GW-1

Project Report on
CCOP-GSJ/AIST Groundwater Phase II Kick-off Meeting
1-2 October 2009, Bangkok, Thailand

COORDINATING COMMITTEE FOR GEOSCIENCE PROGRAMMES

IN EAST AND SOUTHEAST ASIA (CCOP)

in cooperation with

GEOLOGICAL SURVEY OF JAPAN (GSJ), AIST

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Youhei Uchida (Chief Editor)

PREFACE

Groundwater is one of the limited natural resources of the world. Because of the lack a feeling of importance of groundwater, especially, in the late 20th century, groundwater has been significantly damaged by human activities, resulting in groundwater issues, such as land subsidence, seawater intrusion, and groundwater pollution by toxic substances, that have become remarkable problems in everywhere in the world. The countries in the East and Southeast Asia have been also faced the many groundwater problems which are needed international cooperation to be solved.

Since the establishment of the organization in 1966, geological and geophysical surveys have been carried out by the CCOP under the cooperative schemes in the East and Southeast Asia for offshore natural resources. These data have been distributed to member countries as printed maps and publications. As for a groundwater project, “Groundwater database in East and Southeast Asia” had been compiled under the DCGM Phase IV project of CCOP from 2001 to 2004.

The following project, named “Groundwater Assessment and Control in the CCOP Region by CCOP-GSJ/AIST Groundwater project” from 2005 to 2008, had been started from a point of view of finding a solution of issues on an exploration and an exploitation of a groundwater resource. The final results of the project has been presented in the Special Session of the International Association of Hydrogeologists (IAH) meeting in Toyama, Japan in 2008.

The kick-off meeting of the Phase II for the CCOP-GSJ/AIST Groundwater project was held in Bangkok in October 2009. The agreement of the meeting was to release some kinds of hydro-geological map including the latest scientific information for the end-users at the completion of the Phase II project. The CCOP project should yield a data set for groundwater management. Monitoring of groundwater level and quality is the first step for groundwater management, therefore, a hydrological map is available for basic data of groundwater management and assist to design additional monitoring points.

This is the publication which was compiled each country report presented in the kick-off meeting of the Phase II for the CCOP-GSJ/AIST Groundwater project. These reports have made clear the target, framework and cooperation policy of Phase II project, and conducted the agreement at the meeting. I believe we will be able to have some solutions about groundwater management in the CCOP countries.

I am very grateful to the authors for their invaluable contributions and to the Organizations to which the authors belong for their permission to publish those important reports.

Youhei UCHIDA
Chief Editor

CONTENTS

Groundwater Issues in Cambodia

Huot Vorakcheat
Cambodian National Petroleum Authority

1. Historical Development of Groundwater

Groundwater resources of Cambodia may be regarded as a widely available supplemental source to surface water for domestic, small-scale industrial and agricultural uses. Groundwater has been investigated and exploited through different period since 1958 by the United States Operation Mission (USOM).

During 1960-63, 1103 holes were drilled in 16 provinces, of which 795 of approximately 72 percent productive wells at rate were ranging from 1.1L to 2~~,~~96L /min. The productive wells ranged from 2 to 209 m in depth and the average depth was 23.2 m. Only a few analyses of water quality were done at that time. The dissolved-solids concentrations appear to be generally low so that the water is usable for most purposes without treatment.

Due to high iron concentration, water from some wells would have to be aerated and filtered before use.

From 1995-97, European Union provided budget for PRASAC1-2 program (Domestic Water Supply Program). The PRASAC1 project has already drilled 500 wells in Kompong Chhnang and Kompong Cham provinces and the PRASAC2 project has drilled 274 wells in Takeo and Kompong Speu provinces. The depth of the wells was ranging from 5 to 90 m.

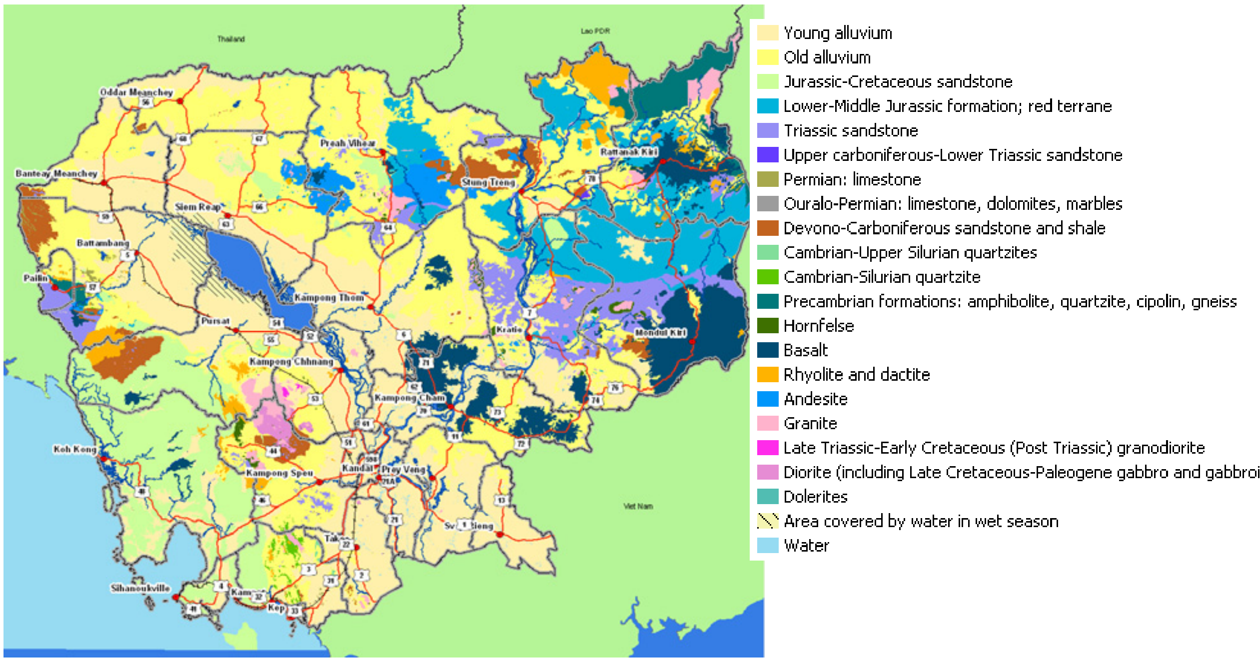
The best well yielded 10m^3 /hr and the average of the production wells was 3m^3 /hr.
Since 1995 UNICEF drilled 10,439 wells, most of them were done in Northwest and Southern Cambodia. Less than 3 % of the wells drilled by UNICEF were reported as having yields in excess of 10m^3/hr.

In 1996, the Japanese government has granted on agreement to fund a project to supply clean water to Phnom Penh and rural area using groundwater~~,~~. The best deep well yielded 200L/min and the average of seven production wells was 80L/min. The groundwater level of existing wells has been measured since February 1997. The measurements continued until November 1997, 26 wells were selected as monthly monitoring wells in the stage.
The results of groundwater level measurement in average are as follows:
-1.7 to 2.5 meters up to the minimum value for dug wells.
-4.75 to 5.5 meters up to the maximum value for bore hole wells.

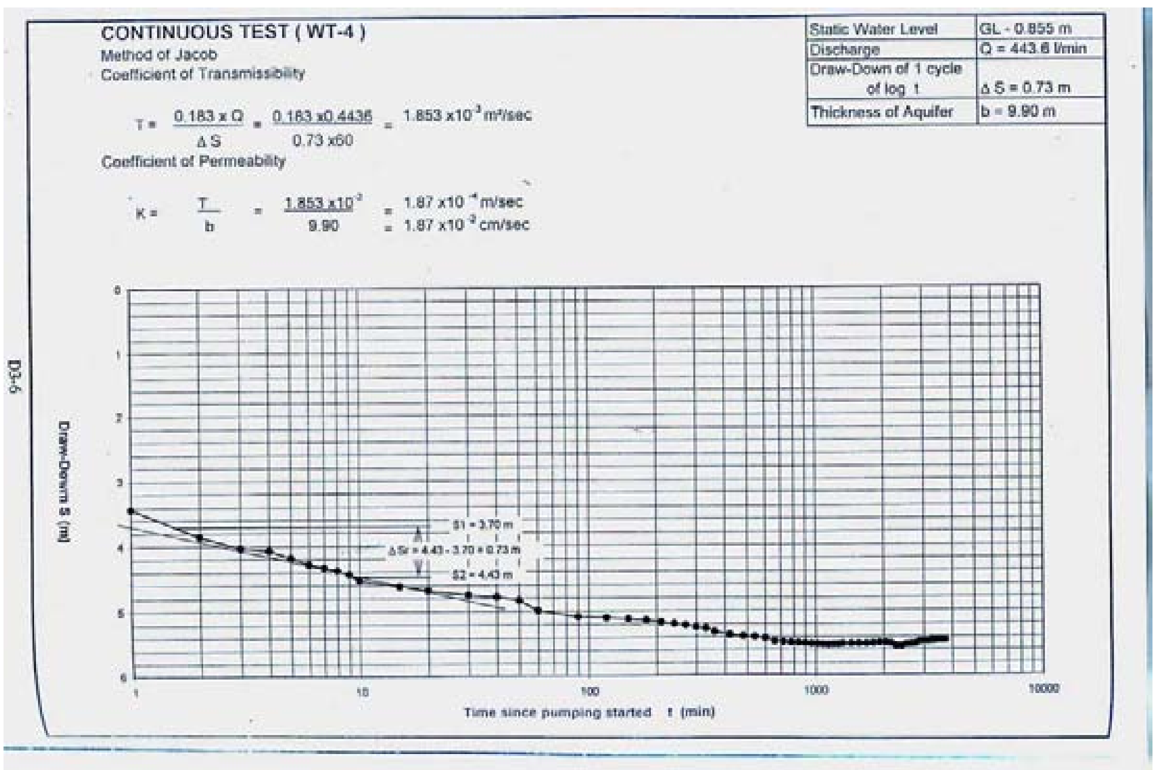
The lowest of groundwater level was observed in January-July 1997 and the highest was observed in October-November 1997.

TABLE1. Records of wells in Khel Kampong Chhnang

Well No,	Town or Village	Locality	Date well completed	Depth (m)	Depth to water (m)	Yield (L/min)	Remarks
Srok Kampong Tralach							
KTr 9?	Khum Tbeng Khpos (Khum ztbeng-Khpas)	Veal Tranh	6-9-62	8			FT, laterite, clay and black earth 8m, AB
Srok Rolea Pier							
RP1	Kampong Chhang	Public Works	1-22-61	22		190	Clay 19m, hard rock 3m L,
RP2	do	Director's house	2-19-61	48		114	Clay 19m, soft rock 14m, fractured rock 15m, L.
RP3	do	Water treatment plant				NP	
RP4	do	Animal farm	3-13-61	30		114	Clay 10m, clay and rock 12m, rock and sand 8m, L,
RP5	Prey Khmer (Khum Rolca Peir)	Phumi Chrey Bak (Chrey Bac School)	5-30-61	28		49	Red sand 5m, clay 10m, stone 13m, L.
RP6	*Khum Kampong Chhang	Phumi Khsam	6-13-61	31		114	Sand and red clay 5m, white clay 5m, rock 21m, L.
RP7	do	Vott Khsam (Wat Khsam)	7-11-61	48		114	Sand and clay 15m, stone 23m, L.
RP8	Prey Khmer	Phumi Chrey Bak (Chrey Bac)		41.7		95	Sand and clay 15m, clay 10m, rock 16.7m, L.
RP9	Phunii Chrey Bak	Police Academy	1-8-63	18		NP	Red sand 18m, AB.
RP10	do	do	1-31-63	80		NP	Red sand 7m, laterite 19m, black rock 61m, AB.



Thailand
Lao PDR
Viet Nam
Oddar Meanchey
Preah Vihear
Banteay Meanchey
Siem Reap
Stung Treng
Rattanak Kiri
Battambang
Pailin
Kampong Thom
Pursat
Kratie
Mondul Kiri
Kampong Chhnang
Kampong Cham
Koh Kong
Kampong Speu
Kandal
Prey Veng
Svay Rieng
Takeo
Sihanoukville
Kep
Young alluvium
Old alluvium
Jurassic-Cretaceous sandstone
Lower-Middle Jurassic formation; red terrane
Triassic sandstone
Upper carboniferous-Lower Triassic sandstone
Permian: limestone
Ouralo-Permian: limestone, dolomites, marbles
Devono-Carboniferous sandstone and shale
Cambrian-Upper Silurian quartzites
Cambrian-Silurian quartzite
Precambrian formations: amphibolite, quartzite, cipolin, gneiss
Hornfelse
Basalt
Rhyolite and dactite
Andesite
Granite
Late Triassic-Early Cretaceous (Post Triassic) granodiorite
Diorite (including Late Cretaceous-Paleogene gabbro and gabbroi
Dolerites
Area covered by water in wet season
Water



CONTINUOUS TEST (WT-4)
Method of Jacob
Coefficient of Transmissibility
T = 0.183 x Q / ΔS = 0.183 x0.4436 / 0.73 x60 = 1.853 x10^-3 m²/sec
Coefficient of Permeability
K = T / b = 1.853 x10^-3 / 9.90 = 1.87 x10^-4 m/sec = 1.87 x10^-2 cm/sec
Static Water Level | GL - 0.855 m
Discharge | Q = 443.6 l/min
Draw-Down of 1 cycle of log t | ΔS = 0.73 m
Thickness of Aquifer | b = 9.90 m
S1 = 3.70 m
ΔSr = 4.43 - 3.70 = 0.73 m
S2 = 4.43 m
Draw-Down S (m)
Time since pumping started t (min)
D3-6

Result of Pumping Test

Japan International Cooperation Agency — July, 1997

The Study on Water Supply System for Siem Reap Region — NIPPON KOEI CO.,LTD

Well No.	Depth (m)	Position of Screen (m)	Static Water Level (GL-m)	Discharge (l/min)	Dynamic Water Level (GL-m)	Specific Capacity (l/min/m)	Groundwater Temp (℃)	pH	Electric Conductivity (μs/㎝)	Fe+ (mg/l) (TONE/JICA)
WT-2	77.00	61.38-73.20								
WT-3	36.00	20.38-32.20	1.640	47.9	18.340	2.9	30.0	5.0	52.4	(*/1.2)
WT-4	29.00	13.38-25.20	0.855	443.6	6.315	81.2	29.7	8.0	34.5	(1.0/0.5)
WT-5	58.00	42.38-54.20	2.895	306.7	23.821	14.7	29.7	6.6	46.0	(1.7/1.5)
WT-6	29.00	13.38-25.20	1.800	306.7	8.490	45.8	29.7	5.2	30.2	(2.7/3.0)
WT-7	60.00	44.38-56.20	0.440	60.5	45.205	1.4	31.4	5.7	51.9	(*/0.2)
WT-8	83.00	67.38-79.20	4.900	-	-	0	29.9	10.7	630.0	(2.8/4.4)
WT-9	42.00	26.38-39.20	3.680	-	-	0	-	-	-	-
WT-10	43.00	27.38-39.20	-	-	-	0	-	-	-	-
WT-11	77.00	61.38-73.20	1.970	-	-	0	-	-	-	-
LTa-1	72.00	63.62-71.90	-	-	-	0	-	-	-	-
LTa-2	35.00	26.61-34.90	3.550	417	6.785	128.9	29.5	5.0	22.0	(10.0/*)
LTb-1	73.00	64.61-72.9	3.319	8.6	183197	0.6	30.1	10.6	418.0	(0.24/*)
LTb-2	40.00	31.61-39.90	2.145	417	11.132	46.4	29.7	5.3	178.0	(0.48/*)

2. Geology and occurrence of Groundwater: it is divided into 3 main regions

1.The Mekong downsream river.

2.The southwestern (high land)

3. The coastal plain.

* Alluviam : old and young

-sandy-silt and silty-clay, which has a low permeability.

The average yielded about 0.7m3/h

-The sandy beds and lenses of the Alluvium, average yield about 16m3/h.

-Groundwater from Alluvium believed to be a good quality.

* Basalt:

-Is located in Kompong Cham.

The quality is good, suitable for most purpose.

-The water yielding capacity ranging 30-50m^3/h.

*Post Triassic Sandstone and conglomerate:

-Located in Posat and Kompong Cham (Tonle Sap).

- No deep wells to penetrate the sandstone and conglomerate beds.

* Other igneous rocks:

- Comprise gabbros, diorite, granite.

- The water yield capacity is similar to basalt.

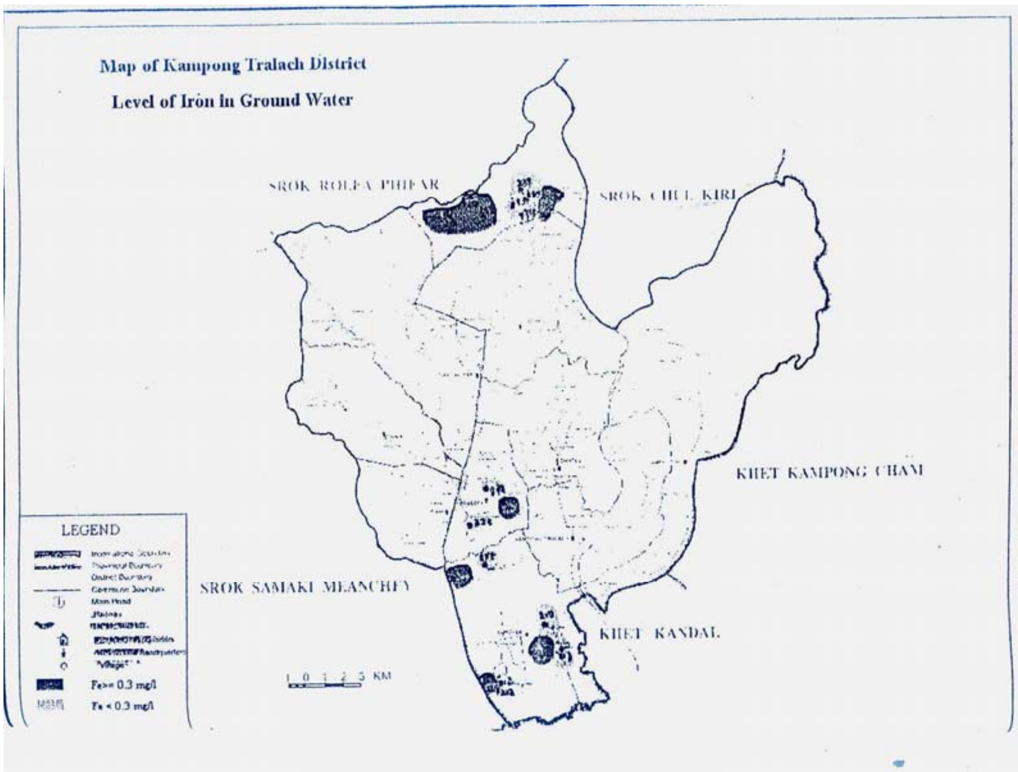
3. Well distribution in each province

There are 13,548 wells in 4,973 villages of 18 provinces. The average is 2.7 wells per village.

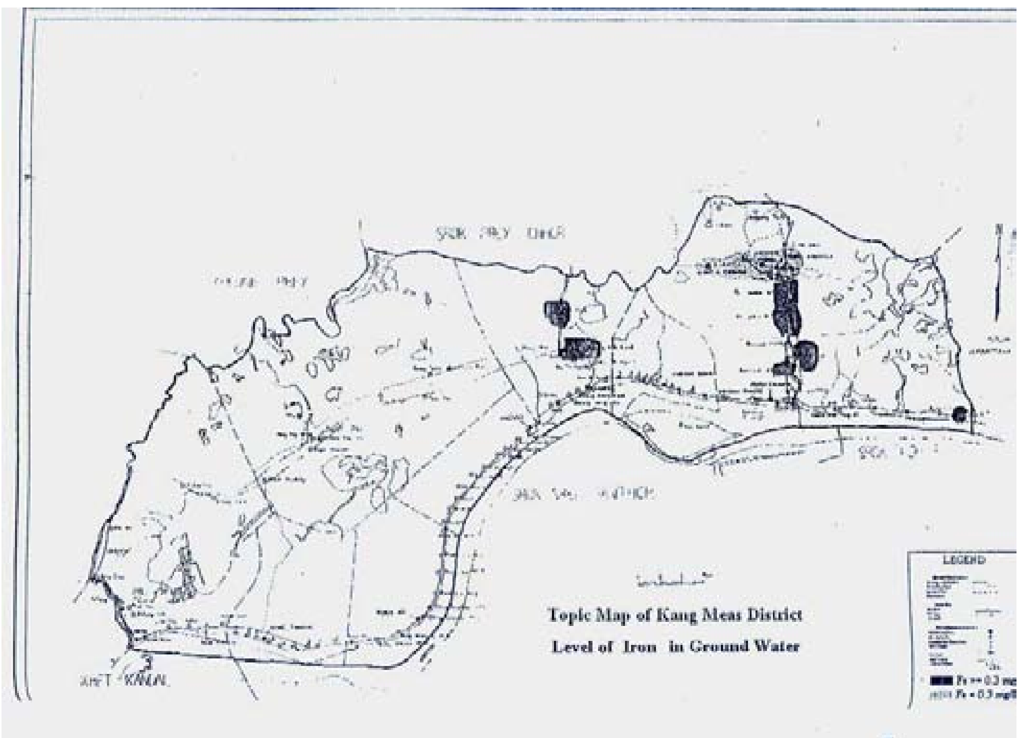
Province	Wells	Villages	Wells per Village
Battambang	665	251	2.7
Bantey Meanchey	321	83	3.9
Kompong Cham	1153	512	2.3
Kompong Chhnang	1473	463	3.2
Kompong Speu	2171	1016	2.1
Kompong Thom	34	13	2.6
Kandal	1991	717	2.8
Koh Kong	4	1	4.0
Krachech	24	10	2.4
Sihanouk Ville	74	48	1.5
Phnom Penh	1062	172	6.2
Pousat	694	200	3.4
Prey Veng	1096	418	2.6
Ratanakiri	10	10	1.0
Siem Reap	229	73	3.1
Stueng Traeng	35	17	2.1
Svay Rieng	467	225	2.1
Takao	2046	744	2.8
TOTAL	13548	4973	2.7

4. Groundwater Quality

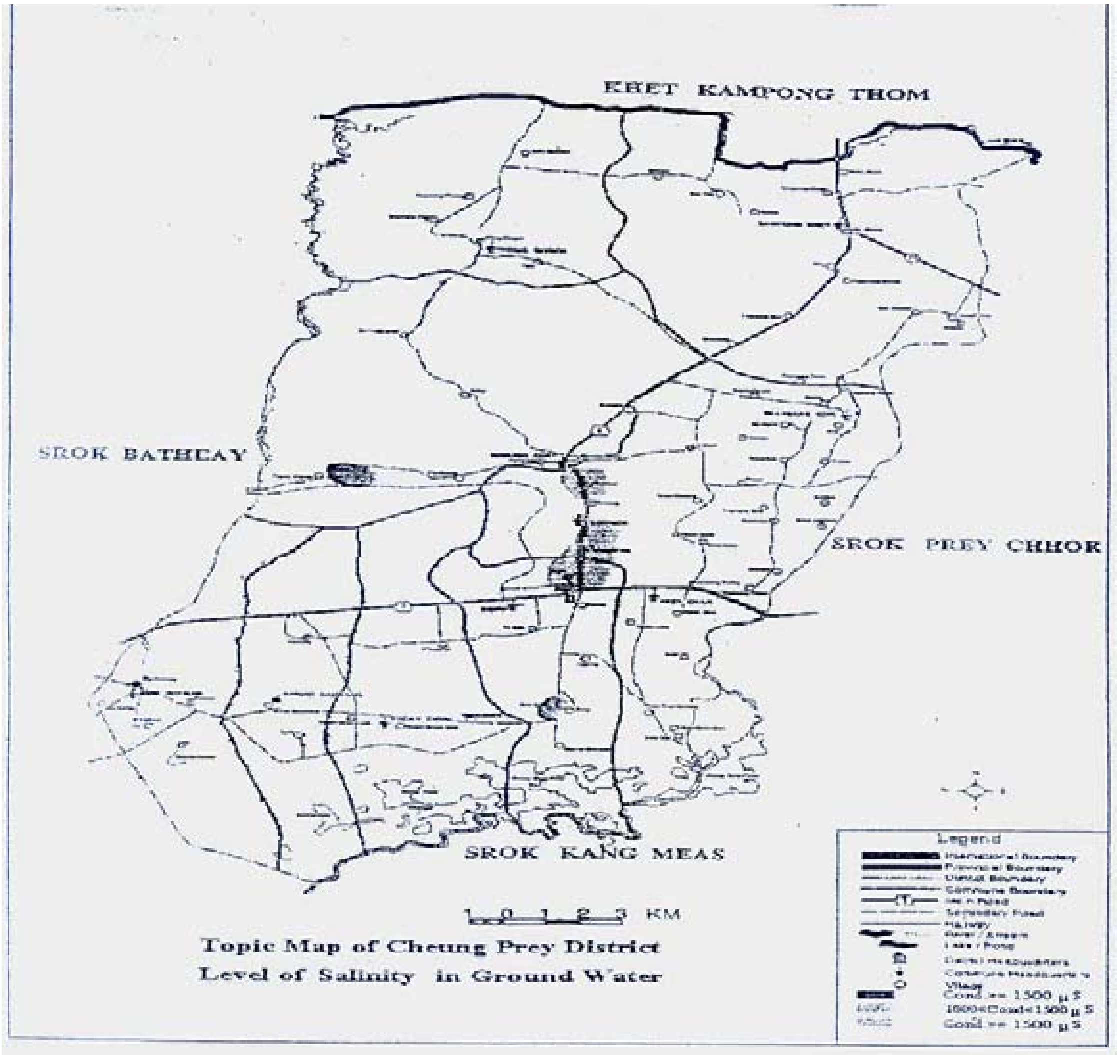
Groundwater quality in Cambodia is generally good, but high level of manganese ion concentration is common. In Svay Reang , Prey Veng, Kompong Chhnang and Konpong Cham provinces, groundwater has high iron concentration and salinity level is increasing. Also water sampled in four provinces(Kompong Chhnang, Kompong Cham, Preah Vihear, and Kompong Thom) shows high iron and TDS concentrations. Fluoride was found in groundwater of Bantey Meanchey, Kompong Chhnang and Kompong Cham provinces.



Map of Kampong Tralach District
Level of Iron in Ground Water
SROK ROLEA PHIEAR
SROK CHUL KIRI
KHET KAMPONG CHAM
SROK SAMAKI MEANCHEY
KHET KANDAL
LEGEND
Fe>= 0.3 mg/l
Fe < 0.3 mg/l
KM



Topic Map of Kang Meas District
Level of Iron in Ground Water
LEGEND
KHET KANDAL



Topic Map of Cheung Prey District
Level of Salinity in Ground Water

Many shallow wells are contaminated by fiscal coliforms. All water samples in Battambang did not conform to the WHO water quality guidelines.

In Kompong Speu, most water samples contain high Ca and HCO3.

In Phnom Penh , most water samples contain high Mg, Na, and HCO3.

In Siem Reap, most water samples contain high Ca, Mg, Fe, HCO3, and Na.

บริษัท ดีเทอร์มิเนชั่น กรุ๊ป จำกัด
Determination Group Co., Ltd.
888/70 ถ.ประชาราษฎร์บำเพ็ญ แขวงสามเสนนอก ห้วยขวาง กทม. 10320
888/70 Pracharatbampen Rd. Samsennok Huaikhwang Bangkok 10320
โทร. 691-2293, 691-2568 โทรสาร. (662) 691-2568
Tel. 691-2293,691-2568 Fax (662) 691-2568

DGC — Water Quality Analysis Report

Laboratory No. 40313
PROJECT LAND SUBSIDENCE, SIEM REAP, CAMBODIA
Well No. **WT-8**
Sampling Method Sampling date June13,97
Remarks

Ref No. 311-314/2540
Date June 26,1997
Sample from *SIAM TONE CO.,LTD.*
5/15 Moo 6(Km.16) Bangna-Trad,Bangcha-long Bangplee
Samutprakarn 10540Tel 312-5261-300 Fax.(66-2)312-5304

Chemical characteristic	Result	Guidline Value*
Calcium (Ca)	16	-
Magnesium (Mg)	2.6	-
Sodium (Na)	133	200
Potassium (K)	2.1	-
Ammonium (NH_4)	3.7	1.5
Total Iron (Fe)	2.8	0.3
Manganese (Mn)	0.02	0.1
Copper (Cu)	0.01	1.0
Zinc (Zn)	-	3
Silica (SiO_2)	47	-
Carbonate (CO_3)	0	-
Bicarbonate (HCO_3)	312	-
Carbondioxide gas(CO_2)	63	-
Chloride(Cl)	11	250
Sulfate (SO_4)	70	250
Nitrite (NO_2)	0.004	3
Nitrate (NO_3)	0.6	50
Fluoride (F)	0.2	1.5
Total Hardness (as $CaCO_3$)	50	-
Permanent Hardness (as$CaCO_3$)	0	-
Total Dissolved Solids (TDS)	438	1,000

Physical characteristic	Result	Guidline
pH	6.9	-
Specific Conductance**	648	-
Turbidity(NTU.)	210	5
Color(Platinum cobal scale)	20	15

Note * Unit milligrame/cubicdecimeter (mg/Liter)
**Unite microsiemen/cm. at 25 degree celcius

Appearance of water *Large amount of insoluble matter.*
Date *July 1-4, 1997*
Analysed by

Approved and examined by
(Mr.Chakan Prayoonchart)
Chemical and research division

The above results are valid exclusively for tested /analysed samples as mentioned in this report

*Guidelines for drinking-water quality 2[nd] Volume1 Recommendations
World Health Organization, Geneva,1993

D4-12

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Determination Group Co., Ltd.
888/70 ถ.ประชาราษฎร์บำเพ็ญ แขวงสามเสนนอก ห้วยขวาง กทม. 10320
888/70 Pracharatbampen Rd. Samsennok Huaikhwang Bangkok 10320
โทร. 691-2293, 691-2568 โทรสาร. (662) 691-2568
Tel. 691-2293,691-2568 Fax (662) 691-2568

DGC — Water Quality Analysis Report

Laboratory No. 40314
PROJECT LAND SUBSIDENCE, SIEM REAP, CAMBODIA
Well No. **WT-6**
Sampling Method Sampling date June14,97
Remarks

Ref No. 311-314/2540
Date June 26,1997
Sample from *SIAM TONE CO.,LTD.*
5/15 Moo 6(Km.15) Bangna-Trad,Bangcha-long Bangplee
Samutprakarn 10540Tel 312-5261-300 Fax.(66-2)312-5304

Chemical characteristic	Result	Guidline Value*
Calcium (Ca)	1.1	-
Magnesium (Mg)	1.7	-
Sodium (Na)	4.6	200
Potassium (K)	0.2	-
Ammonium (NH_4)	1.8	1.5
Total Iron (Fe)	2.7	0.3
Manganese (Mn)	0.12	0.1
Copper (Cu)	0.00	1.0
Zinc (Zn)	-	3
Silica (SiO_2)	15	-
Carbonate (CO_3)	0	-
Bicarbonate (HCO_3)	17	-
Carbondioxide gas(CO_2)	216	-
Chloride(Cl)	3.1	250
Sulfate (SO_4)	0.7	250
Nitrite (NO_2)	0.005	3
Nitrate (NO_3)	0.7	50
Fluoride (F)	0.0	1.5
Total Hardness (as $CaCO_3$)	10	-
Permanent Hardness (as$CaCO_3$)	0	-
Total Dissolved Solids (TDS)	36	1,000

Physical characteristic	Result	Guidline
pH	5.1	-
Specific Conductance**	38	-
Turbidity(NTU.)	16	5
Color(Platinum cobal scale)	12	15

Note * Unit milligrame/cubicdecimeter (mg/Liter)
**Unite microsiemen/cm. at 25 degree celcius

Appearance of water *Precipitated Iron*
Date *July 1-4, 1997*
Analysed by

Approved and examined by
(Mr.Chakan Prayoonchart)
Chemical and research division

The above results are valid exclusively for tested /analysed samples as mentioned in this report

*Guidelines for drinking-water quality 2[nd] Volume1 Recommendations
World Health Organization, Geneva,1993

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5. Conclusion and Recommendation

A groundwater could provide an important source especially in dry season supplement to surface water sources.

