GW-5

Project Report of the

CCOP-GSJ/AIST-DGR

Groundwater Phase III Project Kick-Off Meeting

10-12 February 2015, 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

The CCOP-GSJ/AIST-DGR Groundwater Project Phase III Kick-off Meeting was held on 10-12 February 2015, in Bangkok, Thailand. It was attended by forty-five participants from Cambodia, China, Indonesia, Japan, Korea, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste, Vietnam and the CCOP Technical Secretariat. In the meeting, participants confirmed some issues on Groundwater Project Phase II and discussed outline of Groundwater Project Phase III with the main theme, "Renewal of database for the hydro-geological map in CCOP regions".

Each CCOP Member Country made a country presentation on the topic, "*Country's Activity Plan and Possibility of Compiling GW Data under CCOP GW Project Phase III*". Since the current status on the groundwater database management system varies from one CCOP member country to another, three groups have been formed as DB Group 1, DB Group 2 and Public Policy Group.

This is the publication which was compiled each country report presented in the CCOP-GSJ/AIST-DGR Groundwater Phase III Kick-off Meeting. These reports have made clear the target, framework and cooperation policy of Phase III project, and will conduct outcome of the GW Phase III Project. I believe we will be able to have some solutions about not only groundwater management but also energy problem in the CCOP member 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

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The Minutes of the CCOP-GSJ/AIST-DGR Groundwater Project Phase III Kick-Off Meeting 10-12 February 2015, Bangkok, Thailand

The CCOP-GSJ/AIST-DGR Groundwater Project Phase III Kick-off Meeting was held on 10-12 February 2015, in Bangkok, Thailand. It was attended by forty-five participants from Cambodia, China, Indonesia, Japan, Korea, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste, Vietnam and the CCOP Technical Secretariat.

The Opening Ceremony started with the Welcome Remarks and Addresses delivered by Dr. Adichat Surinkum, Director of the CCOP Technical Secretariat, and Dr. Youhei Uchida, Groundwater Project Leader, Senior Researcher of Geological Survey of Japan, AIST. The Opening Speech was made by Miss Vilavan Thaisongkram, Director of Central Administration, Department of Groundwater Resources, Thailand.

Dr. Youhei Uchida from the Geological Survey of Japan (GSJ/AIST) presented the outline of Groundwater Project Phase III with the main theme, "Renewal of database for the hydro-geological map in CCOP regions". He then made an update on the status of the CCOP Groundwater Sub-Project "Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions". He also introduced the new CCOP project funded by Japan, the Geoinformation Sharing Infrastructure (GSi) Project with the main aim of compiling various geoscientific information in CCOP countries, and constructing a database on an open Web, using the world standard formats and GIS.

Each CCOP Member Country made a country presentation on the topic, *Country's Activity Plan and Possibility of Compiling GW Data under CCOP GW Project Phase III*.

Since the current status on the groundwater database management system varies from one CCOP member country to another, three (3) groups have been formed accordingly as follows, and Group Leader for each was identified:

DB Group I – *China, Indonesia, Japan, Korea (Group Leader), Thailand*

- GW observation system has been installed already
- GW data has been monitored
- Web-based GW DB has been compiled

DB Group II – *Indonesia (Group Leader), Malaysia, Philippines, Vietnam*

- GW observation system has been installed already
- GW data has been monitored
- There is no Web-based GW DB

Public Policy Group – *Cambodia, Lao PDR, Myanmar, PNG, Timor-Leste, CCOP TS / Dr Adichat (Group Leader)*

- There is no GW observation system

For fiscal year 2015, the following workplan for each group has been agreed.

DB Group (I & II)

- System design for GW Geo-Portal (GSJ will propose the design)
- Selection of area for converting Web GIS System
- Try to convert GW data to the Web GIS System

Public Policy Group

- Attending to GW Training program
- Making a report for draft of public policy for GW management

The followings are the DB Group countries' action plan to achieve the 2015 workplan.

China *(Mr Liu Wenbo).* With China Geological Survey's permission, monitoring data (twice/yr) of the whole of China based on the published yearbook will be uploaded to the CCOP GSi Project system. China hydrogeological map with a scale of smaller than 1:5M will be uploaded as well.

Indonesia *(Mr Rudy Suhendar).* Hydrogeological map, groundwater metadata, quantity and quality GW data, aquifer data of the Java Island will be uploaded to the CCOP GSi Project system.

Japan *(Dr Youhei Uchida)****.*** From May 2015 to January 2016, groundwater data of Ishikari Plain, Kanto Plain and Kumamoto Plain will be uploaded to the CCOP GSi Project system.

Korea *(Dr Kyoochul Ha)****.*** Hydrogeological map 1:250,000 and groundwater data available on published yearbook of the whole Korea will be uploaded to the GSi Project system.

Thailand *(Mr Rungroj Benjakul & Ms Rawiwan).* Hydrogeological map (1:50k scale), groundwater map, well data, monitoring well data (gw level twice/yr, gw quality once/yr) of the Upper Chaophraya (2), Sukothai, Phitsanulok and Pichit Provinces.

Malaysia. In 2015, Excel groundwater database of Langat Basin will be uploaded to the CCOP GSi Project system, and by March 2016, hydrogeological and groundwater maps of the same basin will be uploaded.

Philippines. In 2015, groundwater data in excel format of Luzon Island will be uploaded to the CCOP GSi Project system, and by March 2016, GIS groundwater/hydrogeological maps will follow.

Vietnam. In 2015, groundwater data in excel format of Thanh Hoa, Hatinh, Quang Nam and Quang Ngai will be uploaded to the CCOP GSi Project system. With the permission of NAWAPI, GIS data will be uploaded to the system by January 2016.

During the discussion, it was agreed that target data to upload to the CCOP GSi Project are all published data and maps for groundwater.

The **Public Policy Group** has come up with the following plan for the year 2015.

- More than one participant to KIGAM's Regular Training Course on Groundwater.
- Join the KIGAM-CCOP Groundwater Meeting in Bangkok, Thailand scheduled in May 2015.
- Make requests for on-the-job training in selected area of each country member in the group.

Specific issues in each country member of the Data Policy Group were also raised as follows,

<u>Timor Leste</u>
- Hydrogeological mapping, with 100.000 scale
- GW Quality in Dili
- Identify GW Recharge area
- Supporting Geophysical study to identify aquifer layers.
- GW modeling

<u>Lao PDR</u>
- HyGIS in Vientiane province (2015)

<u>Myanmar</u>
- Hydrogeological mapping
- Qualitative and quantitative analyses of GW resources
- Contamination control
- Possibility of organizing GW workshop in Mandalay.
- Conservation for Mandalay area
- INSAR is required
- Waste water management for mining

<u>Cambodia</u>
- Hydrogeological mapping (100.000 Scale)
- Recharge area (identify the GW protection area)

Ms Marivic Uzarraga from the CCOP Technical Secretariat made a presentation on the progress of the recent developments of the CCOP-GSJ Geoinformation Sharing Infrastructure for East and Southeast Asia (GSi) Project, including the tentative date of the GSi Project's First Meeting, 1 – 4 September 2015 in Bangkok, Thailand. Ms Uzarraga also made recommendations to the GW Project Phase III, for the GSi Project as follows:

- Make a Data Inventory of published data in each country, which can be made available to the system.
- Agree on Data Policy, language of data to be made available to the GSi Project System
- Identify possible queries and tools to be used for groundwater data analysis
- GW P3 Members are to be Groundwater Data Coordinators of the GSi Project
- Participate the GSi Project System Training using own data
- Organize Country Working Team Training on the Usage of the GSi Project

System Training using own data.

Dr. Reo Ikawa from GSJ gave a lecture with the title, "Sustainable Water Resource Management and Development Using a Groundwater Database". His presentation gave concrete examples of the use of groundwater database, and provided analytical possibilities which can be embedded in the GSi Project system. He also recommended that aside from groundwater data, surface water data be collected for the Project as well.

Dr. Kyoochul Ha from KIGAM presented on KIGAM's activity for GW training course in CCOP. Updates on the courses offered by KIGAM's International School for Geoscience Resources (IS-Geo) can be found at IS-Geo's website, http://isgeo.kigam.re.kr/.

This minutes is adopted as signed:

Cambodia	Malaysia
China	Myanmar
Indonesia	Philippines
Japan	Thailand
Korea	Timor-Leste
Lao PDR	Vietnam

COUNTRY REPORTS

The Current Status of Groundwater Use in Siem Reap Region

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3-PRESENT STATUS OF GROUNDWATER MONITORING

(1) Monitoring Activities of Siem Reap Water Supply Authority

In the Study Area, 10 monitoring wells were constructed under the Study on Water Supply System for Siem Reap Region in Cambodia (2000). SRWSA has collected the monitoring data every month. Manual measurement of groundwater level has been conducted once a month to confirm the reliability of monitoring system since July 2007.

However, Activities done by SRWSA so far not necessarily enough in reference to recommendations made in the Basic Design Study (report) on the Project for Improvement of Water Supply System on Siem Reap Town (2003). Recommendation conducted by the above Report and actual situations of SRWSA activities are shown in Table 3.1. In addition, existing monitoring wells, reliability of monitoring data, and necessity of calibration are shown in Table 3.2. SRWSA should take proper measures to improving this situation as described in "conclusion and Recommendation".

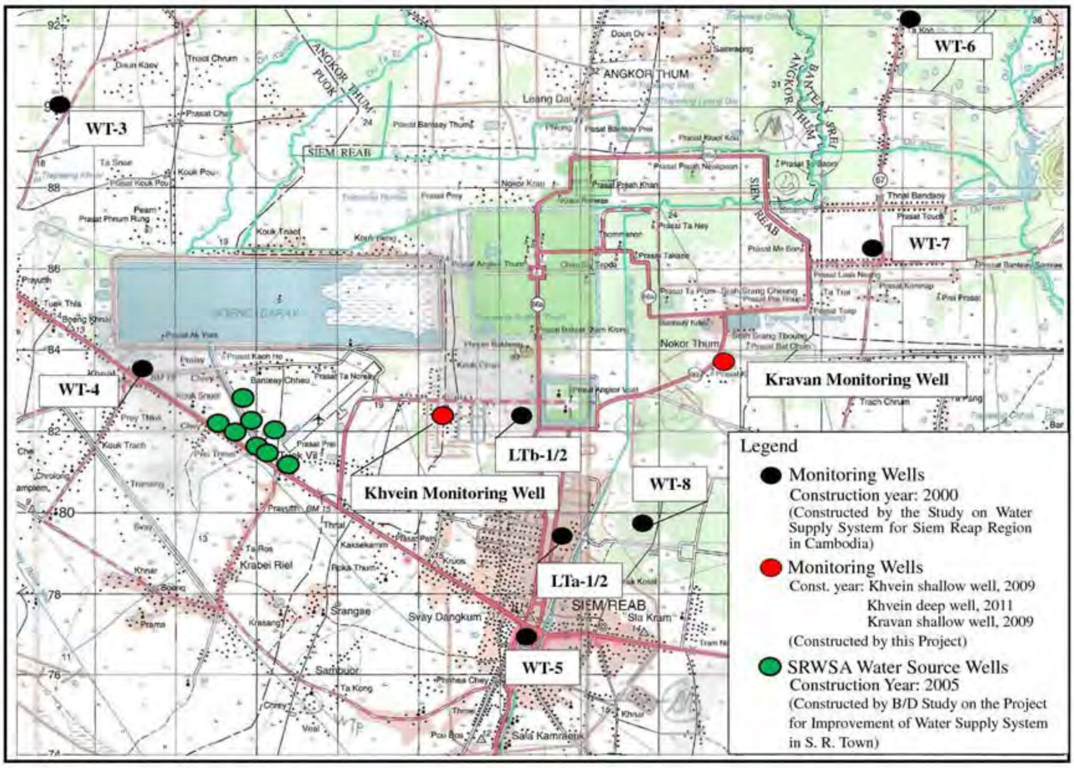

Figure 3.1 Location Map of New and Existing Monitoring Wells

Table 3.1 Outline of Monitoring Wells

No.	Well No.	Well Depth (m)	Casing Size and Materials	Screen Depth (m)	Remarks
1	WT-3	36	PVC 6"	20.38-32.20	
2	WT-4	29	PVC 6"	13.38-25.20	
3	WT-5	58	PVC 6"	42.38-54.20	
4	WT-6	29	PVC 6"	13.38-25.20	
5	WT-7	60	PVC 6"	44.38-56.20	
6	WT-8	83	PVC 6"	67.38-79.20	Under the building of New APSARA building (Now under construction)
7	LTa-1	72	PVC 6"	63.62-71.90	Measurment of Groundwater Level and land
	LTa-2	35	PVC 6"	26.61-34.90	Measurment of Groundwater Level and land
8	LTb-1	73	PVC 6"	64.61-72.90	Measurment of Groundwater Level and land
	LTb-2	40	PVC 6"	31.61-39.90	Measurment of Groundwater Level and land

Table 3.2 Monitoring Activities Done by SRWSA

No.	Recommendations made by 2003 B/D report*	Activities Done by SRWSA
1.	Proper O&M for the supplied monitoring facilities	Some damaged equipment are being left at the sites in disrepair, resulting in missing data.
2.	Making good use of the monitoring data	Data collection has been done; however, analysis on the collected data was not made.
3	Taking proper countermeasures when unusual monitoring data are found.	Manual measurement of groundwater level has been done since July 2007. However, detailed analysis on the collected data has not been conducted. For example, manual and automatic monitoring data were not compared even some malfunction items were found.
4	Disclosure of collected information	Due to difficulties of confirmation of data reliability, SRWSA has not disclosed the data till now.

(Note) 2003 B/D report*: Basic Design Study (report) on the Project for Improvement of Water Supply System in Siem Reap Town in the Kingdom of Cambodia (2003)

(2) Monitoring Activity by DOWRAM (Department of Water Resources and Meteorology)

The government of Cambodia enacted the "Water Resources Management Law" in June 2007 and the monitoring works for water resources were transferred from MIME toMOWRAM. At present, MOWRAM does not still carry out monitoring works on groundwater.

3-2 Construction of New Monitoring Wells

Under this study, a monitoring well (shallow well) was constructed in the premise of Kravan primary school on October 2009 and two monitoring wells (shallow and deep wells) were constructed in Khvein primary school on October 2009 and May 2011, respectively. The Khvein primary school is located at 2.3 km west of the Angkor Wat ruins. The Kravan primary school is located 3.2 km north east of Angkor Wat. These monitoring wells are constructed to monitor influence of the SRWSA production wells and the private wells in the city. Same type of the monitoring equipment used for the existing monitoring wells were installed in the wells as detailed in Table 3.4.

Table 3.3 Existing Monitoring Wells, Reliability of Monitoring Data, and Necessity of Calibration

No.	Well No.	Well Depth (m)	Available Monitoring Data Period	Current Operating Condition and Reliability of Monitoring Data	Necessity of Calibration of Monitoring Equipment
1	WT-3	36	2003/8-2008/4	• Removal of monitoring equipment excluding solar panel and lightning rod (2008/8/21) Removal Reason As WT-6 and LTa monitoring sites were more important than WT-3 site due to locations near the city center and/or many important ruins with no monitoring function, SRWSA transferred WT-3 equipment to them. • Transfer of WT-3 cable sensor to WT-6 site. • Transfer of WT-3 data logger to LTa site Reliability of monitoring data before removal of the equipment have good reliability..	After May 2005, There is no monitoring equipment.
2	WT-4	29	2007/3-Present	Operational monitoring equipment • Monitoring data (2007/3-2008/3) have good reliability. . • Monitoring data after the date of 2008/3 show low reliability.	Necessity of calibration
3	WT-5	58	2007/3-Present	Operational monitoring equipment. Monitoring data have good reliability.	Not necessity of calibration
4	WT-6	29	2008/7- Present	Operational monitoring equipment. Monitoring data show low reliability.	Necessity of calibration
5	WT-7	60	2003/8- Present	Operational monitoring equipment Monitoring data have good reliability.	Not necessity of calibration
6	WT-8	83	2008/4-2010/9	• Operational monitoring equipment. • ASPARA museum building is under construction. Monitoring facility is planned to be left in underground. Under the construction, the inside of monitoring facility was buried and submerged. Monitoring data show low reliability.	Necessity of calibration.
7	LTa-1	72	2008/8- Present	Operational monitoring equipment • Reliability of monitoring data is low. • At the transfer time of WT-3 data logger, equipment's connection error between shallow and deep wells was happened. Thus, monitored data of both wells inverted.	Necessity of calibration.
	LTa-2	35	2008/8- Present	Operational monitoring equipment. • Reliability of monitoring data is low. • At the transfer time of WT-3 data logger, equipment's connection error between shallow and deep wells was happened. Thus, monitored data of both wells inverted.	Necessity of calibration.
8	LTb-1	73	2003/9- Present	Operational monitoring equipment. Monitoring data have good reliability.	Not necessity of calibration
	LTb-2	40	2003/9- Present	Operational monitoring equipment. Monitoring data have good reliability.	Not necessity of calibration

(Note) Present condition of the above table is as of September 13, 2009. On Khvein and Kravan monitoring wells, they were constructed after September 2009. As they kept accuracy of observation, their descriptions in the above

Table 3.4 Outline of Newly Constructed Monitoring Wells in 2009 and 2011

No.	Well No.	Well Depth (m)	Casing Diameter and Materialas	Screen Depth (m)	Static Water Level (m)	Well Location	Construction Year
1	Khvein Well-1	40	UPVC 6"	16-20 24-28	0.40	Khvein Primary School	October 2009
2	Khvein Well-2	80	UPVC 6"				June 2011
3	Kravan Well	40	UPVC 6"	20-24 28-36	0.57	Kravan Primary School	October 2009

(Source) Construction report by Contractor (Octiber 2009 and June 2011)

In the same locations as monitoring well sites, core borings of 80 m depth and core size 66 mm were conducted to check geological conditions prior to well drilling. Observation results of core samples are shown in Supporting Report. The observation survey of the core boring samples showed the following results:

3.2.1 Khvein site

In Khvein site, clay formations are mainly distributed from ground surface to depth of 9 m. In depth of 9 m to 50 m, sand and sandy clay formations are manly distributed. Clay formations with thickness of about 13 m are distributed in depth of 50 m to 63.5 m. Under the clay formations, sand formations are also distributed in depth of 63.5 m to 80 m. Based on their hydrogeological conditions, it is considered that the layers in Khvein site can be divided into two aquifers of shallow and deep ones: shallow aquifer on upper formations than clay formations distributed in depth of 50 m to 63.5 m and deep aquifer on lower formations than the clay formations.

3.2.2 Kravan site

In Kravan site, clay or sandy clay formations in depth of ground surface to 7 m are mainly distributed. In the lower part of the clay or sandy clay formations, sand formations are distributed up to depth of 80 m. Based on the geological formations, it is considered that there is only one aquifer in Kravan site.

Based on the hydrogeological conditions by observation results of core samples as shown in the above, in Khvein site, two monitoring wells for shallow and deep aquifers were constructed and in Kravan site, one monitoring well for shallow aquifer was constructed. The monitored groundwater level at shallow and deep monitoring wells in Khvein site and the level at shallow monitoring well in Kravan site are shown in Supporting Report.

3.3 Private Wells

The Study Team conducted well inventory survey to assess the influence of lowering of groundwater table in the Study Area as described in the previous chapter. A total of 280establishments were selected including 75 hotels, 115 guesthouses, 40 restaurants, 10factory/manufactures, and 40 other establishments as car wash, schools, entertainment centers, and clinics. The data collected included such information as well owner, locations of wells (GPS data), number of wells, well depth, well diameter, screen depth, withdrawal volume of groundwater, water use/purpose, availability of treatment plant etc.

3.3.1 Distribution of Private Wells

A total number of the private wells with a capacity of over 10m3/day are 128 in the surveyed area. Hotels and factories account for over 70 % of the total number of private wells. The private well with a pumping capacity of more than 10m3/day extracts 96 percent of the total volume of groundwater usage in the city.

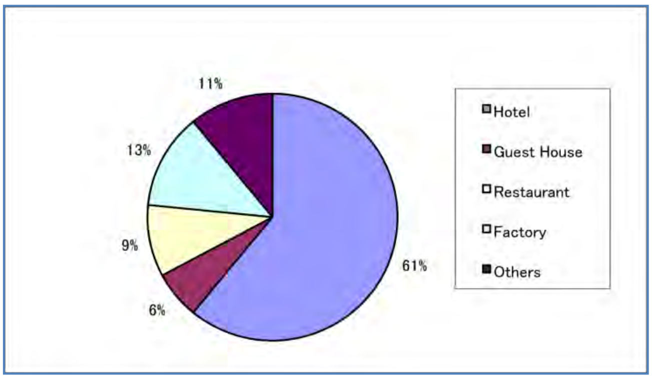

Figure 3.2 Distribution of Private Wells with Pumping Capacity of Over10 m3/day

Through the well inventory survey, the private wells with a pumping capacity of more than 10m3/day were identified by using the GPS data (UTM coordinate). The locations are illustrated in 1km x 1 km grids as shown in Figure 3.3. Figure 3.4 also shows a total extraction volume by the private wells with a capacity of over 10m3/day in each 1 km x 1 km grid.

