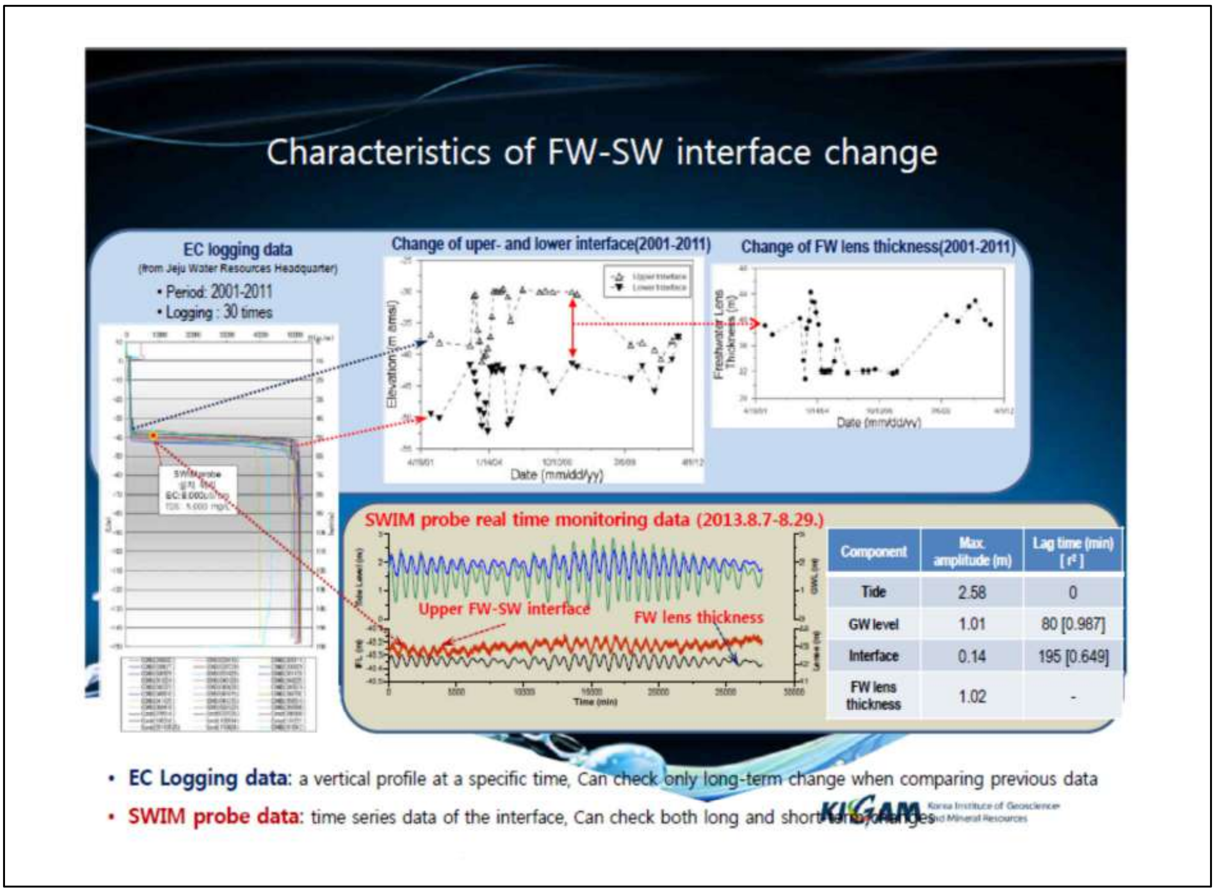

Geological Log
Legend
Hyaloclastites
EC Logging
(from Jeju Water Resources Headquarter)
• Period: 2001-2011
• Logging Events : 30 times
EC: 8 mS/cm
There is a relatively sharp interface near about -54m
(-40 EL) in this monitoring station





Component	Max. amplitude (m)	Lag time (min) [r²]
Tide	2.58	0
GW level	1.01	80 [0.987]
Interface	0.14	195 [0.649]
FW lens thickness	1.02	-


FUTURE STUDY
- Prospecting the interface level change
- Saltwater intrusion warning system
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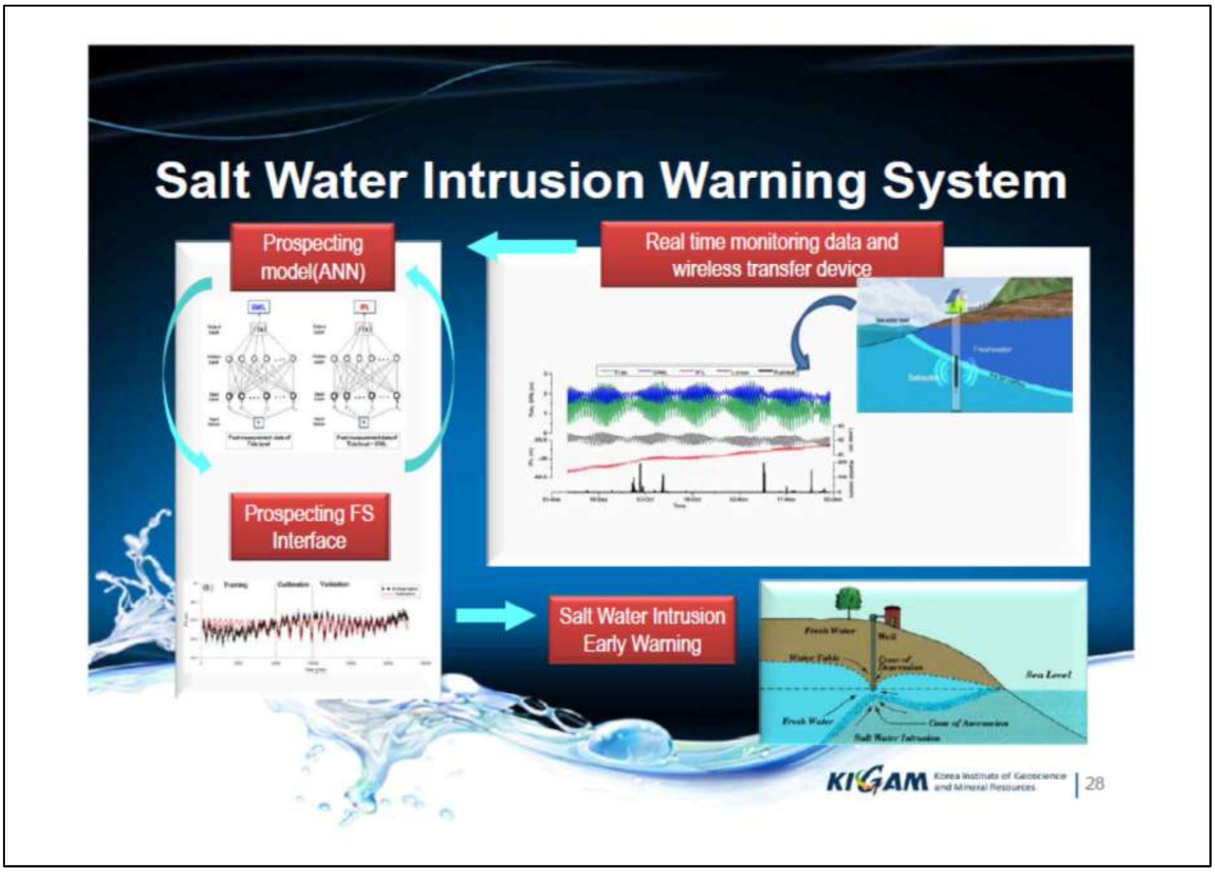
Salt Water Intrusion Warning System
Prospecting model(ANN)
Real time monitoring data and wireless transfer device