It also could be a principle source for domestic, small-scale industrial and agricultural uses in Cambodia.

In Kandal province, arsenic concentration increases with the depth, but no evaluation on it has not been done yet.

A task force for arsenic issue will be needed to bring together for groundwater management and expertise.

Many data have not yet been utilized for evaluation.

Points needed are focused on groundwater assessment, monitoring, and mapping.

Using new data for evaluation of groundwater will provide to advise to the government on laboratory facilities, making quality standard and future groundwater management.

Land Subsidence and Groundwater Withdrawal in the North China Plain

He Qingcheng & Qin Tongchun
(China Institute for Geo-Environment Monitoring)

Abstract:

The North China Plain has witnessed the most excessive groundwater exploitation in the world, and it has caused severe land subsidence in the North China Plain. This paper briefly introduce the general information about the land subsidence and groundwater withdrawal in this region.

Keywords:

Land subsidence, Groundwater withdrawal, North China Plain

1. Introduction

The North China Plain is at the latitude 34°30N-40°30'N and the longitude 113°E-119°30'E, the total area of which is approximately 140,000 km2 (Fig.1).

According to the surface elevation and the formation of this alluvial plain, the North China Plain can be devided into 4 parts: the piedmont plain, the alluvial-fan plain, the proluvial plain and the costal plain. The regions in the southeast, the west and the north are of 100m elevation, while in the coastal plain the elevation is about 4m.

As one of the most important plains in China, the North China Plain is of significance for the economic development. However, by the end of the last century, the continued growth in both population and economy in this region has resulted in the rapid growth of groundwater usage. This in turn caused the occurrence of land subsidence in this region. According to the Economic Loss Assessment Report from the China Institute of Geo-Environment Monitoring (2008), in the North China Plain the total area of land subsidence that over 200mm reached 64296 km2.

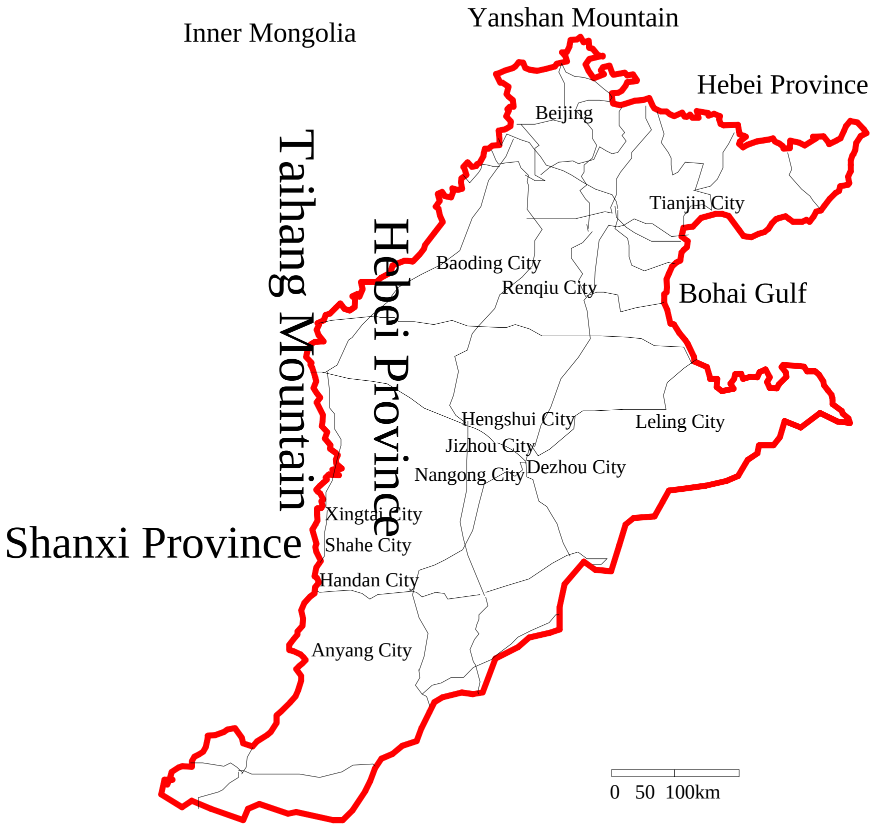

Fig. 1 North China Plain

The North China Plain is located in the secondary tectonic unit- the Huabei Fault Sag. According to the fractures and secondary structural lines in the Huabei Fault Sag, as well as the Cenozoic sediments characteristics, 6 three-level tectonic areas can be divided- Jizhong depression, Huanghua depression, Linqing depression, Cangxian uplift, Chengning uplift, and Neihuang uplift. The depression areas and uplift areas control the characteristics of the quaternary sediments, the structures of the hydrogeology, and the development of aquifers. (He QC, Liu WB, Li ZM, et al, 2006)

The main fracture structures in the North China Plain include Dingxing-Shijiazhuang deep fracture, Xingtai-Anyang deep fracture, Cangzhou-Daming deep fracture, Gu’an-Changli hidden fracture, Wuji-Hengshui hidden fracture, Linzhang-Weixian hidden fracture, Haixing-Ningjing hidden fracure.(Zhang ZH,)

The bedrock in the North China Plain is mainly composed of limestone and dolostone. Oil and gas resources are stored in the tertiary strata, and volcano ash is in tertiary and quaternary strata.

The thickness of the quaternary sediments ranges from 400 to 600 m. The types, the thickness, and the distribution of the quaternary sediments are influenced and controlled by the bedrock structures and the palaeo-geographical conditions. Alluvial deposits and lacustrine deposits are extensively scattered from west to east, and there are residual deposits and coastal deposits in some sedimentary lowland.

Quaternary unconsolidated sediments are extensively scattered in this region, composing the aquifer systems of the North China Plain. Vertically, according to the distribution of sediments, the hydraulic connections of groundwater, and the characteristics of water flows, the quaternary unconsolidated aquifers can be divided into 4 groups. The 1st group and the 2nd group are usually called shallow aquifer groups, because they have the common characteristics of shorter circular periods, notable water alternation, shallow locations, and unconfined hydraulic head. However, the 3rd group and the 4th group are deep aquifer groups for the characteristics of longer circular periods, slow water alternation, deep locations, and confined hydraulic head.

Unconfined aquifer groups lie in the Late Pleistocene- Holocene layers, which are composed of gravels, medium-coarse sands, medium-fine sands, silty sands, etc (Fig.6). Confined aquifer groups are located in the Early Pleistocene strata, Middle Pleistocene strata and parts of Late Pleistocene strata. The groups in the middle and east plain are located under the salt water. The aquifers in the piedmont are made up of sand-pebbles, sand-gravels and medium-coarse sands, while those in the middle and east plain consist of medium-coarse sands, medium-fine sands, fine sands, and silty sands (Fig. 7). Due to long term excessive exploitation, the hydraulic head decreases dramatically, and leakage recharge has become a main recharge source of deep freshwater. (He QC, Liu WB, Li ZM, et al, 2006)

2. Groundwater withdrawal in the North China Plain

In the North China Plain, there are 4 periods of the groundwater level variation procession: natural flow field, partial groundwater level decrease, regional groundwater level decrease, and groundwater level fluctuant decrease (Fei YH, Miao JX, Zhang ZJ, et al, 2009). In the 1st period, before 1964, people seldom exploited groundwater, and the groundwater flow was in the natural flow-field (Fig. 2). In the 2nd period, from 1964 to 1972, gradually increased utilization of groundwater changed the initial situation of the natural flow-field; and groundwater depression cones formed in some parts. In the 3rd period, from 1972 to 1985, the groundwater was mainly used for agricultural, industrial and domestic utilization, in which agricultural utilization accounts for a major part (Fan Pengfei, 1998). Since 1970s, people began to use groundwater massively, especially in Beijing City, Tianjin City, and Hebei Province, where the groundwater utilization took up 45% of all the 16 cities in the North China. In the 4th period, after 1985, regional control of groundwater withdrawal had been carried out, and in some places, like Tianjin and Cangzhou, the groundwater level recovered in some extent.

However, from 1999-2004, because of 6 years droughts, the cumulative deficit of groundwater resource reached 45.0×108m3 and annual deficit was 7.51×108m3. In 2005, although the groundwater withdrawal had been controlled, according to the annual amount of groundwater exploitation, 24×108m3, Beijing was still on the condition of groundwater overexploitation (Sun YH, Duan JP, 2007). Up to 2005, the annual amount of groundwater exploitation was nearly 0.7×108m3(Hao AB, 2005).

After 30 years exploitation, several groundwater depression cones occurred successively in the overexploited regions. In Hebei province, the total area of the cones was 43915 km2 (2006); in Beijing, the total area of the cones reached 1100 km2 (2005). In Cangzhou City, the depth of the central water level was 50.28m in 1975; and in 1985 it reached 75.65m (Figure9). In Shijiazhuang, the capital of Hebei Province, the area of the depression cone was 325km2, and the depth of the central water level reached to 3718m.

If the problem of overexploitation can not be well solved, the 2nd aquifer group will be drained, and the upper layers of the 3rd groups will face the same situation too, which will bring about the severe consequence of using stored water to suffice the requirement.

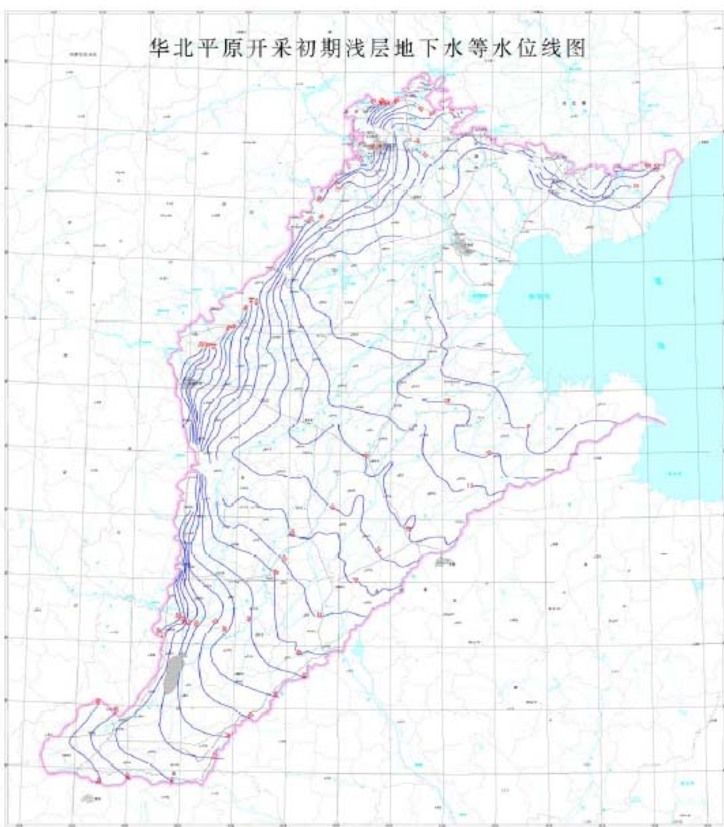

Fig. 2 Groundwater level in or before1960 (the beginning of exploitation)

The deep groundwater depression cones formed in the middle-east of the plain where the groundwater utilization is concentrated in city exploitation and agricultural usage like

Cangzhou cones (Fig. 3). The total area of the deep groundwater depression cones is 43915 km2. With the further exploitation of deep groundwater, the water level continues to decrease and the cones keep on expanding, and at last form a giant-compound cone, the biggest compound cones in the world.

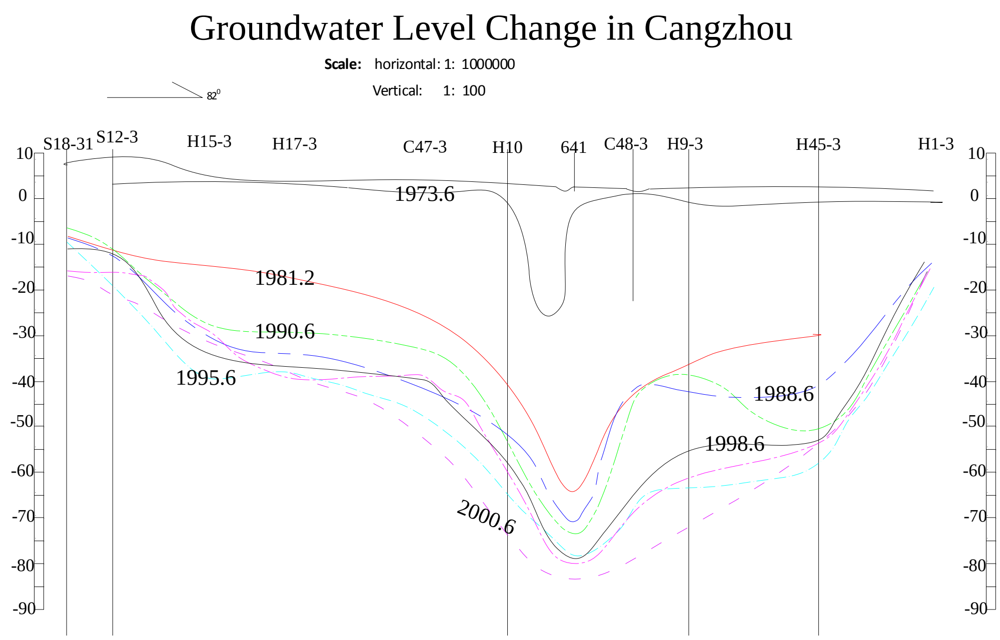

Fig. 3 Groundwater level Change in Cangzhou

3. Land subsidence in the North China Plain

The inducing factors of the land subsidence in the North China Plain can be divided into two parts: natural factors and human factors. The natural factors include tectonic activities, soft layers' self-weight consolidation, and the sea level rise; the human factors are comprised of groundwater, hot-spring, and oil overexploitation, and the massive work of engineering construction. The speed of the land subsidence caused by the tectonic activities in this region is only 1-2mm/a, so the human factors, especially groundwater overexploitation, are the main reasons of the land subsidence (E Jian, Sun Airong, 2007) .

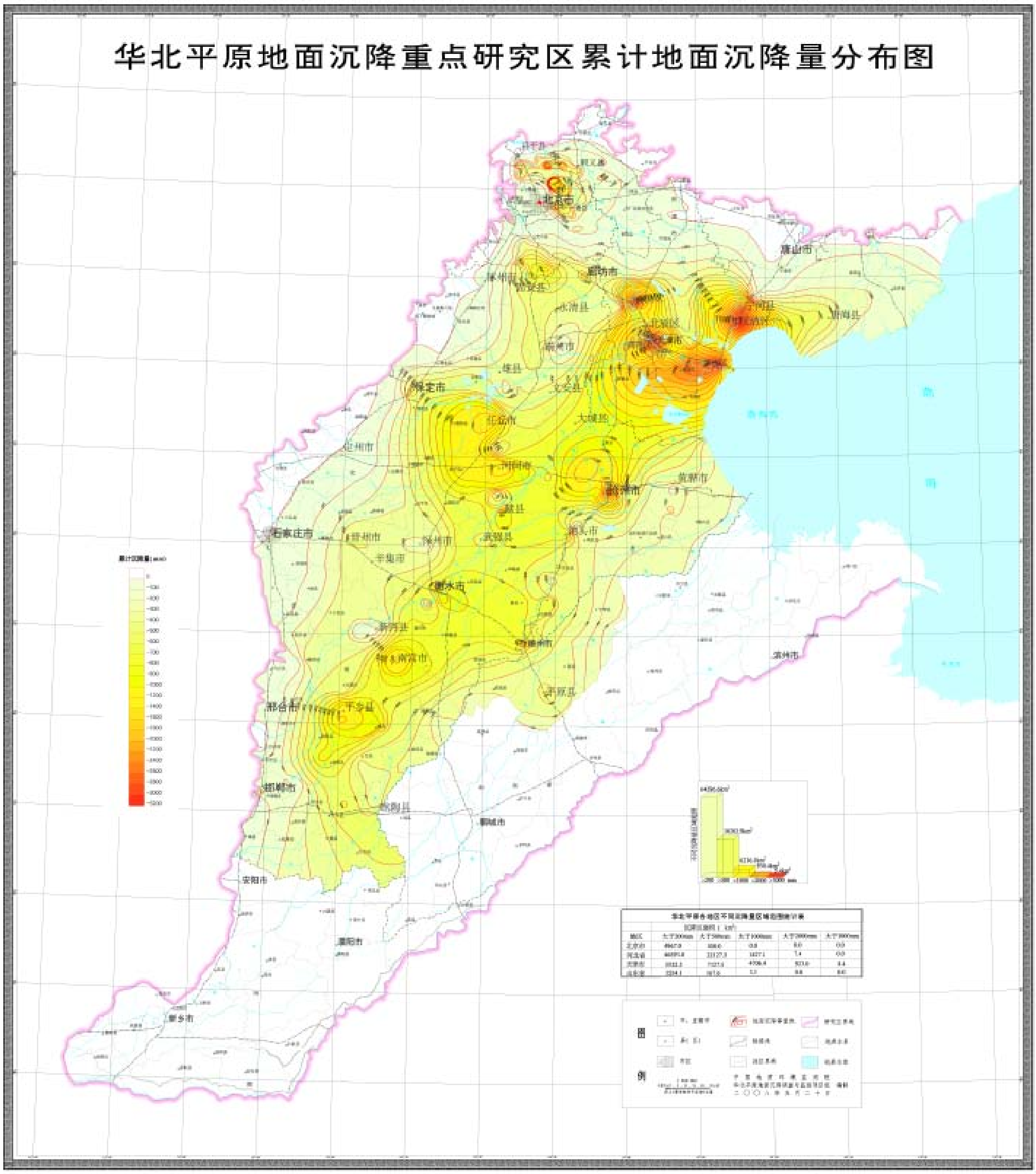

Fig. 4 Land Subsidence in the North China Plain (1960-2007)

According to the preliminary analysis, in the North China Plain, the process of the development of land subsidence is keeping the same and little lagging pace with the process of groundwater exploitation, and the subsiding amount and the groundwater level decreasing amount are positively correlated (Fig 4). The groundwater exploitation is the external inducing factor of the land subsidence, and the different geo-environmental characteristics is the controlling factor of the occurrence of land subsidence, especially the thickness of the quaternary clay layers is the basic factor of the land subsidence. The water-releasing compression of clayed soil in the process of deep water exploitation is unrecoverable. From the statistic analysis, it can be seen that in the subsiding center the depth of the quaternary clay layers is very great. In the biggest subsiding center- Cangzhou subsiding center- the depth of the clay is 214.42m and the depth of the mild clay is 131.41m. In the main exploited area, the depth of the clay is 179.01m and the depth of the mild clay is 64.08m, all of which are the basics of the land subsiding occurrence (Fig 5).

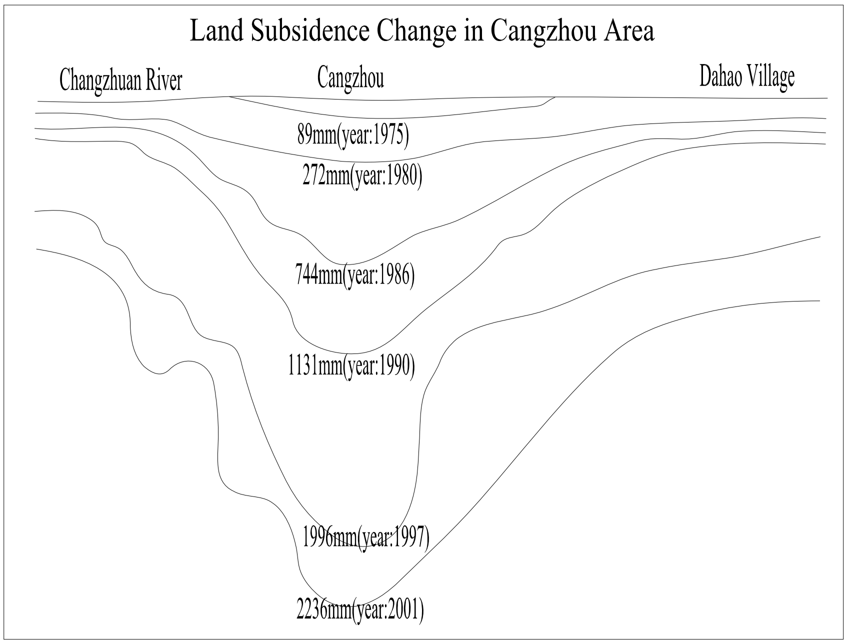

Fig. 5 Land Subsidence Change in Cangzhou Area

4. Conclusion

In the North China Plain, land subsidence not only destroyed the geo-environment and the stability of the buildings, but also increased the loss brought about by the storms and floods; so doing the research about the land subsidence in the North China Plain has important meanings. Groundwater overexploitation is the key reason of the land subsidence in the North China Plain; however the basic reason is coming from the contradiction between the development of social economy and the total amount of groundwater resource. It is significant to concentrate the future work on two ways: using other kinds of water resource and improving the efficiency of water use.

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Groundwater Potency in Indonesia and Their Management

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Abstract

Water, including groundwater, is indispensable for life, but its availability at a sustainable quality and quantity is threaten by many factors, mainly climate pattern for groundwater at unconfined aquifer system and groundwater use at confined aquifer system. Researches on potential effects of climate change on groundwater result the groundwater availability which is comprising quantity and quality are reflection of the precipitation regime, climate variables, landscape characteristics, and human impacts such as agricultural drainage and flow regulation. In other hand, groundwater use at confined aquifer system plays an important role on changing of artesian groundwater quantity.

In order to avoid any negative impacts on groundwater due to the two factors mentioned above, management of groundwater resource have to be done by central government, local government, and other stakeholders in such manner for keeping the resource sustainable. Management base of groundwater resource as stipulated on Article 13 of Law Nr. 7/2004 on Water Resources is groundwater basin. The groundwater management, stated furthermore on Governmental Decree Nr. 43/2008 on Groundwater that comprises activities of planning, actuating, monitoring, and evaluating on groundwater activities that are groundwater conservation, utilization, and controlling on damage capacity of groundwater.

In future, detailed assessment of groundwater resource potential is very important to be performed at each groundwater basin in Indonesia in order to obtain valuable information for planning and management.

Keywords: groundwater resource potential, groundwater basin, groundwater use, groundwater management.

1. Introduction

Groundwater is indispensable for life, but its availability at a sustainable quality and quantity is threaten by many factors, depends on the type of aquifer system in which groundwater occurs. Groundwater at unconfined aquifer system is much more affected by climate pattern, whereas at confined aquifer system is mainly affected by groundwater abstraction.

At current and future, groundwater as a natural resource 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. Therefore God's gift should be managed properly in order to maintain groundwater sustainability for the benefit of mankind.

The use of groundwater in Indonesia, primarily shallow groundwater, have been initiated and developed for centuries. The groundwater from the deep aquifer systems, however, was initially developed in the mid of 19th century. 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 four 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 groundwater, 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, information of groundwater resource potential is absolutely to be provided by central government and local government as a base for proper managing of groundwater to ensure its availability both its quality and quantity and hence, its sustainability can be utilized for the benefit of the people of Indonesia.

This paper intends to discuss briefly groundwater resource potential and their management, firstly describe these resources, their occurrence and properties, groundwater potency, use of groundwater and impacts, and afterwards groundwater management which mainly comprises of legal aspects and technical efforts that have been conducting by Center of Environmental Geology (CEG), Geological Agency (GA), Ministry of Energy and Mineral Resources (MEMR) in order to keep groundwater sustainable.

2. Methodology

This paper can be categorized as a scientific papers that resulting from assessment and evaluation on groundwater engineering. Compiling of this paper is done by performing three steps, that are groundwater data inventory, evaluation and analysis, paper writing.

In general, the materials used for composing this paper were collected from some references as written in Bibiography and some experiences of author especially on managing some activities relating to groundwater exploration and development in area of water shortage in Indonesia.

3. Groundwater Occurrence

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, that are as follow.

1) Groundwater in unconsolidated and semi-consolidated rocks.
2) Groundwater in Quaternary volcanic products.
3) Groundwater in carbonate rocks.
4) Groundwater in consolidated rocks.

3-1. 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, intermontane basin, and river valley, whereas the mode of saturated flow within these aquifers is intergranular.

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 Irian Jaya. The delineation of aquifer zones in these deposits using bore hole 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.

3-2. Groundwater in Quarternary 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 composed by lava, gravel, volcanic sands, and fine materials of volcanic origin. Groundwater flow 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.

3-3. 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 area exposed in Sumatera, Java, Bali, Lombok, Sulawesi until Irian Jaya.

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.

3-4. Groundwater in Consolidated Rocks

Since rocks generally have low permeability, the occurrence of groundwater in consolidated rocks in Indonesai 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 Irian Jaya.

Distribution of the groundwater regions in Indonesia is shown in Fig.1, whereas the more information for Java region can be seen in Fig. 2.

4. Groundwater Basin and their Potency

It is stipulated on Article 13 of Law Nr. 7/2004 on Water Resources, management of groundwater resource should be based on groundwater basin, that is defined as a region which is bordered by hydrologeological boundaries where the hydrogeological processes such as recharging, flowing, and discharging of groundwater occured.

In the evaluation of groundwater resource potential in Indonesia, in general each groundwater basin is assessed. Considering the nature of occurrence and flow of groundwater, it is obvious that the boundaries of groundwater basins do not coincide with administrative or political boundaries.

In Indonesia, 421 groundwater basins were identified and of each groundwater basin were calculated its availability of both free and artesian groundwater. Based on mean annual rainfall which were analysed by Meteorological and Geophysical Agency – MGA (1975) and recharge percentage of various aquifer formation, total groundwater quantity in Indonesia at unconfined aquifer system (Q1) were roughly calculated 496,217x106 m3/year, whereas at confined aquifer system (Q2) which were calculated by applying Darcy’s Law attains 20,906x106 m3/year (Table 1, Geological Agency, 2008).

Table 1 Recapitulation of Groundwater Basin in Indonesia

Nr.	Region	Groundwater Basin (GB)			
		Number of GB	Area [Km2]	Gw Quantity [million m3/year	
				Free Gw (Q1)	Confined Gw (Q2)
1	Sumatera	65	272,843	123,528	6,551
2	Java & Madura	80	81,147	38,851	2,046
3	Kalimantan	22	181,362	67,963	1,102
4	P. Sulawesi	91	37,778	19,694	550
5	Bali	8	4,381	1,577	21
6	West Nusa Tenggara	9	9,475	1,908	107
7	East Nusa Tengara	38	31,929	8,229	200
8	Maluku	68	25,830	11,943	1,231
9	Papua	40	262,870	222,524	9,098
TOTAL		421	907,615	496,217	20,906

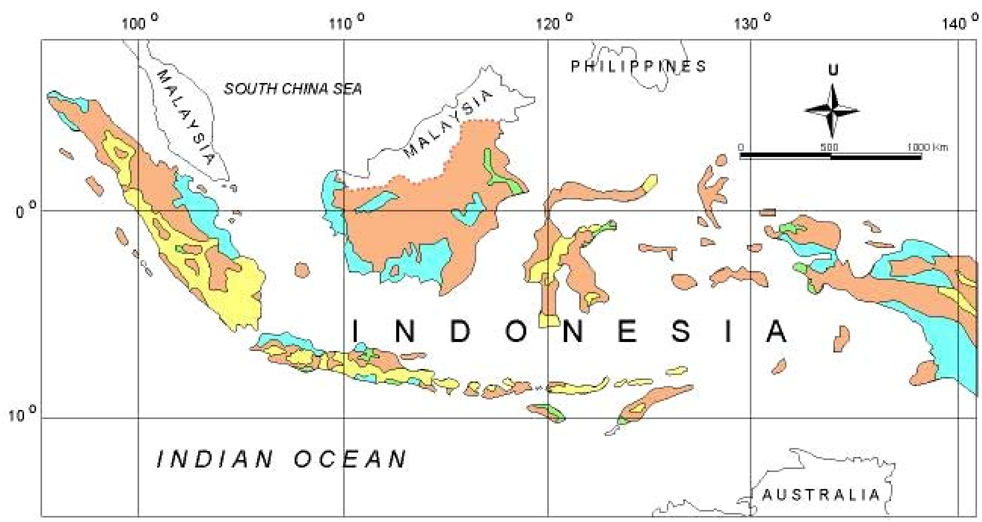

Figure 1 : Occurrence of groundwater in Indonesia (Simplified from Sukardi,1979)

EXPLANATION

Groundwater in unconsolidated and semi-consolidated rocks (Extensive and productive aquifers)

Groundwater in Quarternary volcanic products (Extensive and varied productive aquifers)

Groundwater in of carbonate rocks (Local and varied productive aquifers)

Groundwater in consolidated rocks (Poorly productive aquifers of local importance and region without exploitable groundwater)

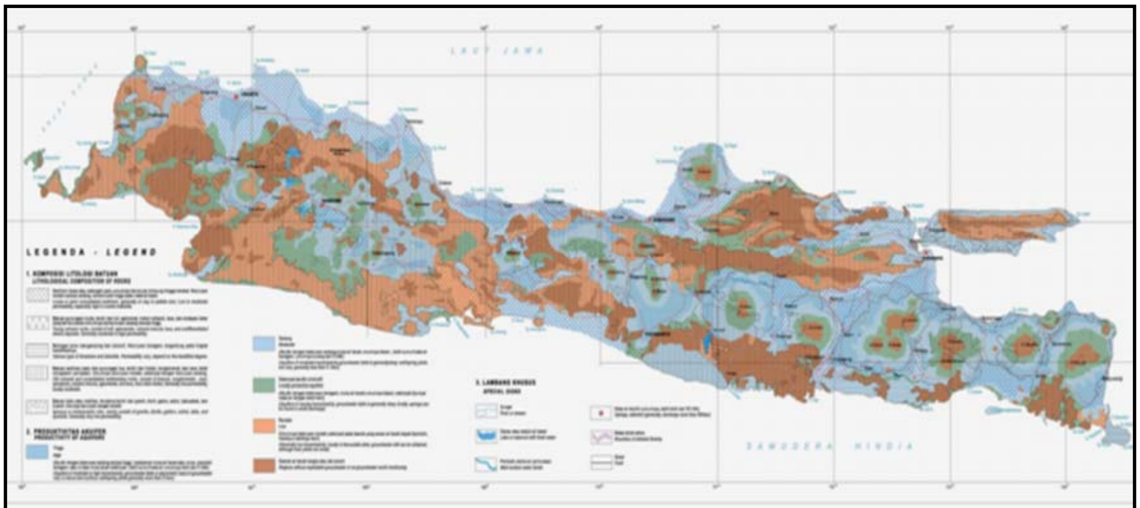

Fig. 2 Hydrogeological Map of Java and Madura Islands Scale 1:2.500.000

5. Groundwater Exploitation

The exploitation of groundwater resources in Indonesia is for various purposes, i.e. drinking water in rural areas, drinking water and industry in urban areas, and for irrigation.