Private Wells with a capacity of over 10m3/day are mostly distributed in the city center. In dry season, extraction volume of groundwater by private wells reaches a total of 5,553 m3/day or 96 % of 5,786 m3/d. The highest extraction of groundwater sources are made in the city center and along the national road number 6 as shown in Figure 3.4 while the 10 – 50 m3/day extraction areas as shown in light blue color are located in the surrounding areas of the city center.

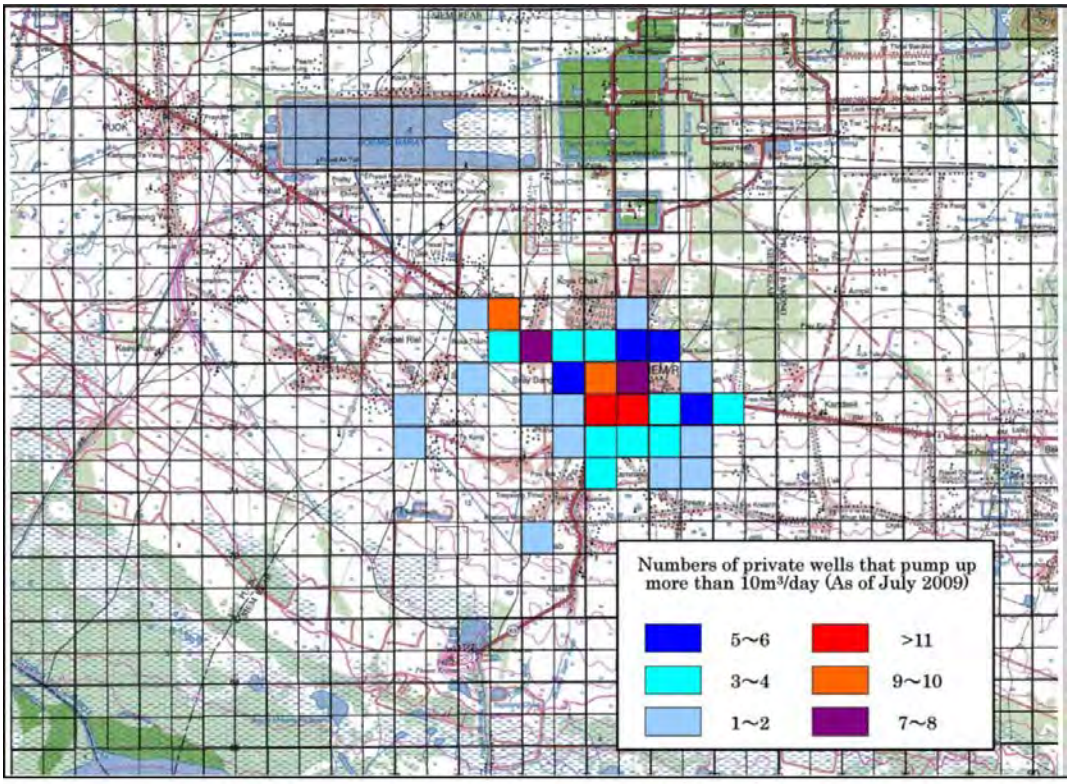

Figure 3.3 Distribution of Private Wells with Pumping Capacity of Over 10 m^3/day

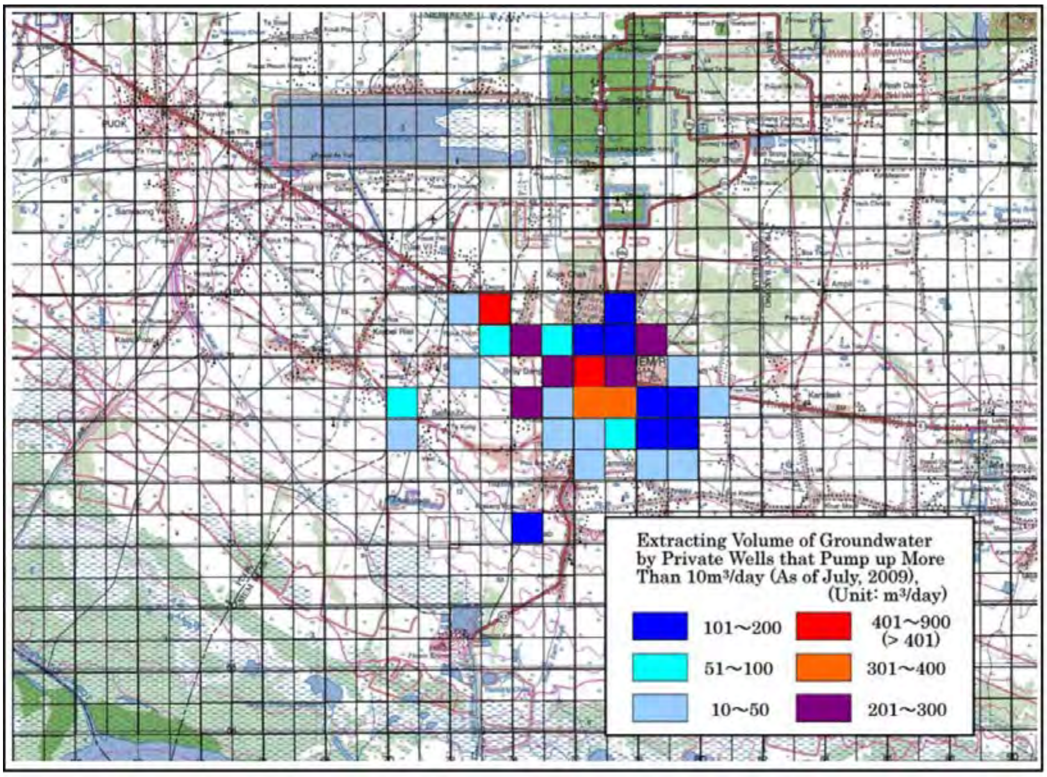

Figure 3.4 Distribution of Extraction Volume by Private Wells with Pumping Capacity of Over10 m3/day

3.3.2 Analysis on Tapped Aquifers and Withdrawal Volume

Based on information gathered in the well inventory survey, tapped aquifer and withdrawal volume of groundwater by the private wells were studied. In checking tapped aquifer, well depth is an important parameter. Every private well had information of well depth. But, setting depth of screens was recorded in only 26 % of a total of 383 wells. Majority of the wells have no information on screen depths.

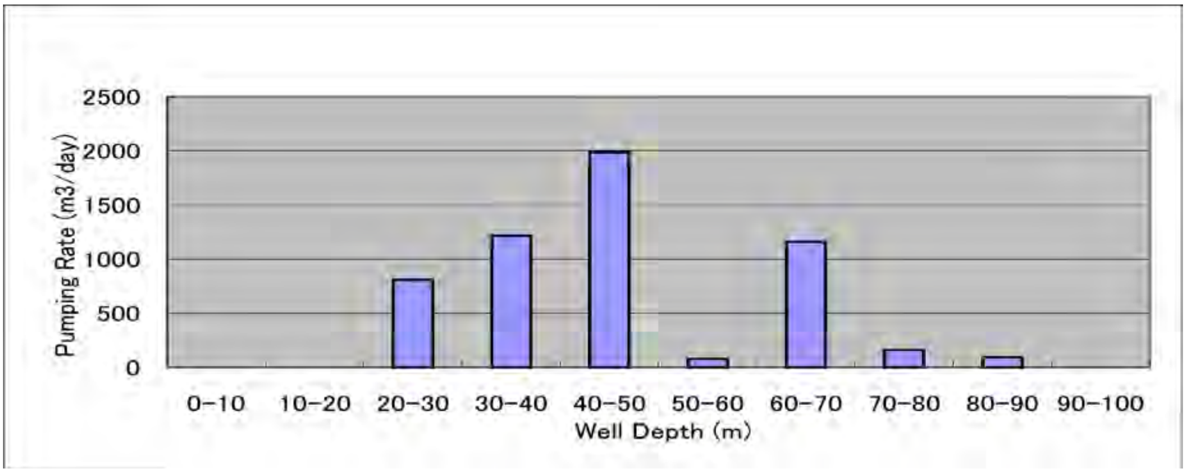

Figure 3.5 Well Depth and Extracted Volume of Groundwater by Private Wells

The collected data show that the screens are set within a depth of 5 to 10 m from the well bottom. Thus, tapped aquifer was identified assuming that the setting depth of screens was set at the depth within 10 m from the well bottoms. Figure 3.5 shows the relationship between well depth and extracted volume of groundwater of the private wells. Groundwater is mainly extracted in the depth of 20 to 50 m and 60 to 70 m. The private wells are mostly located in the city center. Thus, WT-5 monitoring well located in the city center was used for this analysis. The tapped aquifer of WT-5 was identified in the Study on Water Supply System for Siem Reap Region in Cambodia (2000) as illustrated in Figure 3.6.

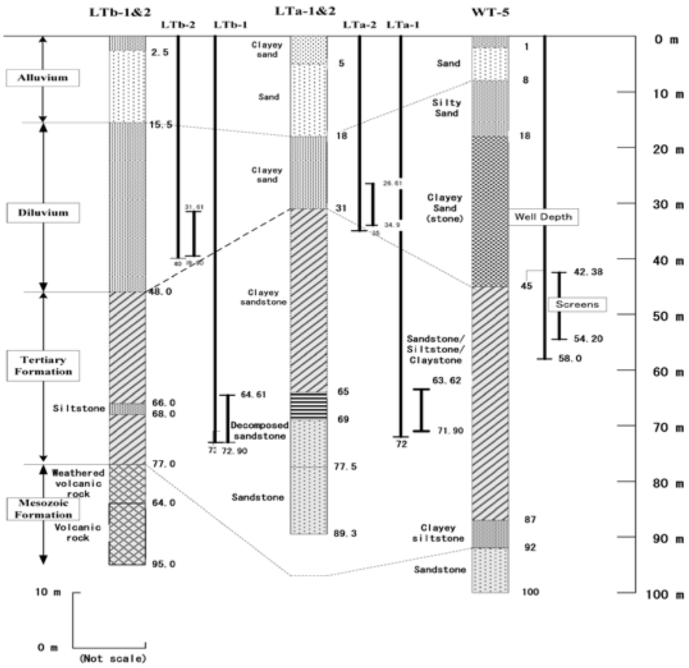

Figure 3.6 Well Structures and Geological Conditions of WT-5, LTa, and LTb

According to the Study on Water Supply System for Siem Reap Region in Cambodia (2000),Alluvium is distributed within the depth of 10 to 20 m. Diluvium is located within the depth of 10to 40 m. Both layers are underlain by Tertiary layers with thickness ranging from 40 to 50 m. Under Tertiary layers; Mesozoic volcanic layers (rocks) are distributed. Alluvium layers are formed by clayey sand/sand. Diluvium is composed of silty sand/clayey sand (stone). Tertiary layers are made up of siltstone/clayey sandstone/clay stone.

Compared with the geological condition shown in Figure 3.6 and tapped aquifers of the private wells shown in Figure 3.5, the private wells are estimated to extract groundwater from the Diluvium and partially from a part of Tertiary formations. Considering the above situations, Tertiary formations of siltstone/clayey sandstone/clay stone may partially have fissures/fractural zones, though they are generally classified as aquiclude.

3.3.3 Analysis on Influence of Pumping Up of Private Wells

Influence of pumping up of the private wells was studied using data of WT-5 and LTb monitoring wells. LTa well data was not used in this study by the reason why a result of cross-check between automatic and manual recording data didn't accord. WT-5 monitoring well is located in the yard of SRWSA office near the Siem Reap River. The old treatment plant used three wells with a depth of about 60 m for water supply until November to December, 2005. The monitoring data of WT-5 recorded before November to December 2005 indicated a large daily fluctuation pattern with lowering of water level of 140 to 157 cm (as of January 2004) as shown in Figure 3.7.

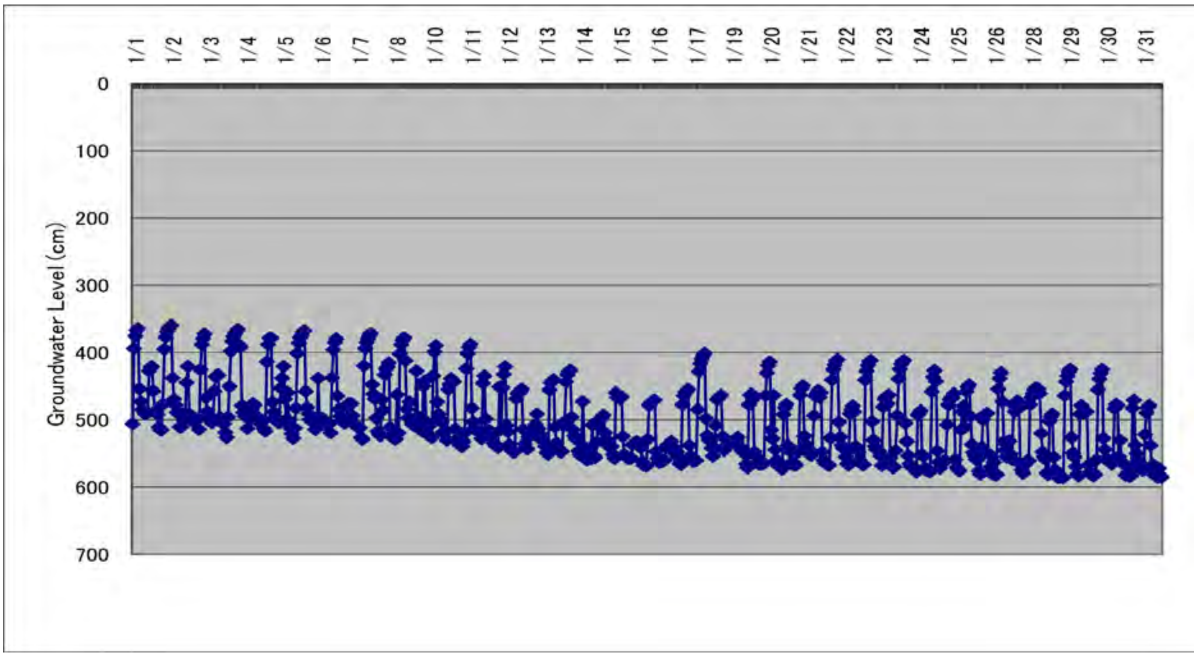

Figure 3.7 Groundwater Level at WT-5, January 2004

After the water treatment plant was abandoned, the monitoring data recorded from 7 to 9 January2008 indicated small daily fluctuation pattern ranging from approximately 3 to 6 cm in the morning time from 7:00 to 11:00 and from approximately 1 to 3 cm in the evening time from16:00 to 19:00. The lowering ranges were almost same trend in the rainy and the dry seasons. This range of water level fluctuation is considered to be influenced by exploitation of groundwater in the city. The example of daily fluctuation at WT-5 monitoring station from 7 to 9 January 2008 is shown in Figure 3.8.

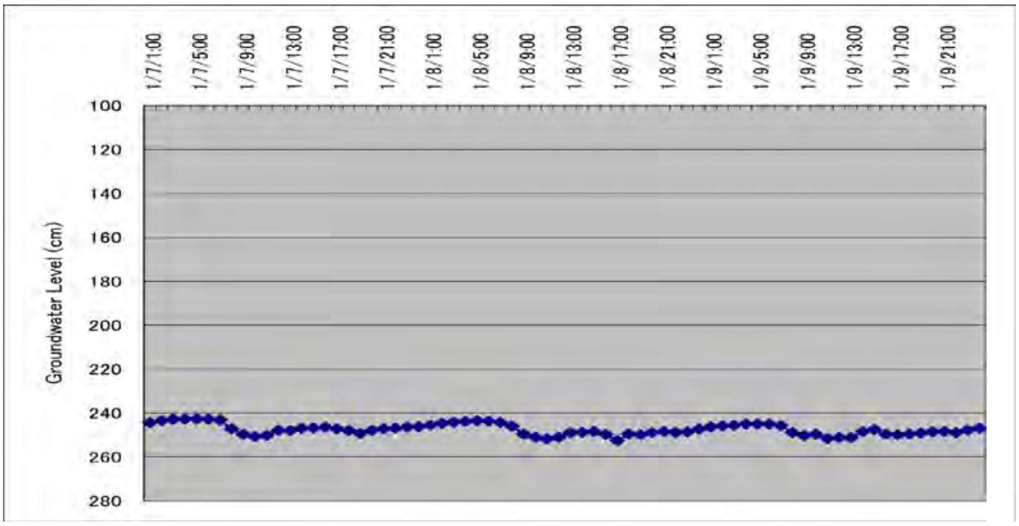

Figure 3.8 Groundwater Level at WT-5, 7-9 January 2008

On the same day, LTb-2 shallow monitoring well recorded fluctuations from 15 to 17 cm in water level which was larger than that of WT-5. One interpretation is that that the WT-5 screen was set atthe Tertiary aquifer, considering the magnitude of daily groundwater level fluctuation and its columnar section. The LTb-2 screens were set in the Diluvium layers so that the lowering of groundwater level at LTb-2 can be larger than that of WT-5. Extraction volume of groundwater from Diluvium layers by the private wells is more than that of Tertiary layers. Daily groundwater fluctuation pattern at LTb-2 is shown in Figure 3.9.

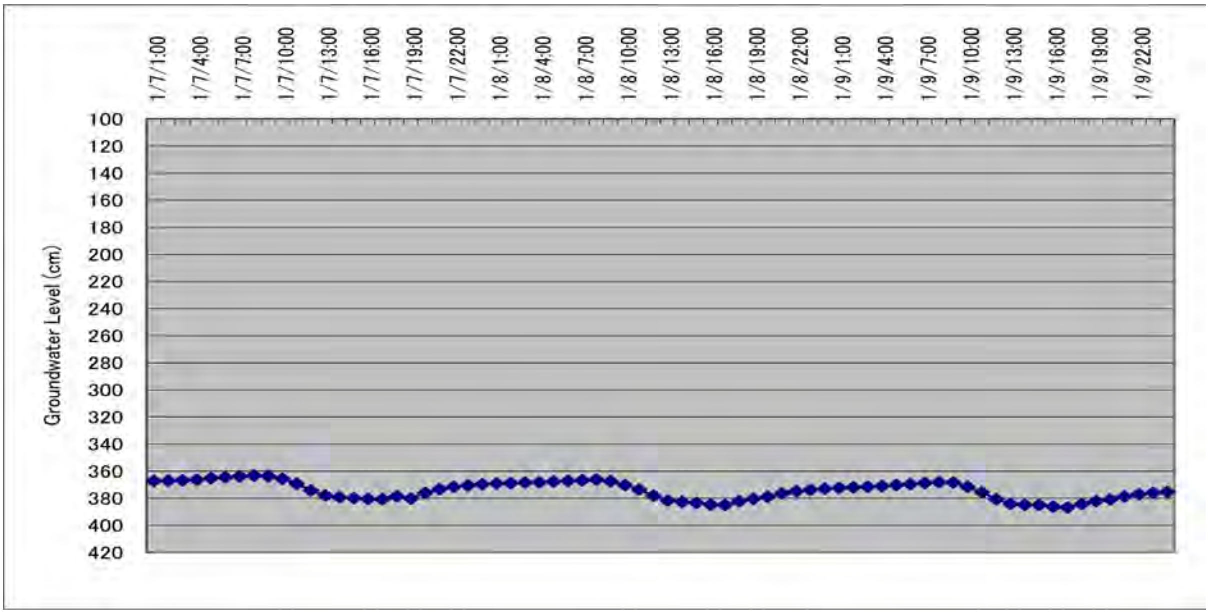

Figure 3.9 Recorded Daily Fluctuation of Groundwater Level at LTb-2, 7-9 January 2008

15 to 17 cm of the fluctuation range of LTb-2 monitoring well is very small compared to yearly fluctuation of groundwater level of about 2-3 m in Siem Reap area.

Monitoring data at LTb-1 deep well didn't indicate clear daily fluctuation pattern. Thus, the fluctuated monitoring data of WT-5 well, located in the city center, showing the lowering of groundwater level from 3 to 5 cm, can be translated to be influence of pumping of groundwater byprivate wells in Tertiary formation. The pumping by private wells did not have an impact to theLTb-1 monitoring site which is located about 5 km from WT-5 monitoring well. Monitoring data of LTb-1 deep well on 7-9 January 2008 is shown in Figure 3.10.