Prospecting FS Interface
Salt Water Intrusion Early Warning
Sea Level
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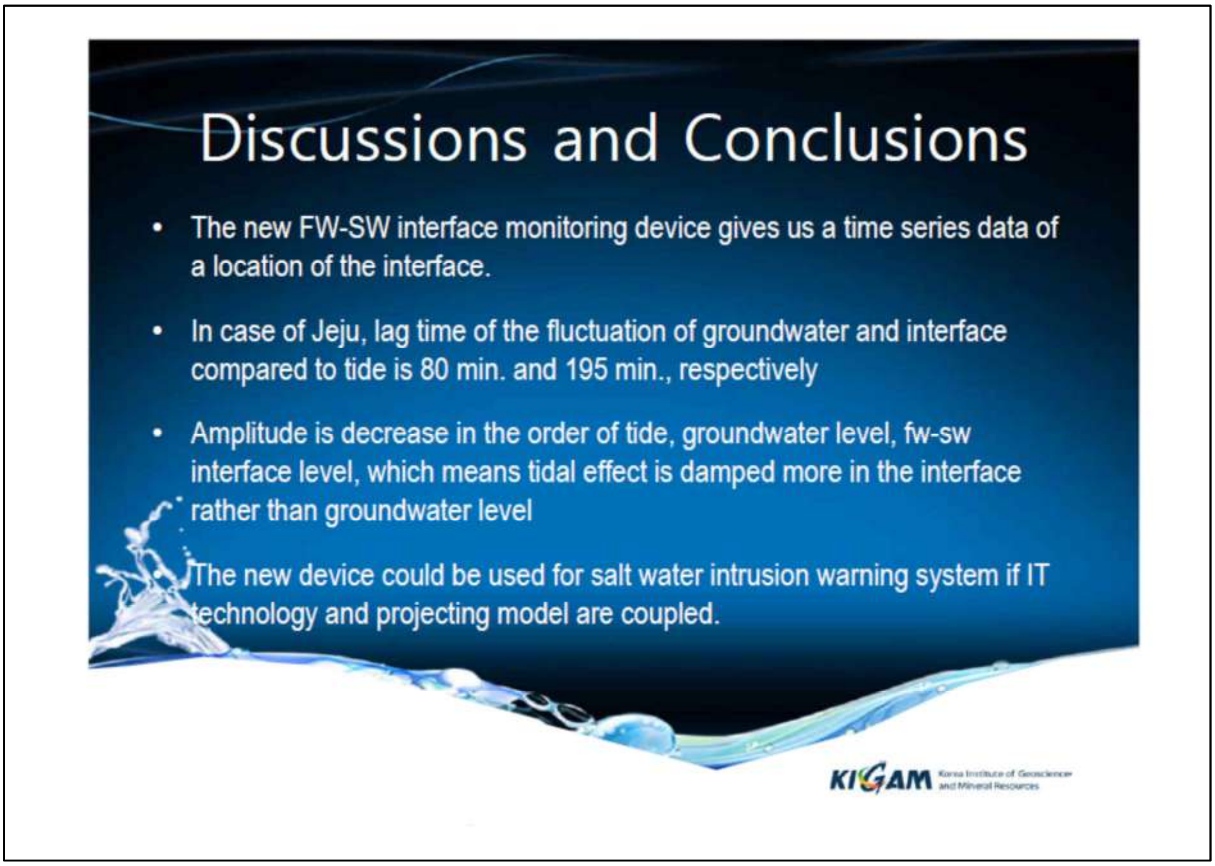
Discussions and Conclusions
• The new FW-SW interface monitoring device gives us a time series data of a location of the interface.
• In case of Jeju, lag time of the fluctuation of groundwater and interface compared to tide is 80 min. and 195 min., respectively
• Amplitude is decrease in the order of tide, groundwater level, fw-sw interface level, which means tidal effect is damped more in the interface rather than groundwater level
• The new device could be used for salt water intrusion warning system if IT technology and projecting model are coupled.
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Closing...
Many countries, cities, islands
need intensive
salt water intrusion monitoring.
Data products from our monitoring system
will provide for reliable water resource management
It's simplicity, intuitive mode of operation,
straightforward data processing and low cost make
it a practical tool for users around the world
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Paradigm Shift
Constrained
Wired or Wireless, but fixed
Flying Free
Source: http://roseman.tistory.com/444
Floating Free
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Thank you for your time
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