5-1. Drinking Water in Rural Areas

More than 80 % of the Indonesian population live in rural area, however, only a few number are using fresh water of standard utility. Most of them are utilizing surface water and groundwater. The groundwater is obtained from shallow well (dug wells or driven wells), whereas the utilization of groundwater resources is roughly estimated about 70 % of the total water rescues.

5-2. Drinking Water and Industrial Requirements in Urban Areas

The demand for water to meet the daily household needs in urban areas is greater compared with the needs of rural areas owing to the higher living standard. In Indonesia, approaching the year 2000 the demand for drinking water in urban areas is projected to be 200 l/person/day, whereas in rural areas will be 100 l/person/day.

In large cities such as Medan, Bandung, Semarang, Surabaya, and Ujung Pandang, the demand for domestic water still rely on groundwater supply. Less than 30 % of the population of these cities used fresh water from the city water supply. The remaining domestic water requirements still rely on the existing groundwater resources.

In the line with the industrial growth rate in many urban areas, the groundwater is also utilized by the industries for the sustainability of the production. The demand of industrial water is far greater than that for domestic uses. Based on the available data concerning the utilization of groundwater in a number of large urban areas, the amount of groundwater extraction has increased rapidly. In Jakarta area, a rapid increase of groundwater abstraction was observed during the period of 1970-1994 from 12.6 x 106 m3/year to 33 x 106 m3/year, and from 1995 to 2000 was decreasing from 32 x 106 m3/year to 17 x 106 m3/year (Fig. 3). In Bandung area from 1970 to 1996 groundwater abstraction was increasing from 10 x 106 m3/year to 76 x 106 m3/year, and from 1997 to 1999 decreasing from 50 x 106 m3/year to 45 x 106 m3/year (Fig. 4). In Yogyakarta area from 1970 to 1997 groundwater abstraction was increasing from 5 x 106 m3/year to 24 x 106 m3/year, and Semarang area from 1982-2000 was increasing from 13.6 x 106 m3/year to 39 x 106 m3/year. During the period of 1997-2000, the general situation of the groundwater abstraction decreased in accordance with the decrease of industrial production, due to monetary crisis.

5-3. Irrigation Water

In Indonesia these have been enormous advances in groundwater utilization since about 1970 when its uses for large scale irrigation in Java e.g. Yogyakarta, East Java (Madiun, Kediri, Nganjuk, Tuban, and Mojokerto), and Central Java projects and these projects are continued in other islands.

The irrigation facility consisted of deep wells equipped with diesel powered turbine pumps capable of yielding 60-100 l/sec, medium wells equipped by centrifugal pumps capable of yielding 25-60 l/sec, and shallow wells equipped by centrifugal pumps yielding of less than 25 l/sec.

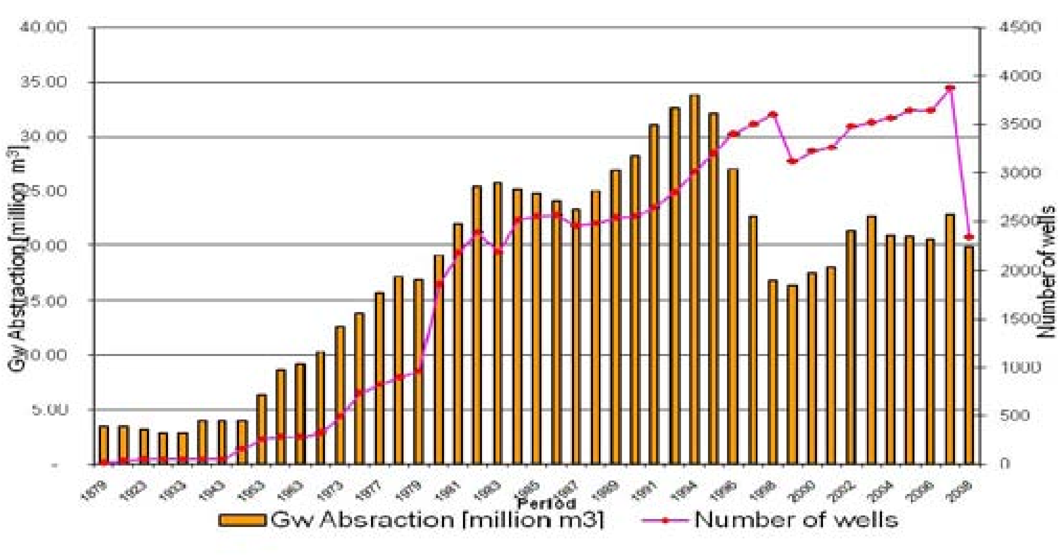

Fig. 3 Total number of well and volume of groundwater abstraction in Jakarta GB

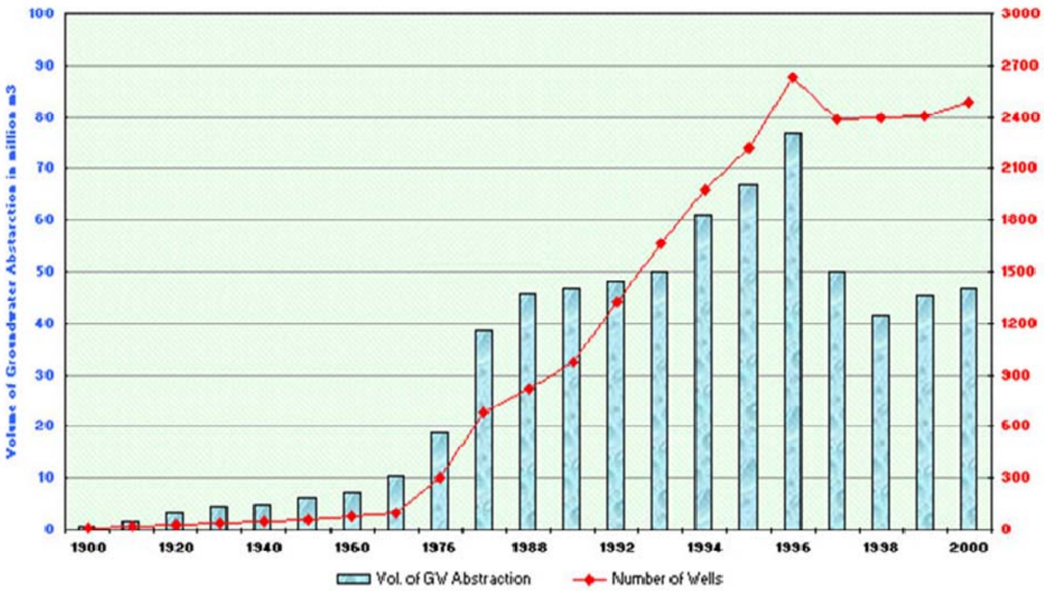

Fig. 4 Total number of well and volume of groundwater abstraction in Bandung GB

Table 2 Irrigation by Groundwater in Indonesia (after Haryadi et.al., 2001)

Province	Deep Wells	Medium Wells	Shallow Wells	Total	Deep Wells	Medium Wells	Shallow Wells	Total
	Number of wells	Irrigated lands (Ha)	Number of wells	Irrigated lands (Ha)	Number of wells	Irrigated lands (Ha)	Number of wells	Irrigated lands (Ha)
W. Java	-	-	14	162	-	-	14	162
Central Java	12	379	10	163	-	-	22	542
East Java	494	23.38	60	488	90	537	644	24,405
Yogyakarta	36	1,150	-	-	-	-	36	1,150
Bali	3	91	-	-	-	-	3	91
West Nusa Tenggara	126	1,717	-	-	-	-	126	1,717
South Sulawesi	-	-	15	176	1	3	16	179
Central Sulawesi	-	-	20	132	-	-	20	132
Total	671	26.71	119	1,121	81	540	881	28,370

6. Impacts of Groundwater Exploitation

6-1. Declining of Groundwater Level

Declining of the groundwater level which induced by the utilization of groundwater has been observed in big cities in Indonesia, such as Jakarta, Bandung, Semarang, and Surabaya.

In the period of 1982 - 2000 groundwater water level in Jakarta dropped by 1-2 m/year, the position of piezometric head of deep aquifer system varies from 20-60 m below mean sea level. In Bandung, especially in industrial areas the position of piezometric head varies from 30-90 m below ground surface, for the last 11 years water level dropped by 2-3 m/year, and in Semarang and Surabaya areas in the period of 9 years groundwater abstraction has led to lowering of piezometric head from 0.5-1.0 m/year, the position of piezometric head varies from 20-30 m below ground surface.

6-2. Salt Water Intrusion

Rapid increase of groundwater exploitation in the densely populated and industrialized areas which are located in coastal zone has led to salt water intrusion. Salt water intrusion into shallow and deep-seated aquifer systems have been recorded in Jakarta, Semarang, Medan, and Denpasar.

In case of Jakarta, brackish - saline zone which might be due to salt water intrusion for shallow aquifer system was observed in 2000 reaching about 8 km inland, whereas for the deep aquifer system reaching 3-7 km, indicated by total dissolved solids of more than 1,000 mg/l, electric conductivity of water greater than 1,500 micromhos/cm, and chloride contents higher than 500 mg/l. In other hand, considerable amount of water are continuously drawn from the unconfined aquifer down into the confined aquifer through the semi-permeable layers. This downward movement may bring about salt water contamination and deterioration to the quality of the confined water.

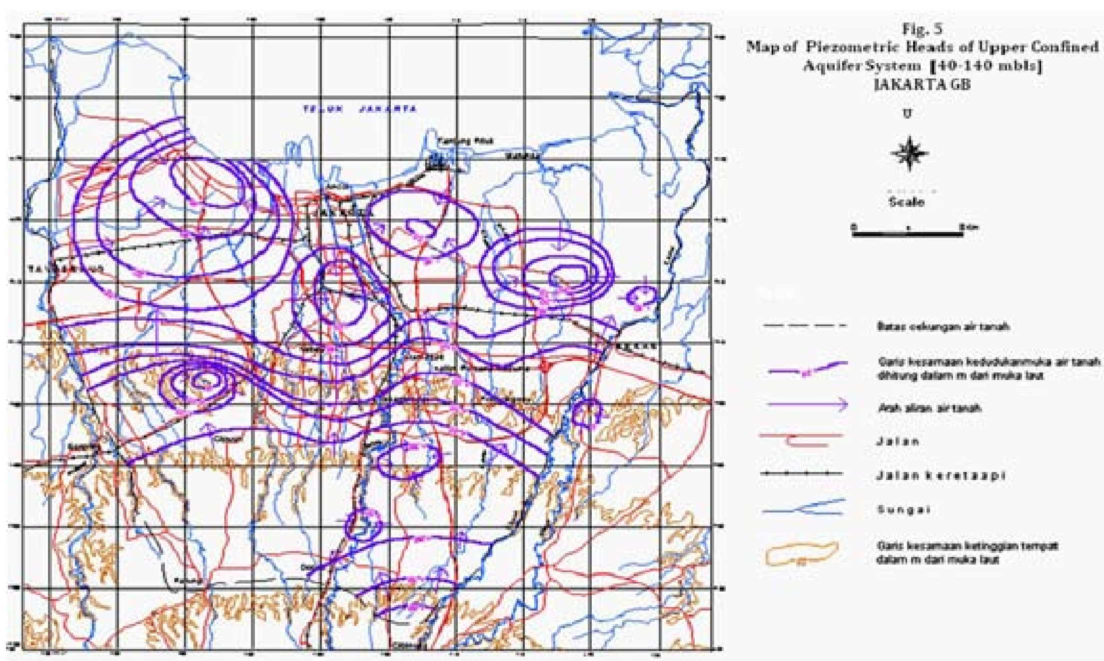

Fig. 5
Map of Piezometric Heads of Upper Confined Aquifer System [40-140 mbls]
JAKARTA GB

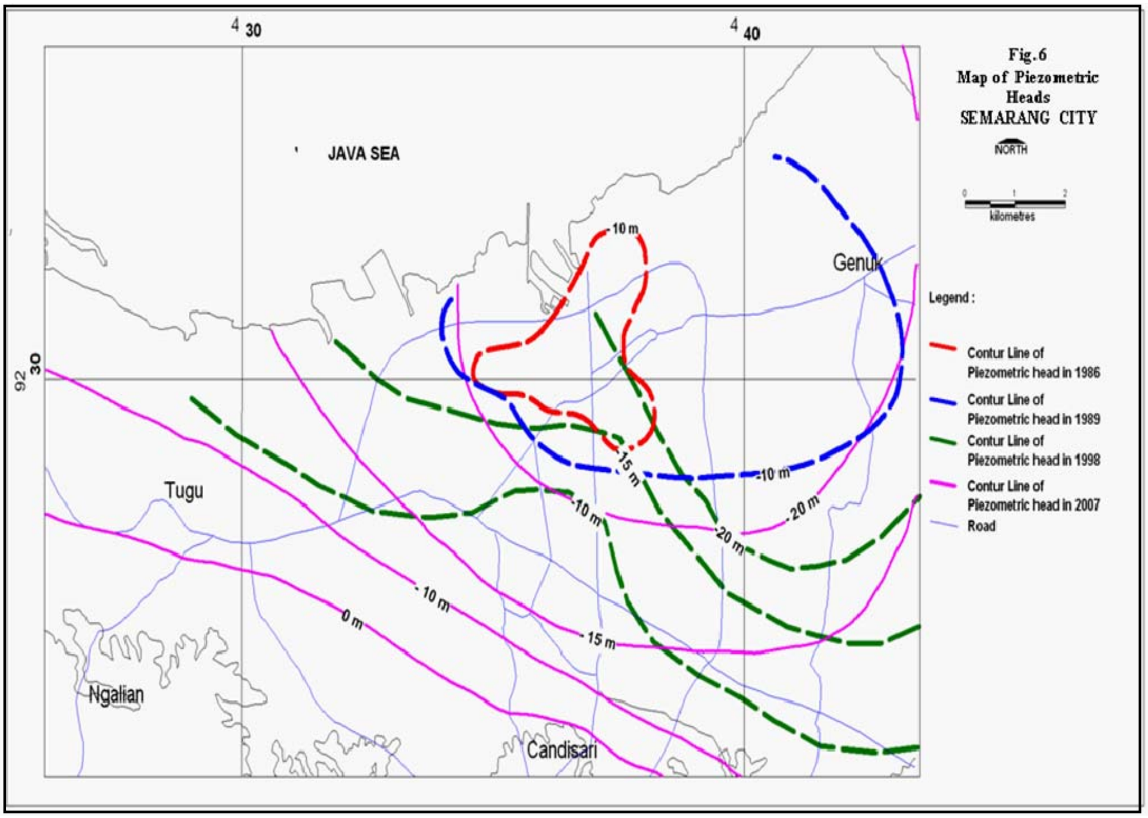
Fig.6
Map of Piezometric Heads
SEMARANG CITY
NORTH
kilometres
JAVA SEA
Genuk
Tugu
Ngalian
Candisari
10 m
15 m
10 m
20 m
10 m
20 m
10 m
0 m
15 m
Legend :
Contur Line of Piezometric head in 1986
Contur Line of Piezometric head in 1989
Contur Line of Piezometric head in 1998
Contur Line of Piezometric head in 2007
Road

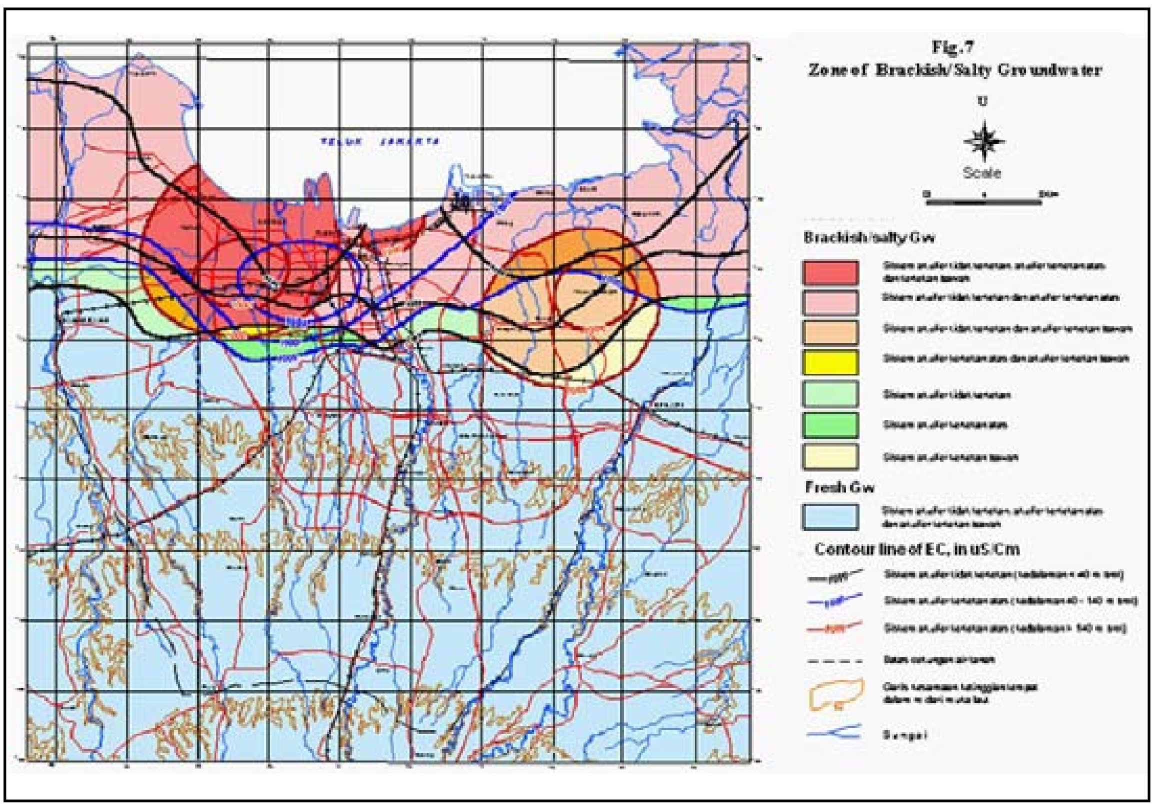
Fig.7
Zone of Brackish/Salty Groundwater
U
Scale
TELUK JAKARTA
Brackish/salty Gw
Fresh Gw
Contour line of EC, in uS/Cm

6-3. Land Subsidence

Land subsidence phenomenon was obvious in some parts of Jakarta and Semarang areas, where the subsided land areas are in general coinciding with zones of groundwater cone of depression.

The geological setting beneath Jakarta, combined with a large amount of groundwater abstraction, have constituted the situation that can bring about land subsidence. The geotechnical model calculation strongly supported the hypothesis, that groundwater abstraction is the main cause of the observed land subsidence (10 - 99 cm in the period of 1978 - 1989, more than 50 cm in a zone of approximately 150 km2). Simulation runs make plausible that the total land subsidence in uncontrolled condition may increase to 5 times the values already observed.

7. Groundwater Management

7-1. Legal Aspect

As stipulated on article (3) Paragraph 33 of the Indonesia Constitution of 1945, "Land and water and natural riches contained therein belong to and are controlled by the state and used for the benefit of the people", therefore the presence of groundwater in Indonesian soils must be used to meet the water demand for the benefit of the people.

Fig. 8
Landsubsidence phenomena
in North Jakarta and
Cengkarang - Tangerang

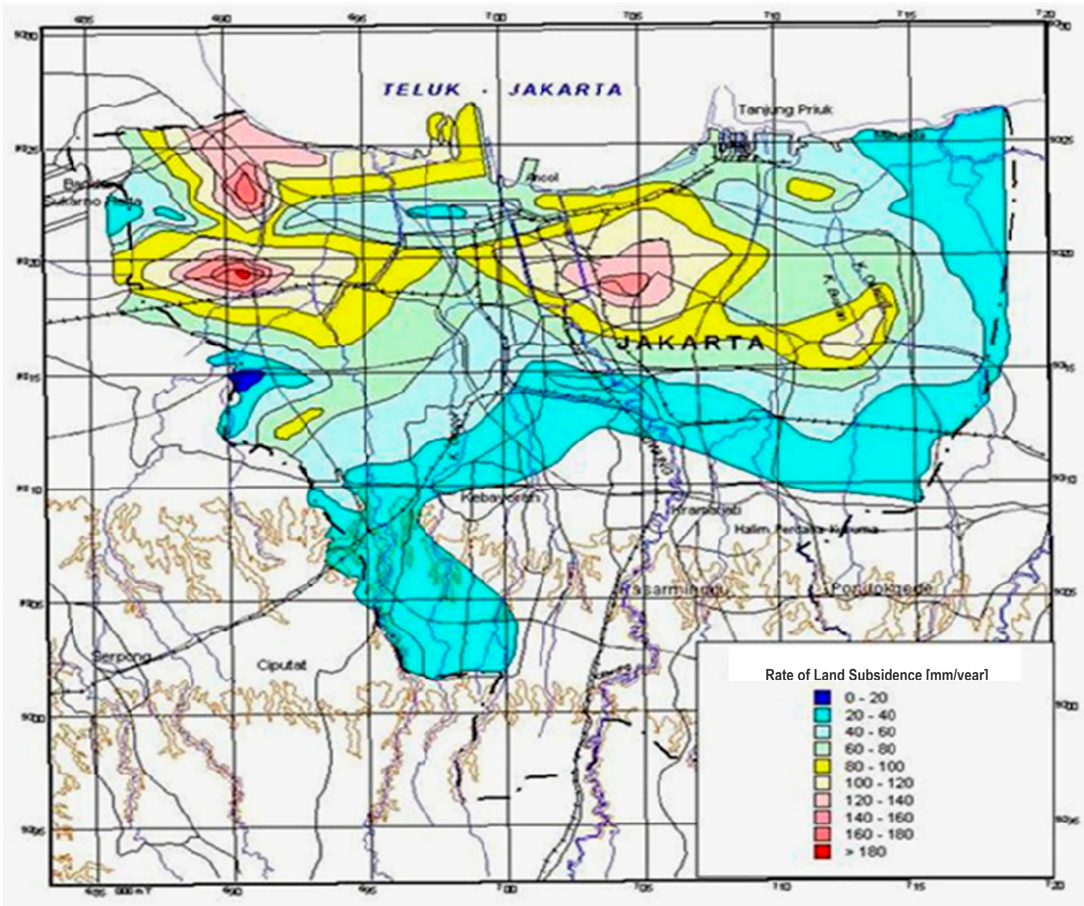

Fig 9
Zone of Land Subsidence in the North of Jakarta

In order to achive the target on groundwater management, some regulations were issued and have to be referred by stakeholders, that are as follow.

A Law Nr. 7 of 2004 on Water Resources.

b Government Decree Nr. 43 of 2008 on Groundwater.

c Presidential Decree on Groundwater Basin, still draft, will be issued by the end of 2009.

d Decree of Minister of Energy & Mineral Resources Nr. 1451K/10/MEM/2000 on Technical Guidelines on Groundwater Management which comprises mainly:

1) Principles, authority and technical steps of groundwater management;

2) Technical guidelines on evaluation of groundwater resources;

3) Technical guidelines on planning and utilization of groundwater resources;

4) Technical guidelines on defining of groundwater abstraction;

5) Procedure on groundwater exploration permit;

6) Procedure on spring capturing and abstraction permit;

7) Procedure on groundwater drilling master permit;

8) Technical guidelines on controlling of production well construction activities;
9) Technical guidelines on groundwater costs for calculating groundwater abstraction tax;
10) Guidelines on reporting of groundwater abstraction.

e Decree of Minister of Energy & Mineral Resources Nr. 716K/40/MEM/2003 on Horizontal Boundary of Groundwater Basins in Java and Madura Islands.

F Decree of Minister of Energy & Mineral Resources Nr. 13 of 2009 on Guideline for Establishment of Decree Draft on Groundwater Basin.

7-2. Technical Efforts

Technical efforts should be performed by stakeholders, mainly by the central government and local governments (province and regency/city) according to their responsibility as stated on Law Nr. 7 of 2004 on Water Resources and Government Decree Nr. 43 of 2008 on Groundwater.

Some technical efforts, for instance which had been conducting by Ministry of Energy and Mineral Resources (MEMR) are mainly as follows.

7-2-1.Groundwater Inventory

As stipulated on Article 21 of the Government Decree Nr. 43 of 2008 on Groundwater, groundwater inventory is done for obtaining data and information on groundwater that comprise of quantity and quality of groundwater, environmental condition related to groundwater, groundwater basin and its means and infrastructures.

Groundwater inventory can be done by several activities as follows:

a Groundwater/hydrogeological apping, e.g. hydrogeological mapping scale 1:250,000, mapping on groundwater recharge and discharge areas, and deliniation and evaluation of groundwater basin boundaries.

b Groundwater/hydrogeological investigation, e.g. investigation which related to assessment on groundwater resource potential of the groundwater basin.

c Groundwater/hydrogeological research, e.g. groundwater quantification and modeling, use of isotop for deliniating groundwater recharge area, etc.

d Groundwater exploration, e.g. exploration and development of groundwater for supplying water consumption in area of water shortage.

7-2-2. Establishment of Zone of Groundwater Conservation

Groundwater data and information obtained from the above activities (groundwater inventory) are used to establish zone of groundwater conservation. This zone consist of stipulation on groundwater conservation and utilization within groundwater basin.

Zone of conservation is presented on map that classify the groundwater basin into zone of preservation which cover groundwater recharge area, and zone of groundwater use that consist of safe, buffer, critical, and damage zones.

7-2-3. Groundwater Monitoring

Groundwater monitoring should be performed in order to know the change of groundwater quantity and quality in a certain groundwater basin, and to be needed for supporting activities on groundwater conservation.

Groundwater monitoring can be done at monitoring wells or production wellds within the groundwater basin that include several items as folows.

a To measure and record groundwater level (phreatic and piezometric levels).

b To measure and examine physical, chemical, biological parameters and radioactive constituent on groundwater.

c To record amount of groundwater use.

d To measure and record the change of groundwater environment, e.g. land subsidence phenomena.

Data and information obtained from groundwater monitoring should be used by central government and/or local goverments as a basis for evaluating the execution on conservation, utilization, and controling on damage capacity of groundwater.