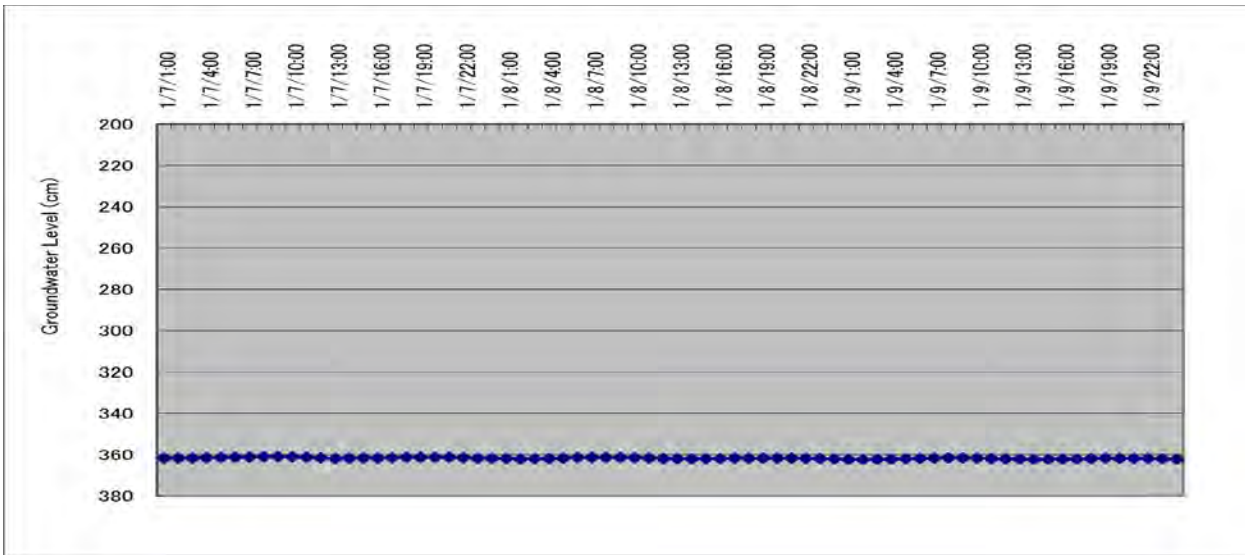

Figure 3.10 Recorded Groundwater Level at LTb-1 Deep Well, 7-9 January 2008

3-4 SRWSA Production Wells

The existing eight wells were constructed at an interval of 450 m in October 2005. The wells are situated 1.7 km south of the West Baray along the National Road No. 6. The locations of the wells are illustrated in Figure 3.1.

3-4-1 Well Structures and Intake Aquifers

Intake layers (aquifers) of the SRWSA production wells were reviewed through geological logs and well structures. The classification of geology is based on the results of the Study on Water Supply System for Siem Reap Region in Cambodia (2000). Table 3.5 summarizes the specifications of SRWSA Production wells.

Table 3.5 Well Structures of SRWSA Production Wells

No.	Well Depth (m)	Well Diameter (mm)	Well Screen (m)	Static Water Level (m)
PW-1	60 m	250 mm	14.0-23.6, 26.0-38.8, 40.0-43.2	- 1.41
PW-2	60 m	250 mm	16.50-19.52, 21.72-44.00	- 1.86
PW-3	60 m	250 mm	14.02-23.45, 26.63-42.49	- 1.41
PW-4	60 m	250 mm	29.12-44.92	- 1.37
PW-5	60 m	250 mm	14.72-40.40	- 1.18
PW-6	60 m	250 mm	14.95-40.43	- 1.51
PW-7	60 m	250 mm	21.72-44.00	- 1.89
PW-8	60 m	250 mm	19.72-45.21	- 2.23

(Note: Static Water Level* Completion Report by Contractor, 2005)

The columnar sections are classified by Alluvium, Diluvium, and Tertiary formation. Alluvium is mainly formed by sand and sandy clay. Diluvium is formed by silty clay/sandy clay and silty sand. Tertiary formation is formed by sandy clay/silty clay. Examination of the relationship between the geology and the setting depth of screens indicates that the wells intakes groundwater from aquifers distributed in the lower part of Alluvium and main portions of Diluvium. The relationship between geology and screen portions is shown in Figure 3.11.

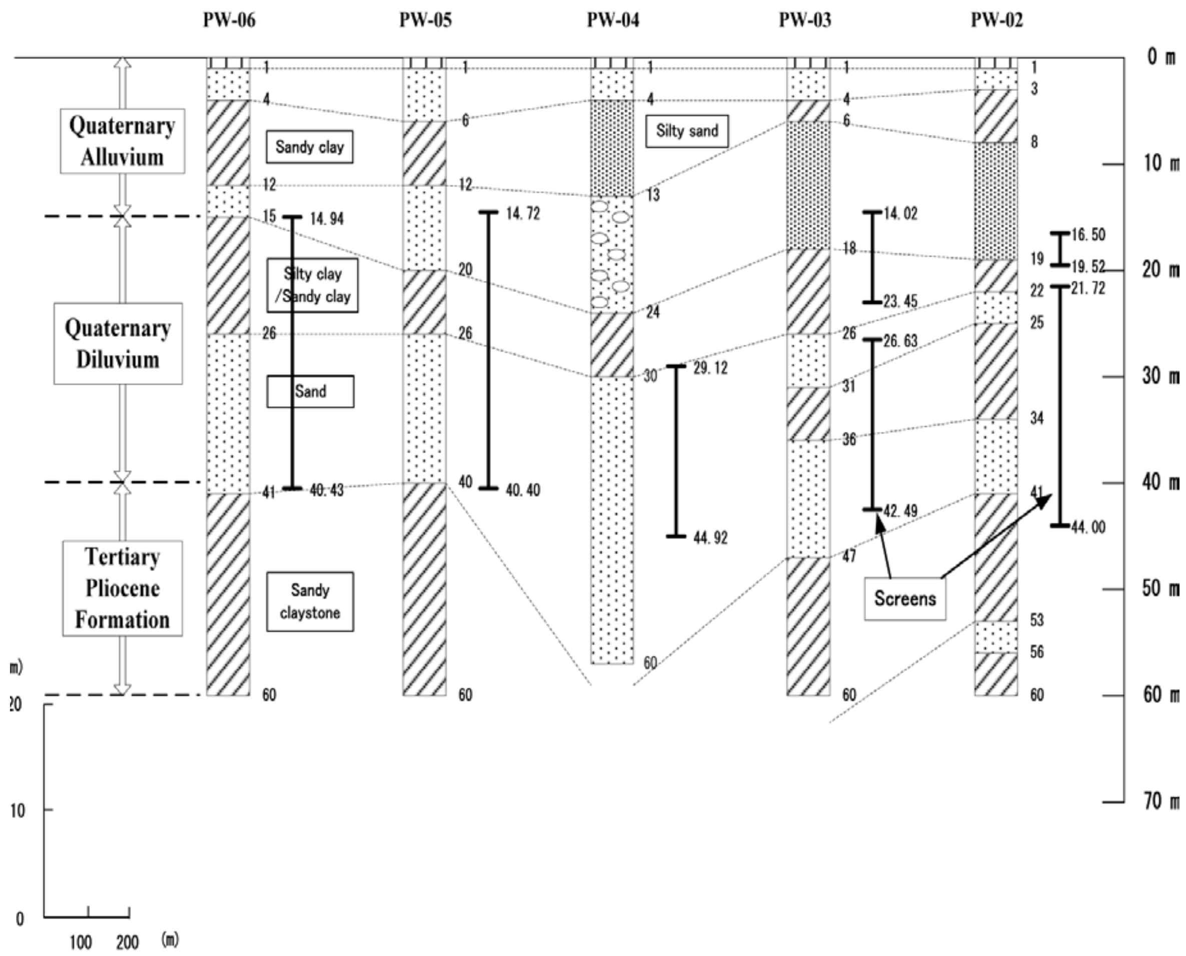

Figure 3.11 Intake Aquifers of SRWSA Production Wells

3.4.2 Operation of SRWSA Production Wells

The SRWSA production wells started pumping up in November 2005. At the beginning, the production did not reach the designed capacity of 8,000 m3/day due to the delay in the expansion of the water supply network. As the water supply network developed, the production capacity increased every month. In December 2007 the production capacity reached 8,000 m3/day and exceeded 9,000 m3/day in August 2009. The pumping rate by each production well and total volume of inflow to the existing water treatment plant has been recorded using an automatic recording system installed at the monitoring room of the plant. However, data was not recorded from April 2008 to March 2009 due to damage of the monitoring systems by lightning. Rehabilitation of the monitoring systems was made under assistance of JICA expert at the beginning of March 2009.

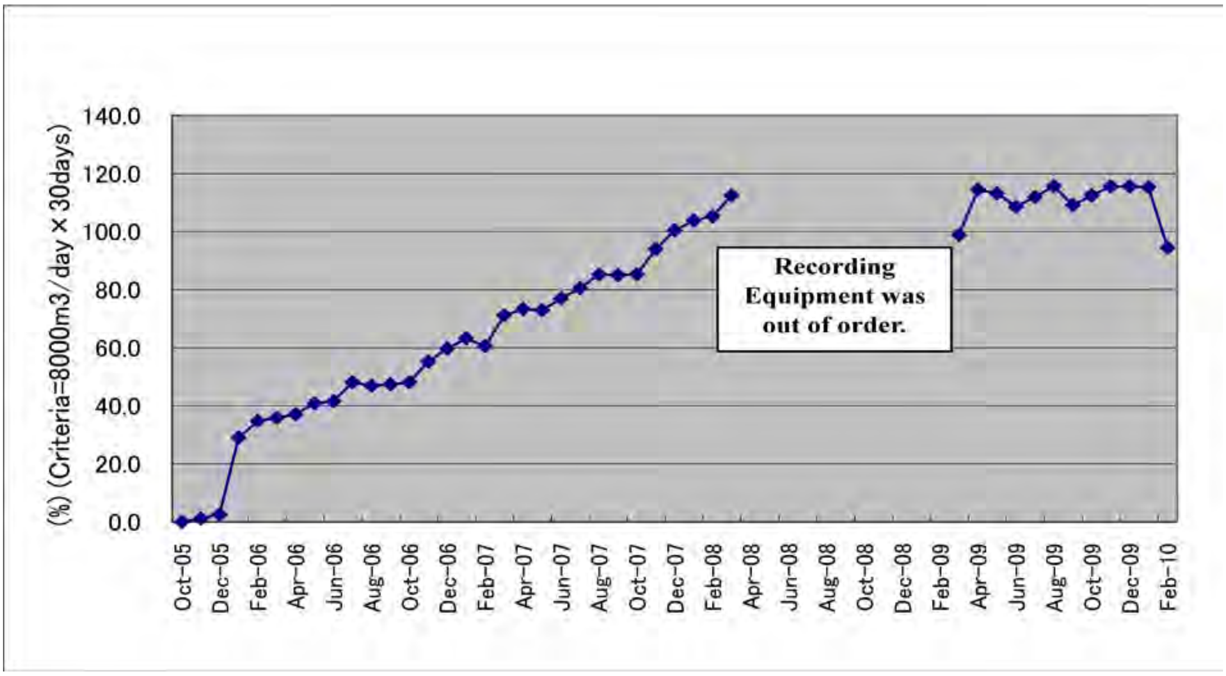

Figure 3.12 Monthly Data of SRWSA Production Wells, October 2005 to February 2010

3.4.3 Analysis on Influence of Pumping Up of SRWSA Production Wells

WT-4 and Khvein monitoring wells were used to study influence of pumping up of the SRWSA production wells. WT-4 and Khvein shallow wells are situates 2.6 km and 4.1 km from the SRWSA production wells, respectively.

(1) Well Structures and Aquifers of WT-4
The screens of WT-4 monitoring well are installed at the lower portion of Alluvium and main portion of Diluvium. This means the screens of WT-4 monitoring well are located at the same tapped aquifers as the SRWSA production wells. Figure 3.13 shows the geological conditions and the setting depth of screens of the WT-4 monitoring well.

(2) Analysis of WT-4 Data
Figure 3.14 shows verified WT-4 monitoring data. Only those data from Mar 2007 through Feb 2008 were identified to be reliable by comparing the manual measurement data and the automatic recorded data. The monitoring data during this period were used for this analysis. The recorded data shows that the fluctuation of groundwater levels of WT-4 was 1.6 m in 2007 to 2008. The highest groundwater level was in October at the end of rainy season and the lowest groundwater level was recorded at the beginning of May at the end of dry season.

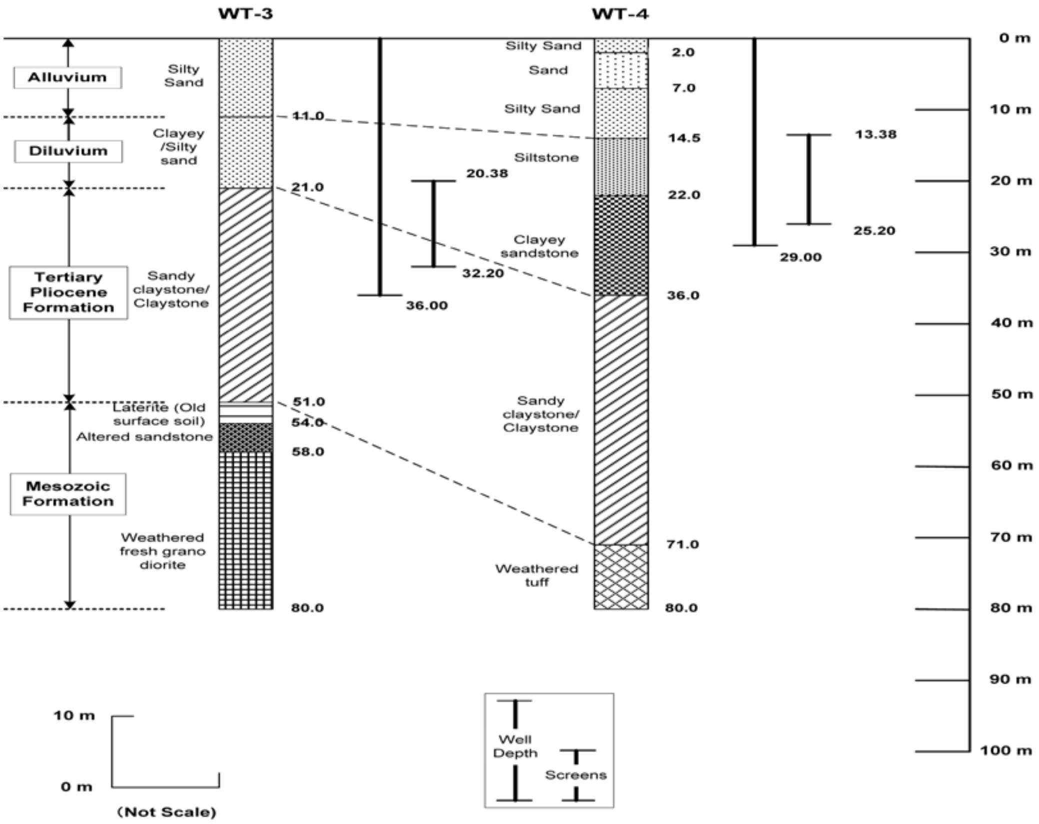

Figure 3.13 Geological Conditions and Depth of Screens of WT-4

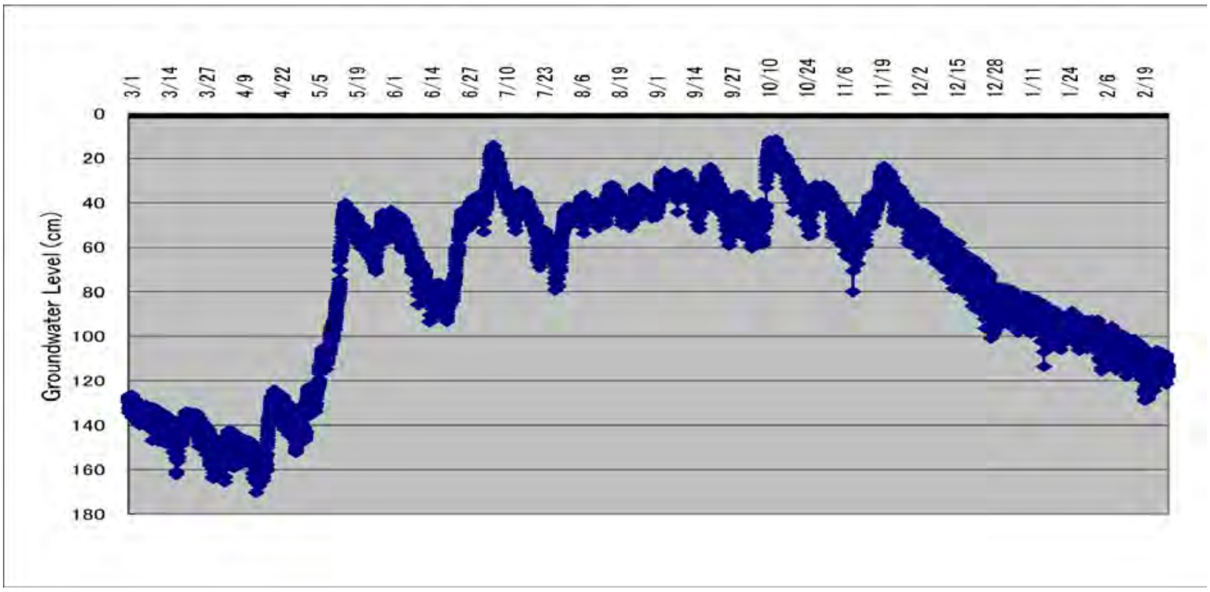

Figure 3.14 Groundwater Level at WT-4, March 2007 to February 2008

As showed in the Study on Water Supply System for Siem Reap Region in Cambodia (2000), yearly groundwater level fluctuation pattern was influenced by the seasonal precipitation. Only those data recorded during the dry season were selected to minimize influence of rainfall in this study. This analysis was conducted by comparing the data when withdrawal of groundwater from the SRWSA production wells was stopped, and the monitored groundwater levels at WT-4.

Further, in order to minimize influence of pumping of neighboring private wells, this analysis was conducted using data during mid-night when pumping of the private wells and the SRWSA production wells were not in operation.

Monitoring data of two days on 8 and 9 January 2008 was then used as full pumping day on 9January and halting day of pumping up of groundwater for about 4 hours on 8 January.

Operating condition of SRWSA production wells on 8 and 9 January 2008 is shown in Figure 3.15and daily pattern of monitoring data in Figure 3.16 and Figure 3.17.