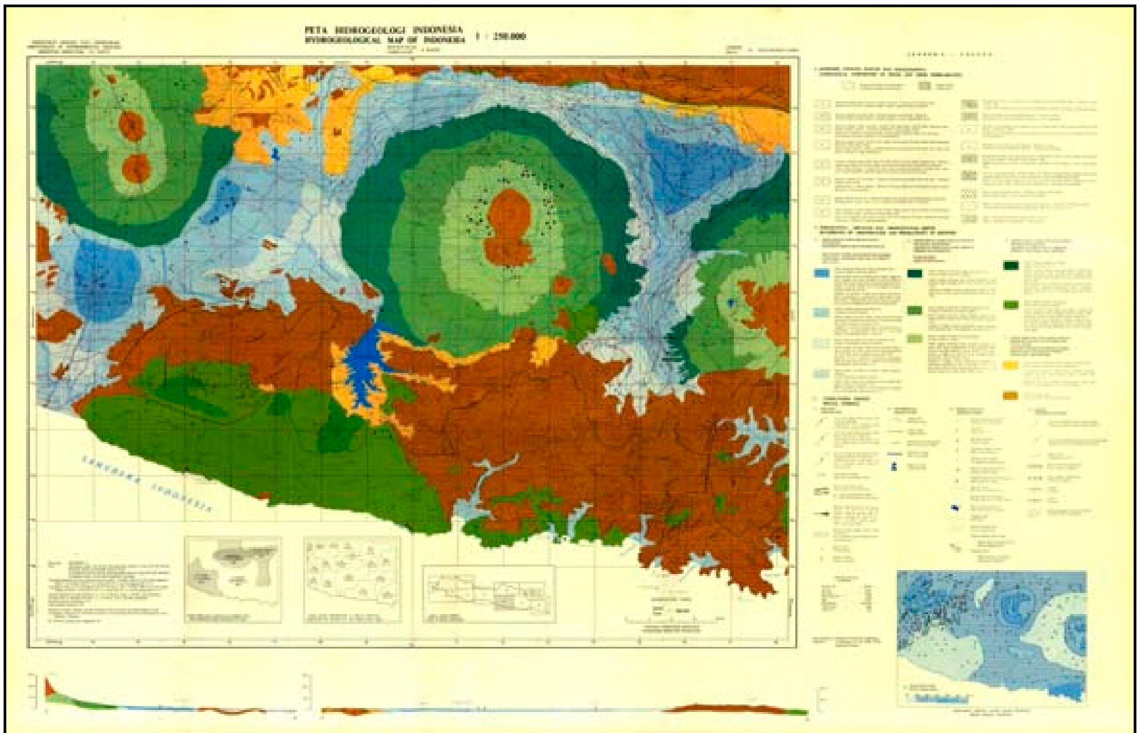

Fig. 10 Example of Hydrogeological Map Scale 1:250,000

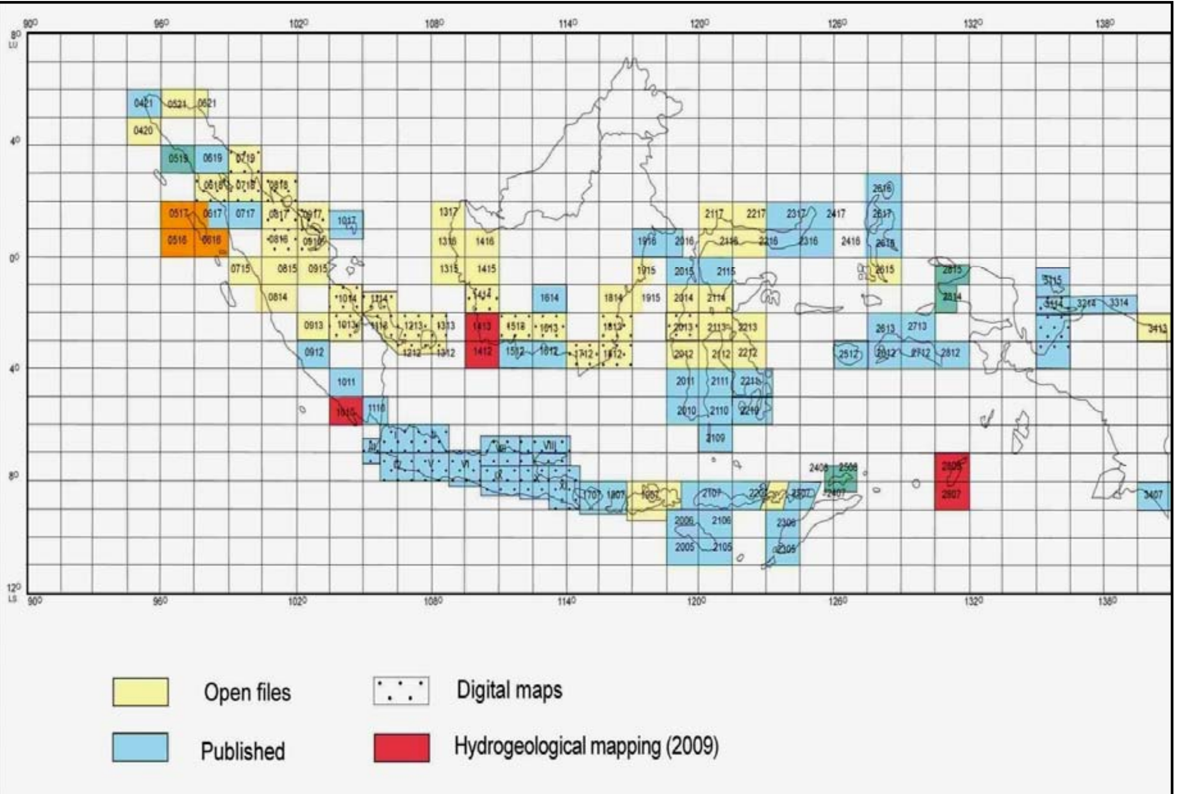

Fig. 11 Status of Hydrogeological Mapping Scale 1:250,000 (September 2009)

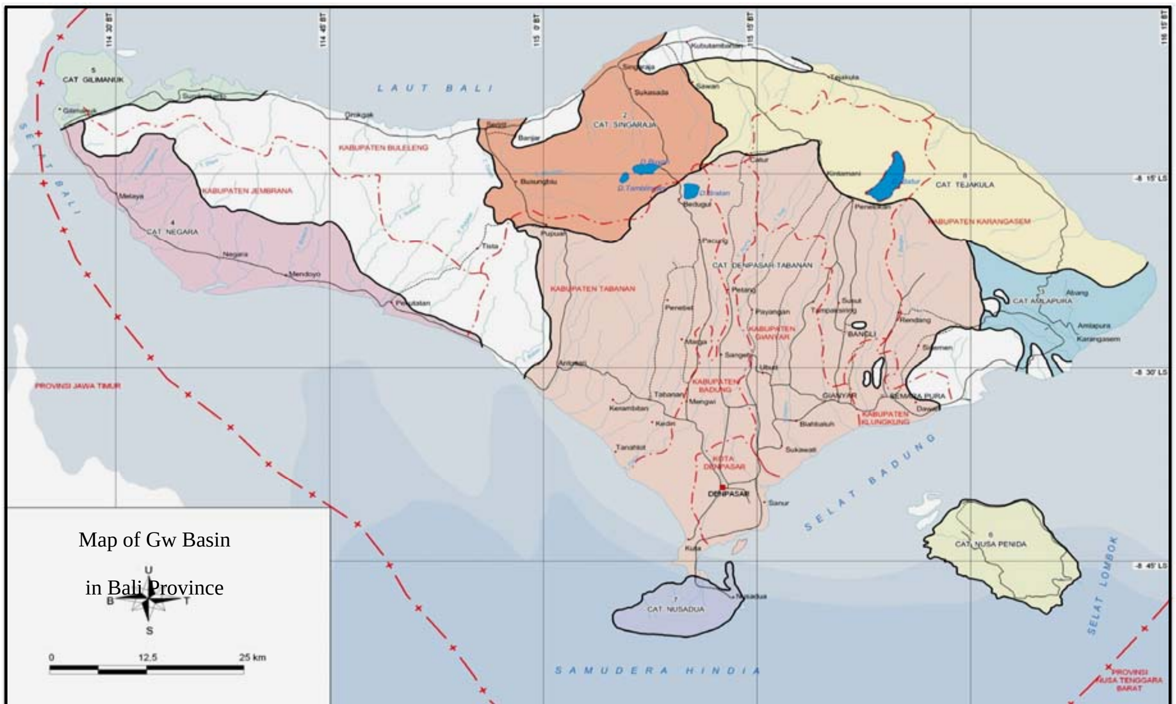

Fig. 12 Deliniation of Groundwater Basin Boundaries

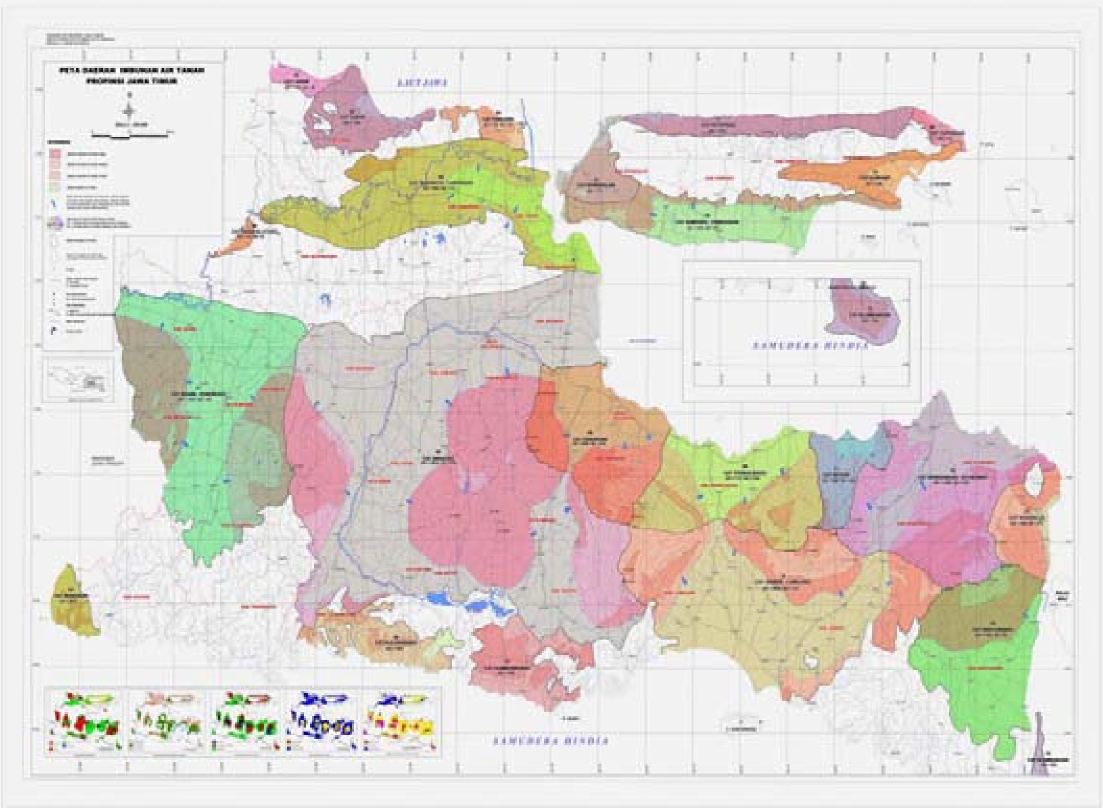

Fig. 12 Mapping on Groundwater Recharge and Discharge Areas

7.2.4 Groundwater Database

Management of groundwater database and information system should be done by central government and local goverments for supporting groundwater management as of their responsible. This groundwater data and information system is as apart of national water resource information network that should be managed at a national, province, and a regency/city levels.

Groundwater data and information that to be managed are mainly consist of:

a Configuration and parameter of aquifer system within groundwater basin.

b Hygrogeology.

c Groundwater potency.

d Groundwater potency.

e Groundwater utilization.

f Condition and environment of groundwater.

g Controlling and supervising of groundwater.

h Policy and regulation on groundwater.

i Social, economical, and cultural activities of society related to groundwater.

Management of groundwater database and information system is performed in several steps, that are

a Data collecting.

b Data storing and processing.

c Data updating.

d Publishing and desemination of data and information.

8. Closing Remarks

a Groundwater has a significant role in providing water for various purposes in Indonesia, that is, drinking water in rural areas, drinking water and industry in urban areas, and for irrigation supplement.

b The increased rate of groundwater exploitation in the major cities in Indonesia has led to negative impacts on groundwater resources, both quantity and quality, and also on the environment surroundings (land subsidence).

c Groundwater potency of each groundwater basin which were identified in Indonesia need to be assessed in detail in order to obtain valuable information needed for planning and management.

d Monitoring and analysis of groundwater conditions should be continuously performed especially in urban groundwater basins, e.g. Jakarta GB, Bandung-Soreang GB, and Semarang-Demak GB in order to know the change of their availability and quality.

e Proposed technical assistance from CCOP relating to groundwater management in Indonesia are mainly as follow:

Groundwater quantity and quality monitoring in urban groundwater basins that are comprising of network design on groundwater monitoring wells, installation and expertise, and also budgeting.

Groundwater quantitication and modeling in urban groundwater basins that are including aplication softwares, expertise, and budgeting.

Hydrogeological research for determining critical groundwatger discharge in urban groundwater basins, e.g. Jakarta GB.

Acknowledgement

The authors wish to thank to the Head of Center of Environmental Geology, Geological Agency, MEMR in encouraging him to participate this meeting. Our warm thank also goes to the Director of CCOP Technical Secreatriat who gave the opportunity to present this paper.

Groundwater Research in Geological Survey of Japan, AIST

— Groundwater Environment in the Present and the Past —

Youhei Uchida (Geological Survey of Japan, AIST)

1. Research of Groundwater RG in GSJ, AIST

Groundwater is one of common keyword for the environment and resource of the nature. Coastal area is an important part from the view point of groundwater flow and human activities. Geological Survey of Japan, AIST is one of national institute for make a research of national program on the coastal area to evaluate the stability of the environment including the deep groundwater flow mechanism. We will have the information of all Japanese islands, and the data is also effective in Carbon dioxide Capture and Storage (CCS) and High-Level Nuclear Waste (HLW) research, unknown Groundwater resources (incl. hot-springs) and ground-heat coupled system.

1-1. Groundwater Study for Coastal area in Japan

Existence of groundwater on the coastal area is very complicated. Fresh water and Sea water have an equilibrium in the shallow zone. On the other hand, deep groundwater flow is controlled by geological structures. And upward flow is made along the interface of freshwater and seawater, or faults which causes the instability of the coastal deep groundwater environment.

Movement of the seawater /freshwater interface and seawater intrusion according to the construction of a huge accelerator was observed in the coast area of Tokai Village, about 150km north-east of Tokyo. The construction has been carried out from 2002, in the virgin pine woodland located on the beach (300m from the coast line). The study was carried out with the purpose of controlling the pumping up water to prevent the seawater intrusion effects in the constructing area, because the average rate of pumping up water was over than 10,000m^3. In the study, we observe the intrusion of seawater and movement of the interface to inland, and also the outer back of its movement after the main construction.

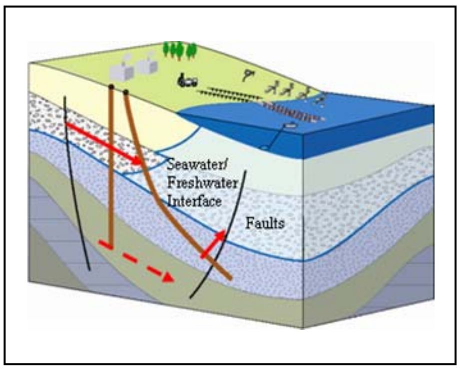

Fig. 1 Image of groundwater on the coastal area.

The shape of the interface is a result of the equilibrium of seawater and freshwater, and also the result of the groundwater upward flow. Seawater had intruded to the land area through the construction, the concentration of Cl$^-$ was observed in 6m below the sea level. We made a team of water drainage control for the keep the water environment of construction and woodland. The team could control the drainage rate in sometimes.

We are faced to variable water problems which needs the international cooperation to catch a solver. The groundwater database is a strong solution of us. We, the member of the CCOP project, already made some kinds of groundwater database in each countries.

History of laws and regulations of south-east Asian countries were summarized as a table and database which is possible to evaluate the areas of non-law in order to enact laws in one country via comparison with other countries' conditions. The legal system in water resources had been already finished by the 1970's, but in the field of drinking water, only just recently revised, in case of Japan. The research that elps to make future laws should be started, and it must be noticed that the theme can be clearly defined by referring to the history of groundwater management and development.

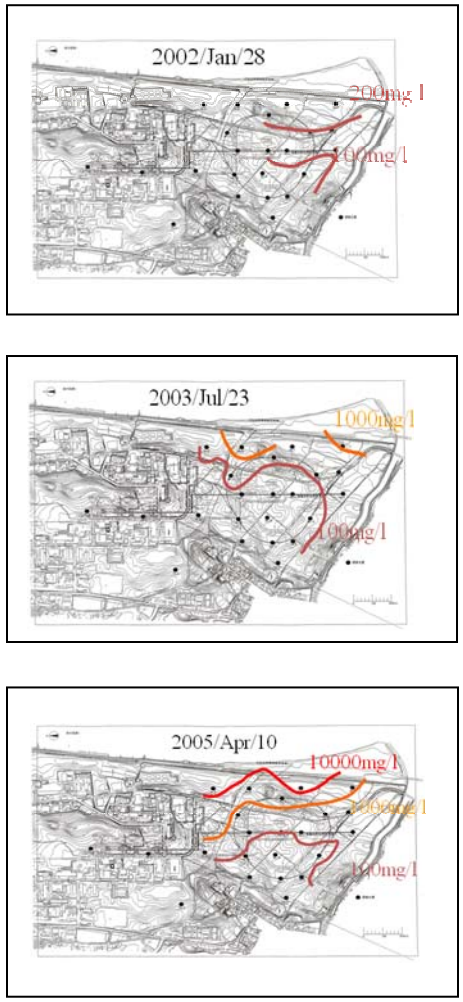

Fig.2 Sea water intrusion was observed by Cl^- concentration and the sequence of observation before the construction is not reported in the previous studies. We made a team of water drainage control for the keep the water environment. The team could control the drainage rate in sometimes (Ito, et al., 2007)

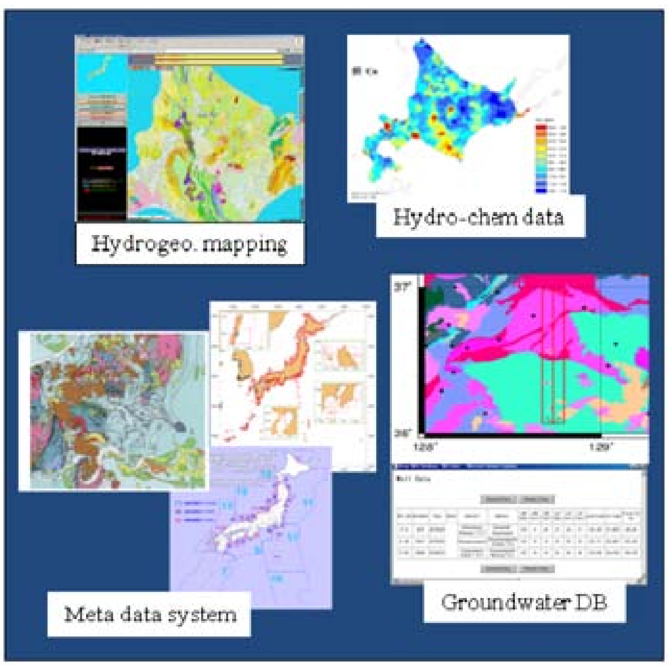

Fig. 3 Groundwater, Hydro- and hydro-relate databases in GSJ, AIST.

1-2. Study for Ground-Coupled Heat Pump System

Promotion of geothermal (ground-coupled) heat-pump systems (see Fig.4) is an invaluable solution to reduce urban heat-island phenomenon in big cities and total CO_2 emission by saving energy and electricity. In winter, the heat energy of warm groundwater is used for heating with a heat pump system of each house. In summer, the groundwater is handled for theair conditioning. The energy in each season is stocked in groundwater, and the usefulness is substantiated in resent studies. For cost-effective system designs, it is essentially important to get subsurface information such as temperature profile, groundwater condition and its flow rate. Our mission is to construct detailed numerical models of groundwater system for major plains in Japan. For this purpose, measurements of temperature profiles in various groundwater observation wells and chemical and isotopic analyses of water samples are conducted. The same study is also carried out in Kamphaeng Phet along the Chao-Phraya River, central Thailand, in collaboration with the Department of Groundwater Resources, Thailand.

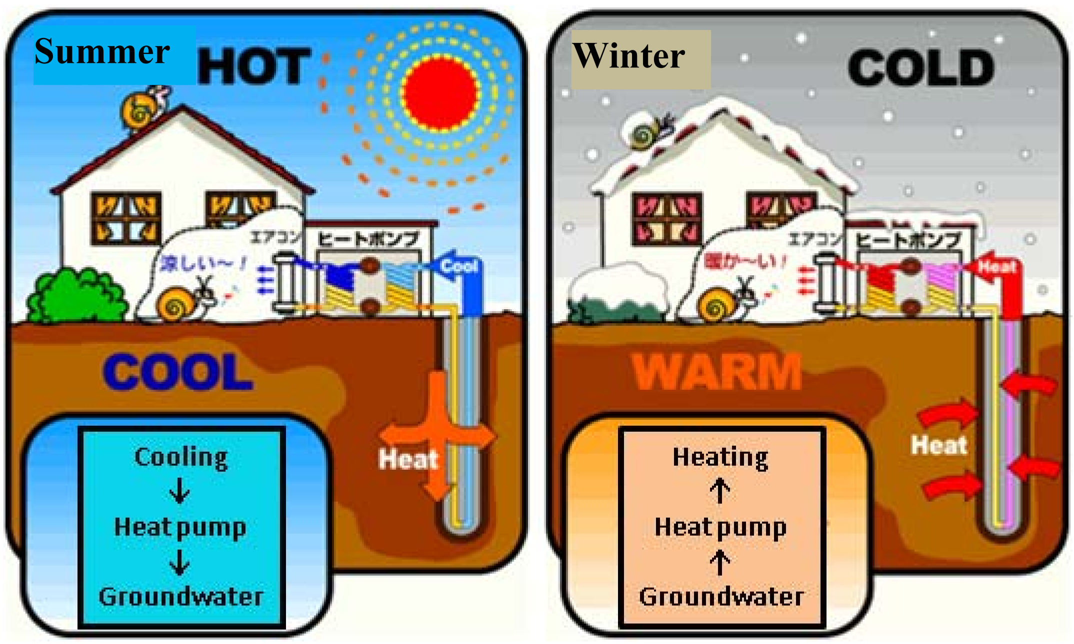

Fig. 4 Ground-coupled heat-pump systems

1-3. Hydro- Environmental Map in Japan

One of main tasks of the Groundwater Research Group is to publish a series of hydro-environmental map. In this map series, we especially attempt to apply multi-tracer technique to analyze regional groundwater flow systems. The technique is based on the data combination of groundwater level, water chemistry, stable isotopes and subsurface ground temperature as tracers.

Although each tracer has both advantages and disadvantages in water flow analysis, application of multiple tracers may compensate disadvantages of each tracer. The water environmental maps are provided in compact electronic media (CD-ROM) with database of groundwater quality and other hydrological and geological information, giving users a hint to solve groundwater problems. Five hydro-environmental maps, entitled “Sendai Plain”, “Akita Plain”, “Kanto Plain”, “Nobi Plain” and “Chikushi Plain” were already published, which will be followed by a map of “Yamagara Basin” and “Ishikari Plain” in 2009. Fig. 5 shows areas of water environmental maps. In Chikushi Plain map, we purposely added some “scientific flavor”, i.e., reference of technical terms, including explanations about principal of stable isotope method, theory of temperature profile method, etc. The map may be useful for not only local governments and residents but also students who study groundwater hydrology.

Fig. 5 Areas covered by Hydro-Environmental Maps (left) and main control window of Sendai Plain Map (right)

2. Outline of Seawater Intrusion in Japan

2-1. History of groundwater use in Japan

Since late 19^{th} century, Japan has been trying to accomplish economic growth, especially, in the field of industry and agriculture. The economic growth has mainly supported by groundwater. As the result of over pumping, groundwater level has gradually decreased and land subsidence has discovered in the main industrial regions such as Tokyo and Osaka. During the World War II, groundwater level has rapidly recovered and land subsidence has temporarily stopped due to decrease of groundwater withdrawal shown in Fig. 6.

After the war, economy of Japan has grown remarkably and groundwater has withdrawn in disorder. The newly constructed factories along the seaside have needed groundwater much and withdrawn it more than recharge. Severe land subsidence and sea water intrusion occurred in almost all the seaside industrial regions in Japan as shown in Fig.7.

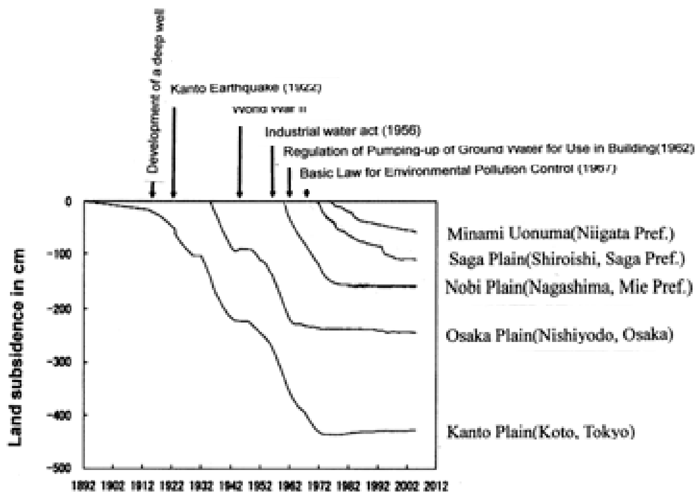

Fig. 6 Land subsidence in Japan*(after Ministry of Environment of Japan, 2005)*

From around 1960's, many local governments located in the industrial regions adopted countermeasure acts such as industrial water act (1962) for heavy groundwater withdrawal. According to the acts, most factories in such a region have changed water supply from groundwater to surface water. In consequence, groundwater level has gradually recovered and land subsidence has stopped along seaside after late 1970's as shown in Fig.6.

2-2. Seawater intrusion in Japan

Japan has already experienced severe seawater intrusion in many industrial regions along the seaside. In this section, some typical examples of sea water intrusion occurred in Japan are described as follows;

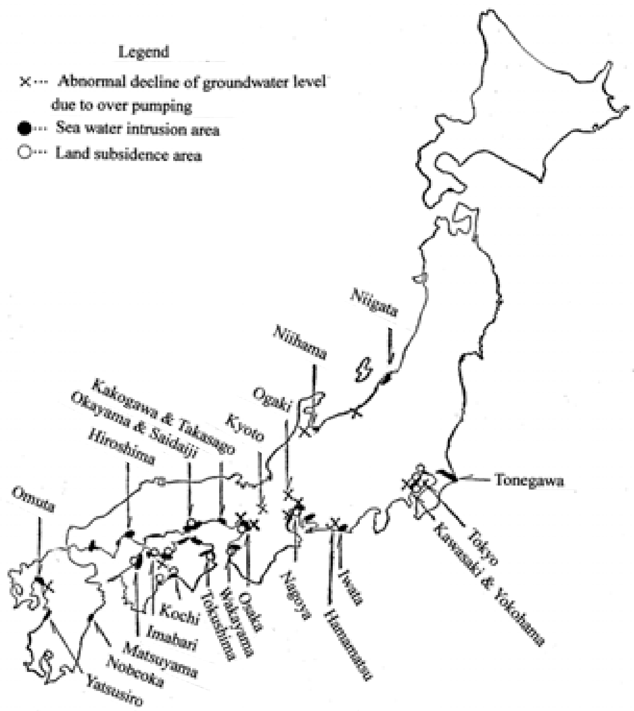

Fig. 7 Groundwater issues in 1960's in Japan*(after Kurata, 1960)*

1) Kawasaki

Kawasaki is located next to Tokyo and is famous for heavy, chemical, and other industries. Almost all the factories needed large amount of water. According to excessive groundwater pumping, groundwater level had quickly declined and groundwater quality was severely polluted by seawater. Nagai and Murashita (1976) investigated groundwater quality in the region and detected sea water intrusion for the 2nd, 3rd, and the deeper aquifers had occurred from the seaside toward the inland. Groundwater quality in the region had gradually shifted to a seawater type on a Piper's diagram. It was clear that groundwater quality is changing from a river water type to seawater one on the line where an old course of the River Tamagawa is buried. The contour lines for 30, 50, 200, 500, 1,000, and 2,000 mg/l of chloride ion concentration in groundwater have advanced from the seaside toward the inland year by year from 1956 to 1975 along the buried river course as shown in Fig. 8.

Fig. 8 Area of Sea Water Intrusion in 1956,1966,and 1975

2) Fuji

Fuji City is located on the foot of Mt. Fuji. There are many paper manufacturing factories, which need a large amount of water, in the city. It is the reason why there are excellent aquifers holding good quality fresh water from Mt. Fuji. The New Fuji volcano ejecta are good aquifers for the factories. As groundwater potential of those aquifers was very high, groundwater had flowed without pumping. Since 1955, groundwater had withdrawn in large quantities. The potential of main aquifers, the New Fuji volcano ejecta, lying around 100 m below the sea level was extremely declined and intruded by seawater. Especially after 1961, the potential of the groundwater always lowered below the sea level and chloride ion concentration of the aquifer had been inclined toward that of the seawater. As shown in Fig.9, the groundwater level is in inverse proportion to the chloride ion concentration.

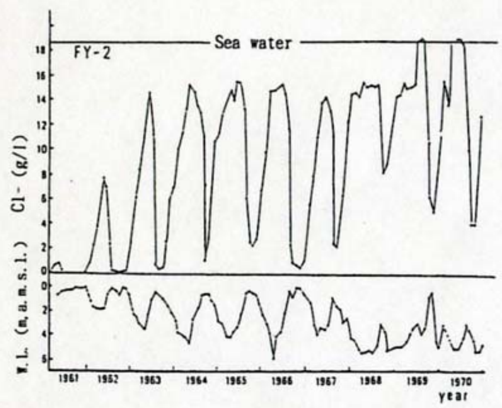

Fig.9 Changes in annual amplitude of Cl concentration and groundwater level in New -Fuji lava aquifer.

3) Osaka

Osaka is the second major industrial region in Japan. According to Tsurumaki (1992), 12,368 m^3 of groundwater was withdrawn in Osaka city. Among them, 10,121 m^3 was for industries (total number 614 wells) and 2,247 m3 was for building (total number 441 wells). About 69 % of total 1,055 deep wells in this area was within 100 m deep from the land surface and was 43 % of total amount of withdrawal in this area. Due to over pumping from the rather shallow wells, seawater could easily intruded to the aquifers and the shallower aquifers were polluted by seawater as shown in Fig.10.

Fig. 11 shows the vertical distribution of chloride ion concentration of the area. It is clear that seawater intrusion directly occurred from the sea or the river mouth of this area.

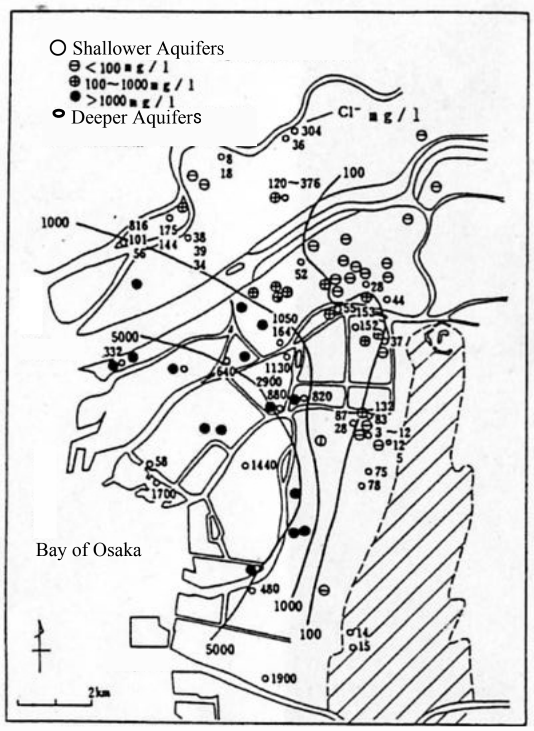

Fig. 10 Distribution of Chloride Ion Concentration for Confined Groundwater in Osaka

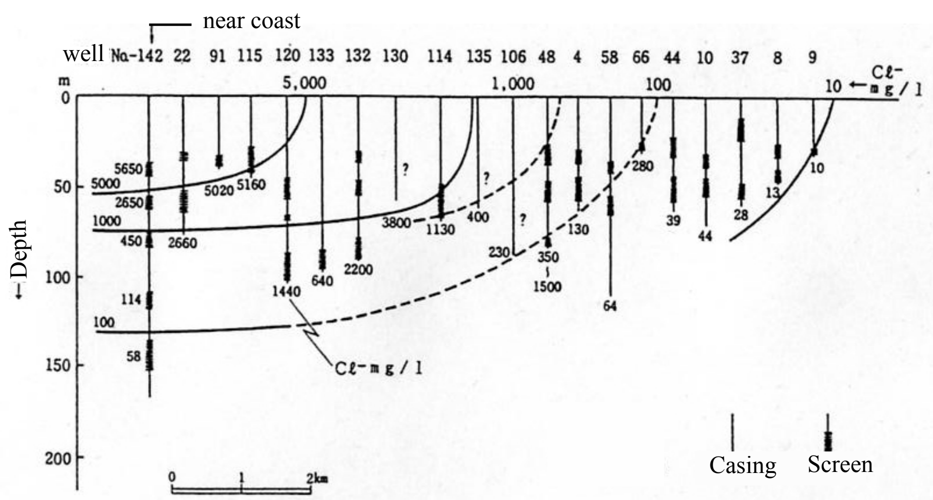

Fig. 11 Vertical Distribution of Chloride Ion Concentration For Confined Groundwater in Osaka

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Groundwater Research in Korea Institute of Geoscience and Mineral Resources
— Assessment of Groundwater Resource Vulnerability According to Climate Change —

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Abstract

Groundwater is one of common key word for 21 century due to climate change. KIGAM has been conducting “Assessment of groundwater resource vulnerability according to climate change” as a basic project in groundwater research. Water budget analyses and contamination assessments have been accomplished, and assessments for both groundwater quality and quantity in a large scale basin have been done. Based on present groundwater uses and predicted climate change, the future status of groundwater resource in the basin shall be estimated. Sea level rise impact on groundwater resource was also investigated through modelling study in Jeju Island. For active groundwater security, recirculation and well injection as artificial groundwater recharge system have been applied to a basin and Jeju Island.

Keywords

Groundwater resource, vulnerability, Climate change, Artificial groundwater recharge

1. Introduction

Due to greenhouse gas emissions most regions of the Earth are expected to experience significant increases in mean annual temperature (i.e. >2 °C) by the end of the present century (IPCC, 2007). As a result of associated warming of the oceans, and their areal expansion via sea-level rise, it is also expected that there will eventually be overall increases in continental precipitation because of greater evaporation from the oceans (Lofgren, 2004), with general increases of 10~20% at latitudes above 45° and within 5° of the Equator but with decreases of 5~20% between latitudes of 5 and 40° (IPCC, 2007). However there is likely to be a lag between increases in air versus ocean temperatures owing to the much greater heat capacity of the oceans. Thus it is also likely that wherever increases in continental precipitation occur, they will lag increases in air temperature. Accordingly it is unclear whether increases in continental precipitation will be great enough to maintain current levels of mean annual runoff. Any decrease in runoff will then threaten surface water supplies and riparian habitats and may also alter fluvial geomorphic processes. Decreases in runoff also imply decreases in soil moisture and thus have adverse implications for agriculture. Accordingly there is great interest in developing methods for predicting the effect of climate change on river discharge (Gardner, 2009). At present, most forecasts for the effect of climate change on runoff are largely based on regionalized global circulation models (GCMs). Depending on the scenario for greenhouse gas emissions assumed for the model, the GCM outputs scenarios for temperature and precipitation, the latter of which is far more uncertain than the former. These uncertainties are then propagated into the distributed or lumped parameter hydrologic model used to predict runoff. The hydrologic model in turn usually requires calibration and validation against historical climatic and discharge data before it can be used to forecast runoff under a particular GCM scenario (Jiang et al., 2007).

Fig.1. shows the influence on groundwater resource by climate change. By global warming, atmospheric temperature in general is expected to be increased. As a result, evaporation and transpiration will also be increased, but extreme cases such as flood and drought are expected to be prospective in Korea. Then, direct runoff shall be increased and groundwater recharge may be decreased in some areas. The decrease of groundwater recharge means the decrease of the groundwater storage in subsurface, and it results in the reduction of the available groundwater resource. Sea level rise will make freshwater storage diminish on the coastal area, and it will make worse in groundwater supplies.

Temperature increases affect vegetation types of dominant species and crop cultivation pattern, and land uses including agricultural areas will be changed. Then, pesticide and chemicals related to agricultural activities may infiltrate into the subsurface and influence groundwater qualities. In those cases, groundwater contamination vulnerability will be augmented. In addition to the natural changes, water demand will rise from any community development, urbanization and population increase, etc.

From these comprehensive influences by climate change, groundwater resources should be needed to be evaluated and assessed for the groundwater development and management according to climate change.

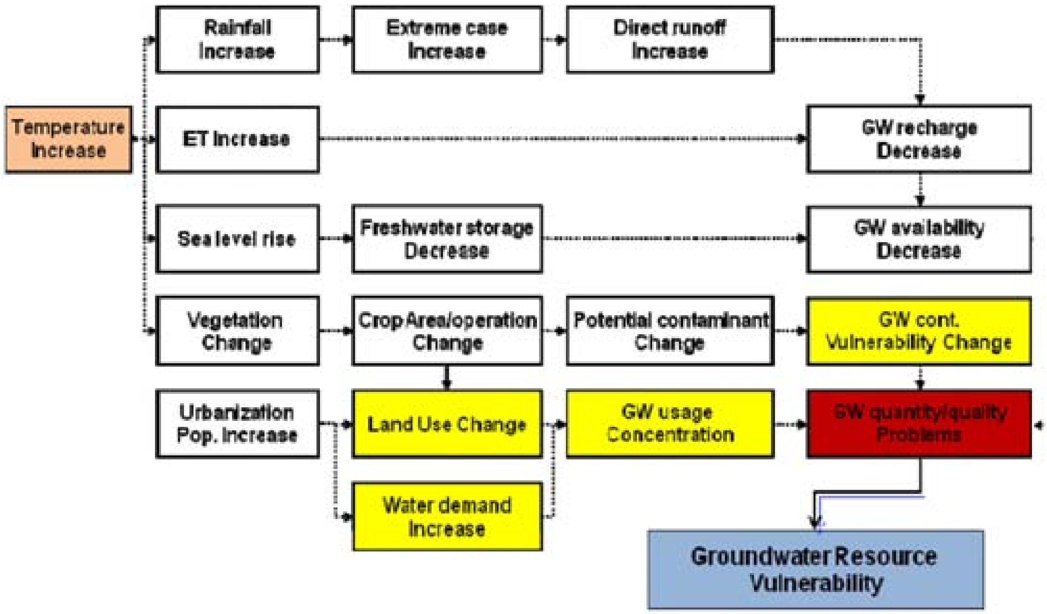

Fig. 1 Influences on groundwater resources by climate change.

2. Assessment of Groundwater resources according to climate change

The KIGAM basic Project for groundwater is composed of the following subjects, which is related to climate change and its influences on groundwater.

- Assessment of Groundwater resources in Kum river basin
  - Water budget analyses (including recharge, base flow etc.)
  - Groundwater productivity, availability and sustainability
  - Groundwater vulnerability to contaminations
- Seawater level rise with climate change
  - Groundwater availability change in Jeju island

2.1. Study areas

There are 4 largest river in Korea, which are Han river, Nakdong river, Kum river, and Youngsan river. For the assessment of groundwater resource vulnerability about both quality and quantity, Kum river basin was selected, which is located in the middle part of the Korean peninsula (Fig. 2). There are 2 big reservoirs in the basin, which are Daecheong dam and Yongdam dam. They are used as water supply sources for drinking water and agricultural irrigation. 18 sub-basins were classified for the groundwater budget analyses

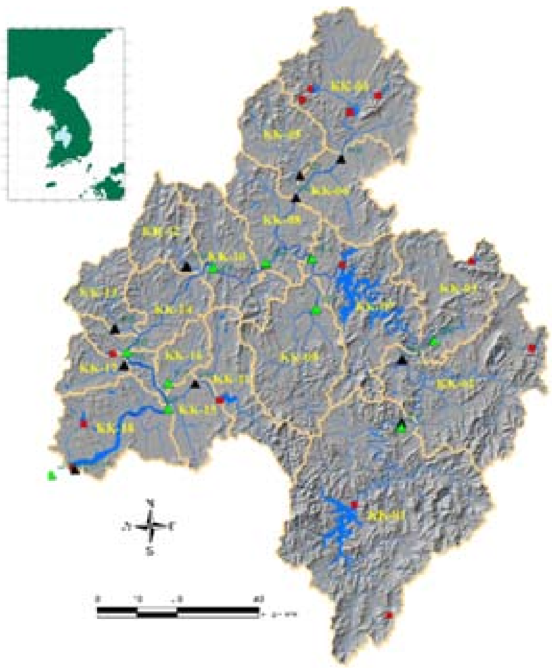

Fig. 2. Location map of Kum river basin and sub-basins.

The other study area is Jeju island, which is 73km wide and 41km long with a total area of 1,848 km^2, the largest island in South Korea.

2.2. Results

2.2.1. Kum river basin

2.2.1.1. Groundwater level variations

Trend analyses for groundwater level data of National Groundwater Monitoring Network (about 10 years) were conducted. From the analyses, 50% of the total groundwater monitoring wells are decreasing, 35% are increasing, and 15% are constant. The average groundwater decrease rate is 1.5 mm/yr. The analysis method is linear regression as the following equation.

$h_t = \beta_0 + \beta_1 t + \varepsilon_t$ (linear regression)

Groundwater levels may change with pumping, and the groundwater level variation increases. It decreases more in the low rainfall season than in normal times. Since rainfall fluctuations are so severe spatially and seasonally, it is highly possible that groundwater resource vulnerability may be deepened.

2.2.1.2. Evapotranspiration evaluation

MM5(meso-scale meteorological model) modeling with remote sensing data from MODIS were analyzed and evapotranspiration map of 250m×250m, 1day resolution for Kum river basin were made out. Ko-flux tower of eddy covariance system in Kwangneung and Haenam area were used to calibrate evapotranspiration map, and the reliability were secured through the comparison between the calculated and monitoring data.

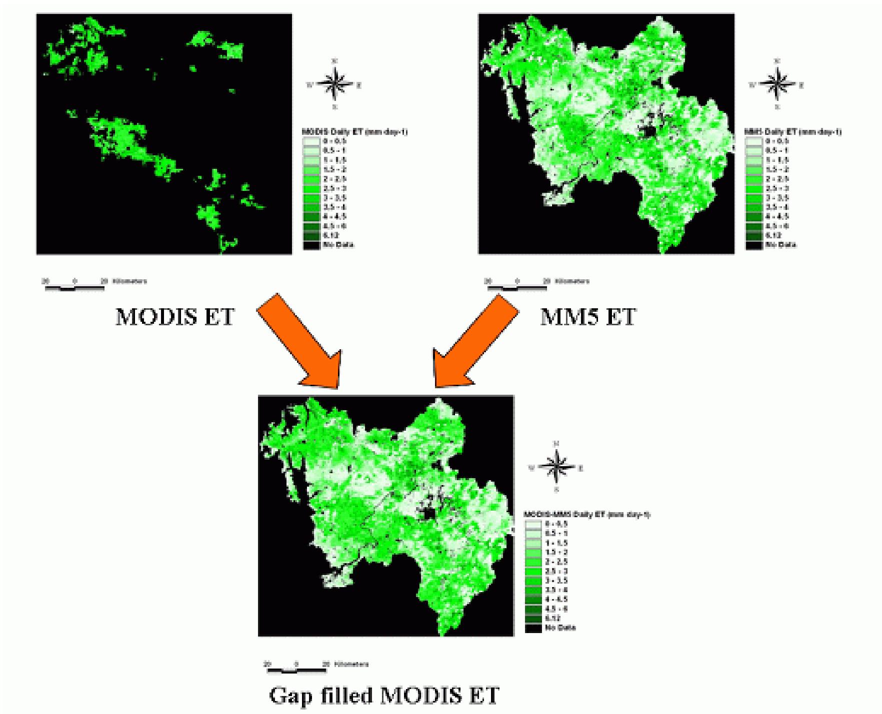

Fig. 3. Gap filling of MODIS evapotranspiration map using MM5 evapotranspiration map.

2.2.1.3. River discharge measurement for base flow estimation

Groundwater recharge need to be evaluated for water budget in a basin, and base flow method was applied to estimate groundwater recharge in this study. At 17 national river monitoring points, ADCP(Acoustic Doppler Current Profiler) and velocity-area method for discharge measurement were applied in low flow season in April, 2009.

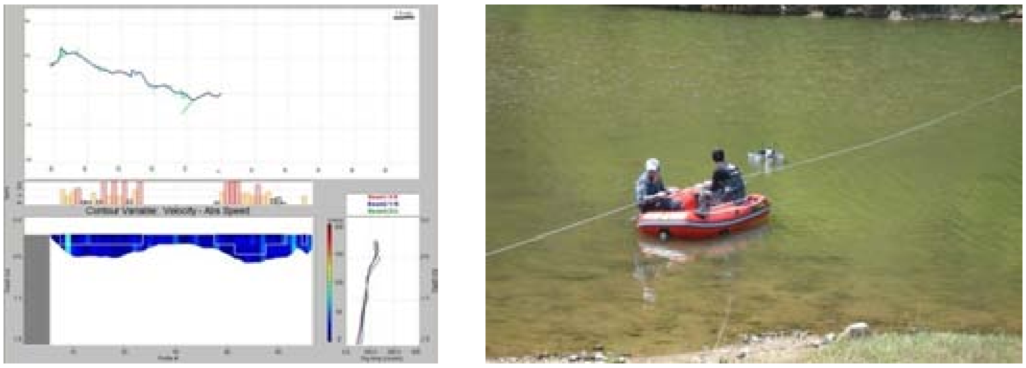

Fig. 4. River discharge measurement for base flow estimation, ADCP method for measurement was used.

2.2.1.4. Groundwater productivity

The developed well data from National Groundwater Information system (http://www.gims.go.kr) were collected and analyzed for well discharge capacity, which shows groundwater productivity in the basin and groundwater use status.

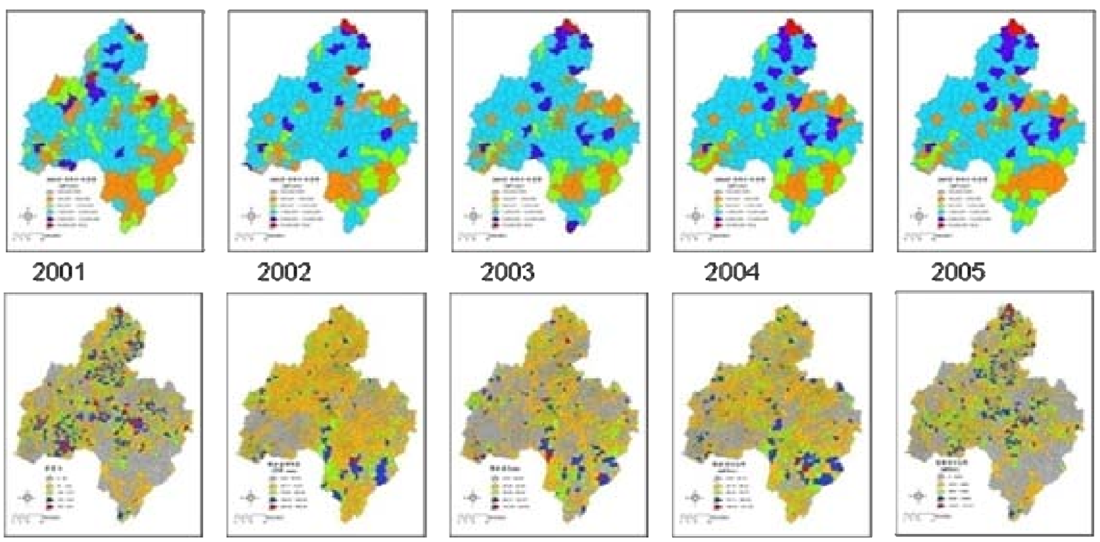

Fig.5. Total well productivity and well status from 2001 to 2005 in the Kum basin.

2.2.1.5. Lineament and its relation to well productivity

Well productivities were compared with regional geologic structures, lineament and faults. In the northern part of the basin, high well productivities had good relationship with the lineament distributions. In some fault areas, deep wells had high productivities, but they do not always show agreements with each other.

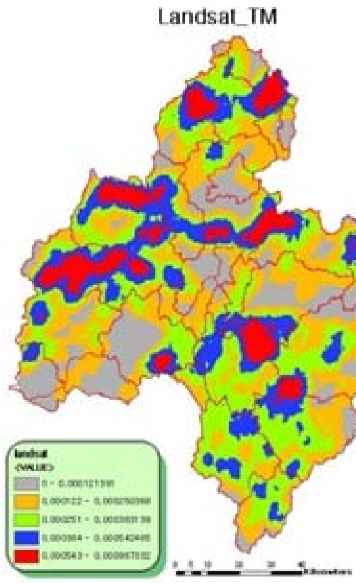

Fig.6. Lineament density map of the Kum river basin.

2.2.1.6. Groundwater quality

About 1,000 groundwater samples were collected and analyzed for understanding and assessing groundwater quality in the basin. NO3-N, Na, an Cl concentrations were highly correlated with land use, and F, SO4 concentrations reflected geological features.

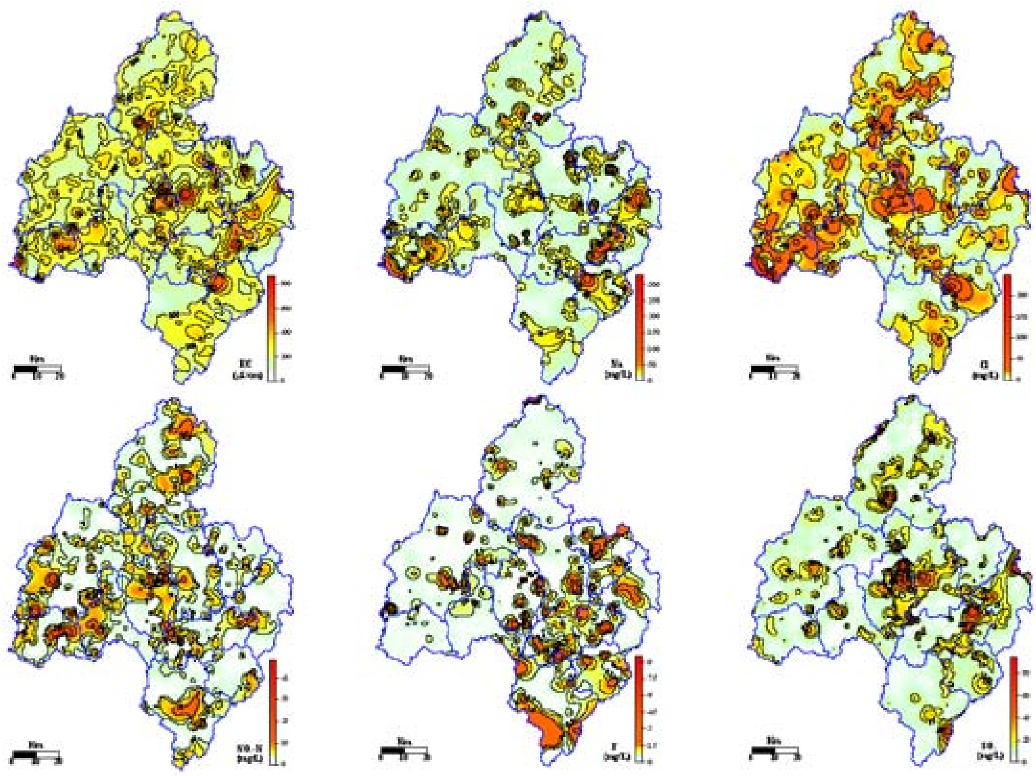

Fig.7. Groundwater quality in the Kum river basin.

2.2.1.7. Groundwater contamination vulnerability

Hydrogeological factors influencing groundwater contamination were considered, and each factor has its index value. The total index rating shows the groundwater contamination vulnerability. The factors are Depth to water, net Recharge, Aquifer Media, Soil Media, Topography, Impact of vadose zone media, hydraulic Conductivity of the aquifer), and it is called as DRASTIC method.

$$\text{DRASTIC index} = r_D Dw + r_R Rw + r_A Aw + r_S Sw + r_T Tw + r_I Iw + r_C Cw$$

r_a is index value, and w is weighting value of each factor.

Groundwater level distributions were drawn from Kriging analysis from groundwater level measurements, and net groundwater recharge was estimated through SCS-CN method. Aquifer media, vadose zone media, and hydraulic conductivity data were drawn from geological map. Soil media data were classified on the basis of the soil map provided by NAAS (National Academy of Agricultural Science). Topography data were made using digital elevation model. Generally, groundwater contamination vulnerability is high in the areas of alluvial and limestone.

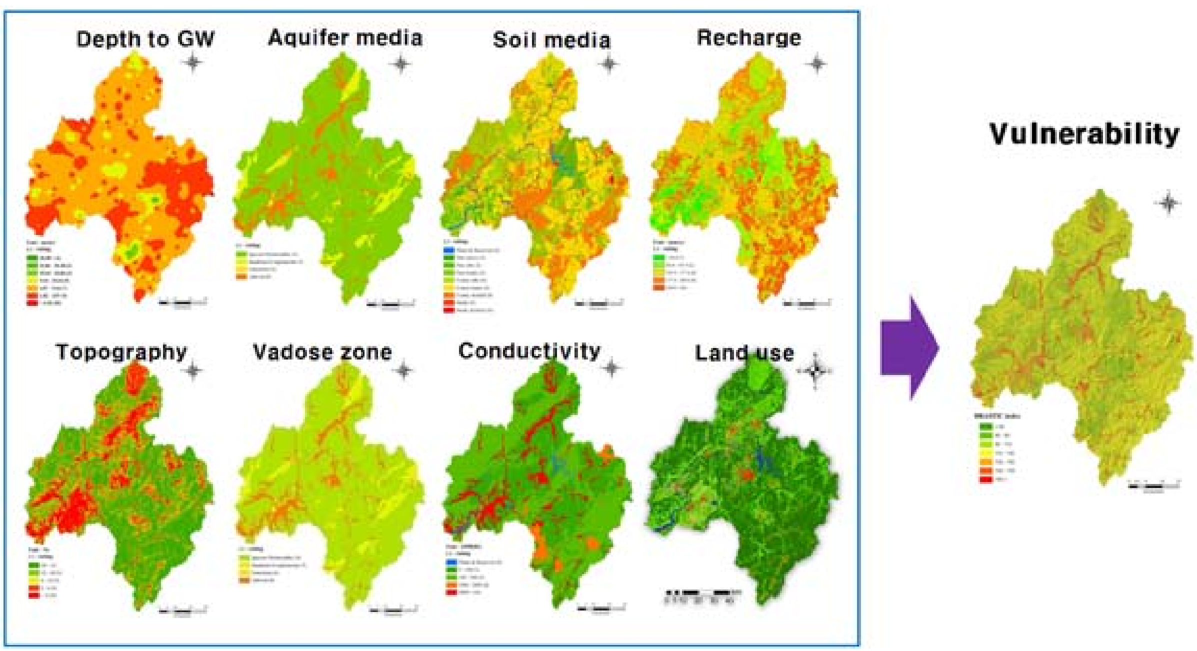

Fig.8. Groundwater contamination vulnerability map.

2.2.2. Jeju Island

Jeju Island is a volcanic one located about 140 km south of the Korean peninsula (Fig. 9). It is one of the most heavily raining areas in Korea. The average annual rainfall on the island is 1,975 mm, compared to 1,283 mm for the Korean mainland. But, waters on the island are occurring mostly beneath the ground. The geology of Jeju Island is composed predominantly of permeable basalts into which rain and stream waters easily percolate and accumulate while moving slowly towards accessible and exploitable aquifers. Only a portion of the water can be obtained from springs and streams found along the coast. Therefore, most of the water will have to be pumped from the ground through drilled wells, collection galleries and other types of excavations. The successful exploitation and management of groundwater resources on the island is essentially dependent on understanding the groundwater occurrence and its movement dynamics.

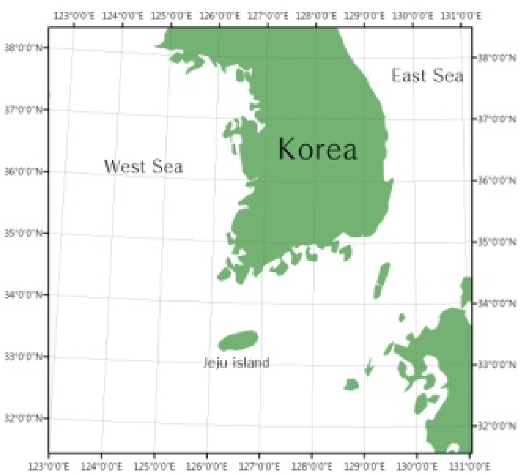

Fig.9. Location map of Jeju Island

2.2.2.1. land use change and runoff

Land use changes were analyzed from LANDSAT, remote sensing data from 1975 to 2000 for Jeju Island. Fig 10 shows the parts of the results. The areas of urbanization and agricultural land increased, but forest area decreased. Since less permeable areas extended, the infiltration capacity decreased and runoff increased. The estimation for runoff was conducted through SCS-CN method. The increase of runoff may bring about the reduction of groundwater resources from recharge amount decrease.

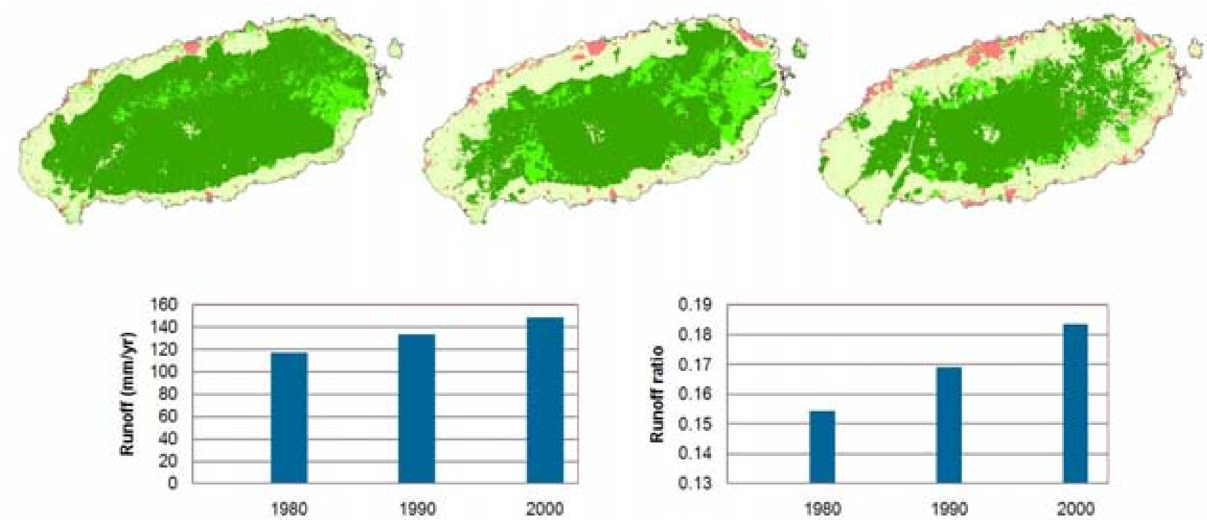

Fig.10. Land use change and runoff

2.2.2.2. Seawater intrusion with climate change

7 wells in Jeju island were monitored at various depth for the groundwater resources assessment near shore and seawater level rise impacts by climate change. Electrical conductivity and temperature including groundwater level have been monitored.

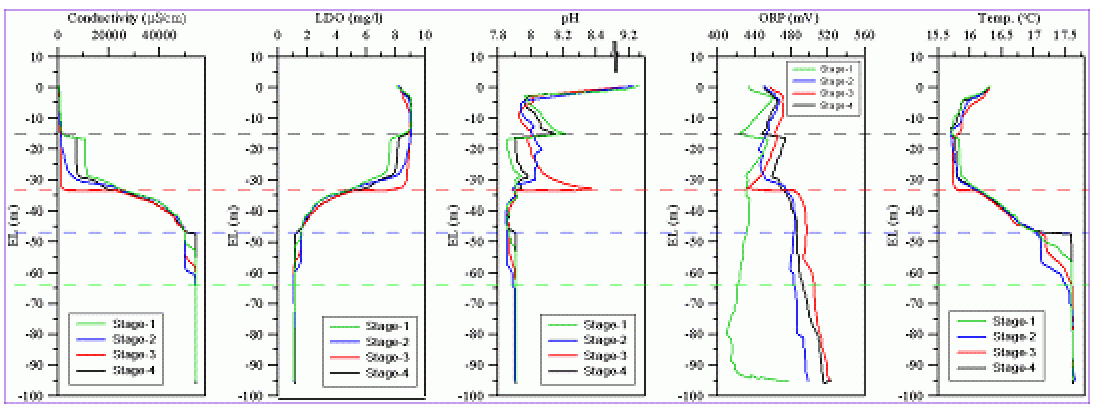

Fig.11. Groundwater quality monitoring with depth near shore

2.2.2.3. Modeling Sea level rise to groundwater

There are so many kind of permeable layers in Jeju Island, which are scoria, lava tube, clinkers, and fractured basalt and trachyte. Thus, the hydrogeology of Jeju island is so heterogeneous and the groundwater flow modelling should be conducted considering these heterogeneous conditions. By conceptual modelling, freshwater interface moving inland by sea level rise and permeable layers play a role to accelerate the seawater intrusions.

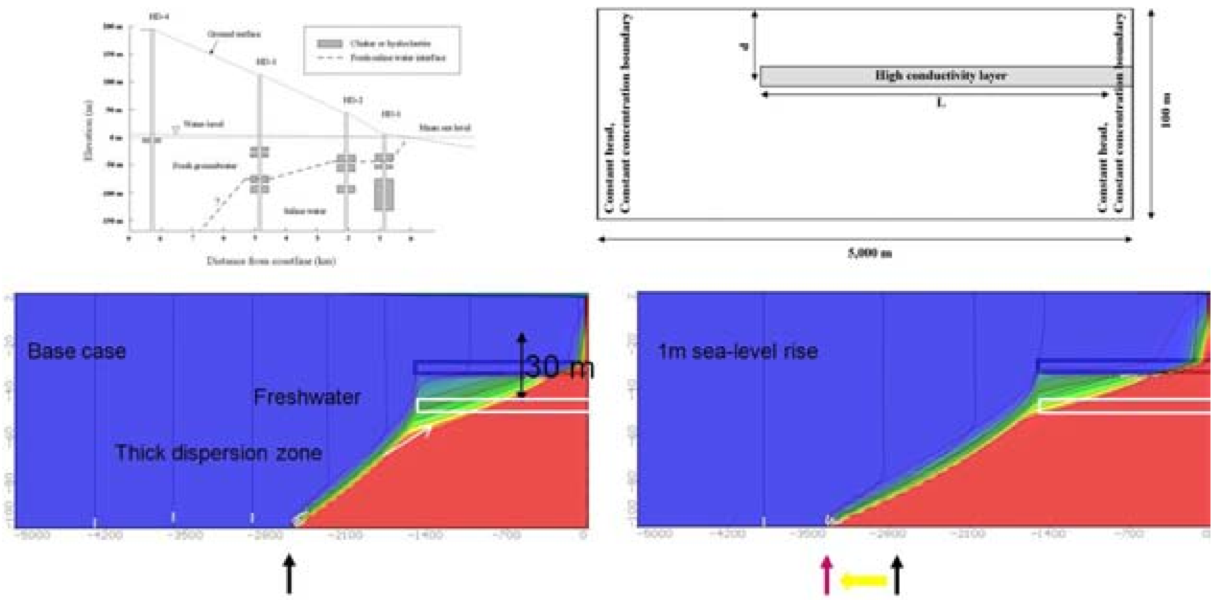

Fig.12. Modelling for sea level rise impacts on groundwater in Jeju island.