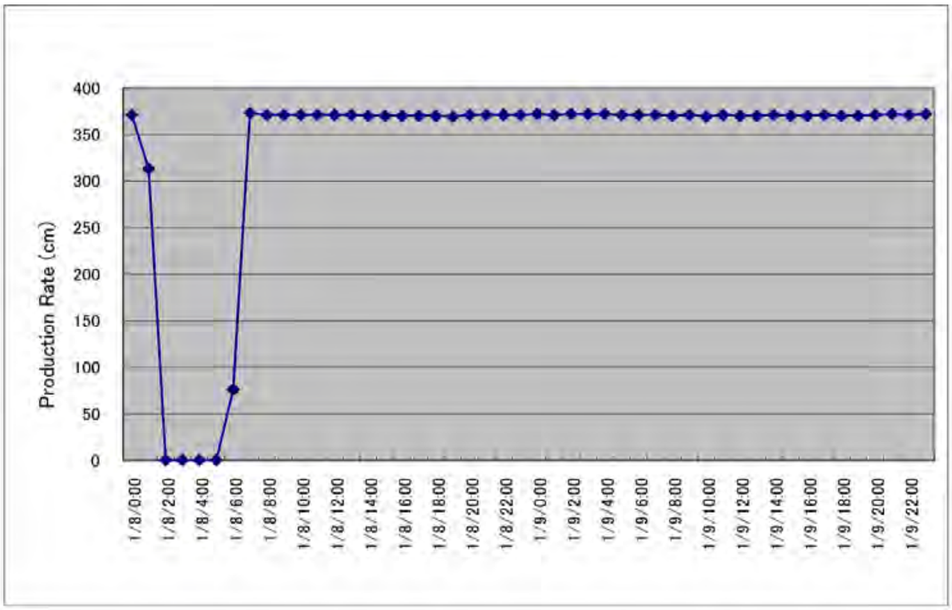

Figure 3.15 Operating Record of SRWSA Production Wells, 8 and 9 January 2008

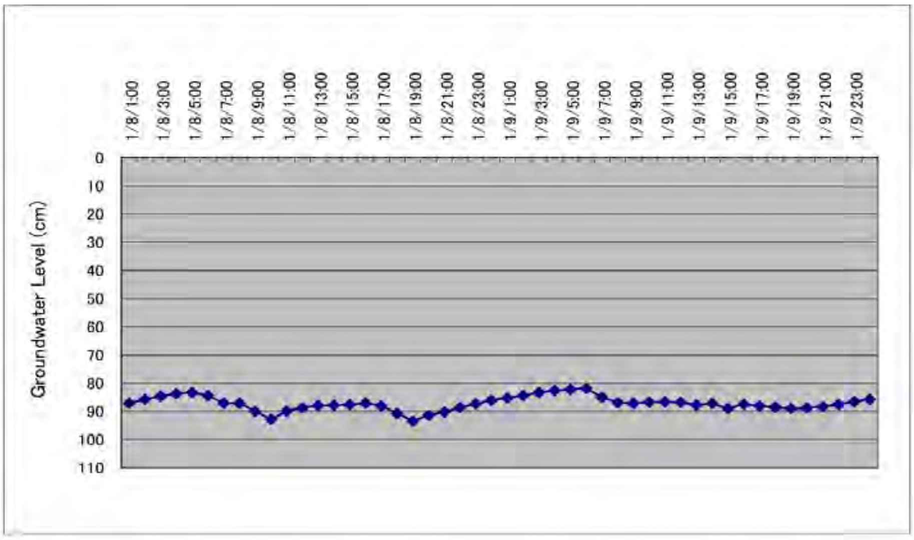

Figure 3.16 Daily Fluctuation of Groundwater Level of WT-4 on 8 and 9 January 2008

Operating Conditions of SRWSA production wells are as follows:

Day	Operating/Non- operating hours	Pumping rate
8 Jan. 2008	Full operating (0:00, 7:00-23:00) Halting of pumping up (2:00 – 5:00) Decrease of pumping rate (1:00, 6:00)	369 – 373 m^3/hour (Total: 7,062 m^3/day)
9 Jan. 2008	24 hours: Full operating	369 – 372 m^3/hour (Total: 8,901m^3/day)

(Note) Full operating means operation of all production wells and halting means the halting of all production wells.

As shown in the following figure showing the fluctuation of groundwater level for two days, the lowering in observed in the morning (5:00-10:00) and in the evening (17:00-19:00). Magnitude of the fluctuation approximately ranges from 5 to 8 cm. The fluctuation of groundwater level is considered to occur when neighboring private wells are operating.

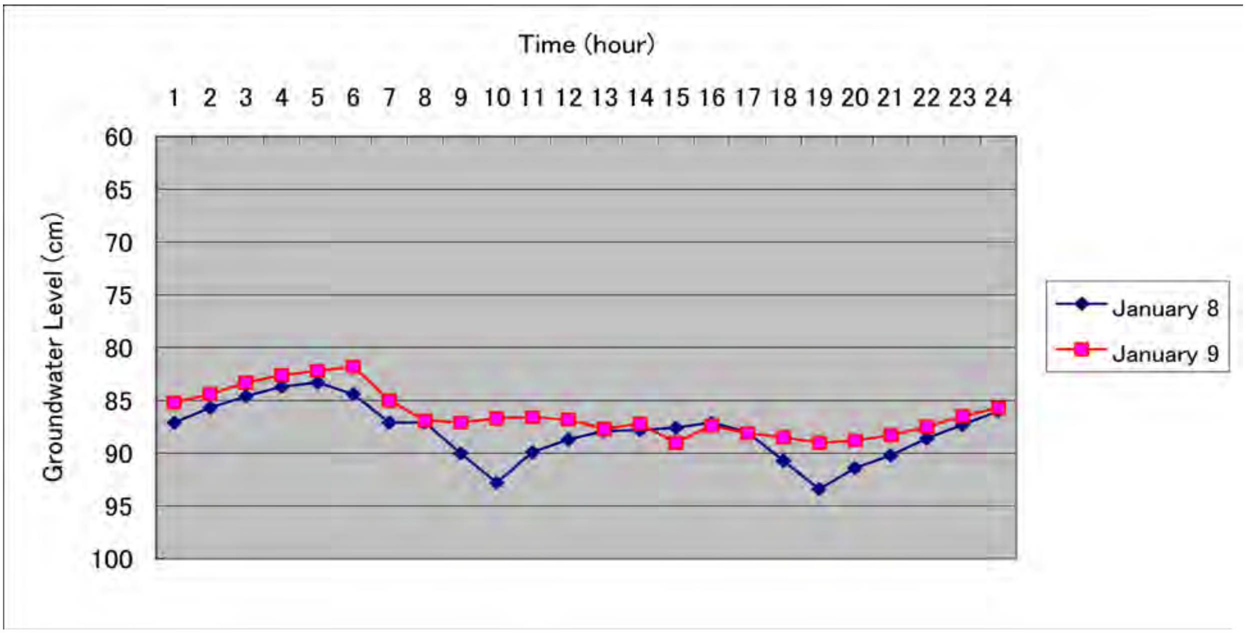

Figure 3.17 shows comparison of Daily Fluctuation of the groundwater level within 24 hours on two days on 8 and 9 January 2008.

Their daily fluctuation patterns indicate that:

-Data on 8 January 2008 shows that SRWSA stopped pumping up from 0:00. After 2:00up to 5:00, the pumping was fully stopped. Then, from 5:00, pumping up was stated up again. However, fluctuation tendency of groundwater level showed the same as that of 9January when SRWSA operated the pumps for 24 hours in reference to Figure 3.17. This phenomenon indicates that SRWSA wells do not have any impact to WT-4. Because, if the SRWSA wells have some impact on WT-4, the water level at that time between 2:00 to 5:00on 9 January should be lower than that of 8 January.

-Thus, interference radius of pumping of the SRWSA production wells is considered not to have a negative influence on monitored groundwater level of WT-4.

-The same tendency was confirmed on the monitored data on 14 to 16 December 2007.

-Likewise, the correlation between the operating conditions (pumping rates) of the SRWSA production wells and the monitored groundwater levels at WT-4 were studied based on correlation analysis method. Results shows that the determination coefficients were calculated to be R2=0.148547 for the case on 8 and 9 January 2008 and R2=0.12983for case on 14 to 16 December 2007. Therefore, correlations between the pumping rates and the monitored groundwater levels were not identified.

-As a result, in WT-4 monitoring well located about 2.6 km away from the SRWSA production wells, the influence of pumping of SRWSA wells were not observed.

In the similar way, the same comparison on 8 and 9 January 2008 was conducted on LTb-2 data.

Figure 3.18 shows comparison result of daily fluctuation in both days.

Figure 3.18 Comparison of Daily Fluctuation on 8 and 9 January 2008 of LTb-2

Figure 3.18 shows the followings:

- Though SRWSA wells stopped to pump up groundwater on Jan. 8, from 2:00 to 5:00, daily fluctuation pattern of groundwater levels is almost the similar to that in full pumping mode on Jan. 9. Thus, likewise to WT-4, daily fluctuation pattern doesn’t indicate influence of pumping of SRWSA wells.

- Difference of groundwater levels in both days is caused by seasonal drawdown in thedry season. The daily drawdown is about 3 cm.

- Compared with WT-4, daily fluctuation is large with range of 18 to 19 cm. Its drawdown starts from 8:00 in the morning. The lowest level happens in 17:00 in the evening. Since LTb-2 well is located near the city center, compared with distance from SRWSA wells, this large daily fluctuation is considered to be caused by pumping of many private wells located in the city center.

(3) Analysis of Khvein Shallow Well Data

The Khvein monitoring shallow well was constructed in October 2009 under this study and the monitoring equipment was installed in February 2010. Monitoring was started from February 17/2010. The well is situated about 4.1 km away and northwest of the SRWSA production wells.

The location is illustrated in Figure 3.1. It is considered that SRWSA production wells and Khvein shallow well are tapped in the same shallow aquifers as Alluvium and Diluvium. In the same manner as that of WT-4monitoring well, the influence of pumping by the SRWSA production wells was studied.

Operation of the pumps of the SRWSA production wells was temporarily halted about two hours in the midnight on 7 and 9 May 2010 as shown in Figure 3-19. Based on the data recorded during the stopping of the SRWSA production wells, the influence against monitored water level at Khvein shallow well were analyzed.

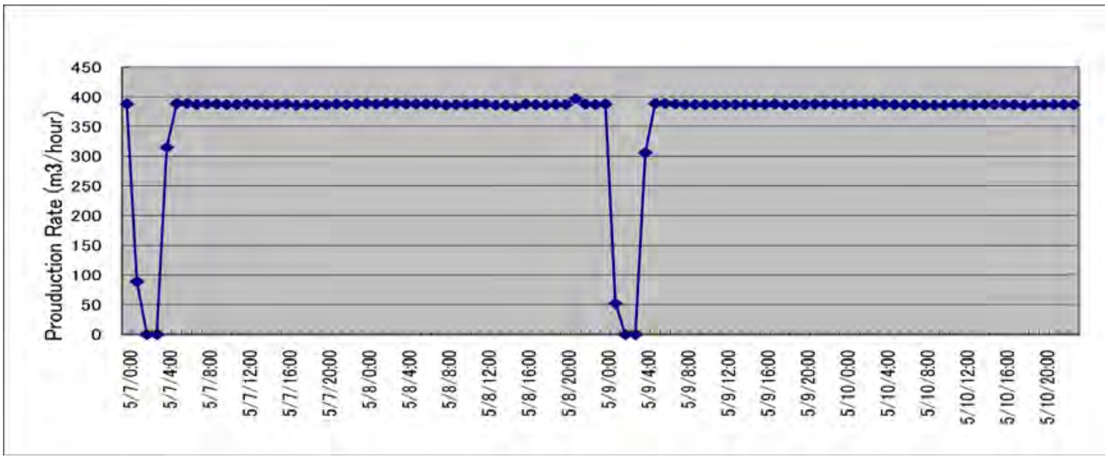

Figure 3.19 Operation of SRWSA Production Wells, 7 to 10 May 2010

Operating Conditions of SRWSA production wells are summarized below:

Day	Operating/Non- operating hours	Pumping rate
7 May 2010	Full operating (0:00, 5:00-23:00) Halting of pumping up (2:00 – 3:00) Decrease of pumping rate (1:00, 4:00)	387 - 389 m^3/hour (Total: 8,154 m^3/day)
8 May 2010	24 hours: Full operating	384 - 389 m^3/hour (Total: 9,306 m^3/day)
9 May 2010	Full operating (0:00, 5:00-23:00) Halting of pumping up (2:00 – 3:00) Decrease of pumping rate (1:00, 4:00)	386 - 389 m^3/hour (Total: 8,106 m^3/day)
10 May 2010	24 hours: Full operating	386 – 389 m3/hour (Total: 9,285 m^3/day)

(Note) Full operating means operation of all production wells and halting means the halting of all production wells.

The fluctuation patterns of groundwater levels based on 24 hours full operation on 8 and 10 May2010 and halting of pumping of the SRWSA production wells for two hours on 7 and 9 May 2010were compared. Comparison of fluctuation patterns of groundwater levels are shown in Figure3-20.

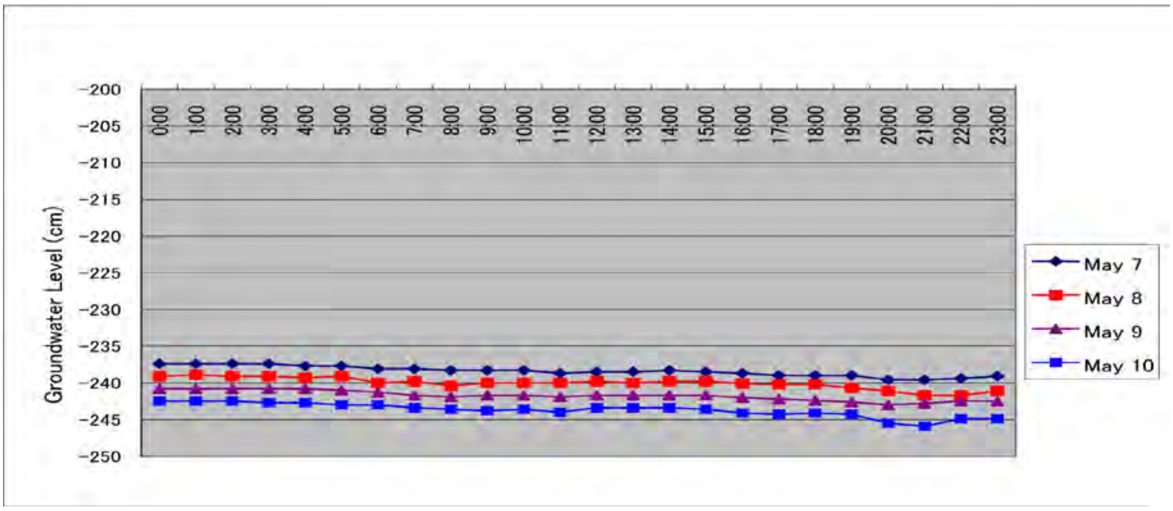

Figure 3.20 Comparison of Daily Fluctuation of Khvein Shallow Well, 7 to 10 May 2010

Figure 3-20 indicates that:

-For this period, the recorded groundwater level generally lowers every day by 1.7 cm. It was in dry season. Though all of the SRWSA production wells were stopped for two hours from 2:00 to 3:00 on 7 and 9 May 2010, groundwater level did not go up. All of the groundwater levels for these four days have shown the similar fluctuation patterns.

-If the SRWSA production wells have some impact to the Khvein monitoring well, the data recorded from 2:00 to 3:00 on 8 and 10 May 2010 should be lower compared to those of the data recorded from 2:00 to 3:00 on 7 and 9 May 2010. The actual data shows that water levels recorded were not significantly different. Thus, it is considered that the SRWSA production wells didn't influence to the Khvein monitoring shallow well.

-This phenomenon suggests that the SRWSA production wells doesn't influence against the environment including around the Angkor Wat ruins which is located 6.5 km away from the SRWSA production wells.

6-2 Recommendation

(1) In a dry year of 50 return years, groundwater simulation results revealed that potential land Subsidence to world heritage would occur, not only scenario 3 which used groundwater as the only source for water supply but also scenario 2 which continued groundwater use by the present amount. To improve these situations, it is hoped that new water supply system which is supplied by lake water of Tonle Sap as water source is completed as soon as possible.

(2) If new water supply system which is supplied by lake water of Tonle Sap is completed in the future, the ban of pumping by private large establishments' wells should be conducted. For this purpose, ordinances and regulations by Siem Reap Province and APSARA should be enforced together with campaign to enhance residence's awareness.

(3) SRWSA generally collects monitoring data of groundwater levels and land subsidence once a month from monitoring wells and also conducts manual measurement of groundwater level to check data reliability at the same time. However, collected data of manual

measurement often lack for mismatch of collecting time. SRWSA should keep and conduct thoroughly setting manners for data collection.

(4) SRWSA should check reliability of auto monitoring data by comparison between manual measurement and auto monitoring data. It is necessary to compare and put manual measurement and auto monitoring data at the same observation day/time in the same table and to check the difference of groundwater levels and correlation by drawing on graph.

(5) SRWSA immediately should restore mal-function monitoring equipment. Present conditions of each monitoring wells are described in "Chapter 3, 3-1 Current Status of Groundwater Monitoring."

(6) SRWSA should builds up mechanism and structure for sharing and putting each monitoring data to practical use with APSARA and DOWRAM.

Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in China

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Abstract

This report firstly maps out the China's 3-level groundwater monitoring Organization composed of 1 national institute (CIGEM), 31 provincial institutes and 268 prefectural substations. Then this paper describes the situation of China's GW monitoring system through analyzing various classifications for the total China's 16876 GW monitoring wells and the inclusive 1820 national-level observation wells. As a complement to the monitoring situation, more than 1000 auto-monitoring/transmission wells updated by several projects financed by CGS, especially the 712 auto-monitoring wells updated by the project--"*Investigation and evaluation of Groundwater dynamics for Plains-of-North-China*", is emphasized in the following sections. And then, the paper looks to the situation in the future 3 years, during which total 10808 auto-monitoring wells will be under constructing; among those total, 7580 wells should be newly designed and 3228 should be updated from the available old wells. The 2nd section briefly introduces the general condition about one main database available to satisfy the demand for Data storage, analysis and releasing for groundwater monitoring in China; also the other database specially built for *Plains-of-North-China* are describes as having more complex structure, more advanced capability to receive and store real-time data from auto-monitoring/transmission wells. Further statement in this paper focuses on the possibility of compiling GW datum which would base on the two series of YEARBOOKs published for China's GW level as well as GW quality in recent years. Finally, this report goes into a newly launched project aiming at building a GW monitoring Info-Sys, which having a 3-year schedule and the progression of which would synchronize with the CCOP GW Project Phase III. As a conclusion, converting GW data to CCOP DB using open Web GIS as discussed in Phase II is restrictively possible. At least, the seasonal GW observation data published in YEARBOOKs could be sharing with CCOP Project.

Keywords: groundwater, monitoring, database, active plan, China

1. Introduction

Groundwater monitoring in China has a history of about 60 years, from 1957 up to 2013. Organization of China's groundwater monitoring is composed of a three-level organization, including 1 national institute, 31 provincial institutes and 268 prefectural substations. For a long time, maintaining close ties with 31 provincial monitoring institutes and their 268 subordinate stations(Tab. 1 & Fig. 1.), China Institute of Geo-Environmental Monitoring(CIGME) directly responsible for nationwide groundwater monitoring. Thus, the CIGEM, 31 provincial monitoring institutes and their 268 subordinate monitoring stations together forms the groundwater monitoring system, which provides basic datum supports for China Geological Survey (CGS), Ministry of Land and Resources (MLR) and the other relevant ministries and commissions.

These years, together with a continuous special financial project, several projects sponsored by CGS have been conducted to improve the GW monitoring ability in China.

Tab. 1 Amounts of Groundwater Monitoring Substations for each Provinces (Autonomous regions & Municipalities) in China

Provinces (Auto-reg. s & Municipalities)	Amounts of Substations	Provinces (Auto-reg. s & Municipalities)	Amounts of Substations
Beijing	0	Henan	18
Tianjin	0	Hubei	7
Hebei	11	Hunan	6
Shanxi	13	Guangdong	12
Inner Mongolia	7	Guangxi	15
Liaoning	14	Hainan	0
Jilin	10	Chongqing	4
Heilongjiang	5	Sichuan	21
Shanghai	0	Guizhou	8
Jiangsu	10	Yunnan	7
Zhejiang	26	Xizang (Tibet)	2
Anhui	16	Shaanxi	10
Fujian	7	Gansu	7
Jiangxi	8	Ningxia	4
Shandong	12	Qinghai	1
Hongkong	N/A	Xinjiang	7
Macao	N/A	Taiwan	N/A

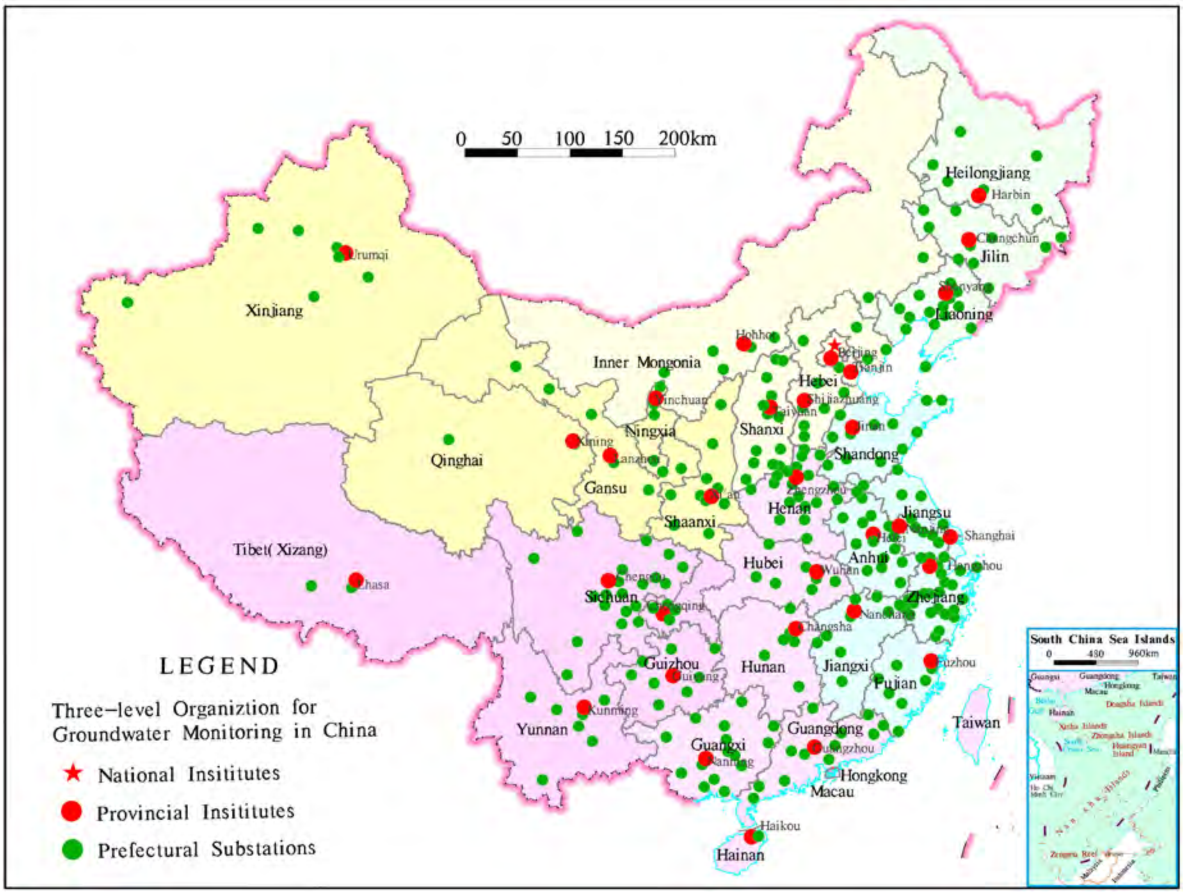

Fig. 1. Three-level Organization for Groundwater Monitoring in China

2. Situation of Groundwater Monitoring System and Database

1) Situation of GW Monitoring System

A. Nationwide GW Monitoring Network

Covering 1.1 million km^2, the nationwide monitoring network composed of 16876 (ever reached 23800 in 1990's) observation wells had been set up, from which 1820 wells were selected as national-level observation wells to obtain the groundwater dynamics of some key areas such as the main plains, basins or water supply fields.