2.2.3.Artificial Groundwater recharge

KIGAM is trying to develop two types of artificial groundwater recharge system. In Kum river basin, there are lots of green houses for crop cultivations, and water demand during crop growing seasons is very high. Groundwater pumping during the season may make groundwater level lowering and induce water shortage. Recirculation system was developed to solve the problem (Fig. 13).

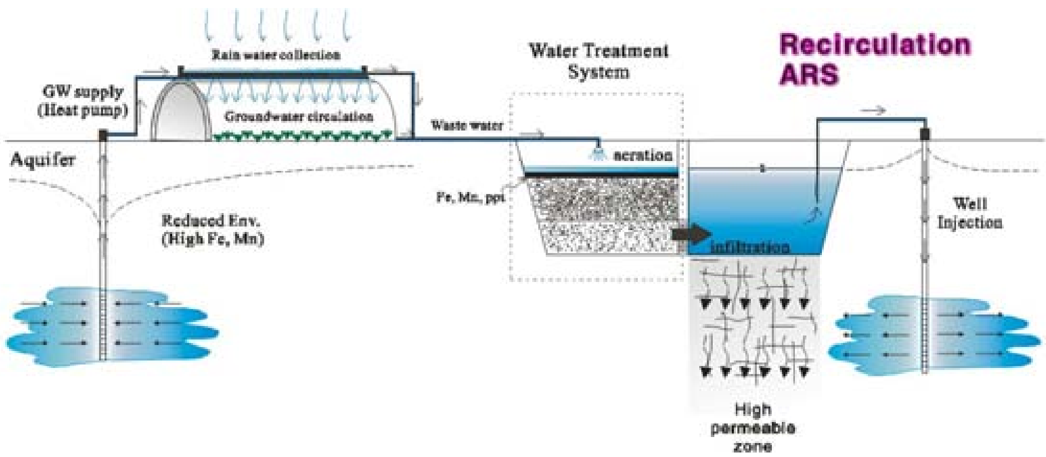

Fig.13. Artificial recharge using recirculation system.

Jeju-friendly aquifer recharge technology (J-ART) is a technology for securing sustainable water resources by capturing ephemeral stream water with no interference in the environment such as natural recharge or eco-system, recharging it through designed borehole after appropriate treatment, and then making it to be used at down-gradient production wells (Fig. 14). Precipitation pattern in this area is shifting to more sparsely-distributed and heavier rain type in summer season which reduces infiltration and/or groundwater recharge but increases runoff and flash flood on stream. Stream water as a source is available only a few times a year because the stream bed is highly feasible to be percolated.

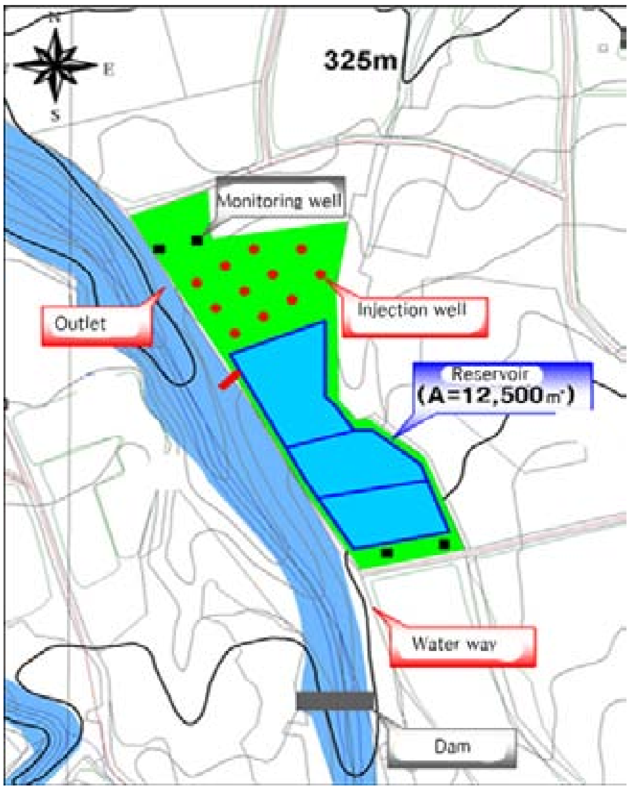

Fig.14. Artificial recharge using reservoir and injection wells

3. Other researches

3.1. Hydrogeological Mapping

Groundwater Law in Korea provides the clause which government should carry out comprehensive groundwater investigation on each district in order to get the information of actual conditions of groundwater exploitation, use, water quality, and manage groundwater efficiently. KIGAM (Korea Institute of Geoscience and Mineral Resouces) as a official institute for the project accomplished investigations on Dangjin and Naju areas in 2008. As a large number of hydrogeological data are collected and analyzed on each district, they can provide fundamental DB(database) for other groundwater research projects and be used for strategy establishments of proper development, protection, and conservation of groundwater by national and provincial governments.

3.2. Heat Pump system

KIGAM constructed a research building equipped with air-conditioning and heating system using heat pump. Borehole heat exchanger from 28 boreholes was installed and each borehole depth is 200m, and the interval is 7 meter. Various geophysical method and temperature logging were applied to evaluate the aquifer and geothermal systems, and groundwater modelling and monitoring works have been done.

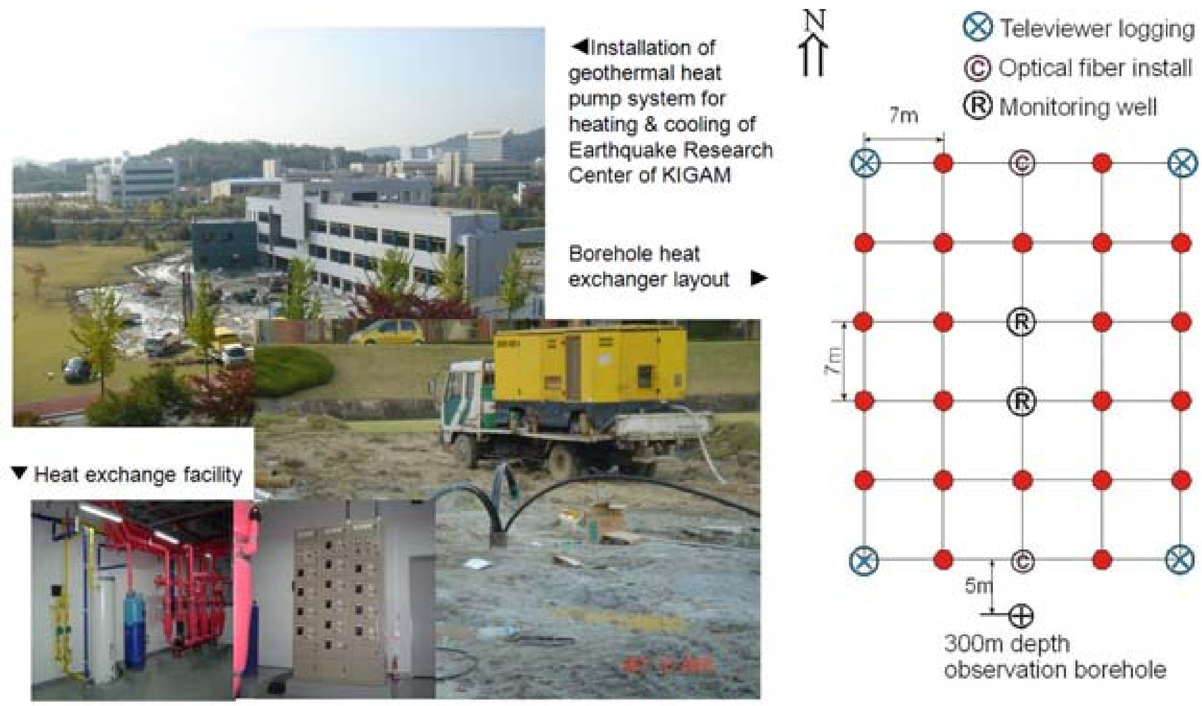

Fig.15. Heat pump system in KIGAM

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Groundwater Resources Management in the Philippines: Issues and Concern

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Abstract: Groundwater is one of the most important natural resources available for man but it is a finite resource that can become depleted in time especially if not properly managed and protected. In order for future generation resource user to benefit from it, there should be an established sustainable management in place under the present dispensation The water sector in the Philippines is managed by different water related agencies that are responsible for certain aspects of water resources development and this in a sense makes the task of water management intricate. Data and information on the Philippine water sector as well as the issues and concern arising from water governance are presented. Addressing these problems is a common task that is being given priority and taken seriously particularly the authorities working in the field of geosciences who utilizes scientific approach to find solutions to existing concern of salt water intrusion, groundwater level decline/depletion, groundwater pollution, and subsidence.

Keywords: Water governance, Groundwater management, Hydrologic unit, Groundwater resource, Water demand

1. Introduction

Recognizing the importance of groundwater as indispensible resource, its management is initiated to ensure its sustainability and protection. As far back as the 1950's management of the water sector in the Philippines has commenced and has slowly evolved to adapt to changing times as with changing climatic and environmental conditions. The twelve (12) water resources regions (WRR) which coincides with the major river basins or watershed were adapted as water resources management unit given the fact that river basins are established topographical and hydrologic unit that can be taken as guide to organize water resources management in a holistic approach and manner. Institutional arrangement were put in place where water related agencies in the Philippines operate within their own sectoral field of responsibility, and with the National Water Resources Board (NWRB) as an authoritative organization to coordinate and integrate all activities in water resources development and management towards an Integrated Water Resources Management (IWRM)

2. Philippine Groundwater Resources Facts and Figures.

Available water resources based on the water capacity of geologic formations were calculated per water resources region (WRR). Further, demand based on water utilization was likewise determined and projected such that water supply is presented vis-a-vis water use so that an overview of water excesses and/or deficiency per basin would become apparent. (Table 1)

Table 1 Groundwater Availability (in MCM)

Source: 1998, NWRB and JICA, Master Plan Study on Water Resources Management in the Republic of the Philippines

WRR	Groundwater Potential	Surface water Potential	Total Water Resources	Water Demand (2025)	Water Balance (2025)
1. Ilocos	2,072	3,250	5,322	4,427	895
2 .Cagayan Valley	3,592	8,510	12,103	12,429	-327
3 Central Luzon	2,592	7,890	10,482	21,328	-1,084
4 Southern Tagalog	4,068	6,370	10,438	21,835	-11,397
5 Bicol	2,065	3,060	5,125	4,638	487
6 Western Visayas	2,525	14,200	16,725	12,135	4,590
7 Central Visayas	1,111	2,060	3,171	3,405	-234
8 Eastern Visayas	2,856	9,350	12,206	2,953	9,253
9 Western Mindanao	1,827	12,100	13,927	2,944	10,983
10 Northern Mindanao	2,766	29,000	31,766	3,980	27,786
11 Southeastern Mindanao	3,293	11,300	14,593	4,362	10,231
12 Southern Mindanao	2,787	18,700	21,486	11,847	9,640
Total	31,554	125,790	157,344	106,283	51,061

2.1 Groundwater Storage

Over 50% of the rock formations in the Philippines are without significant primary interconnected porosity so that groundwater prospects are restricted to sufficiently leached and/or fractured zones. To a limited extent, groundwater in these formations is used fro small scale irrigation, domestic and stock use with yields of less than 0.01 lps to 1.5 lps. Most of dry season base low comes from the forested watershed of these formations.

About 30 % of the Philippine land area is underlain by unconsolidated and loosely consolidated river and coastal deposits and semi-consolidated Pleistocene marine sedimentary and terrestial pyroclastic formations. The unconfined alluvial aquifers supporting rice paddies are usually saturated to near surface after the first rains of 0.4 to over 1 meter, depending on the specific yield, which varies from about 5 to 20 %. The higher elevated sandstone, conglomerates, shale and pyroclastics require more water and as long as three to five months to attain optimum saturation, due largely to a thicker unsaturated zone and therefore greater moisture requirement. Specific yield is from less than 3 to close to 10 %.

Less than 8% is occupied by limestone deposits characterized by sinkholes-solution channelway groundwater systems that annually discharge over one million cubic meters of groundwater through spring outlets. These aquifers are not sufficiently tested except in Baguio, Cebu and Tagbilaran cities where test yields of about 30 to 120 lps are reported in several 150 m deepwells. Spring discharge is from less than 1 to 1,000 lps during the dry season.

2.2 Groundwater Use and Water Demand

Water demand for both surface water and groundwater is 310 MCM /day. Eighty Six percent (86%) of the total water demand is for agricultural use covering about 1.9 Million hectares of agricultural land. Over 70,000 hectares of riceland are irrigated by pumpwells using shallow water. Over 1000,000 hectares of sugarcane lands are similarly irrigated. On the other hand, eight percent (8%) of the total water demand is for industrial use. Manufacturing industry may have over 820,000m3/day capacity derived from groundwater sources. The remaining six percent (6%) of the total demand is devoted for combined domestic/municipal and commercial use. Other uses of both groundwater and surface water includes livestock, recreation, fishery, and hydropower (Table 2)

Table 2 Water Demand in the Philippines (in MCM)

Source: 1998, NWRB and JICA, Master Plan Study on Water Resources Management in the Republic of the Philippines

Water Demand	1996	2025		% of Total (1996)
		Low	High	
Municipalities	2187	7430	8573	7.30
Industrial	2234	3310	4997	7.46
Agriculture	25533	49860	72973	85.24
Irrigation	18466	38837	59741	61.64
Livestock	107	217	433	0.36
Fisheries	10806	10806	12799	23.24
Total Demand	29944	60600	85400	100

3. Groundwater Management.

The task to manage water resources was institutionalized through the passage of policies and laws that covers the creation of office/agencies where mandates and responsibilities are stipulated and delineated.

3.1 Policies and regulating Laws

A number of water governing policies and laws were passed and promulgated as guide to water management. A couple of these are presented and are considered as the major ones. The details, salient points, and coverage of which are herein included

3.1.1 Presidential Decree No. 1067 (Water Code of the Philippines of 1978)

The decree revises and consolidates the laws governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources .The decree gave the National Water Resources Board (NWRB) power to control and regulate the utilization, exploitation, development, conservation and protection of all water resources of the country, and therefore it is in charged with the responsibility of assessing water resources specially on the quality and available quantity for allocation to users – the water permit applicants

3.1.2 Republic Act No.9725.

The act is known as the Philippine Clean Water Act of 2004. It reiterates that the State shall pursue a policy of economic growth in a manner consistent with the protection, preservation and revival of the quality of our fresh, brackish and marine waters. To achieve this end, the framework of sustainable development shall be pursued. The coverage of this Act shall apply to water quality management in all water bodies. One of the salient points is the mandate to conduct groundwater vulnerability assessment assigned to NWRB and the Mines and Geosciences Bureau (MGB) -DENR to produce a tool in designating certain areas as water quality management areas using appropriate physiographic units such as watersheds, river basins or water resource regions.

3.2 Water Management Institutional Arrangement.

To understand water governance involving different institutions, it is imperative to understand the major components of the water sector in the Philippines and the corresponding and responsible water related agencies

3.2.1. Water Resource Planning.

The development and management of the country's water resources depends, to a large extent, on an orderly and systematic planning that requires direction The National Economic Development Authority (NEDA) plans, approves, and incorporates all sectoral projects including the water sector into the medium to long term development plans of the country.

3.2.2 Water Resources Allocation.

It pertains to the coordination and regulation of water-related activities and the formulation and development of policies in water resources management. This is one of the mandates of the National Water Resources Board (NWRB)

3.2.3 Water Resource Assessment

Water resources assessment relies mainly on water data collected and evaluation of ground and surface water resources. The Mines and Geosciences Bureau (MGB) under the Department of Environment and Natural Resources (DENR) is conducting groundwater resources assessment on a continuing basis. Likewise, the Local Water Utilities Administration (LWUA), being a technical and financing agency responsible to assist local water districts, conducts feasibility study that includes water resource assessment to guide in the evaluation and approval of prospective projects of beneficiaries

3.2.4 Water Use Regulation

Water permits are issued for each specific site and purpose of water resource extraction. These water permits are issued in accordance with the rules and regulations prescribed under the Water Code of the Philippines. NWRB is the responsible agency for this component.

3.2.5 Water Quality and Sanitation

This includes monitoring of surface water and is done regionally. It involves gathering of water quality data principally to classify surface water bodies for different types of beneficial use. Monitoring of drinking water is a basic activity. The Department of Health (DOH) monitors water quality (particularly for possible presence of bacteriological component) of exiting private and public wells to keep the community informed of the quality of local aquifers. The Environmental Management Bureau (EMB) under DENR, on the other hand, conducts analysis of water quality of both surface and groundwater to monitor effects of effluents from industries on water quality, particularly river systems. Further, municipal and provincial government under the jurisdiction of the Department of Interior and Local (DILG) likewise undertakes sanitary inspection and monitoring of quality of water supply by sampling public and private wells, also to keep the local people informed of the quality of local water source.

3.2.6 Tariff Regulation of Water

The imposition and collection of reasonable fees or charges for water resources development from water appropriations is being implemented by NWRB.

3.2.7 Watershed Management

This is the formulation and recommendation of policies and programs to effectively nurture, protect, develop, manage and conserve forestlands and watershed. The Forest Management Bureau (under DENR) protects existing forest reserves using the watershed management approach, while the River Basin Control Office (RBCO, also under DENR) includes one of its mandates protection of water resources under the river basin system, taking into account that groundwater management should encompass basin wide issues and initiatives because water cycles from the air to the river basin before it reaches the groundwater table. Department of Agriculture (DA) also utilizes the watershed approach as strategy to protect and manage agricultural lands.

3.3 Public Water Supply Distribution and Management

Focusing on public and domestic water supply, the distribution and management covering the Greater Metro Manila Area (with 17 cities and a population of roughly 10 Million) is being handled by Manila Water Sewerage System (MWSS) - a government institution with two (2) domestic and foreign private investors/concessinaires under its supervision and jurisdiction.

On the other hand, the distribution and management of water supply in areas outside Metro Manila becomes the responsility of established water service providers. The Water Districts (WD), for example, most of which were established through the technical and financial assistance of LWUA, caters particularly the water demand/requirement of urban cities. For towns or municipality, the local government establish and operate their own municipal water supply office to focus on the distribution of domestic water supply for the local population. The smallest unit of government known as barangay (also covered by municipality) are sometimes inaccessible, and therefore water distribution pipes become limited only to areas that can be easily reached. In such cases rural water supply office is being put up by the local municipal government to complement the water need of unreached barangays, utilizing, developing and establishing small impounding project from springs as water source. Lastly, the water requirements for special economic zones (e.g. Subic Base Management Authority and Clark Airbase – the two (2) former US bases now turned economic zones hosting business manufacturing and industrial establishment) are met by private water concessionaires.

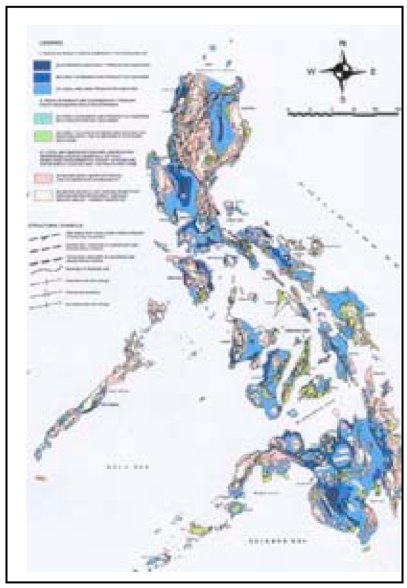
4. Projects and Programs On Water Resources

As far back as the period of approval and passage of water laws and creation of water related agencies, major and special projects were initiated and were since then carried out in a continuing basis. Particularly for groundwater, the MGB and NWRB under the DENR, have embarked on projects on a national scale to produce technical documents and outputs that are utilized as management tool to guide authorities and decision makers in the management of available groundwater resources. Following are the major ones.

4.1 Groundwater Resources of the Philippines (1970-1980)

The Mines and Geosciences Bureau is mandated to conduct field mapping to evaluate groundwater resources in the various rock units in the country. Geological and hydrogeological data gathered by the earliest geoscientists at MGB beginning in the late 1950's were collated and incorporated and produced the map, Groundwater Availability Map of the Philippines (Fig. 1)

Dark Blue areas are extensive and productive aquifers with high permeability. Highly productive aquifers have average potential recharge of 0.5 to 1 meter with known production well yields mostly between 50 to 100 lps but as high as 150 lps in some sites. Fairly productive aquifers have an average potential re-charge of 0.3 to 0.8 meters with known production well yields between 20 but as high as high as 60 lps in some sites.



Light Blue areas are local and less productive aquifers with very low to moderate permeability. Well yields mostly about 2 lps but as high as 20 lps in some sites

Green Areas are fairly to less extensive aquifers in which flow is dominantly through fractures and/or solution openings. Potential recharge varies from low to high

Pink Areas are regions underlain by impermeable rocks generally without significant groundwater except in residuum, sufficiently leached and/or fractured zone

Fig.1 Groundwater Availability Map

4.2 Rapid Assessment Studies

The National Water Resources Board in 1982 has embarked on a project to roughly assess the country's groundwater resources at the provincial and municipal levels to provide a comprehensive and workable guide for water supply planners/ designers and local officials in setting development priorities for water supply projects in rural communities. With this project, areas were mapped on a regional scale and were delineated wether they are potential areas of high yielding well, shallow well areas, deep well areas, difficult areas,or areas with salt water intrusion..

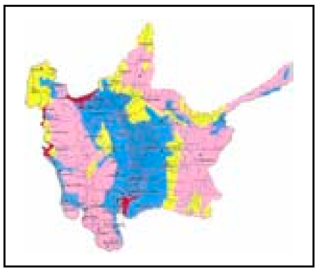
Yellow - Deep well areas

Dark Blue - Areas of high yielding well

Light Blue - Shallow and deep well areas

Pink - Difficult areas

Maroon - Areas with salt water intrusion



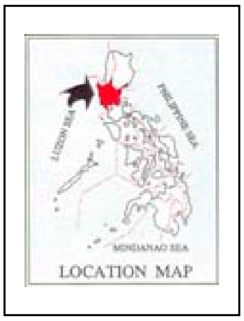


Fig. 2 Rapid Groundwater Assessment Map of Central Luzon

4.3 National Water Data Collection Network (NWDCN)

This project was spearheaded by the National Water Rsources Baoard and participated by the Mines and Geosciences Bureau (for groundwater), Environment Management Bureau (for water Quality) and the Bureau of Research and Standards (BRS) under the Department of Public Works and Highways (DPWH) for surface water. The study is basically for groundwater, surface water, and water quality database designed for purposes of water resource planning. It includes 1) policy guidelines for data collection 2) design of data base and analysis, and 3) evaluation of water availability

4.4 National Water Information Network (NWIN)

The NWIN is an off shoot of the NWDCN. It is a project that created a computer-based system that links databases of water resources by all the collecting agencies. It provide easy access to users and data generating agencies. It includes streamflow data, water quality data, groundwater data, rainfall data, rivers, water permitees, project programs, and publications. The computer input of all data and information on water resources collected from the participating agencies can be accessed through the website: www.nwin.nwrb.gov.ph

5. Groundwater Related Problems, Issues and Concern.

Iissues and problems arises due to a number of contributing factors. Notably, existing issues on groundwater is related, for example, to population growth and urbanization.

5.1 Saltwater intrusion due to excessive groundwater abstraction

Areas closer to the sea are the first to be affected by the landward movement of seawater flowing into areas of reduced aquifer pressure due to excessive groundwater withdrawals. Wells previously pumping freshwater would experience to pump brackish groundwater progressively until the quality (EC>150 microsiemens/cm) exceeds the desireable limit for drinking water. Cases of salt water intrusion were recorded in the coastal areas of the Philippines, one area of which is the City of Cebu, central Philippines where limestone formation in coastal area acting as aquifers becomes vulnerable to be encroached with sea water during excessive pumping and in the rainy season due to its relatively high permeability.

5.2 Groundwater table decline due to groundwater overabstraction

Groundwater level decline is a commonplace in areas where demand for groundwater is high. Urban areas are the first to be affected by this problems due to the increasing demand for water to cope with the pace of development. Metro Manila, for example, has experienced this as documented in several groundwater level measurement survey conducted several years apart. The Piezometric level configuration in 1955 when Metro Manila groundwater level was first surveyed show that groundwater flow follow the course of topographic divides (e.g one direction of groundwaterflow is towards northeast to Laguna Lake and the other is towards northwest to Manila Bay in Bacoor area; while in the central portion, at Laguna lake shoreline (uppermost portion of Pasig River), the groundwater flow is towards the direction following the course of Pasig River to Manila Bay). After 39 years since 1955, the groundwater flow pattern was significantly altered due to excessive withdrawal of groundwater in the aquifer. The 1994 Piezometric Water Level for Metro Manila, show prominently three distinct cones of depressions, namely Paranaque, Pasig, and Valenzuela cones of depressions. The latest groundwater level map for Metro Manila aquifer done in 2004 depicts a worsened situation. More cones of depression appear while previous ones becomes more extensive and deeper. The 10-year groundwater decline of groundwater surface from 1994 – 2004, for example, shows specific areas having minimum decline of 60 mbsl and in others to a maximum of 100 mbsl.

5.3 Groundwater contamination and pollution

Contributing factors and/ or sector comes from the industry, municipal and domestic waste, and in some degree from agriculture

5.3.1 Industry

About 35% of the 405 Underground Storage Tanks (UST's) identified by previous study in Metro Manila is suspected to be leaking and contaminating the groundwater. On the other hand, large number of industries make use of surface water as disposal of effluents, and the polluted river and lake waters leak/inflow into the aquifer for which the groundwater is utilized for various use (e.g rivers surrounding Laguna Lake which is located adjacent to Metro Manila is inevitably affected by effluents from industries in the Metropolis).

5.3.2 Municipal/domestic source

Opened - bottomed septic tanks still exist in violation to building requirements and somehow allow accumulated human wastes to percolate downward and contaminate the groundwater. On the other hand, open dumpsite in areas with shallow groundwater and where the underlying soil cover or formations are permeable pose a great risk on groundwater quality. The method of refuse disposal for Metro Manila has high risk of polluting groundwater due to leachate and surface runoff in imroperly selected sites.

5.3.3 Agriculture

Excessive use of fertilizer in agricultural areas especially is area where unconfined aquifer having shallow water table likewise pose a great risk for the groundwater to be contaminated.

5.4 Land Subsidence

Only few and undocumented cases of land subsidence due to groundwater over abstraction is known in the country. An isolated and apparent case of land subsidence because of too much extraction of groundwater in the southern Metro Manila area covering the City of Muntinlupa was investigated .

6. Conclusion

The water resources management under the Philippine set up has its own uniqueness but possess certain commonness and similiarities with that of its neighboring counties whose management style and set-up are patterened to international standards. In consideration of the Philippines' geographical setting, there are certain water related issues and problems that are prevalent to an archipelagic setting. Issues of salt water intrusion, for exampke is a serious concern epecially because major cites (e.g. Metro Manila and Cebu City) with fast growing population are located along coastal regions. Moreover, concomitant to growing population is a growing demand for water that put strain to existing limited water resource and therefore cause groundwater table to decline. The ballooning population is a serious concern because they greatly contribute to the production of solid waste that are improperly disposed and pollute source of clean water. With this, it has become apparent that the issues and concern are related to growing population and urbanization. However, it is noticeable that certain problems arises also from the way the resource itself is being managed. There is the difficulties in implementing and compliance to laws, lack of water resource monitoring programs (both for quality & quantity), institutional weaknesses, considerable percentage of groundwater extraction is without water rights permit resulting in indiscriminate withdrawal of groundwater (where unregulated, private well users continue to increase without being registered), and permitees drawing more than the granted amount. It has become apparent that there is a need to strengthen and improve management style and set-up to address these issues, and up to now this remains as a challenge to authorities including those working in the field of geosciences.

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Groundwater, a threat from mining activities in Papua New Guinea

Simon S. Egara (Mineral Resources Authority of PNG)

1. Introduction

Papua New Guinea national government derives over 65% of its gross income from the mineral sector since the early 70's and to date is still dependent on it. Other commodities such as hydrocarbon, timber, fish, tourism and agricultural produce account for the remaining 35 % of the income. In addition hydrocarbon projects have accounted for the larger portion of the 35% of the income generated from non-mineral commodities.

The number of operating mine, mainly gold/copper ranging in size from large to small, has increased from one in the 70's to over 7 to date with several others under construction (Fig. 1).

Because of the abundance of surface water as a source of water supply in and around these mine sites very little attention has been given to groundwater resources. Major river systems in the mine impact areas have been polluted but little attention were given to the problem of the river systems and environment by the authorities in charge as well as the operators of the mine.

Only recently after the Angabanga River system was polluted from Tolukuma mine tailings discharge and accidental spillage of cyanide and a series of court action taken out by the people affected living down streams of the mine.

On a larger scale, the largest operating copper/gold mines in Papua New Guinea, the Panguna Copper Mine (closed) faced some controversy over the pollution of Java river system and Ok Tedi Mine was taken to court in 1994 over pollution of the environment and the Fly River system. In all these cases both, the government and the companies downplayed the issues and to date nothing much is said about the extent of the damages done from the mining activities.

2. Operating mines

There are currently three large operating mines (Ok Tedi, Porgera, and Lihir), and four small operating mines (Sinivit, Kainantu, Simberi and Tolukuma). A few other prospects are in advanced stage and will be operational within a year or less.