It's shown in Tab. 2 that all-China's groundwater monitoring wells(16876 totally) could be classified into two major type, that is, 11303 daily and 5573 seasonal observation wells according to monitoring frequency. These 11303 daily observation wells are composed of 1820 national-level, 8165 provincial-level and 1318 prefectural-level wells according to the administrative classification, or 9478 manual and 1825 automatic monitoring wells regarding the monitoring methods.

As for the running condition about all the China's daily-observation wells, it is indicated that wells under excellent condition are less than 7988, among the rests, 2423 wells are mild-clogging and 892 severe-clogging.

Tab.3 goes into details about the National-level monitoring wells allover China. It shows that, among the total 1820 observation wells of National-level, 914 wells monitor porous-phreatic aquifer, 572 porous-confined aquifer, 85 fissured aquifer and 249 karst aquifer. However, most of them (1461) are manual observation wells, and the rest 359 are auto-observation wells; the majority(1370) of them runs in very good condition.

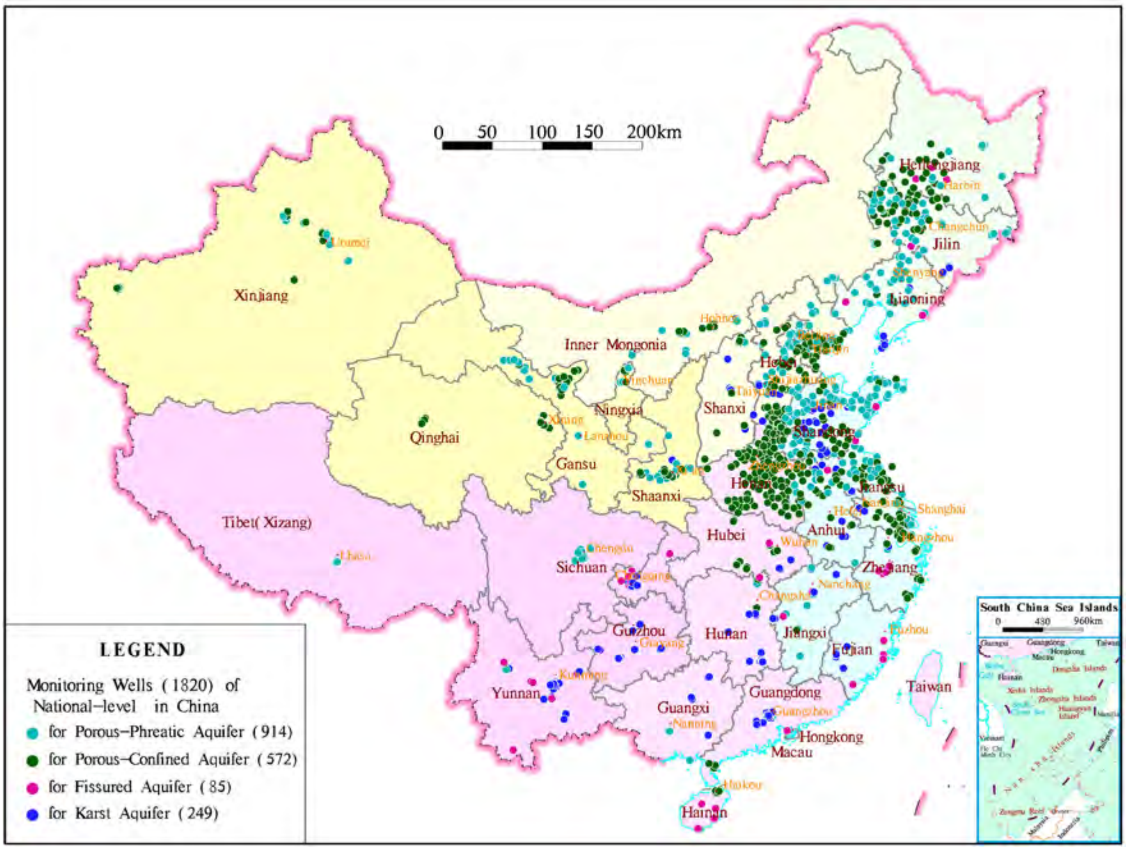

Fig. 2 Distribution of the National-level Monitoring Wells in China

Tab. 2 List of National-wide GW Monitoring Wells According to Various Classifications

Major categories (due to monitoring Frequency)	Amounts	Classification	Sub-calss	subtotal	Percentage
Daily Monitor wells	11303 (67.0%)	Wells of Different levels	National	1820	16.1%
			Privincial	8165	72.2%
			prefectural	1318	11.7%
		Wells using various methods	Auto	1825	32.7%
			Manual	9478	170.1%
Seasonal Monitor Wells	5573 (33.0%)				
SUM	16876				

Tab. 3 List of National-level GW Monitoring Wells According to Various Sub-classes

Wells Classification	Sub-class	subtotal	Percentage
Monitoring various aquifers	porous-phreatic aquifer	914	50.2%
	porous-confined aquifer	572	31.4%
	fissured aquifer	85	4.7%
	karst aquifer	249	13.7%
Using Various methods	Auto	359	19.7%
	Manual	1461	80.3%
Total	1820		

B. Recent Updating for GW monitoring system

Regional Monitoring system updating was initiated by *Sino-Dutch Groundwater Monitoring Project* carried out during 2003 to 2007. In this cooperation project, hundreds of monitoring wells had been equipped with automatic detector to gather groundwater pressure, temperature in Beijing, Shandong and Xinjiang. As an entirely new methods for groundwater monitoring, frequent monitoring records could be stored in a built-in (embedded) memory card, which gave access for yearly data collecting through cable, thus to improve efficiency and reduce manpower costs.

Then during 2007 to 2013, under the support of China Geological Survey, a project—"*Groundwater Monitoring for Typical Demonstration Areas*" had been conducted to continue the updating work in Beijing plain, Jinan spring basin of Shandong province and Urumqi river basin of Xinjiang autonomous. Till now, total 432(315 for Beijing, 61 for Jinan and 56 for Xinjiang) auto-detecting & wireless-transmitting divers had been setup for frequent monitoring in this project.

Also sponsored by CGS, CIGEM have completed another important project—"*Investigation and evaluation of Groundwater dynamics for Plains-of-North-China*", the fundamental purpose of which is to update monitoring system over 7 basins/plains in North China, namely, Songnen Plain, the lower Liaohe River Plain, North China Plain, Ordos basin, Yinchuan Plain, Hexi corridor and Jungar basin. After 5 years effort, a network including 712 auto-monitoring & auto-transmitting wells covering the above 7 basins/plains has been constructed during 2008 to 2013(Tab. 4, Fig. 3).

Tab. 4 Amounts of the Auto-Monitoring / transmitting Wells
and control sections for each plain in North China

No.	Plains of North China	Amounts of Auto-Monitoring Wells	Control section lines	
			Cross section	Vertical section
1	Songnen Plain(Heilongjiang)	78	2	3
	Songnen Plain(Jilin)	84	5	9
2	the lower Liaohe River Plain	21	1	1
3	North China Plain	126	5	3
4	Ordos basin	100	4	2
5	Yinchuan Plain	90	13	1
6	Hexi corridor	132	4	13
7	and Jungar basin	81	3	10
Sum		712	27 Cross；35 Vertical	

Fig. 3 Auto-Monitoring / transmitting Wells updated for Plains-of-North-China

C. Future GW Monitoring Ability Upgrading

After long-term effort, an application of “***National Groundwater Monitoring Project***” submitted by CIGEM have been authorized by National Development and Reform Commission (NDRC) in the end of 2014. The main objective of this project is to construct a comprehensive monitoring network covering the 16 dominant plains/basins in China, thus to promote groundwater monitoring ability. Total 10808 auto-monitoring wells are schemed in the future 3 years, among which 7580 wells should be newly designed and 3228 should be upgraded from the available old wells (Fig. 4).

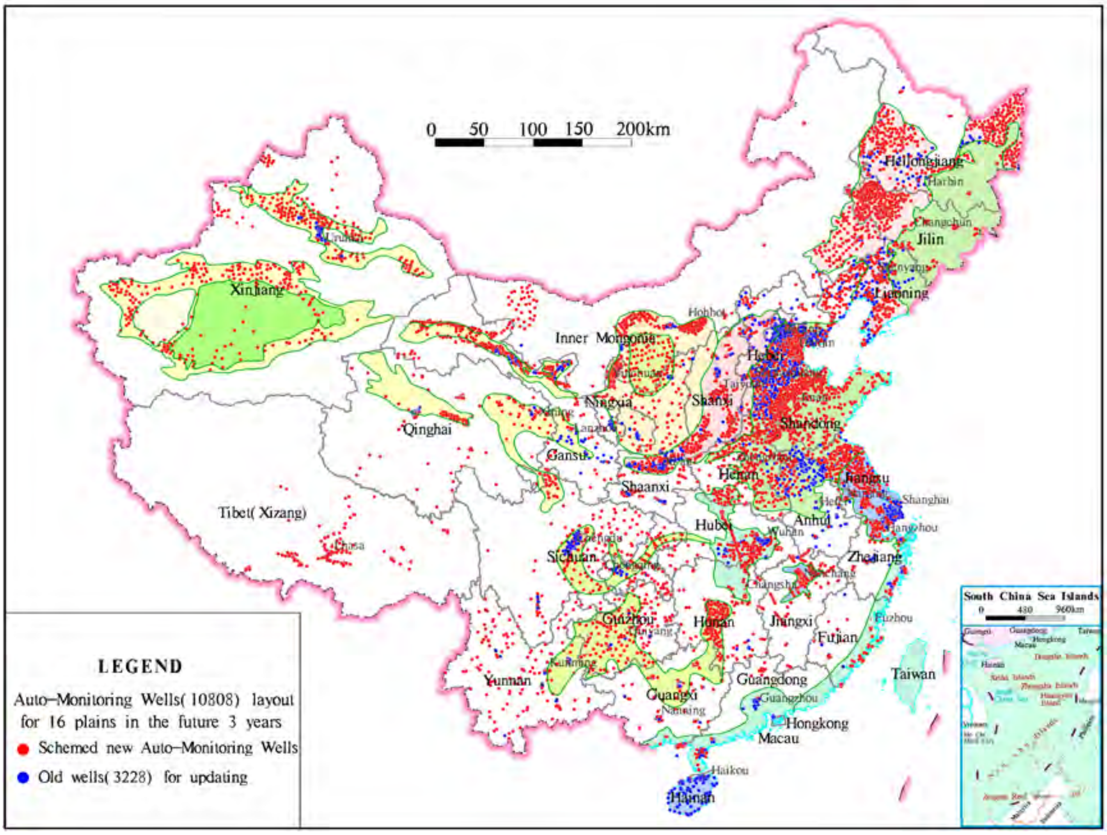

Fig. 4 Layout of the auto-monitoring wells network in the future 3 years

2) Database for groundwater monitoring in China

There are two main database running to satisfy the demand for Data storage, analysis and releasing for groundwater monitoring in China.

The original database for all-China groundwater monitoring run under MS-DOS in 1990's. Till now, after several-times version updates, all-China groundwater monitoring Database have developed to being a flexible Windows tools for daily data processing. This database holds 5 normative tables to record general wells condition, water level, water quality, water temperature and pump discharge respectively. Function modules such as data importing, data check, statistical analysis, reports generating, water quality assessment, curve plotting and yearbook (annual) exporting are included in this database system. Generally, this database is very easy for using, but it is limited to managing the 1820 monitoring wells of national-level. Since 2005, some information of this database are released for viewing on the website: http://www.cigem.gov.cn/dxs/.

Another new database had been taken into consideration as one of the main tasks for the project "*Investigation and evaluation of Groundwater dynamics for Plains-of-North-China*", as mentioned in previous section. This improved database holds 19 relational tables to deal with complex data structure, to store mass data based on SQL SEVER 2000. After 4 years effort, this database not only have the capacity to store and deal with all-China national-level groundwater monitoring datum, but also support real-time data gathering from the auto-monitoring/ transmission wells.

Unfortunately, both of the above two database remains Chinese version only.

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

The China's GW database, with a yearly storage of 300,000 records, have gathered great amounts of monitoring datum since 1980. Till now, total 3,820,000 GW records have been stored in the database, which is composed of 2,500,000 water level records and 1,000,000 water quality records, the rest are water temperature or quantity records accounts for relatively small amounts.

Based on the national-level monitoring wells records from the database, datum for water level have been exported, compiled and published as "***CHINA GROUNDWATER LEVEL YEARBOOK***" (Fig. 5). Each YEAR BOOK contains about 40,000 records available since 2005. In addition, a series of "***CHINA GROUNDWATER QUALITY YEARBOOK***"(Fig. 6) have been compiled since 2008. But for some reason, these books still remains unpublished.

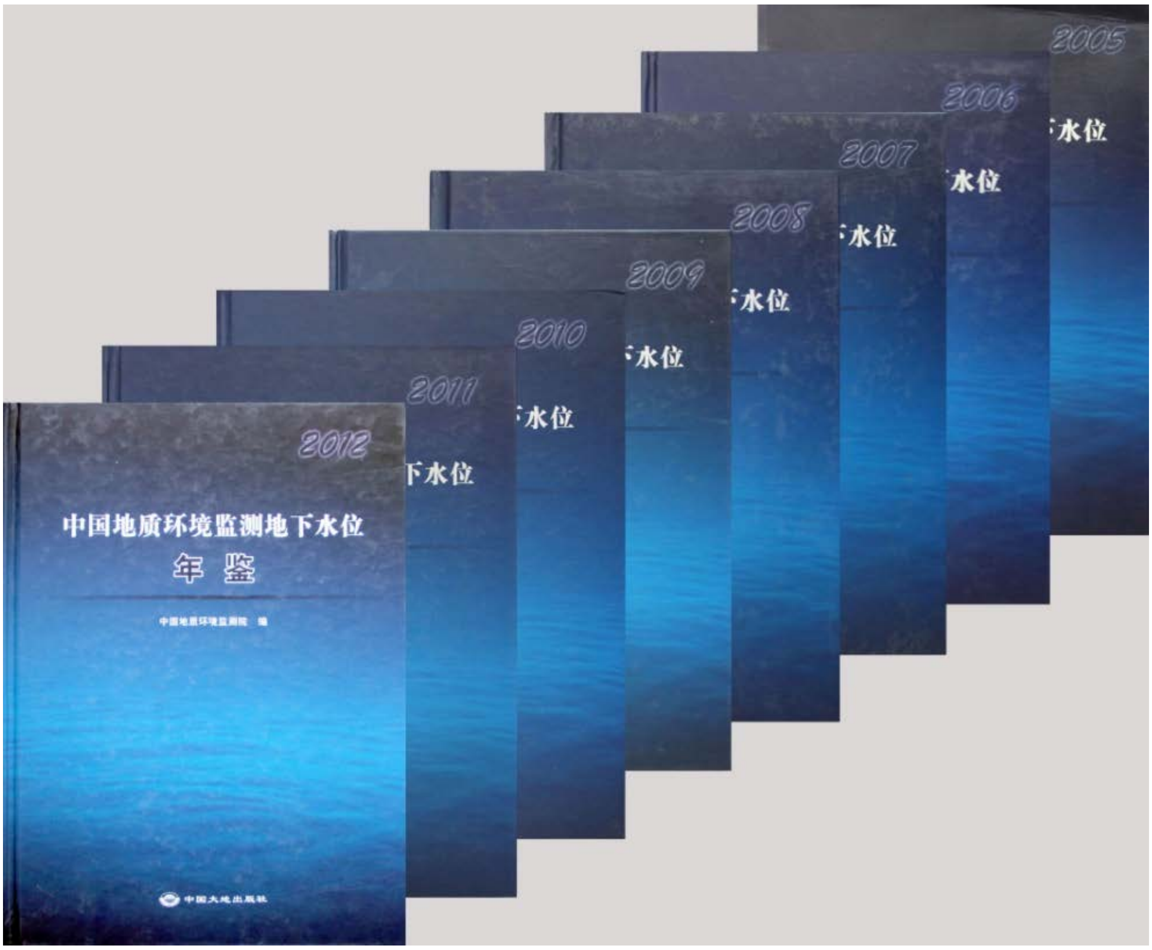

Fig. 5 YEAR BOOKs for China's GW level monitoring published since 2005

Fig. 6 YEAR BOOK FOR CHINA'S GW QUALITY MONITORING
(unpublished) since 2008

4. Activity Plan for CCOP GW Project Phase III

A. GW Monitoring Info-Sys Development

At the end of 2014, CIGEM launched a new project to construct a GW Monitoring Info-Sys, the main purpose of which is to integrate the former monitoring results including all the existing databases. For this project is schemed to last for 3 years, so the progression of project would synchronize with the CCOP GW Project Phase III.

B. Data Service on Internet

The above Info-Sys will be built on the basis of GIS, information and internet technology so as to supply web browsing service. We plan to apply for a special domain, add links to websites of CIGEM, CIGEM and MLR through 1-2 year's efforts.

Except for some highly sensitive, controversial or secret-related datum, we'd like to supply data service for CCOP GW Project by converting GW data to CCOP DB using open Web GIS as discussed in Project Phase II. At least, the seasonal GW observation data as published in YEARBOOKs could be sharing with the CCOP Project.

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Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Indonesia

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Abstract

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

For support the groundwater management, it would require also on groundwater data management that are very useful for various purposes. National groundwater database was done by collecting of data and information on groundwater from the central, provincial and district/city also other stakeholders. Data and Information in the national groundwater database system is divided into a) the configuration of the groundwater basin, b) hydrogeology, c) soil water potential, d) soil water conservation, e) the utilization of ground water, f) environmental conditions and groundwater, g) controlling and monitoring groundwater, h) policies and regulations in the field of ground water and socio-economic activities i) associated with groundwater culture.

National Groundwater database was development using web mapping technology also using standard data exchange Web Service Feature (WFS) and Web Mapping Service (WMS). Infrastructure for groundwater database development utilizing open source technologies such as LINUX for the operating system, POSTGRES and MySQL for the database engine, PHP for the programming language and DRUPAL for content management system for interface database. The national database of groundwater development has been published in web base (http://siat.bgl.esdm.go.id).

Keywords: groundwater management, groundwater data management, standard data exchange.

1. Introduction

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

The awareness of the importance of groundwater management is absolutely necessary for all stakeholders. The presence of water especially groundwater must be observed, recorded and collected, archived in a database that is easily exchanged and utilized, which will be the state assets which is very useful for the ruling government in managing the water resources for sustainable development with the goal of welfare of the people.

2. Situation of Groundwater Monitoring System and Database

Geological Agency of Indonesia (GAI) is responsible for monitoring and managing groundwater in Indonesia on behalf of the Ministry of Energy and Mineral Resources. It is also responsible for the oversight of groundwater recommendation for licensing.

Groundwater, like surface water, is vulnerable to drought and climate change and so the allocation of this resource is carefully managed and monitored.

National groundwater database was developed by collecting of data and information on groundwater from the central, provincial and district/city also the other stakeholders. Data and Information in the national groundwater database system is divided into a) the configuration of the groundwater basin, b) hydrogeology, c) soil water potential, d) soil water conservation, e) the utilization of ground water, f) environmental conditions and groundwater, g) controlling and monitoring groundwater, h) policies and regulations in the field of ground water and socio-economic activities i) associated with groundwater culture.

For support the groundwater database, GAI has developed the national groundwater information system using open source program. National Groundwater database was development using web mapping technology also using standard data exchange Web Service Feature (WFS) and Web Mapping Service (WMS). Infrastructure for groundwater database development utilizing open source technologies such as LINUX for the operating system, POSTGRES and MySQL for the database engine, PHP for the programming language and DRUPAL for content management system for interface database.

The national database of groundwater development has been published in web base (http://siat.bgl.esdm.go.id)

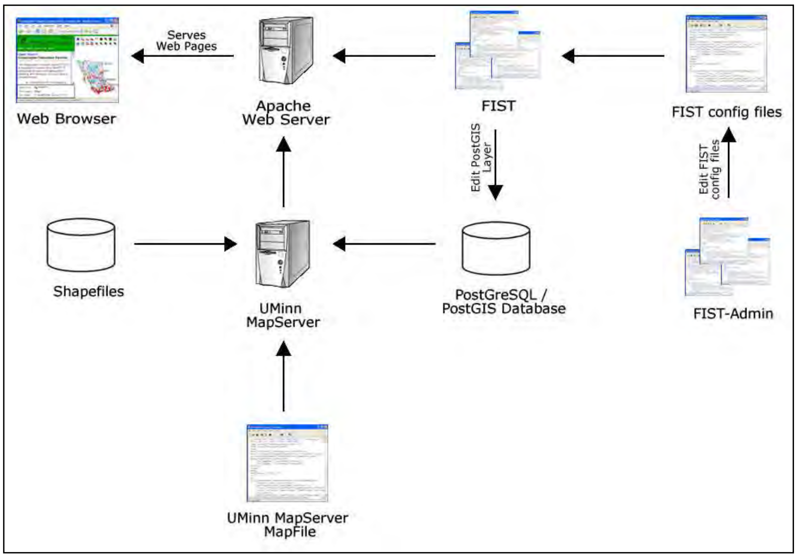

Fig. 1 WebGIS structure in Geological Agency

The spatial data can be processed by online system using mapping application that consists of Transaction Web Feature Service (WFS-T). The technology is operated by the internet data exchange medium and the final outcome in the form of a digital map database can be viewed online just by using a browser or use a desktop application that has the facilities WMS / WFS client.

The general groundwater database that has been developed by GAI consists of some information bellow:

a. Monitoring Well Database

The technology used is the Automatic Well Level Response (AWLR) through GSM (SMS) periodically two-way

GAI manages the National observation network (by GAI and some Province Governments) which monitors groundwater levels at more 100 sites throughout the national area. The data generated through regular monitoring provides essential information for the sustainable management of groundwater resources into the future.

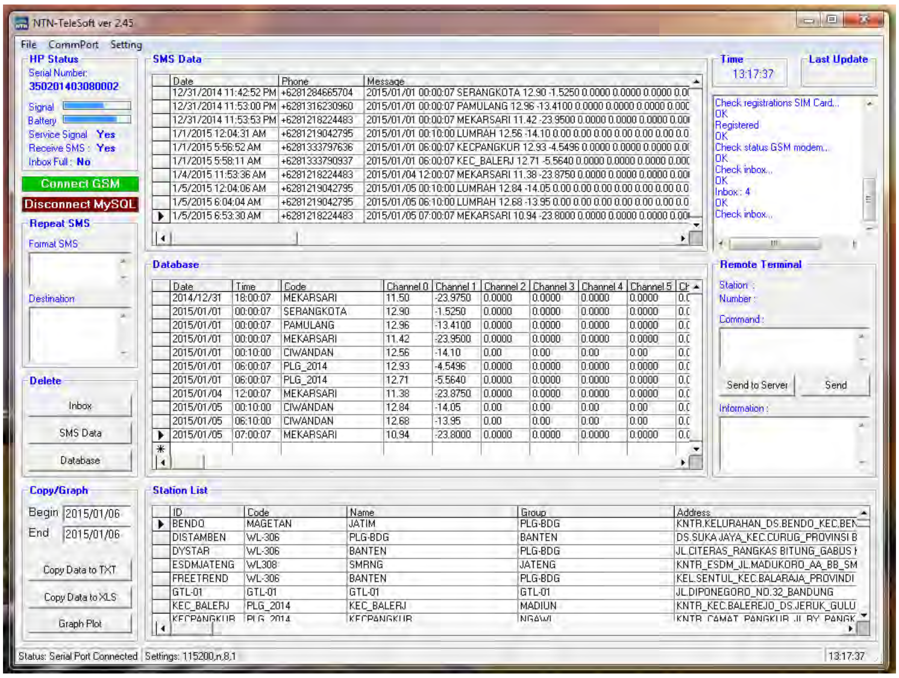

Fig. 2 Monitoring Wells Application based on telemetry system

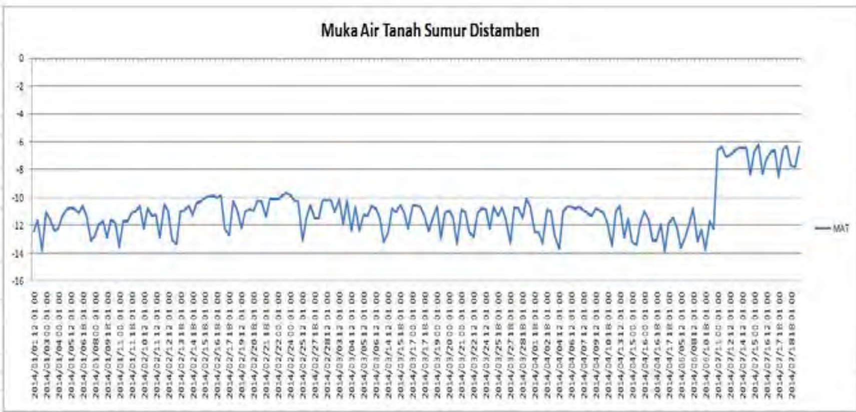

Fig. 3 Monitoring Wells Graph based on telemetry system

b. Hydrogeological Map Database

Hydrogeological map database is a web-based application that provides the hydrogeological map data which is published by GAI.

Fig. 4 Hydrogeological Map Database

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

Groundwater data compilation is very possible to be done using the existing data structures such as a link system, while if used new data structure, the CCOP GW Project must manage again the raw data. Compilation of Indonesia hydrogeological maps have been done on the previous CCOP project.

The possibility of groundwater level data compilation is very easy to do because the data in the spreadsheet form.

4. Propose Activities for CCOP GW Project Phase III

The proposed activities for CCOP GW Project Phase III are:

a. Groundwater data collection which has managed and collected by each member country;
b. Develop the standard of groundwater database structure;
c. Develop the groundwater database system adapted to the availability of groundwater data in each member country; and
d. Groundwater database management training.

Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Japan

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Abstract

The CCOP Groundwater Project Phase II had released hydrological map of the Chao-Phraya Plain, Thailand and the Red River Delta, Vietnam. For the next phase, GSJ have plan for the next project to compile various geoscientific information including groundwater in CCOP countries and to construct a web based database. Moreover, CCOP GW Sub-Project "Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions" started at 2013 is aimed to develop renewable energy for GSHP system in CCOP regions making good use of not only subsurface temperature, but also hydrological environment in each area.

Keywords: Groundwater, Hydro-Geological Map, CCOP Region

1. CCOP Hydrological Map under GW Project Phase II

The CCOP-GSJ/AIST Groundwater Phase II Kick off Meeting was held on October 2009 in Bangkok, Thailand. After the kick-off meeting, the CCOP-GSJ/AIST Hydrological Mapping Working Group Meeting under CCOP Groundwater Project was held on March 2010 in Bangkok, Thailand. The GSJ and Hydrological Mapping Working Group had performed field work, hydrological analysis and compiled groundwater data to construct groundwater database. In addition, new sub-project under CCOP GW Project using CCOP groundwater database started at April 2013 entitled "Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions".

CCOP Hydrological Map under GW Project Phase II served by CD-ROM and the working group is editing final stage. CCOP GW DB includes not only map system but also simple tables by Excel file, because, Microsoft Excel File is used for groundwater modeling, such as MODFLOW, GMS and/or MT3D.

Fig. 1 shows opening window of CCOP Hydrological Map. GW data of Chao Phraya Plain, Thailand, and Red River Delta, Vietnam had compiled under this project. By clicking country name on start page, zoom map is displayed as shown in Fig. 2. Fig. 2 shows zoom map around Thailand and Vietnam. By clicking name on map "Thailand", data area map of Chao Phraya Plain is displayed as shown in Fig. 3. The data area map shows distribution of observation point (right side) which chosen in the sub frame (left side). By clicking observation point, observation data window is displayed as shown in Fig. 4. The observation data shows well information (location, well depth, screen depth, EC, pH, and quality) in the left window, groundwater quality plotted by stiff diagram in upper right window and groundwater temperature in lower right window.

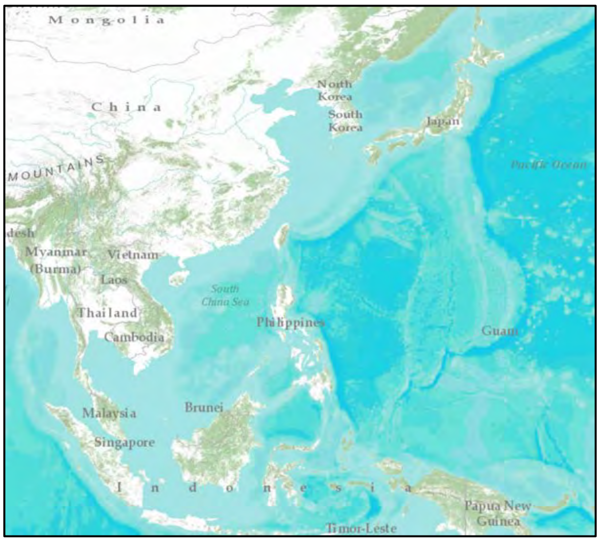

Fig. 1. Opening window of CCOP Hydrological Map

Fig. 2. Zoom map around Thailand and Vietnam.

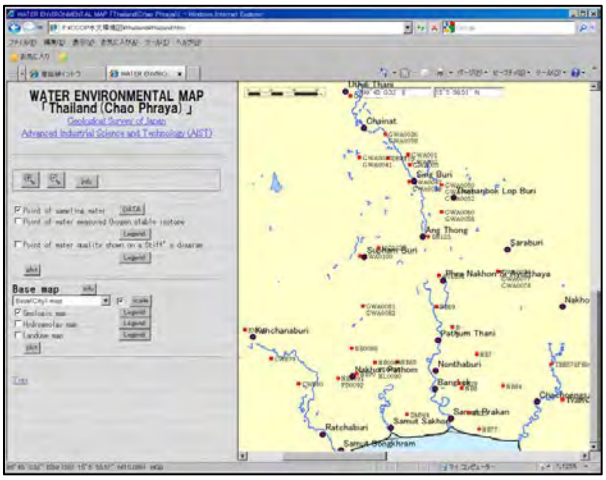

Fig. 3. Data areal Map of Chao Phraya Plain.

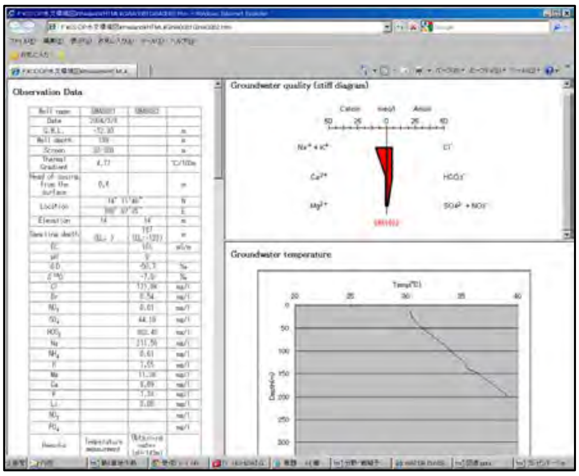

Fig. 4. Observation data window

In east-Asia, where significant economical growth in this century is expected, energy saving and environmental protection will be major matters of importance. Intensive installation of Ground-Source Heat Pump (GSHP) System (Fig. 5) may contribute to energy (electricity) savings and protection of the environment. However, generally in tropics where air cooling system is needed, subsurface temperature is higher than atmospheric one through a year and underground is not suitable as a cool heat source. Nevertheless in tropical regions, underground may be used as cold source if there exist slight change of atmospheric temperature and subsurface temperature is rather low.

Based on the above background, new sub-project under CCOP GW Project using CCOP GW DB started at April 2013 entitled “Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions”. Chulalongkorn University, Akita University and GSJ have cooperation program under the CCOP sub-project and installed GSHP System on premise of Chulalongkorn University.

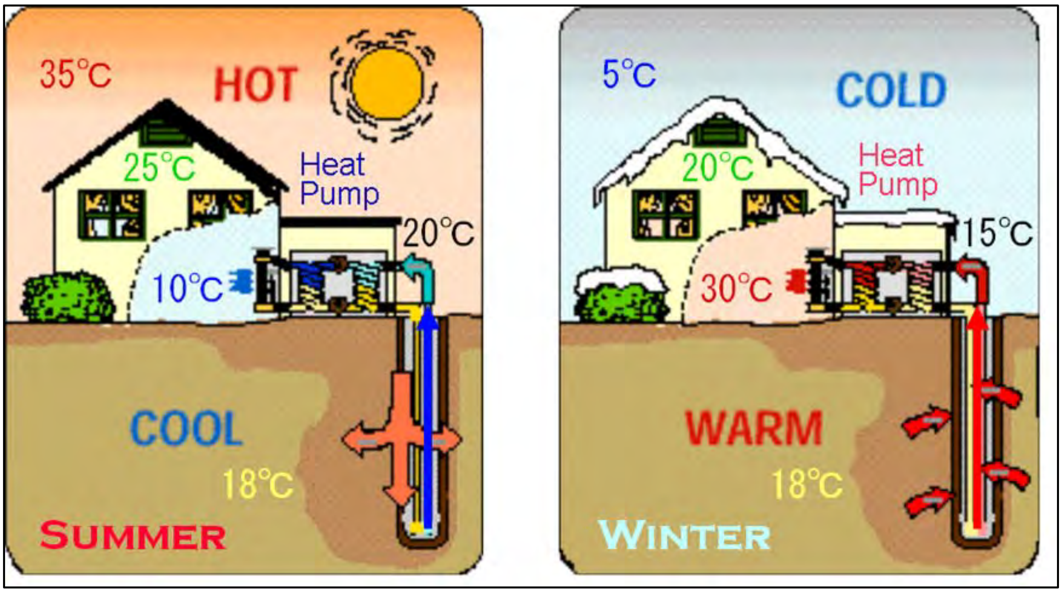

Fig. 5. Schematic of Ground-Source Heat Pump (GSHP) System

Study objects of this sub-project are;

1. To demonstrate GSHP system in BKK City, Thailand,
2. To develop adjustment of GSHP system for tropical region
3. To develop suitable maps for GSHP system in Thailand reflected large-scale groundwater flow/heat transport model.

2. Situation of Groundwater Monitoring System and Database

There are many observation wells in Japan which are used for monitoring groundwater level and land subsidence (Photo 1, left). Each observation site has two or three nested observation wells, and these wells are designed for single screen well. Each screen depth is set at the different aquifer, therefore we can get three-dimensional distribution of hydraulic head and groundwater qualities. Moreover, we measured groundwater temperature at 2 m intervals in those observation wells using digital thermistor (Photo 1, right). The precision of thermometer which we used is 0.01 degree C.

Photo 1 Observation well for monitoring of groundwater level and land subsidence in Japan (left), digital thermistor with 300m cables (right), respectively.

It is known that subsurface temperature distribution is generally affected not only by thermal conduction but also by advection owing to groundwater flow (Uchida et al., 2003). The effect of thermal advection is especially large in shallow sedimentary layer with high groundwater flux.

Groundwater temperature measured in an observation well is assumed to be identical to subsurface temperature, because there exists thermal equilibrium between the water in a borehole and its surrounding subsurface layers. Temperature profiles are one-dimensional sequential data arrays so that areally distributed temperature profiles provide three-dimensional subsurface information. Fig.1 shows groundwater flow system and subsurface thermal regime (modified form Domenico and Palciauskas, 1973). If there is no groundwater flow or static groundwater condition (Fig.1a), subsurface thermal regime is governed only by thermal conduction and subsurface temperature gradient is constant (Fig. 1b). When a simple regional groundwater flow system due to topographic driving (Fig. 1c) is assumed, thermal regime will be disturbed by thermal advection owing to groundwater flow (Fig. 1d). In the groundwater recharge area, subsurface temperatures and gradients are lower than that of under static groundwater condition (Fig. 1b). In the discharge area, on the other hand, temperatures and gradients are larger than that of under static condition.

GSJ made the hydrological map of the country. The map gives digital information in various kinds of hydrogeological understanding. Water quality including isotope analysis, temperature, flow condition, and water level have prepared in the information. The information of deposited layers about Quaternary and Tertiary of the whole Japanese Island had been analyzed and the total volume of water was estimated. We released “Kumamoto Plain, Kyushu” and “Ishikari Plain, Hokkaido” in the end of FY 2014, and also intended “Mt. Fuji area” in 2015.

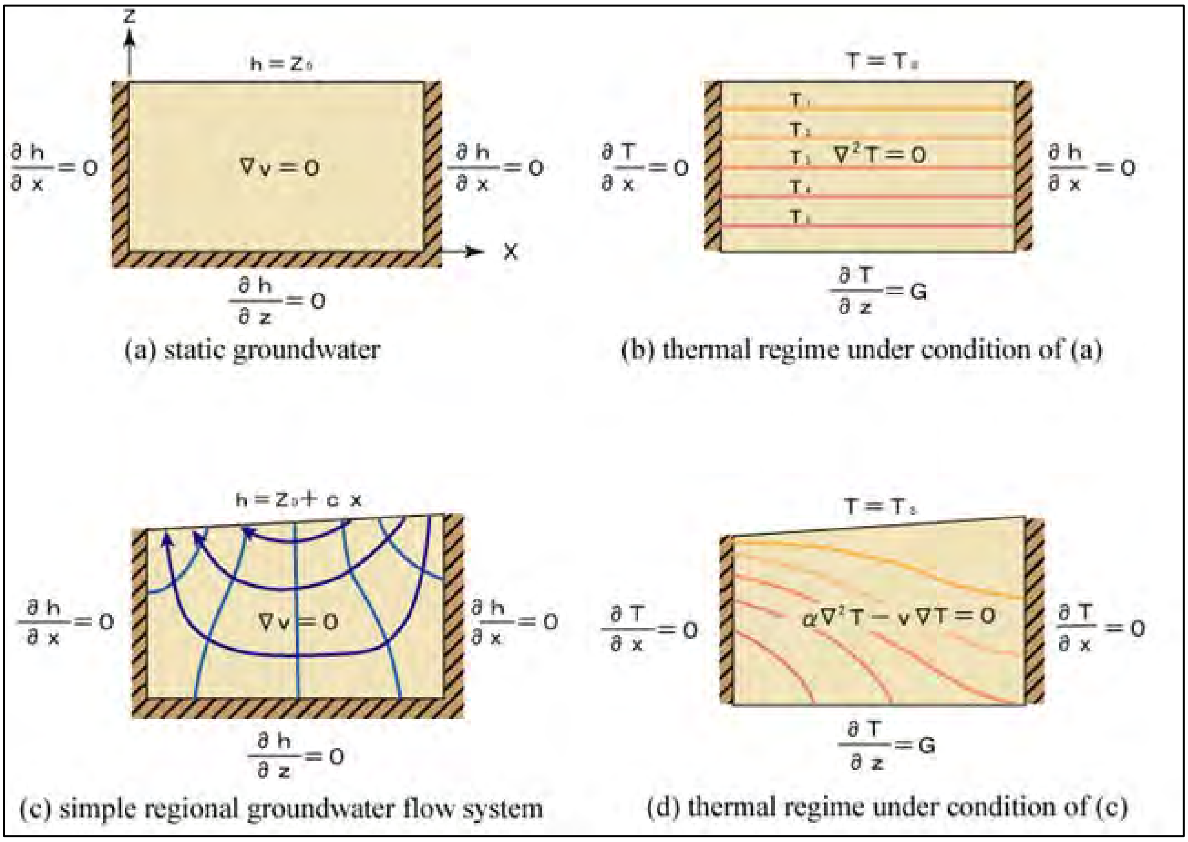

Fig. 6 Groundwater flow system and subsurface temperature distribution (modified from Domenico and Palciauskas, 1973)

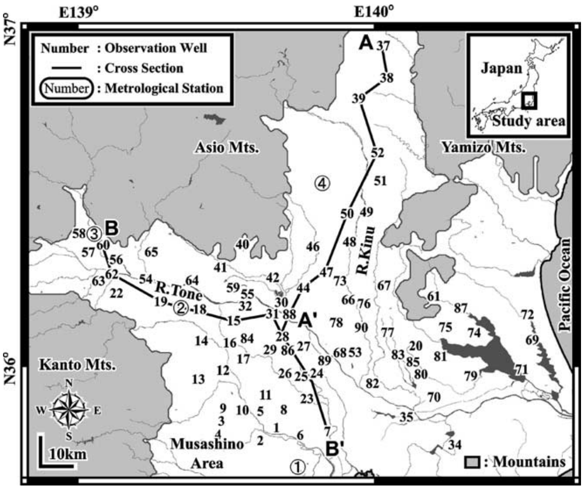

Fig. 7 Location Map of the study area and distribution of observation well.