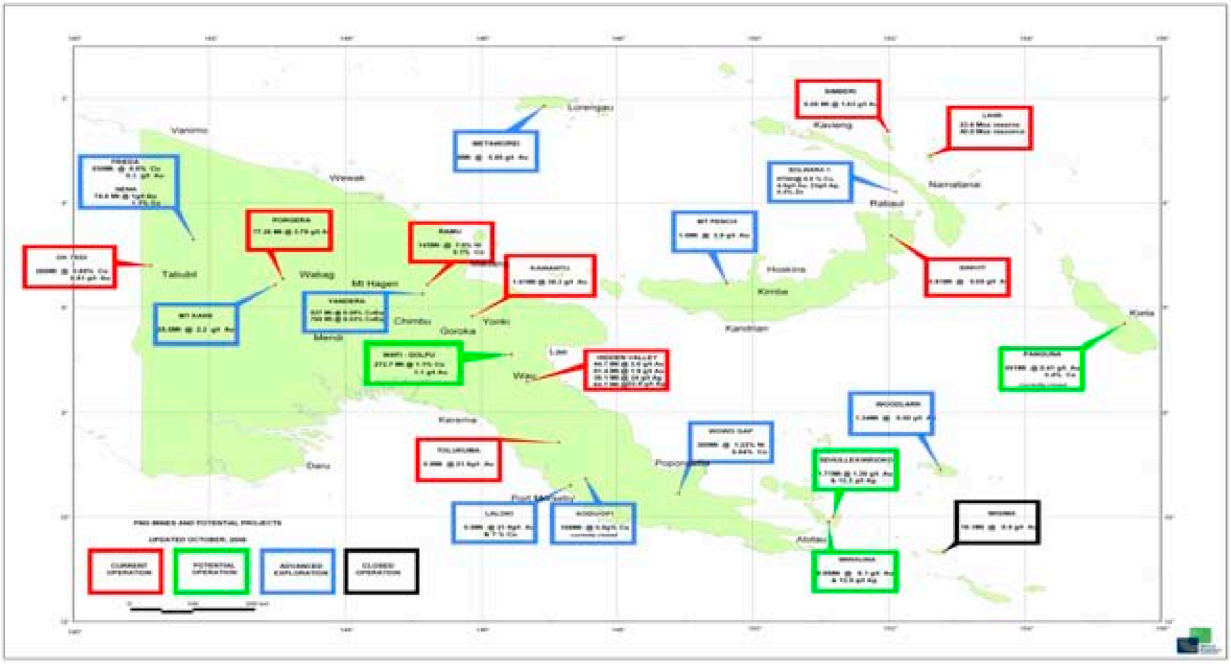

Fig. 1 Map showing various stages of mining and mineral explorations in Papua New Guinea as updated by the Mineral Resources Authority (MRA) 2009.

2.1 Ok Tedi mine

The Ok Tedi mine located in the central part of mainland PNG (Fig. 1) produces copper and gold. It is operated by the Australian-British mining giant BHP-Billiton.

Since its operation in 1984 BHP has dumped well over 80,000 tons of tailings (rock waste) containing copper, zinc, cadmium and lead directly into the Fly and Ok Tedi Rivers every day for more than two decades. These have ruined the lands of thousands of subsistence farmers, poisoned some 2,000 square kilometers of forest, polluted the Ok Tedi River and contaminated a section of the Fly River, PNG’s second largest river system, severely depleting fishing stock. Water from the polluted river systems has been made undrinkable.

Fig. 2 Ok Tedi Mine with the gold and copper mill atop of the hill, on the lower right hand corner.

Groundwater quality along the affected alluvial plains has not been researched and hence any account on the quality and quantity could not be provided here, however there is a strong feeling that groundwater is also heavily contaminated. Because of the surface water being contaminated, it was reported that the Ok Tedi Mine has embarked on a program of providing rainwater catchment and borehole water supply systems to the affected communities. There is no report available from the borehole-drilling program carried out in 2007.

Fig. 3 Sediment load in the Ok Tedi River.

Fig. 4 Dead vegetation shows the extent of the environmental damage done from the sediment of tailings (waste rock) along the Fly River system.

2.2 Lihir gold mine

The Lihir gold mine is located on a small volcanic island northeast of the mainland (Fig. 5). It is situated at near sea level and hence virtually has no problem about contamination of fresh water. Most of the waste rock mass is dumped offshore.

Water supply for the mine site is sourced from a surface water source from the island away from the mine site and processed for consumption. Surface water source is abundant on the island; however groundwater is also abstracted for use on some parts of the island particularly as community water supply source or for schools and health outposts.

Fig. 5 Lihir gold mine on Lihir Island, Papua New Guinea(NASA satellite image)

Fig. 6 View of the processing plant and other facilities at the Lihir gold mine.

2.3 Porgera gold mine

Porgera gold mine is located in the central highlands of the mainland of PNG. Waste disposal (waste rock) is disposed off in deeply dissected V-shaped valleys. Although there is not much groundwater resources in this part of the country the river systems in which the waste material is dumped is also heavily contaminated thus making water undrinkable. However the inhabitants of the affected areas have plentiful surface water sources to rely on for potable water source.

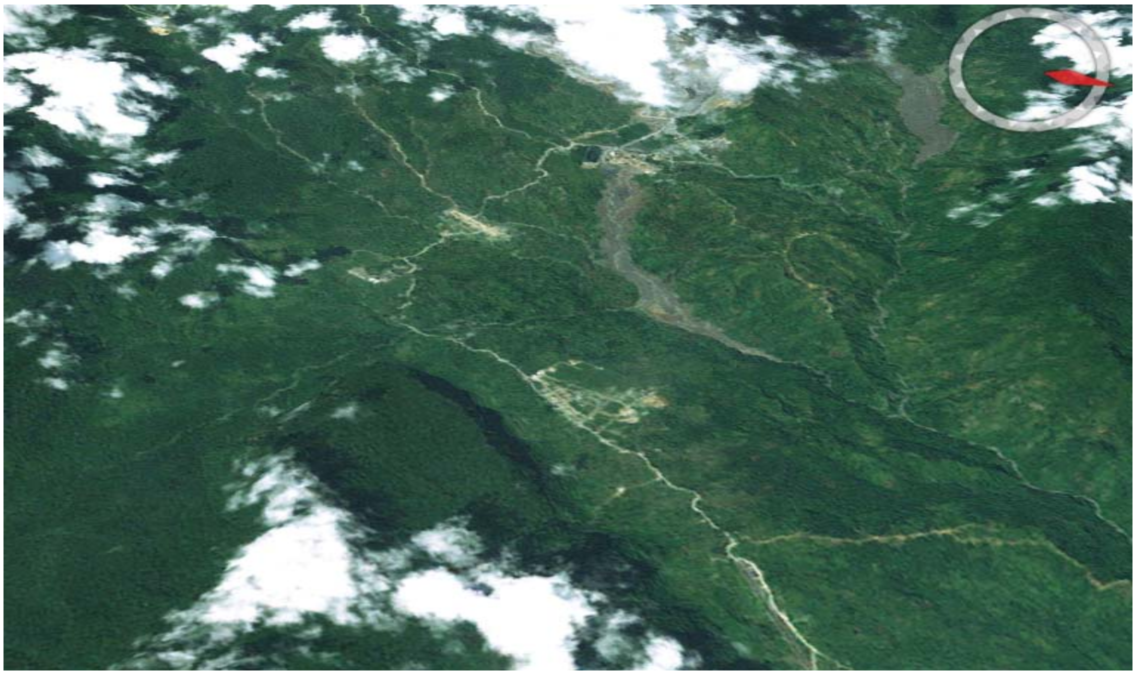

Fig. 7 Landsat image of the Porgera gold mine.

Fig. 8 Close up view of the open cut mine at Porgera.

Fig. 9 View of the processing plant from the main pit area at the Porgera gold mine.

Although there is no concern for groundwater in and around the mine impact area, we should still be mindful of the fact that acid leached from waste rock dumps and any leaching of chemicals from the processing plants will affect groundwater further down-streams from the mine site, particularly in the low lying alluvial valleys.

3. Groundwater contamination

There is no documented case nor reports of groundwater contamination in the mine affected areas, however undocumented reports from affected local communities and villages have indicated that traditional groundwater sources have become contaminated, people have become sick, and new born babies have defected after drinking groundwater.

Because of the abundance in surface water sources, groundwater was a rarely used resource and the government and mining companies in their attempt to make more money were generally less concerned about pollution of the surface water sources, aquatic life and environment. Even to date, the same tactics are used by both the government and the companies, which extracting natural resources from the country.

If and when an investigation is commissioned to investigate incident(s) of contamination from rural communities or villagers, private consulting companies that are aligned to the companies are engaged to conduct the investigation and the results are often made in favor of the companies and are never impartial.

4. Present and future protection of groundwater from contamination.

At present groundwater protection and use policy is implemented by a government department, the Department of Environment and Conservation (DEC). DEC is generally more concerned and mostly involved in policing not for groundwater but only for the environment and the surface water abstraction and protection.

Thus it leaves groundwater vulnerable to anybody contaminating the resources without being detected and the resources mismanaged. Clear examples of these being the operating mining companies dumping chemical and mine waste materials in the upper basin causes the groundwater pollution in the lower plain areas.

The hydrogeology section of the Geological Survey of Papua New Guinea, which is essentially the organization that should be entrusted to implement the policies and regulations regarding groundwater, has only one hydrogeologist to cater for this very large complicated task for the whole country. With the lack of available groundwater specialists, funding and equipment available, the functions of protecting groundwater resources from contamination and mismanagement could not be implemented. As a result many companies and private individuals abuse very valuable groundwater resources at will.

In other words, it can be said that groundwater resources are currently not protected and the future also looks very glum. There is a great need for the protection of the resources but the needs to implement the policy and inject more funds, equipment and personnel have to come from the higher authorities' in-charge of the resources.

5. Conclusions

Groundwater resources have for far too long been left unprotected by authorities entrusted to protect it (DEC) but in the attempt to generated more income from the mineral sector in the country. The government has turned a blind eye on it however, as for a concerned individual and groundwater specialist, groundwater is a non-renewable resource and hence, it must be protected and managed well for the benefit of the people who are dependent on it and for the future generation of the country.

6. Recommendations

In an attempt to start the process of groundwater resources protection and management from contamination from the existing mining activities and in the light of a few new mining operations that will come online for production within the next 18 months or so, I kindly hereby take this opportunity to request CCOP and its member countries to assist us with expertise in conducting GROUNDWATER BASELINE studies before the actual operation of the new mines as part of this project on groundwater.

Case study: Groundwater evaluation and proposed direction for sustainable development in Tha Chin and Mae Klong basins, Thailand

Adisai CHARURATNA
(Department of Groundwater Resources)

Abstract

A total area of Tha Chin and Mae Klong watersheds is 44,313 Km2 coverage both consolidated and unconsolidated aquifers but huge groundwater abstraction is mostly in extensive unconsolidated sediments for various activities in terms of agriculture, industry and consumption. Study area in this report is only to evaluate groundwater potential in unconsolidated aquifers covering an area of 12,296 Km2 by using mathematical modeling. There are 4 essential aquifers having more directly affected and extended to recharge area in the region namely Bangkok, Phra Padaeng, Nakhon Luang and Nonthaburi aquifers by forming as flood plain, alluvial fan, low terrace and high terrace respectively. The other 4 well-known deeper aquifers underlain these aquifers and expansion in the Lower Chao Phraya basin where Bangkok located are Sam Khok, Phaya Thai, Thonburi and Pak Nam aquifers. The amount of water is approximately 969 million cu m per year circulating in the system by having 409 million cu m for groundwater abstraction. Some areas have been affected in environment impact due to excessive pumping. Therefore, some proposed guidelines are suggested for future sustainable management.

Key words

Unconsolidated sediments, groundwater budget, proposed future management

1. Hydrogeological setting

Unconsolidated sediments aquifers in The Chin and Mae Klong basins are essentially recharge area in western part of Lower Chao Phraya plain and high groundwater potential as well. By geomorphologic features, two types are mainly characterized as low flat terrain – along the banks of The Chin and Mae Klong rivers including the broaden plain coverage with marine clay on the top layer. The other is higher terrain formed as alluvial fans and terraces along western rim of the basins, the unconsolidated sediments are consisted of mostly sand and gravel with silt and clay in Quaternary period with total thickness ranging from 200-250 m. These hydrogeological units or aquifers can be briefly classified as fallows.

1-1. Bangkok aquifer (BK)

The upper aquifer is generally a total depth less than 50 m and its typical characteristic varies from north to south. As for the north, the aquifer is mostly alluvial deposits of The Chin

River whereas in the south is flat terrain overlain by marine clay and some parts of aquifer linkage with alluvial deposits of Mae Klong river on the west side. Actually, it is good aquifer that average yield is possibly more than 20 cu m/ h and good water quality, except in the area overlying of marine clay is normally brackish or saline water.

1-2. Pra Padaeng aquifer (PD)

The aquifer is overlain by Bangkok aquifer at approximately depth ranging from 50-100 m. Along the western rim of the basins, the exposed aquifer is obviously formed as deified young and old alluvial fans including low terrace. Widely groundwater abstraction and the yield can be obtained more than 10 m3/hr, particularly in upper zone of the basins. In some areas of coastal line, water quality is brackish or saline.

1-3. Nakhon Laung aquifer (NL)

The aquifer under Pra Padaeng aquifer ranging from 100-150 m in depth. As a good aquifer with high ground water potential and good water quality is normally obtained. Some parts are connected with higher topographic level formed as low terrace on the western side of the basins.

1-4. Nonthaburi aquifer (NB)

Extensively under Nakhon Laung aquifer, it is lower part of young unconsolidated sediments at the depth ranging from 150-250 m. The farthest expansion expected to be formed as high terrace along the western periphery of the basins. High groundwater potential and good water quality are normally obtained as well.

In addition, the other 4 well-known deeper aquifers as semi-consolidated sediment are namely Sam Khok (SK), Phaya Thai (PT), Thonburi (TB), and Paknam (PN) aquifers can be obtained at the depth more than 250 m, particularly in lower part of the basins.

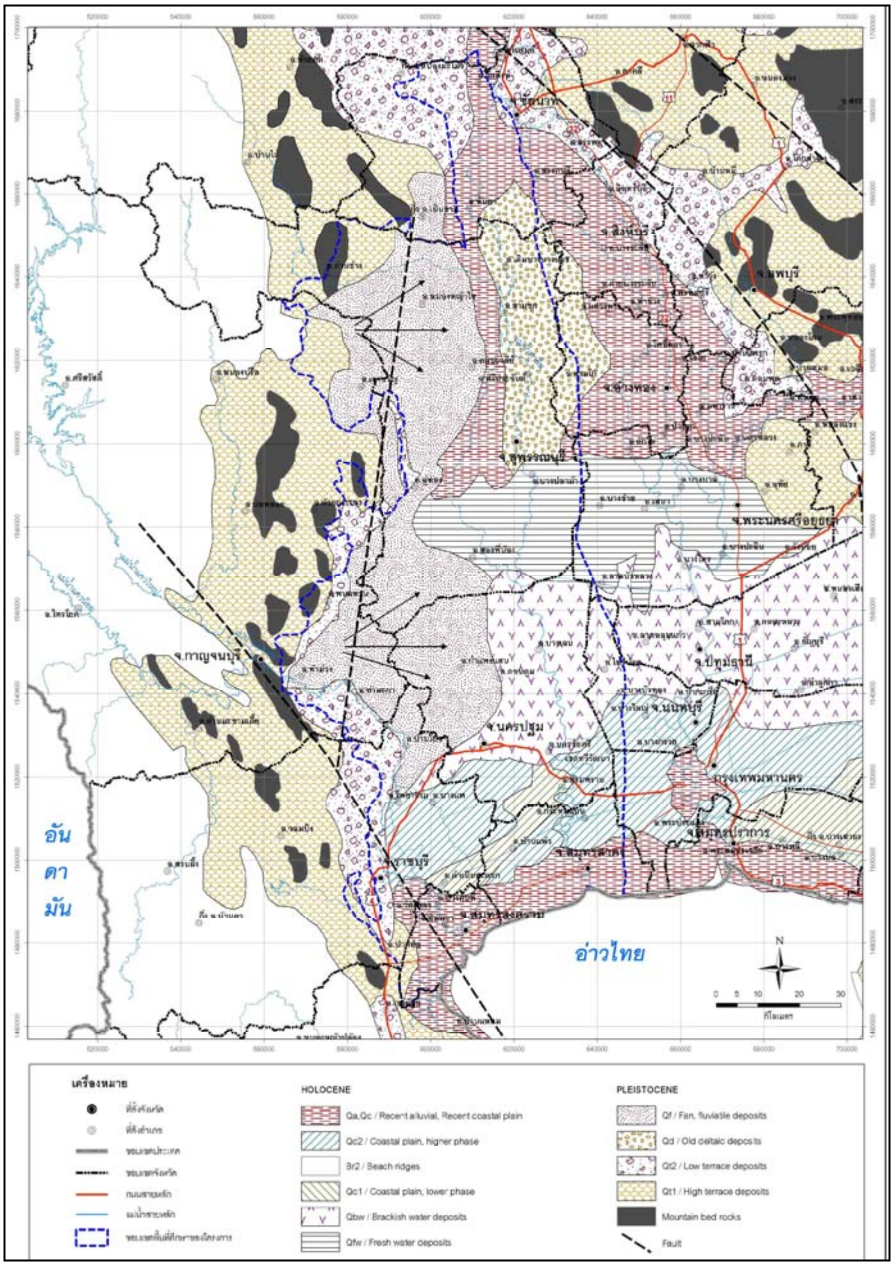

Fig 1 Study area and geomorphologic classification

2. Groundwater assessment

Groundwater balance in the basins has been evaluated by applying numerical modeling that used Vision MODFLOW program. The results showed that the amount of water is a total approximately of 969 million m3/year circulating into the system. This figure was calibrated by using existing data during 1999-2003 and their outputs of one round year at the end of 2003 as follows:

Previous storage + Rainfall recharge + Inflow from boundaries + Inflow from rivers

= Groundwater pumping + Outflow to boundaries + Outflow to rivers +

Evapotranspiration + Remaining storage (million m3)

236.4 + 375.4 + 228.6 + 128.5	=	409.4 + 50.8 + 78.9 + 0.54 + 429.4	
969	=	969	million m3

Groundwater budgets in each district and province were evaluated and to be shown in Table 1. As the result, exceptionally in Samut Sakhon province indicates that groundwater balance is deficit and apparently affected by increasing land subsidence and salty water intrusion due to excessive groundwater pumping.

3. Guidelines for sustainable groundwater development

The unconsolidated sediments of Tha Chin and Mae Klong basins are essential groundwater resources of lower Chao Phraya plain. The amount of groundwater abstraction must be controlled in order to diminish environmental impacts such as land subsidence or salty water intrusion etc. However, the country's economics have to forward progress together with sustainable consumption and conservative groundwater resources for people in next generation. In order to manage groundwater in these basins, some guidelines are proposed by considering from knowledge-based outputs of groundwater investigation and mathematic model simulation as fallows.

3-1 Induced – recharge method

Due to unconsolidated sediments consisting of sand, gravel and pebble can be found along the river bed of Mae Klong and connected to shallow aquifers with high groundwater yield. It is good location for established industrial estates that require huge groundwater usage for their production by applying induced – recharge method. The concept of this method is to withdraw groundwater in shallow aquifer along the river banks in order to induce continually additional recharge coming from the river. For an example, an industry located on the river bank is paper-making that abstracts groundwater over 2,000 m3/day by having many wells of 300 mm in diameter and 60 – 80 m in depth. Each well can pump water at the rate of more than 50 m3/h with a little water level decreased.

3-2 Artificial recharge

In the recharge areas actually located along alluvial fans, high terrace and low terraces have many existing network irrigation canals conveying water from dam or river to agriculture crops and finally to the sea. Normally, these canal's beds have lining with clay or cement to protect water seepage into underground. In the wet season, having plenty of water, it exceeds for needs in various activities and has to be gravitationally drained to the sea. Instead of drainage this excessive water, artificial recharge can be applied by injecting directly to shallow aquifer in order to increase water level and storage. As for day season, nothing to do for artificial recharge because of crucial water requirement. Hence, people can use water as usual. The concept of this process is to construct many shallow wells in the middle of provided compartment of irrigation canals and having inlets to control water level beyond injection wells. Water will automatically flow through the wells by gravity itself.

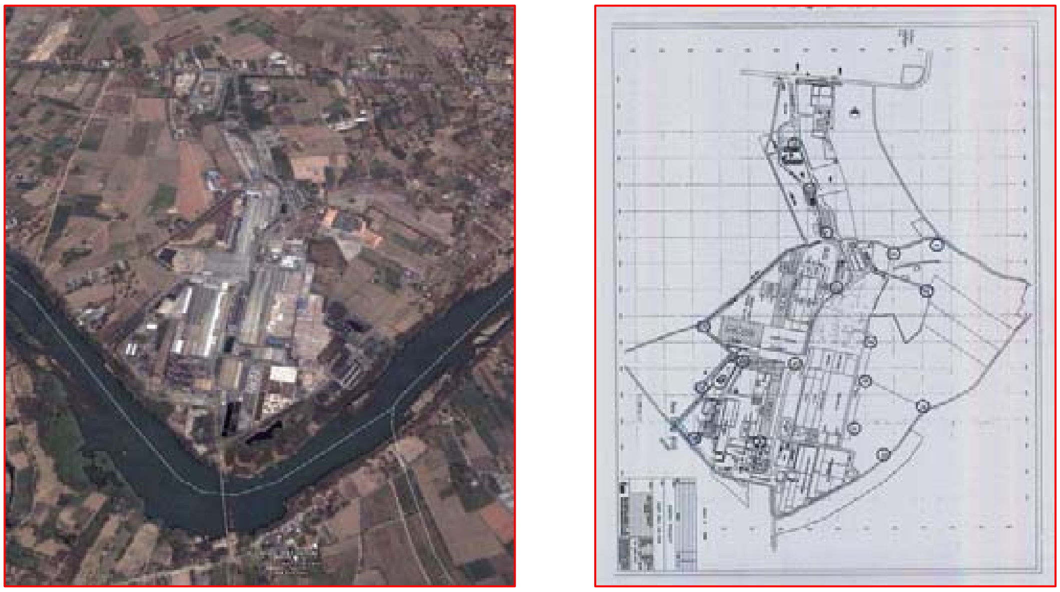

Fig. 2 Example of industry located nearby river bank and induced-recharge method applied.

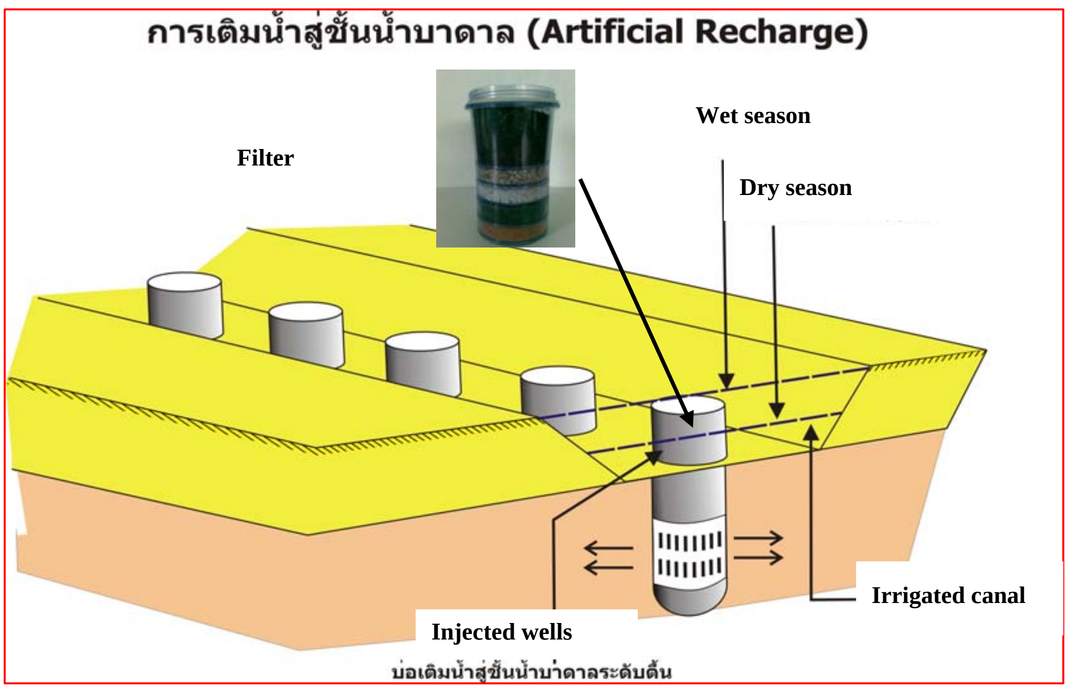

Fig. 3 Artificial recharge by injecting water through shallow wells in irrigated canal

Table 5 Table 1.Groundwater budget in each province

No.	Province	Existing groundwater amount used						Safe Yield (m^3/day)						Groundwater amount that can be developed (m3/day)					
		Aquifer 1 (BK)	Aquifer 2 (PD)	Aquifer 3 (NL)	Aquifer 4 (NB)	Aquifers 5-8 (SK-PN)	Total	Aquifer 1 (BK)	Aquifer 2 (PD)	Aquifer 3 (NL)	Aquifer 4 (NB)	Aquifers 5-8 (SK-PN)	Total	Aquifer 1 (BK)	Aquifer 2 (PD)	Aquifer 3 (NL)	Aquifer 4 (NB)	Aquifers 5-8 (SK-PN)	Total
1	Chainat	0	881	2,891	0	0	3,772	0	7,914	36,473	0	0	44,387	0	7,033	33,582	0	0	40,615
2	Suphan Buri	0	37,873	64,217	10,312	4,441	116,843	0	140,219	264,736	193,748	150,265	748,968	0	102,346	200,519	183,436	145,824	632,125
3	Nakhon Pathom	4,945	43,993	129,383	89,332	5,760	273,413	63,439	110,947	158,845	113,979	99,870	547,080	58,494	66,954	29,462	24,647	94,110	273,667
4	Kanchanaburi	1,553	8,315	7,112	66,266	1,523	84,769	6,784	33,197	43,219	46,779	15,265	145,244	5,231	24,882	36,107	-19,487	13,742	60,475
5	Ratchaburi	9,187	41,509	71,251	50,057	942	172,946	25,812	40,554	69,830	76,246	51,857	264,299	16,625	-955	-1,421	26,189	50,915	91,353
6	Samut Sakhon	270	16,652	92,931	152,584	133,940	396,377	24,150	23,160	63,460	35,200	100,560	246,530	23,880	6,508	-29,471	-117,384	-33,380	-149,847
7	Samut Songkhram	118	14,790	14,839	2,788	0	32,535	9,067	17,297	28,884	20,357	16,209	91,814	8,949	2,507	14,045	17,569	16,209	59,279
8	Bangkok	0	241	643	3,745	2,380	7,009	0	0	1,200	1,950	3,410	6,560	0	-241	557	-1,795	1,030	-449
9	Nonthaburi	0	50	914	13,179	421	14,564	0	280	17,200	15,465	10,900	43,845	0	230	16,286	2,286	10,479	29,281
10	Ayutthaya	0	0	495	1,235	0	1,730	0	0	2,300	1,714	1,150	5,164	0	0	1,805	479	1,150	3,434
11	Ang Thong	0	768	676	450	100	1,994	0	9,160	15,515	6,645	4,660	35,980	0	8,392	14,839	6,195	4,560	33,986
Total		**16,073**	**165,072**	**385,352**	**389,948**	**149,507**	**1,105,952**	**129,252**	**382,728**	**701,662**	**512,083**	**454,146**	**2,179,871**	**113,179**	**217,656**	**316,310**	**122,135**	**304,639**	**1,073,919**

Likewise, in the area located nearby coastal line having huge groundwater pumping, such as Samut Sakorn province, the aquifers less than 300 m in depth have been contaminated by salty water intrusion. To rehabilitate these aquifers or to protect saline water expansion, the line of injection wells along Khlong Damneon Saduak that is located 10 km to the north from existing affected area would be applied. This man – made canal or Khlong Damneon Saduak is extended parallel to coastal line in east – west direction and good enough water quality for simple treatment before injection process. The groundwater flow direction will be downwards to push saline water away the affected area in each aquifer depth.

Fig 4 Artificial recharge by injecting water through deep well stations

3-3 Management of groundwater usage

To reduce overdraft of groundwater, the authorities concerned have to bind the critical zones and limitation of groundwater pumping in the line with groundwater budget and existing vulnerable water quality. By strictly groundwater act enforcement including efficient registration of groundwater consumption and GIS database, the current situation of environment impacts would be refrained and slowdown concretely in the future.

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GROUNDWATER RESOURCES MONITORING IN VIETNAM AND RISING PROBLEMS

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Abstract: In social-economic development, water resources monitoring plays very important role. It provides for people useful and accurate information about quantity and quality of water resources.

Since 1989, the groundwater resources monitoring networks has started to build in 3 main economic regions: Red river delta plain, Mekong river delta plain and Central plateau.

1. Development history of Groundwater resources monitoring

1.1. Groundwater resources monitoring

The first period (1989-1995): construction of network:

Groundwater resources monitoring in Red river delta Mekong river delta plains has been started to build since 1989, in Central plateau in 1990 and completed in 1995.

The second period (1996-2007): operates monitoring in whole 3 regions with one project

In 1996, "The national monitoring networks of groundwater regime in three regions" project were carried out.

Third period (From 2007): operation and improvement of GWRMN

On 29th January 2007, "National integrated Planning for Monitoring Network for Environment and Natural resources up to 2020" was approved by Prime Minister following the decision number 16/2007-QĐ-TTg. In the Plan, groundwater resources monitoring networks will be maintained and improved . Up to 2020, it will have total 70 stations, 692 points, and 1331 units. Regards to Surface water resources monitoring networks there will be 78 gauging-stations on main river basins will be construted up to 2020.

Currently, there are total 612 national groundwater units.

Beside the national network, provincial network have established such as Ho Chi Minh City (28 units), Binh Duong (10 units), Binh Phuoc (21 units), Can Tho (30 units), Hau Giang (24 units), Dong Thap (14 units), Soc Trang (119 units), Ba Ria – Vung Tau (20 units), Dong Nai (13 units), Ha Noi capital (143 units).

1.2. Surface water resources monitoring

According to the "National Planning for environmental monitoring of groundwater resources to 2020", 78 gauging-stations on main river basins will be built such as: Thai Binh, Bang Giang-Ky Cung, Ma, Gianh, Hourng, Vu Gia-Thu Bon, Con, Cai Nha Trang, Cai Ninh Thuan, Dong Nai and Me Cong River .

2. The achievements

The factors, frequency and monitoring devices:

- Water level (flow)
  - Tidal dominate Region: 1hour/time
  - Non tidal dominate Region: 1-3-6 day/time.
- Temperature: measure 1-3-6 day.
  - ✓ Water quality: water sample are taken and analyzed twice a year (one time in dry season, and other in rainy season).
  - ✓ Major component samples: Ca, Mg, Na, K, Cl, HCO3, CO3, SO4...
  - ✓ Heavy metal sample: As, Hg, Se, Br, Cr, pb, Cu, Zn, Mn, Ni,
  - ✓ I, F, CN, Fe...
  - ✓ Environment and polluted sample: pH, NH^{+}_{4}, NO_2^-, NO_3^-, PO_4^{-3}, Eh, BOD, COD

Devices: water level are measured by hand and chemical sample are taken by

submerge pump Grundfos - MP1.