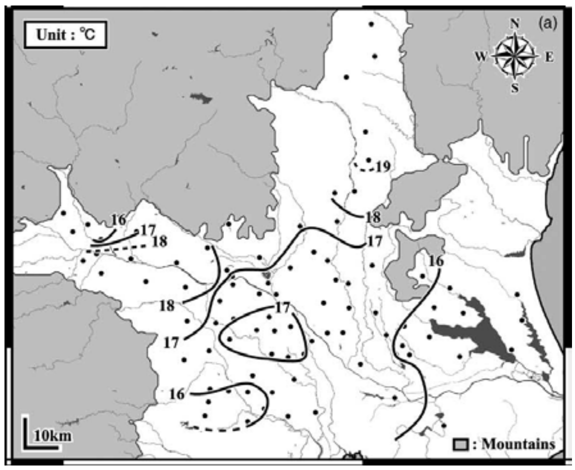

Fig. 8 Isotherms of subsurface temperature at 50 m.

Kanto Plain is the largest plain in Japan and there are a lot of large cities such as Metropolis of Tokyo. Groundwater in the Kanto Plain has been used since 20th century. There are some studies of groundwater flow system in the Kanto Plain, but all of studies is limited in the local of the Kanto Plain, not the whole area of it. The purpose of this study was to clarify the regional groundwater flow system of the Kanto plain from the distribution of hydraulic heads and subsurface temperature.

Groundwater levels and temperature–depth profiles were measured on 88 observation wells in the Kanto Plain, East Japan (Fig. 7). From observation results, subsurface temperature distribution in the Kanto Plain is assumed to be strongly affected by thermal advection due to groundwater flow, which has regional difference between high temperature area and low temperature area (Fig. 8). The high temperature area is located in a low land around the Kinu, Tone Rivers and central part of the Kanto Plain. The low temperature area, on the other hand, is located in a high land and/or a mountain area around the Kanto Plain. Considering from observed distribution of subsurface temperatures and hydraulic heads, two local groundwater flow systems which discharge to the Tone River in Gunma Prefecture and to the Kinu River in Tochigi Prefecture, and one regional groundwater flow system which recharged in the peripheral area in the plain and discharges to central part of the plain are estimated.

Observation results of hydraulic head bore out the above estimation. Fig. 9a and 9b show vertical 2-D distribution of hydraulic heads along the Kinu river (A–A') and the Tone river (B–B'), respectively. Hydraulic heads are high in the surroundings of the plain such as hills or uplands, and low in the lowland which is located along the river. Areas with high hydraulic heads located on hills and uplands around the plain, and hydraulic heads gradually decrease from highlands to lowlands. Especially, in the lowland which is located in central part of the plain, hydraulic heads are anomalous low. There were a lot of artesian wells in the central part of the plain before 1970 (Kino, 1970). At present, there are very few artesian wells in this area, because of effects of pumping (Tochigi Prefecture, Japan, 1999; Saitama Prefecture, Japan, 1999). These distributions show the existence of groundwater flow system, which groundwater is recharged in hills and upland and discharged at lowland.

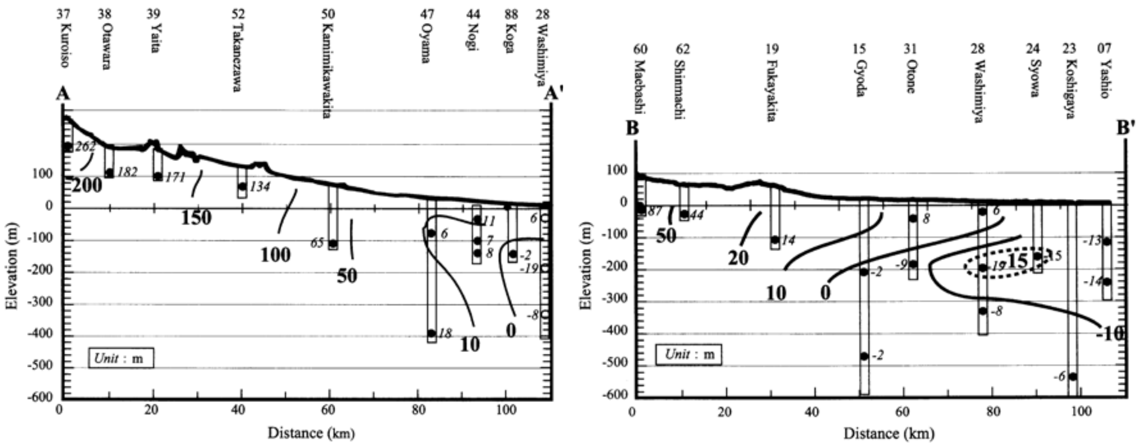

Fig. 9. Vertical distribution of hydraulic heads in cross section along (a) A–A0, (b) B–B0 in Fig. 6. Italic number shows the hydraulic head at the screen.

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

GSJ has released hydrological maps of 8 areas (Fig. 10) and we have possibility of compiling GW data in some areas, such as Kanto Plain around Tokyo Metropolis or Ishikari Plain around Sapporo City for the next project Phase III. These hydrological data can be converted for open Web GIS system.

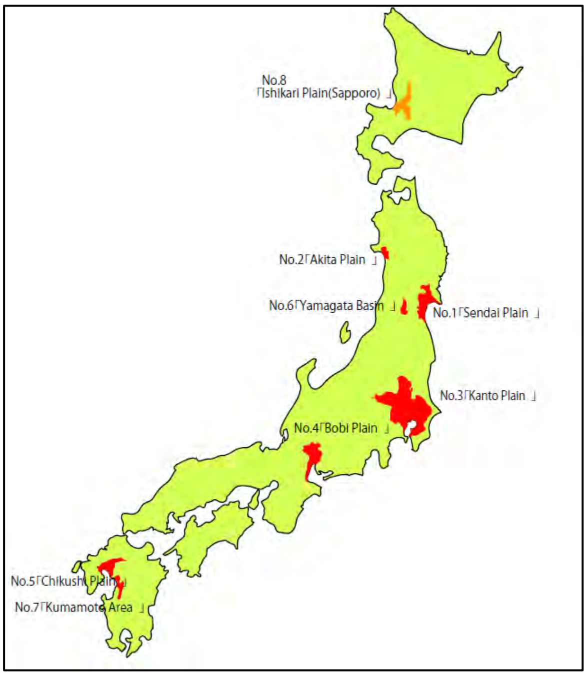

Fig.10 Published area of hydrological maps in Japan

4. Activity Plan for CCOP GW Project Phase III

GSJ have activity plan for the next CCOP GW Project Phase III as follows;

1. Managing GW Project Phase III.
2. Proposing design of new database system using Open Web GIS.
3. Supporting for hydrological field survey and construction of CCOP DB using Open Web GIS.

4. Managing GW Sub-project for Ground-Source Heat Pump System.

5. Conclusions

The CCOP Groundwater Project Phase II will release hydrological map of the Chao-Phraya Plain, Thailand and the Red River Delta, Vietnam. The map gives digital information in various kinds of hydrological understanding. Water quality, temperature, flow condition, and water level have prepared in the information. CCOP GW Sub-Project “Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions” is aimed to develop renewable energy for GSHP system in CCOP regions making good use of not only subsurface temperature, but also hydrological environment in each area. We have a plan for the next project to compile various geoscienfic information including groundwater water in CCOP countries and to construct a web based database.

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Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Korea

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Abstract

Groundwater resources in Korea are developed mostly for domestic and agricultural uses. Although the annual precipitation is higher than the world average value, available water resources are not enough due to population density. There are various types of groundwater database in Korea. Groundwater monitoring networks in Korea are well organized under various Ministries and systems. All the groundwater data are not freely distributed to the public, but some published reports or papers, and maps could be integrated in the CCOP region.

Keywords: Groundwater, Korea, Database

1. Introduction

The annual precipitation is 1,277.4 mm, which is averaged from 1978 to 2007. The world average precipitation is 807 mm, and the precipitation of Korea is higher than the world average value by 1.6 times. However, the total annual precipitation per person is 2,629 m^3 due to high population density, which is 1/6 of the world average 16,427 m^3. Korea is categorized as a water stressed country according to PAI (Population Action International) criterion. Furthermore, ~~T~~the precipitation varies considerably with time and space. 70% of the annual precipitation occurs during summer season from June to September, and yearly rainfall appears in large deviations from the lowest 754 mm in 1939 to the highest of 1,792 mm in 2003.

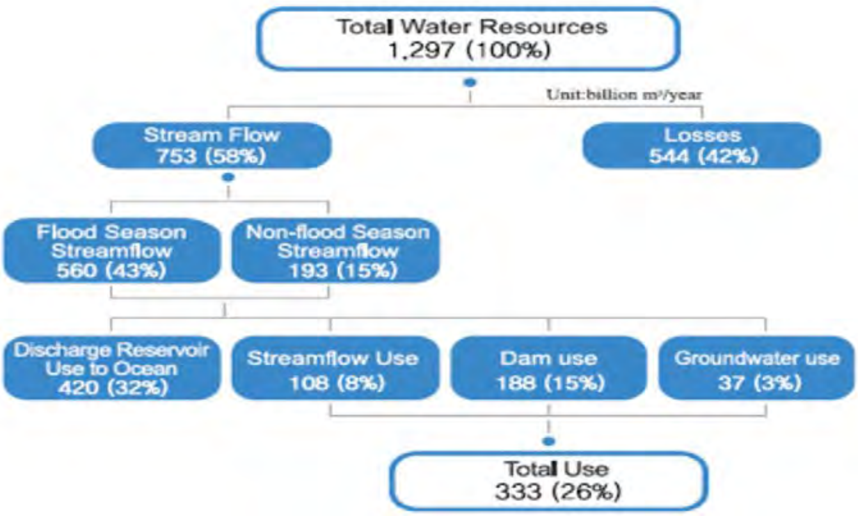

Fig. 1. Water use in Korea

The total amount of water resources is 124 billion m^3 and the annual water use is 33.7 billion m^3. The groundwater recharge rate is 14.4% of rainfall, and the development potentials, so called sustainable yields, is 12.9 billion m^3. Groundwater use of Korea in 2010 is 3.8 billion m^3. The total groundwater recharge is 18.8 billion m^3/yr, and groundwater development potentials is 12.9 billion m^3/yr, which is about 68.4% of the recharge amount.

The number of the developed groundwater wells is 1,381 thousand, and the total groundwater use is about 3.8 billion m^3/yr. The groundwater resources are mostly used for residential and agricultural purpose. Residential wells are more than agricultural wells in numbers, but agricultural use is more than residential

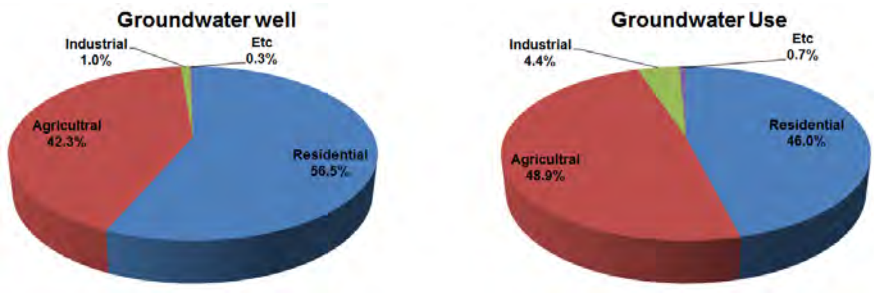

Fig. 2. Groundwater use in Korea

Unconsolidated aquifers are widely distributed near main rivers, and the thicknesses are 2~40 m, and mostly 10~15 m. Well yields of the unconsolidated aquifers are 30~800 m^3/day. For bedrock aquifer, hydraulic properties are primarily controlled by the secondary interstices such as fractures and faults because most rocks consist of crystalline rocks. Well yields of the bedrock aquifers are 10~5,000 m^3/day.

2. Groundwater Monitoring System and Database

There are 5 types of groundwater monitoring networks in Korea. The primary network is the National Groundwater Monitoring Network (NGWN), and there are 497 monitoring wells, which is operated and managed by Ministry of Land and Transport and K-water. The other primary monitoring network is for the groundwater quality monitoring, and there are 2,579 wells operated by Ministry of Environment and KECO. The secondary networks are subsidiary groundwater monitoring network operated by each local government. At present, about 3,000 wells are used for the purpose, and there is a plan to increase them to 10,000 wells nationwide. Supplementary networks are used for the special purposes such as seawater intrusion and drinking water monitoring.

Table 1. Groundwater monitoring networks in Korea

Monitoring network	Number of wells	Management/operation
National Groundwater Monitoring Network (NGMN)	497	Ministry of Land and Transport/K-Water
Groundwater Quality Monitoring Network (GQMN)	2,579	Ministry of Environment/KECO
Subsidiary Groundwater Monitoring Network(SGMN)	10,000 (target number)	Local governments like Seoul and Jeju
Seawater Intrusion Monitoring Network (SIMN)	117	Ministry for Food, Agriculture, Forestry and Fisheries/KRC (as of 2012)
Drinking Water Monitoring Network (DWMN)	not known	Ministry of Environment

The data from various groundwater monitoring networks are managed by each organization, and mostly they are serviced by internet to the public. The biggest groundwater database serviced by internet in Korea is the National Groundwater Information Management and Service Center under Ministry of Land and Transportation (http://www.gims.go.kr). Besides groundwater monitoring data, there are various scale hydrogeological maps in the site.

Table 2. Groundwater monitoring networks in Korea

Contents	Amounts of data	Details
Well information	the whole wells in Korea about 1.4 million wells	• well location, well facility specifications (diameter, depth, pumping capacity, development year, etc) • use type (purpose, yield, quality analysis)
Groundwater monitoring network	NGMS (334 stations) GQMN (2,457 wells) SGMN (about 800 wells) SIMN (192 wells)	• groundwater head, temperature, electrical conductivity (hourly) • groundwater quality analysis data (twice a year) • major cations and anions analysis data (intermittently)
Groundwater basic survey (Hydrogeological map)	75 districts ($39,848\ km^2$)	• hydrogeological map (map scale 1/50,000), thematic map (depth to groundwater, groundwater vulnerability, quality map, lineament map, etc) • groundwater level/quality monitoring data • hydraulic parameters (hydraulic conductivity, storage coefficient, etc) • drilling log, geophysical survey data, water budget analysis data
Reports related groundwater	about hundreds of reports	• standard, guide and reports for groundwater

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

There are various types of groundwater database in Korea, but they cannot be integrated into one system because of each Ministry interest. Lots of laws and regulations under different Ministries exist, and it is difficult to compile all the GW data under CCOP GW Project. In aspect of Hydrogeological Maps, 1:250,000 scale paper maps could be used, and the data from the annual reports of groundwater monitoring and surveys also can be compiled. The data from the published papers of course could be used in the project Phase III.

4. Activity Plan for CCOP GW Project Phase III

Activity plan for CCOP GW Project III is shown in the figure below. In 2015, data such as hydrogeological map and annual report data will be collected. After the data collection, database has to be constructed in the second year, 2016. And, the constructed DB will be supplemented in the final stage. Compiling additional database and published papers will be executed continually, and there will be some administrative measures for using and sharing data.

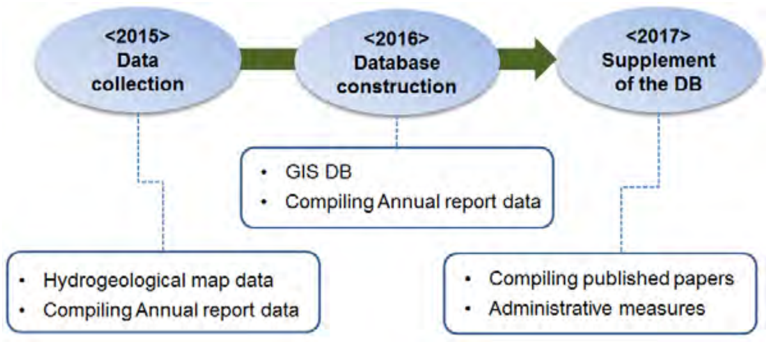

Fig. 3. Groundwater use in Korea

Ground Water Management and National Water Resources in Lao PDR

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Abstract

The generally ground water management in Lao PDR are crucial for the livelihood of people in the country whose majority live in rural areas, adjacent to river, mash, stream, canal and other ecosystem. The most of people earn a living are related to water, source of food, and have income generated from water resources such as: agriculture-livestock, fishery, aquatic vegetables, bamboo shoot and others. Therefore it is necessary to increase roles, responsibilities, and raise capacity of organizations involving in water resource management. Development of plans and utilization of tools appropriately in planning are needed to guide both public and private sector investment, to create a balance between economic development and environmental protection with aim to reduce poverty and accomplish socio-economic development goals.

1. General Information of Groundwater in Laos

Laos is divided into two major geological regions, the Annamian region in the north and east of the country and the Indosinian region mainly along the Mekong River. The Annamian region includes granites, metamorphics and palaeozoics. The Indosinian region consists of sandstones, siltstones, shales, mudstones, limestones, conglomerates and basalt. Groundwater is contained within shallow and deep aquifers that are composed of fractured hardrock, consolidated marine or terrestrial sediments and alluvial/fluvial deposits along major watercourses. Groundwater is thought to be available in many areas, however aquifers are often much localized and variably productive (Landon, 2012). Well yields are highly dependent on the local geology and are highly variable spatially due to complex depositional and post-depositional process. For example in the uplands of Khamounan province, pumping rates for individual wells can vary from 1-2 L/s for sandstones and siltstones to 10-20 L/s for limestones. In the fresh alluvial aquifers of the Vientiane Plains that overly rock salt layers pumping rates are modest (1-3 L/s) limiting the scale of the development potential?

FAO's country-level AQUASTAT database was used to calculate a value for annual groundwater replenishment for Laos of around 37,900 Mm^3/yr, equivalent to 20% of the surface water resources generated internally in the country. In area equivalent terms this amounts to 160 mm/yr of groundwater recharge across the country. The estimated groundwater use from rural and provincial supplies across the two major sectors (small towns and, here it is assumed, 75% of the rural population) amounts to just 0.2 percent of the annual replenishment. Whilst neglecting the irrigation and industrial sub-sectors, which are likely to be minor, and given the crudity of the estimates, the figures suggest a grossly underutilized resource with significant scope for expansion in high-value economic sectors such as irrigation and industry, provided that continued reliability and expansion can be assured for the domestic use sector.

Groundwater demand is highly spatially dependent on the productivity and accessibility of the groundwater, its attractiveness against alternative sources of supply and demands from the various socio-economic sectors. Hotspots where groundwater development can have the greatest impact at the household or community levels for livelihoods and the economy correlate with areas where the recourse potential is high and groundwater use is highest at present (see Figure 1). The areas of highest need are situated in the lowland floodplains of the Mekong, and include large parts of the provinces of Vientiane Capital, Vientiane, Savannakhet, Saravan and Champassak.