The result of monitoring

- ✓ Having national water monitoring software to create and update database.
- ✓ Each region has its own database. The Centre for Water Resources Monitoring and Forecast will combine regional databases to one database.
- ✓ Make the announce, warning to the Department of Natural Resources and Environment (DONRE) in province every three months.
- ✓ Every 6 months, send announce, warning to website and management organisations (such as Department of Geology and Minerals of Vietnam, Department of Water Resources Management, General Department for Environment), making the report and send it to the public media, ..
- ✓ Compile and public groundwater resource regime annual book.
- ✓ Compile and public characteristics of groundwater resource every 5 years.

In the regions effected by exploiting, water level is continuous declining.

- Ha Noi City: the deepest water level in monitoring unit P.41a in the centre of Ha Dinh well fields is 35,2m in July 2008 (see fig 1). Forecasting water level in June 2009 is 36.01m.

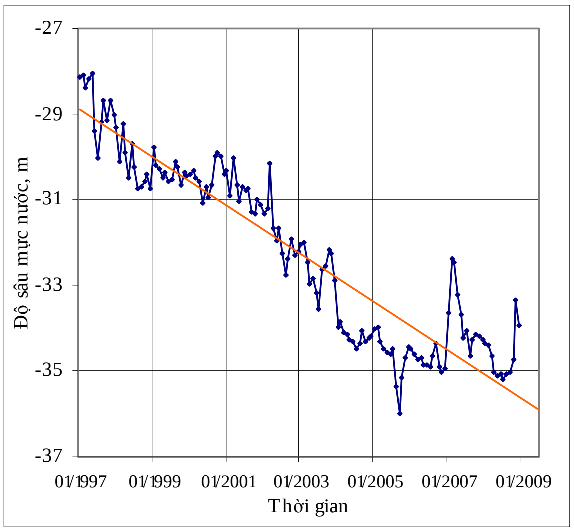

Fig 1. The water level fluctuation at P.41a in Pleistocene aquifer in Ha Noi City.

- Ho Chi Minh city: The deepest depth of GW level at Q808040 (fig 2) is 16,67m (date 24/6/2008) lowering 1.03m compare with it in the same time in 2007

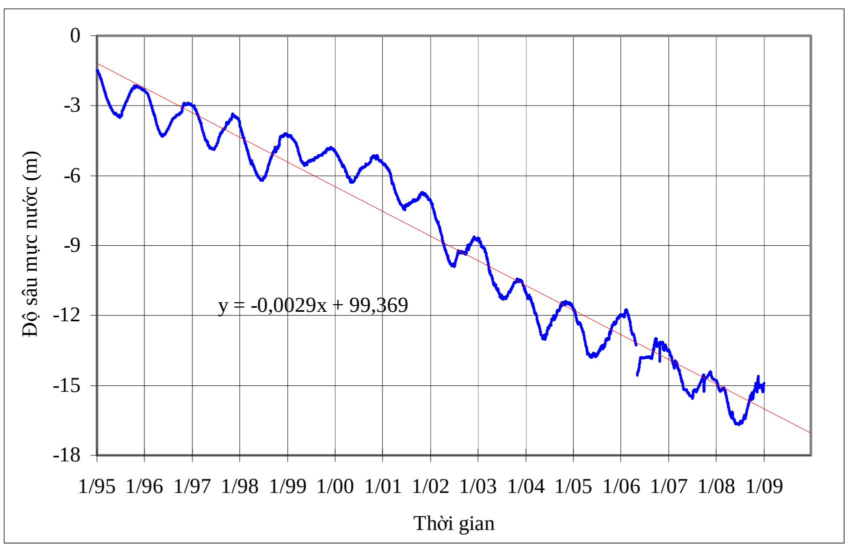

Fig 2. GW level fluctuation at Q808040

n_2^2 aquifer in Ho Chi Minh city

- ✓ The areas which ammonia value higher than standard limitation are Ha Noi (Thanh Tri, Tu Liem, Hoai Duc, Dan Phuong), Ha Nam, Nam Dinh, Soc Trang, Binh Duong, Ho Chi minh city.

3. Developing plan

a. The plans of construction and improving monitoring network

The plan of construction new monitoring regions, Improvement and operate monitoring network will be done up to 2020. The existing GWMTNs will be improved on. The new monitoring network will be constructed in Coastal province in North central region, North Eastern and North Western, the main aquifer is shown in table 1. Beside that 78 surface water stations will be constructed too.

Table 1. These main monitoring aquifer in monitoring region

No	Monitoring region	These monitoring aquifers		
		Present	2008-2010	2011-2020
1	North Eastern			q, t_3, C-P, ε-O, PR, O_3-S_1
2	Red river delta plain	qh_1, qh_2, qp,	qh_1, qh_2, qp, n_2, n_1	qh_1, qh_2, qp, n_2, n_1
3	North Western			q, t_2
4	Coastal province in North central region		qh, qp	qh,qp, n_2, C-P, O_{3-} Q , K
5	Coastal province in South central region		qh, qp	qh,qp, β, n_2
6	Central plateau	q, $βq_2$, $βN_2$-q_1, n	q, $βq_2$, $βN_2$-q_1, n	q, $βq_2$, $βN_2$-q_1, n
7	Mekong river delta plain	qh, qp_2, qp_1, n_2^2,n_2^2, n_1^1, n_1^2	qh, qp_2, qp_1, n_2^2,n_2^2, n_1^1, n_1^2	qh, qp_2, qp_1, n_2^2,n_2^2, n_1^1, n_1^2

b. Monitoring factor

- Water level
- Temperature

- Water quality: as same as present, and study more other criteria such as Styren, Benzenpyren, Diclorometan, 1/2 Dicloroctan, 1/1/1 Tricloroetan; Benzen, Toluen, H^2, H^3, O^{18}, C^{13} , C^{14}, N^{15}, Lindane; HCB, Dieldrin, Aldrin, Methoxychlo, hexachlobenzen, and Radioactivity: α, β rays

c. Monitoring devices

Water level and temperature.

There is 10 precent units using semiautomatic devices (mechanics or electronics) and the datas are taken in unit every month. Equipments, machines should be invested and modernized in various periods.

- *Period 2008-2010 :*

+ 30 percent units using semiautomatic devices (data logger).

- *Period 2011- 2015:*

+ 50 percent units using semiautomatic devices and 10 percent using automatic devices (collect and transfer data directly to the offices).

- *Period 2016- 2020:*

+ 70 percent units using semiautomatic devices and 20 percent using automatic devices (collect and transfer data directly to the offices).

4. Propose next study

a. Design some monitoring points to study affect of climate change to goundwater. It can be in two points:

- Study groundwater pollution due to flood in Hanoi/Ho Chi Minh
- Study saline intrusion in shallow aquifer due to sea level rising.

b. Design monitoring network in 1 river basin for integrated water resources management for following tasks:

- Planning for allocation of water resources
- Forecast for water resources
- Protection of water resources

IMPACT OF EL-NINO

ON LABUAN ISLAND, SABAH, MALAYSIA

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El-Nino Phenomena

El Niño, is an anomalous oceanographic and atmospheric event in the equatorial Pacific Ocean that usually occurs every three to seven years and is characterized by an increase in the sea-surface temperature in the eastern equatorial Pacific Ocean. ENSO is thought to be responsible for anomalous climatic conditions spanning most of the globe.

El-Nino Impacts

Many of the resulting impacts of El Niño are negative, causing drought, famine, and floods. However, some impacts are beneficial. Research shows that El Niño reduces the intensity and number of Atlantic hurricanes and reduces the number of tornadoes in the central United States.

Labuan Island, Sabah, Malaysia Scenario

Labuan Island is located near Kota Kinabalu in Sabah State in Malaysia (75km2). It is situated 115km from Kota Kinabalu and about 20 minutes by plane. It is smaller than Penang Island This island is almost flat with only 70-80m high hills. It lies 8km off the mainland of Sabah at the northern mouth of Brunei Bay.

Labuan Island, Sabah, Malaysia Scenario

In Malaysia especially in Labuan Island, the El-Nino effect causes drought, lack of water, dry season.

Water supply for Labuan Island is about 56 MLD.

Impact of El-Nino on Labuan Island, Sabah, Malaysia

The water supply was dropped to 44.40 MLD due to water problem @ estimated 11.6 MLD (less 19%). The sources of water for Labuan Island:

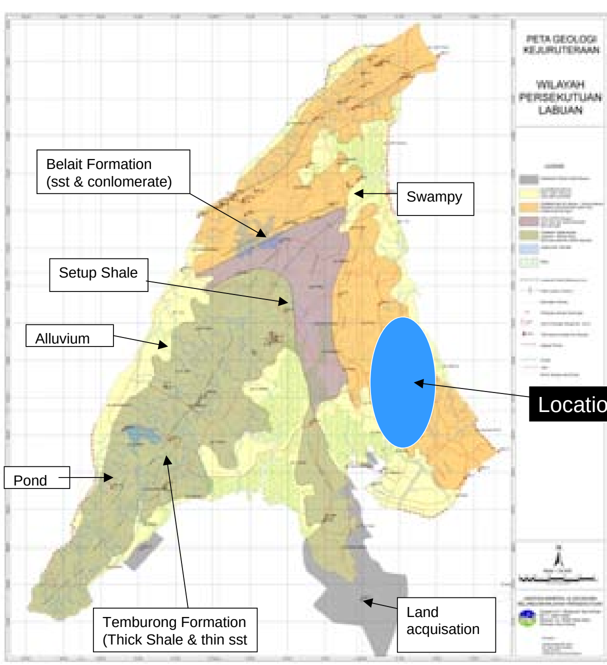
1.Surface water supply from 2 waterworks thru pipeline from Menumbuk (Mainland) is about 44 MLD. Now waterworks at Sungai Pagar Dam was shutdown due to lack of water and

2.Groundwater from Island itself is about 6 MLD from Jalan Kolam Waterwork. JBA have success in rehabilitate 5 tube wells and 14 more are under rehabilitate. Average depth of tube wells is 140m.

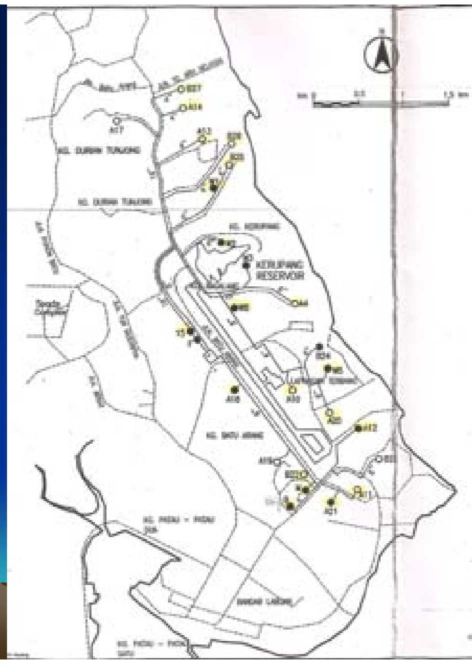
Remedial action

So, to cover the less water supply from surface water,

- Rehabilitation existing tube wells by private company
- Government try to increase the water demand with digging more tube wells (estimated 14 deep tube wells) as soon as possible. This project is now undertaking by SIME DARBY Water resources Sdn. Bhd. which are involved more than RM 13 million.



GEOLOGY MAP OF LABUAN

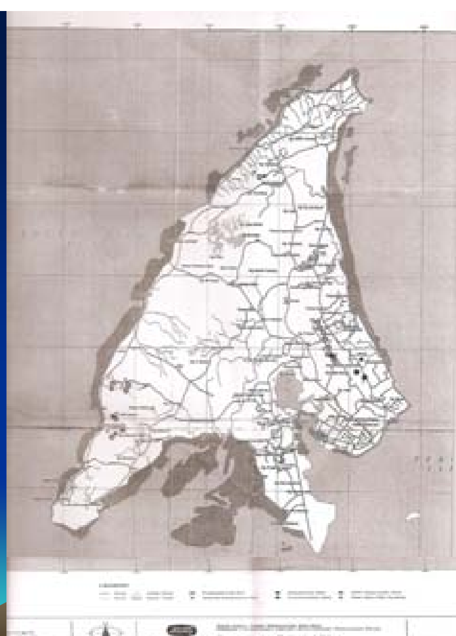


TUBE WELLS THAT NEEDS REHABILITATION

Borehole No.			Location	Well Condition
JKR	MWA	2004 Test		
W1	LE1		Jln. Kerupang 2	Non – Operable
W2	LE2		Jln. Kerupang 1	Non – Operable
W3	LE3A		Kg. Nagalang (N)	Non – Operable
W4	LE4	A4	Kg. Nagalang (E)	OK, In Working Condition
W5	LE5		Taman Sentosa	Non – Operable
W6	LW6		Air Force Base	Non – Operable
10	LW10	A10	Helipad	OK, In Working Condition
W11	LE11	A11	Rakyat Camp	OK, In Working Condition
A12	EB1		Membedai	Non – Operable
13		A13	Kerupang No. 4	OK, In Working Condition
14	EB2	A14	Junction of Jln. Durian Tunjung	OK, In Working Condition
15			Jln. Batu Arang ex. Well G	Non – Operable
17	EB3	A17	Jln. Haji Kudus	OK, In Working Condition
A18	O		Jln. Batu Arang ex. Well 1	Non – Operable
19	L	A19		OK, In Working Condition
A20		A20	Airport Tank	OK, In Working Condition
21			Jln. Pahlawan	Non – Operable
22	K	B22	Jln. Batu Arang RMAF Gate	OK, In Working Condition
B23		B23	Jln. Sawangan China	OK, In Working Condition
B24			RMAF Nagalang Camp	Non – Operable
25		B25	Kerupang No. 2	OK, In Working Condition
26		B26	Kerupang No. 3	OK, In Working Condition
27		B27	Tanjung Aru Nelayan	OK, In Working Condition
F			Water Works	Non – Operable
B			Botanical Gardens	Non – Operable
M			Botanical Gardens	Non – Operable

Legend:
Road
Pipeline
Tube well (OK)
Tube well (Damaged)

LIST OF EXISTING WELLS IN LABUAN



Location of wells proposed by SIME DARBY


New Sabah Times
HOME

Labuan's water shortage: UMS wants to assist

Prof Datuk Dr Kamaruzaman Ampon

Projek air bawah tanah tidak beri kesan negatif

SEVERAL ARTICLES REGARDING OF LABUAN'S WATER SHORTAGE

SG PAGAR DAM CLOSED

THANK YOU

Mr. Joao da Costa Soares

1st October 2009

GEOLOGICAL MAPPING PROGRAM TIMOR-LESTE

Introduction

- The Government of Timor-Leste through SERN has been preparing a geological mapping program for the whole country of Timor-Leste

Program Objectives

- Complete a detailed geological survey of Timor-Leste over the next five years
- Build and develop a trained team of Timorese geologists for continual exploration and research activities within Timor-Leste
- Development and updating the current available geoscientific information within Timor-Leste
- Conduct detailed geological field mapping
- Compilation of geological maps (at a scale of 1:12500), respective cross sections, and stratigraphic fence diagrams

Program Objectives

- Compilation of field progress reports and final progress reports for each project area for presentation and archival in SERN, Timor-Leste
- Provision of an overall greater understanding of: the geological, structural, depositional, and stratigraphic history of Timor-Leste, including; the identifying mineral wealth and potentials in Timor-Leste through mineral assessment and geologic interpretations

Program Description

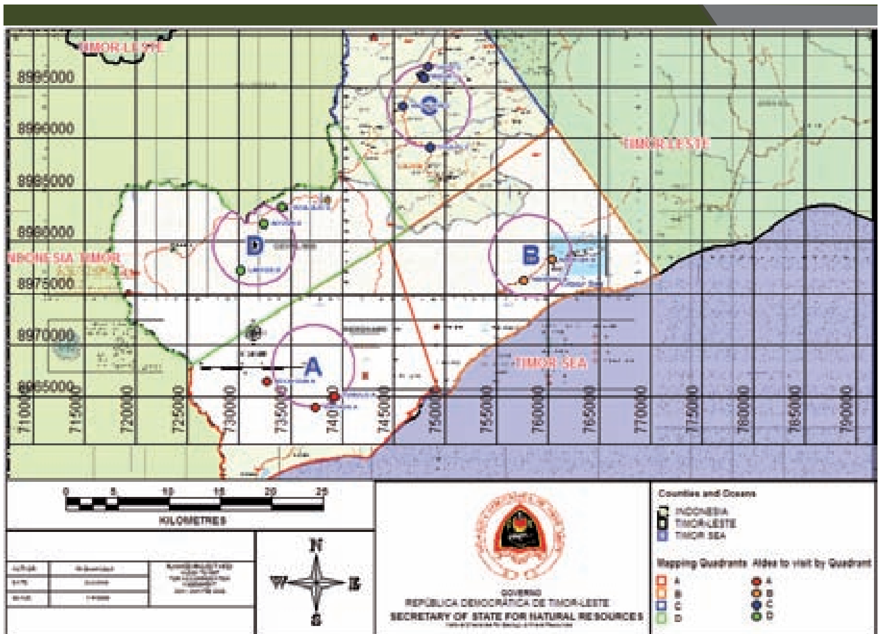
- The program will be split down into several project areas ~40km x 40km in size (1600km^2)
- Each year a project area will be chosen for the focus of geological mapping and investigation
- The first project area has been pre-selected as an area of approximately 37km x 37km, located within the District of Covalima
- This project area is called TLGS-PA1 (***T***imor-***L***este ***G***eological ***S***urvey - ***P***roject ***A***rea ***1***)

Project Description TLGS-PA1

- The TLGS-PA1 Project is aimed at;
  - Providing Timorese Geologists with the opportunity to develop practical field skills and experience,
  - Providing the Natural Resource Department with updated geological information (1:12500 scale geologic maps, cross-sections, section logs, stratigraphic relation diagrams, and reports on structural, depositional and stratigraphic history of Timor-Leste in addition to mineral wealth potential
  - The project will aim at building and developing a team of geologists capable of undertaking regular exploration and research for the Natural Resource Department in Timor-Leste

Project Description: TLGS-PA1

- The first project area (TLGS-PA1) designated to the district of Covalima TLGS-PA1 has been subdivided into four quadrants A, B, C, and D
- The following map displays the project area (TLGS-PA1) and it's respective quadrants



Project Description TLGS-PA1

- The Project Plan is split into four phases;
  - **Phase 1 will involve;**
    - Project planning and design,
    - Acquiring resources including; topographic maps, research papers, and earlier geological maps
    - Hiring staff
    - Purchase of geological equipment
    - Training of Timorese geologists [GIS, basic field mapping techniques (perform some exercises around Behau-Manatutu area)]
    - Meetings with the Lian Nain
    - Reconnaissance/familiarization of the project area

Project Description TLGS-PA1

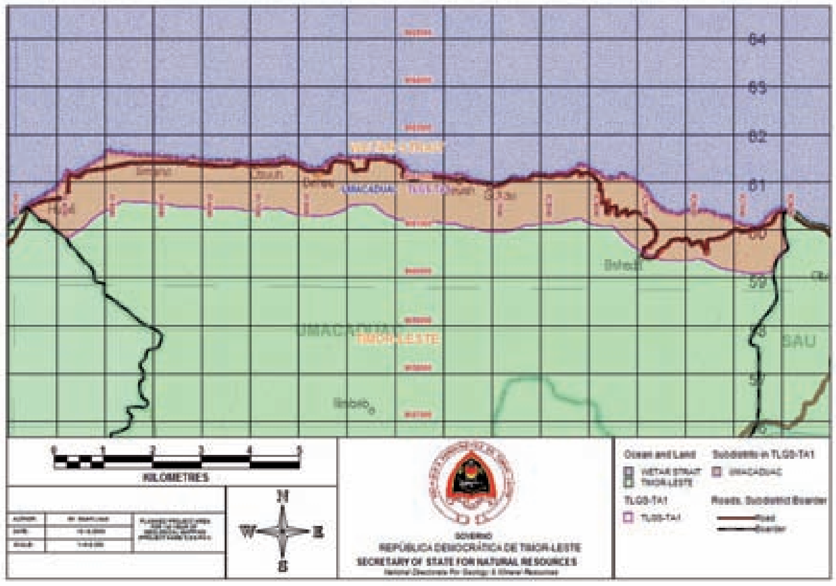
- Project Staff
  - During Phase 1 recruitment of staff will be conducted
  - The minimum staff required for the project will include;
    - Director of Geology and Minerals/Program Officer x 1
    - Project Manager x 1
    - Advisory Board x 8
    - Logistics Officer - Drivers x 4
    - Logistics Officer – Field Assistants x 8
    - Logistics Officer – Cooks/Cleaners x 4
    - Geological Specialists x 4
    - Senior Geologists x 4
    - Junior Geologists x 12

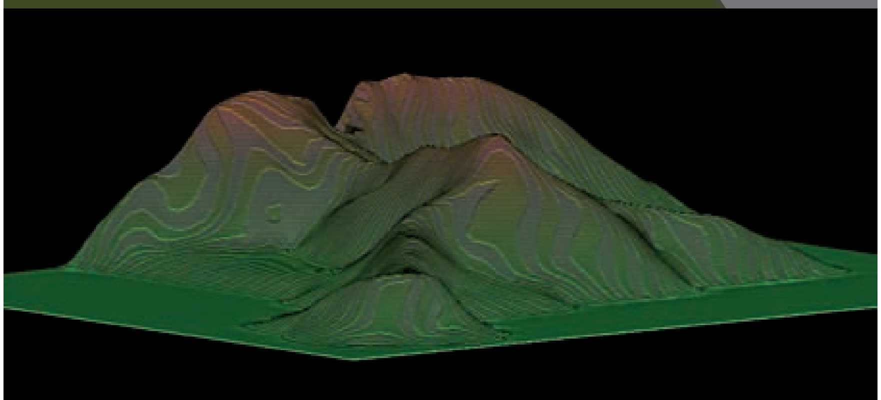
Project Description TLGS-PA1

- **Training (During Phase 1)**
  - The training period for the Junior Geologists will cover topics such as;
  - Understanding Topographical and Geological maps, and planning Traverses for surveys,
  - Identification of lithological rock types; focussing particularly on sedimentary rocks (fossils, sedimentary structures, grain size, sordidness, stratification, colour, roundness),
  - Identification, measuring, and recording geological structures
  - Mineral identification
  - Cross section construction and interpretation

Project Description TLGS-PA1

- **Training (During Phase 1)**
  - Methods of mapping, sampling, and data recording
  - Basic GIS (using MapInfo, surfer 7/surfer 8, Didger 4, and additional geo-software programs)
  - An area for geological mapping exercises has been designed along the main road between Dili and Manatutu (TLGS-TA1). Basic rock, mineral, and structure identification will be conducted, however the main focus will be in the eastern end of the area where very good outcrops of fossiliferous sedimentary units are located. Kristo Rei will also be used as a site for training





Model of Kristo Rei and surrounding mountains

Project Description TLGS-PA1

- **Training (During Phase 1)**
  - Training in Behau – Manatuto area has been planned for at least two weeks in early April each year as new staff come on board
  - Prior to field training some basic theory training will be provided with some GIS training thereafter
  - Actual mapping of project areas are aimed to commence from early May each year (this is the time generally when the monsoon season has ended)

Project Description TLGS-PA1

- **Phase 2 will involve;**
  - Implementation of the geological field mapping work within the project area
  - Monthly meetings with Geological Specialists and Advisory Board

Project Description TLGS-PA1

- Mapping Method during phase 2
  - The TLGS-PA1 project area is designed to have an area of 37km x 37km (1369 square km)
  - As previously mentioned, this area has been broken down into four quadrants
  - The field staff will be broken down into four groups
  - Each of the four field teams will spend three weeks in each quadrant during the course of the phase 2

Project Description TLGS-PA1

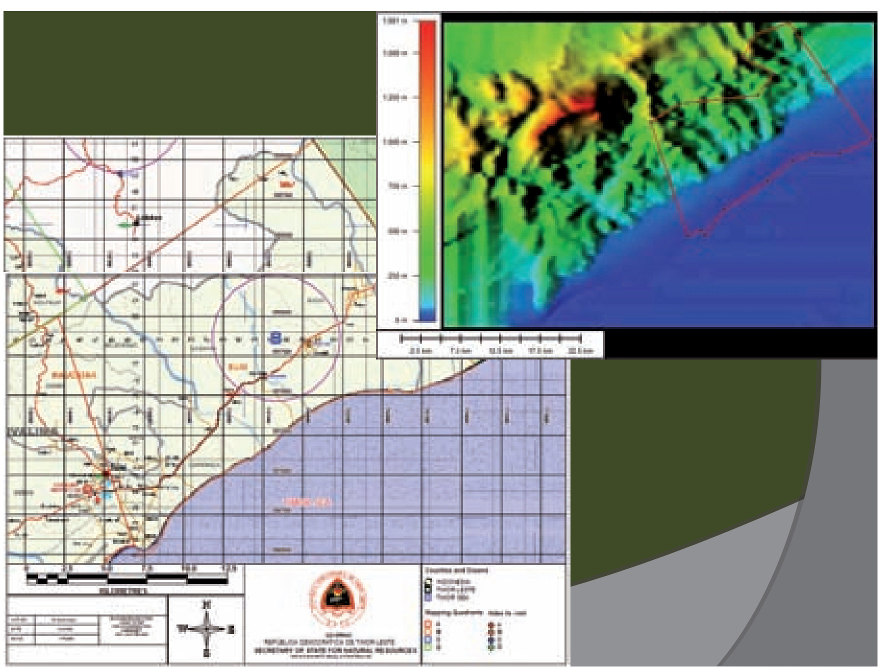
- After a field team spends 3 weeks in a quadrant, a meeting shall be held for a week in Dili with all groups including the specialists and the advisory board to discuss the overall progress of the project and generate ideas/interpretations of the data plus to provide a means of data quality control
- If however, the project does not contain enough staff to map the entire area of TLGS-PA1, quadrant B will be selected for mapping
- Whilst quadrant B is being mapped, a continual search for other staff will be conducted and other quadrants will be mapped as staff are hired

Project Description TLGS-PA1

- Mapping Method during phase 2
  - During the mapping period, data and samples will be reviewed by the specialist geologists
  - The specialists can then start generating theories based on the data and provide additional concepts to strengthen the quality of the field work
  - Each group will prepare for the next quadrant they will be working in through reading up on data gathered by previous groups work

Project Description TLGS-PA1

- Each group will move to the next quadrant in a clockwise direction
- Again, if not enough staff are available to work in all four quadrants, quadrant B will be focused upon. In this case quadrant B may be sub-divided into sub-quadrants B1, B2, B3, and B4.
- Traverses for mapping will follow main rivers, tributaries, and where locations lack drainage systems for ease of mapping, linear traverses



Project Description TLGS-PA1

- **Phase 3 will involve;**
  - This is the interpretive phase
  - Compilation of field reports
  - GIS work and map production
  - Cross-section and stratigraphic relations diagrams
  - Laboratory sample analyses (palynological and thin section analyses)
  - Interpretation and organisation of data, and
  - Presentation of project results

Project Description TLGS-PA1

- **Phase 4 will involve;**
  - Debriefing on current progress, what was learned and what modifications need to be made in preparation for the next project area
  - Designing, planning, discussing next project area, and
  - Overall preparations and training for the next project area

Phase 2: Project Contingency Plans

- The previous sections described the program implementation at 100% capacity (all geological mapping staff positions filled)
- The following section will briefly suggest project implementation at 75%, 50%, and 25% capacity
- At 75% capacity, project implementation will essentially, be the same as at 100% capacity however only three teams will be active in the project area per month. This means one quadrant will be inactive per month of mapping. In this scenario the TLGS-PA1 Project will be broken down into four quadrants as normal and mapped by each of the available groups. The project area will remain the same size and each individual team will still be expected to complete one quadrant per month.

Phase 2: Project Contingency Plans

- At 50% capacity, to maintain a reasonable standard of quality control, only two quadrants may be focused upon over the total four month period (i.e. two months will be spent per selected quadrant). What would happen is a follows;
  - the two highest priority quadrants would be selected,
  - each selected quadrant would be split into two sub-quadrants,
  - the first quadrant to be mapped will be selected,
  - each team would then spend three weeks in each sub-quadrant and one week discussion in Dili per month, focussing on the first selected quadrant (swapping data and discussing results during the week in Dili)
  - both mapping teams would then move off to the next selected quadrant where the same procedure would be applied for the final two months.

Phase 2: Project Contingency Plans

- At 25% capacity, (which is applicable to the current situation for TLGS), to maintain a reasonable standard of quality, only one quadrant will be focused upon over the total four month period as there is only enough staff members to make one field team. What would happen is a follows;
  - the highest priority quadrant would be selected,
  - the quadrant would be split into four sub-quadrants,
  - the team would then spend three weeks in each sub-quadrant and one week discussion in Dili per month, until four months work is achieved

Current Project Status

- The project is currently running at 25% capacity; that is, there are 3 junior geologists, 1 senior geologist, 1 project manager, but no specialists.
- The quadrant chosen to be mapped is TLGS-PA1 Quadrant B. The project staff are currently conducting reconnaissance mapping via four major river systems running through quadrant B.
- Due to the rapidly approaching monsoon, the team only has a maximum of one month to complete the reconnaissance; essentially that means one week will each be designated to one of the four major rivers.
- Although reconnaissance is taking place, phase one is ongoing especially with regards to locating all necessary data, maps, etc... and properly cataloguing, storing and recording these into databases

Challenges

- There are several challenges faced during the implementation of this program;
- Lack of human resources
- Lack of finance
- Lack of equipment and software required to undertake thorough geological field investigation
  - With regards to the lack of human resources; there are few trained national geologists within the country of Timor-Leste, those that are have been trained to a general level of geology not to a more advanced / scientific level required for high quality field investigation
  - With regards to lack of finance, this of course is a major challenge as it effects not only buying power for equipment and software, it also retards the logistics of the program, often delaying an activity by several weeks

Conclusion

- GovTL via SERN has a geological mapping program for the country of Timor-Leste which is aimed at completing a detailed geological survey of Timor-Leste over the next five years, building/development of a trained team of Timorese geologists, development/update the current available geoscientific information within Timor-Leste
- Administrative setup, staffing, and training will comprise phase one of the program, this is ongoing.
- Implementation of reconnaissance and detailed geological field investigation comprises phase two, this is current
- Interpretation, reporting, and presentation will comprise phase three
- Debriefing and project modifications will comprise phase four
- The project is currently running at 25% capacity and is faced with human resource, equipment/software, and financial challenges