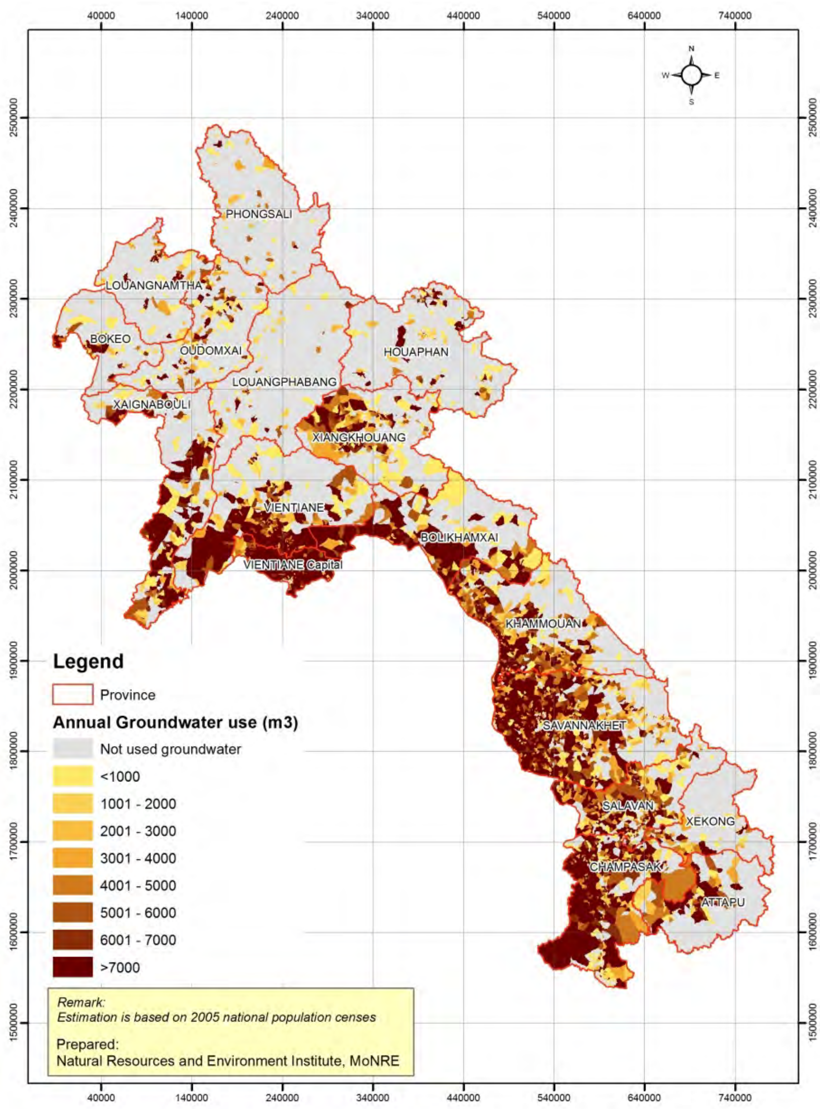

Figure1. Distribution of groundwater use by householders in Laos, estimated from village-level census data in 2005. Source: NREI based on 2005 national population census data.

1.1 Challenges in Managing Groundwater Resources

Groundwater is a largely invisible resource that is seen only by those who know or take the effort to consider it and is thus easily neglected, misunderstood, mismanaged or simply taken for granted. The ease of access, and the lack of differentiation in the legal entitlements for land and water in many countries, can create tension between the perceptions that private, individual access equates to a sense of outright ownership of groundwater, incompatible with the practicality that groundwater must be a common pool resource. Problems can thus emerge with falling water levels, higher pumping costs, reduced water quality and competition or even conflict amongst competing water users.

Well-known and documented examples of such issues include those in the densely populated and agriculturally productive plains of India and North China (Giordano, 2009). Even within the LMRB, localized and less well-known examples emerge. In parts of southern Cambodia recent rapid and unregulated growth of small-scale groundwater irrigation has raised concerns about competition with domestic supplies (IDE, 2005). In the Mekong Delta region over-pumping for irrigation, industrial and domestic uses is resulting in a lowering of the water table and salt water intrusion (IUCN, 2011).

2. Situation of Groundwater Monitoring System and Database

Groundwater governance involves decision making processes from the individual through to institutional level, whereby all players have freedom to exercise their political, economic and administrative authority and/or rights. For example, a farmer choosing to increase the rate of groundwater pumping to a small farm is as much an issue of governance as a water supply authority organizing that restrictions be placed on land-polluting practices within the capture zone of a well field used for urban water supply.

A number of methods have been conceived to define the quality of groundwater governance. A 'checklist' type of approach described by Foster et al., (2010) is perhaps the most straightforward to apply here for Laos. These authors have identified a series of indicators of successful governance, grouped into four categories: technical, legal and institutional, cross-sector policy coordination and operational success. If we were to hypothetically apply this approach to Laos, it is judged that only 1of the 20 indicators would be considered as being addressed in any meaningful way. Adapting the checklist of Foster et al. to the local context raises no shortage of issues associated with the current state of groundwater governance in Laos:

- General lack of knowledge of the resource by those tasked and trained to manage it (except at the broadest scale and in a few localities) and an absence of hydrogeological maps, making development a high risk option
- Lack of capacity amongst field technicians/practitioners resulting in poor drilling practices, lack of sufficient data collection and sound technical advice, high cost of groundwater development and high running and maintenance costs of bores
- Lack of understanding at the community level about groundwater leading to misconceptions, and costly and/or failed projects
- Data records and information systems that are inadequate or too fragmented for effective planning and evaluation
- Absence of a national, or even a regional, monitoring well network to support planning and development
- Inadequate coordination between the concerned stakeholders, including within relevant government agencies, to pool efforts and to manage effectively
- Laws and regulations outpace the field realities (e.g. absence of a well permitting system)
- Presence of potential water quality problems in specific regions due to water quality constituents such as arsenic, iron, manganese and hardness
- Rapid urbanization and population growth, combined with poor sewerage systems is resulting in contamination of shallow groundwater
- Some skepticism and curtailment of investments due to lack of knowledge in locating exploitable quantities of water suitable for domestic supplies

3. Water Resources Management and Policy

Despite the Lao Government's effort in developing laws and regulations, water resource management in Lao PDR has not match with the rapid growth of socio-economic development throughout the country. Weakness and gaps exist in the understanding and application of the regulation for an effective and integrated water resource management. The purpose of this National Water Resource Strategy is to provide guidance for the participating Government agencies and investors in water sector to carry out appropriate and well-coordinated water management and utilization activities.

The National Water Resource Policy reflects the Government's direction and vision in water resource management, to ensure equitable water use, benefit sharing and utilization of benefits from water development to contribute to poverty reduction, protection and restoration of the water environment and increased water security.

The National Water Resource Strategy will be reference for improvement of the Law on Water and Water Resources and other legislations. It will also contribute to the national socio-economic development planning and private sector investment management at the central and local levels. The National Water Resource Strategy is an important foundation to define the water resource action plans for every five year periods.

4. Problems Related to Water Resources

- ❖ Coordination and cooperation for water resources development with line agency well yet;
- ❖ Poor knowledge and capacity building of groundwater management;
- ❖ Don't have Long-term plan for groundwater management and water usage;
- ❖ People don't understand of water resources management;
- ❖ Laws and regulations not clear yet

5. Plans for Cooperation to Solve the Problems

5.1 International Water Resources Management and Cooperation

River basins are diverse in terms of water quantity and human activities both within river basins and their downstream. With this reason, water management has been changed to river basin based management which is a more effective way. In the United State America, relevant organizations are trying to find a way to protect water quality by establishing a monitor and evaluation system for a daily maximum chemical allowed in water, based on conditions and capacity of river basin to absorb contaminated substances. The European Union also uses water resource management plan to improve water quality of all rivers through a well-coordinated river basin management.

After the International Conference on Water and Environment in Dublin and Rio de Janeiro in 1992, the integrated water resource management received special interest, though no clear definition and answer on its application provided. Four Dublin principles, agreed by the UN conference on Environment and Development in Rio de Janeiro, in Brazil in 1992 and accepted by world community as a direction for the integrated water resource management, include:

1) Freshwater is a finite and vulnerable resource, essential to sustain life, development, and environment.

2) Water development and management should be based on participatory approach, involving users, planers, and policy-makers at all levels.

3) Women plays a central part in the provision, management, and safeguarding of water.

4) Water has economic value in all its competing uses and should be recognized as an economic goods based on the equitable standard and affordability by the poor.

5.2 Regional Cooperation

Water resource management in Lao PDR has been carried out in cooperation with the region for a long time. Such cooperation has several forms, specifically: becoming a member of the South East Asian Nations or ASEAN and Mekong sub-region cooperation.

Cooperation with ASEAN countries in water resource management has started since 2002 until now, with the vision: "achieve sustainable water resource management to ensure sufficiency and acceptable water quality and quantity to assure and meet the needs of people in ASEAN countries in terms of health, food, economy and environment".

Mekong sub-region cooperation particularly under the Agreement in 1995 of four countries: Lao PDR, Vietnam, Cambodia and Thailand, have covered all aspects in sustainable development, utilization, management, protection of water and related resources in Mekong river basin including irrigation, hydropower, boat transportation, flood protection, fishery, river logging, recreation and tourism through optimal use of many models and for mutual benefits of the party countries and impact mitigation from natural phenomena and man-made activities. The Agreement agreed to establish the Mekong River Commission where currently the secretariat is located in Vientiane Capital, Lao PDR, and in Phnom Phen, Cambodia.

5.3 National Cooperation

- ❖ Develop coordination mechanism for effective and efficient water resource management and development.

- ❖ Ensure management, development, conservation and rehabilitation of water resource nationwide to meet the needs, while ensuring the management for the outmost benefits and sustainability which also includes protection, mitigation and addressing hazardous issues as to reduce impact on society and ecosystem.

- ❖ Improve management and conservation of water and water resources by using basin for worthwhile and sustainable economic production, while ensure river basin environment protection and social benefits.

- ❖ Improve water resource management to meet water needs both in terms of quantity and quality in river basin and increase measures to protect drought, flood, and erosion and subside in river basin areas.

- ❖ Increase production value from using natural resources such as: land, water, forest, minerals and others.

- ❖ Renovate and develop meteorological stations and early warning system nationwide to serve agricultural production and climate change adaptation.

For Example: Implement for Ground Water Management in Keoudom, Phonehong, Thoulakome and Viengkham districts in Vientiane Province.

Location map of the 30 wells measured SWL

Table 1: Measurement of Groundwater level within 4 districts in Vientiane province,

Code	Longitude	Latitude	District	Villages	Location of Well	High level from pipe surface (m)	Deep level from pipe to water surface(m) date 17-18/9/2014	Deep level from pipe to water surface(m) date 16-17/10/2014	Deep level from pipe to water surface(m) date 17-18/11/2014	Deep level from pipe to water surface(m) date 16-18/12/2014
V52-2/2	18.5615	102.5	*Keoudome*	Phonekham	PhonkhameTemple	0.41	8.78	11.12	10.39	9.56
V1-2/2-1	18.4892	102.41323	*Ponhong*	Phonsitay	Police station	0.35	0.85	1.18	1.56	1.91
V1-2/2-2	18.4895	102.4125	*Ponehong*	Phonsitay	Hospital station	0.20	0.62	1.44	1.95	2.56
V13-2/2	18.5009	102.43	*Ponehong*	Nachou	Sibounhieng temple	0.50	1.37	2.20	2.43	2.77
V18-1/2	18.4949	102.4644	*Ponehong*	Phonsavath	Phonsavath temple	0.25	7.61	9.25	9.70	10.14
V18-2/2	18.4957	102.4636	*Ponehong*	Phonsavath	Primary school	0.43	5.31	6.56	7.05	7.57
V19-2/3	18.4936	102.4718	*Ponehong*	Nalao	IN font of house No 234	0.42	10.88	12.42	12.21	12.55
V2-1/1	18.5161	102.4249	*Ponehong*	Naphonnua	Naphonnua temple	0.63	0.85	1.63	1.87	2.30
V23-3/4	18.3103	102.4602	*Ponehong*	Mai	Primary school	0.17	1.37	2.25	2.41	2.62
V25-1/3	18.3555	102.463	*Ponehong*	Eachange	In font of house No 256					
V25-2/3	18.3566	102.4624	*Ponehong*	Eachange	Eachange temple	0.60				5.55
V25-3/3	18.3583	102.4616	*Ponehong*	Eachange	Secondary school	0.80	3.34	4.00	4.29	4.73
V30-2/3	18.3976	102.4252	*Ponehong*	Vangmone	In font of house No 143	0.16	4.62	6.28	6.74	7.29
V3-1/2	18.527	102.43	*Ponehong*	Phonhor	Phonhor school	0.60			4.50	4.88
V32-2/3	18.4047	102.4264	*Ponehong*	Saka	In font of Saka temple	0.45	3.11	4.15	4.51	4.89
V37-3/6	18.4244	102.4567	*Ponehong*	Nafaitai	Teep house	0.00	2.20	3.05	3.41	3.70
V9-1/1	18.5511	102.396	*Ponehong*	Pear	Pear temple	0.48	1.35	1.99	2.17	1.89
V48-2/2	18.34	102.6597	*Thoulakome*	Parkhang	Parkhang temple	0.49	1.10	1.57	1.71	1.87

V49-1/4 N	18.3182	102.6682	*Thoulakome*	Napeng	Household No10	0.10	0.16	0.66	0.87	1.13
V49-2/4 N	18.3294	102.666	*Thoulakome*	Pakor	Pakor temple	0.00	0.52	1.10	1.25	1.30
V49-4/4	18.3182	102.6691	*Thoulakome*	Napeng	Napeng temple	0.80	0.56	0.90	1.19	1.43
V39-5/9	18.4303	102.5364	*Viengkhame*	Muangkao	Public Health	0.42	3.65	5.68	6.42	7.13
V39-9/9	18.4567	102.4963	*Viengkhame*	Parkjengnua	Soldier Camp					
V61-2/2	18.4427	102.515	*Viengkhame*	Nonsavang	Behind of Education and sports office	0.25	10.55	11.79	12.13	12.40
V36-3/7	18.4846	102.4855	*Viengkhame*	Phonmee	Village office (near old market)	0.00	2.44	3.54	3.56	4.03
V36-4/7	18.4848	102.4885	*Viengkhame*	Phonmee	Phonmee school	0.30	2.30	3.92	3.97	4.35
V36-7/7	18.4805	102.4844	*Viengkhame*	Phonmee	Near phoneme temple	0.00	1.12	1.60	1.64	2.08
V36-8/7	18.4802	102.485	*Viengkhame*	Phonmee	Phonmee temple	0.00	1.25	1.75	1.90	2.40
V36-9/7	18.4822	102.4842	*Viengkhame*	Phonmee	Near household of paddy field	0.16	1.10	1.69	1.84	2.44
V41-2/2	18.3951	102.542	*Viengkhame*	Donkuad	Donkuad hospital	0.40	6.25	8.34	8.98	9.38

6. Conclusion

Ground water management and national water resources is key to the sustainability of the economic activities of people in the rural areas. Likewise, it determines the pace and extent of industrial development in urban and commercial centers in Lao PDR. The wise management and utilization of water resource as embodied in this Action Plan provides guide for all stakeholders to cooperate and collaborate together to achieve a sound IWRM for greater societal benefits.

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Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Langat Basin, Malaysia

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Abstract

Langat Basin's total catchment area is 2,750 km^2 which includes Kuala Langat, Sepang and Hulu Langat of Selangor State and the western part of Seremban of Negeri Seremban State in Malaysia. The basin covers mountainous areas, hilly areas and flat lowlands, with source of recharge of groundwater at mountainous and hilly areas and the aquifer distributes widely in the lowlands. The lowlands are divided into four layers; surface peat/peaty clay, clayey soil, sand & gravel and bedrock. The sand & gravel of the Lower Member of Simpang Formation, which is continuously distributed, is considered as an important aquifer in the Basin. It is located at a depth of 20 to more than 100 m below the ground. Based on JICA (Japan International Cooperation Agency) study in 2002, safe yield for groundwater extraction from this aquifer is estimated at 45 MLD.

Industry such as Megasteel Sdn. Bhd., a steel mill, which is the main user of the groundwater, is using the groundwater for its Laminar Cooling System. Tin mining industry such as Lion Tin Sdn. Bhd. would also carried out groundwater abstraction for dewatering purposes in order to carry out mining operation. These groundwater abstractions are closely monitored because any uncontrolled use would result in serious environmental problems such as land subsidence, saline intrusion and also may induced possible migration of surface pollutions resulted from agriculture and industry activities and landfills into the aquifer. Groundwater monitoring was carried out from year 2002 until present on its water quality, water level and land subsidence. Arsenic was widely detected although mostly was under drinking standard of 0.05 mg/l. Traces of organic compounds; m&p-Xylene, o-Xylene, 1,2,4-Trimethylbenzene, Napthalene and 2-Methylnapthaline were also detected.

The Minerals and Geoscience Department Malaysia's groundwater database development, through series of data management system had started since early 1980s with its latest, HYDRODAT, which is part of MINGEODAT (Minerals and Geoscience Database) system. The HYDRODAT stored data of a wide variety of sources and it is collection of hydrological, hydrogeological, geochemical and geological data. It is automatically linked to the ArcGis map through HYDROGIS, which is part of MINGEOGIS. This GIS application is used in analyzing and managing geoscience data to produce useful informative maps for landuse and development planning purposes. MINGEODAT and MINGEOSIS are part of MINGEOSIS (Minerals and Geoscience Information System).

Data stored inside the HYDRODAT and HYDROGIS would be useful for the proposed construction an open web based database for the development of Geoinformation Sharing Infrastructure for East and Southeast Asia.

There is an activity plan of great importance in the near future to enhance the monitoring process for the heavy metals, organic compounds, saline intrusion and land subsidence. These works are needed to establish an integrated groundwater resource and environmental management plan to achieve a sustainable groundwater resources and favorable groundwater quality for future generations and to have a healthy and clean environment.

Keywords: groundwater, Asia

1. Introduction

Langat Basin covers three (3) major tributaries, namely Sg. Semenyih, Sg. Beranang and Sg. Labu which includes areas such Kuala Langat, Sepang and Hulu Langat of Selangor State and the western part of Seremban of Negeri Seremban State in Malaysia. The area is estimated to be 2,750 km^2 which covers mountainous areas, hilly areas and flat lowlands. JICA (2002) reported that the source of recharge of groundwater is at mountainous and hilly areas and aquifer covers beneath the lowlands. The lowland's surface which is covered with peat or peaty clay (0.5 to 5.5m in depth) is underlain by clay. Underlying this clay layer (40 to 50m in depth) is the sand & gravel with bedrock underneath it (Jurutera Perunding Zaaba Sdn. Bhd., 2014). This sand & gravel of the Lower Member of Simpang Formation is continuously distributed and is considered as an important aquifer in the Basin. It is located at a depth of 20 to more than 100 m below the ground.

The groundwater is considered as an alternative source to surface water during the dry season in Selangor State, Malaysia. Industry such as Megasteel Sdn. Bhd. had started abstracting groundwater for their own use such as for their cooling system. Tin mining industry such as Lion Tin Sdn. Bhd. carried out dewatering process before any mining operation started.

Jurutera Perunding Zaaba Sdn. Bhd. in 2014 reported that Langat Basin is an important water catchment area providing raw water supply and other amenities to approximately 1.2 million people within the basin.

2. Situation of Groundwater Monitoring System and Database

Groundwater monitoring system at Langat Basin was implemented since 2002. It involves monitoring a total of 48 wells and 24 levelling survey points.

Water samples were collected from the wells after water level measurements were recorded. The samples were sent to Geochemistry Laboratory to analyse for its water quality. Any changes in water quality especially the chloride content or any significant presents of heavy metals or organic compound were monitored to identify for any sign of saline intrusion or contamination. At present no significant changes in chloride contents. Arsenic was widely detected although mostly was under drinking standard of 0.05 mg/l. Traces of organic compounds; m&p-Xylene, o-Xylene, 1,2,4-Trimethylbenzene, Napthalene and 2-Methylnapthaline were also detected.

Water level measurements were needed to analyse the groundwater flow which can imply; a possible area source of recharge, a sign of limit to groundwater abstractions and finally a possible sign of saline intrusions.

The survey points or benchmarks were constructed, spread over the Langat Basin with most of the points or benchmarks were constructed near to the groundwater extractions area in order to detect the immediate sign of subsidence due to groundwater abstractions. Minerals and Geoscience Department Malaysia and National Remote Sensing Agency (ARSM) have conducted an intergrated monitoring on the subsidence (Aros, 2009).

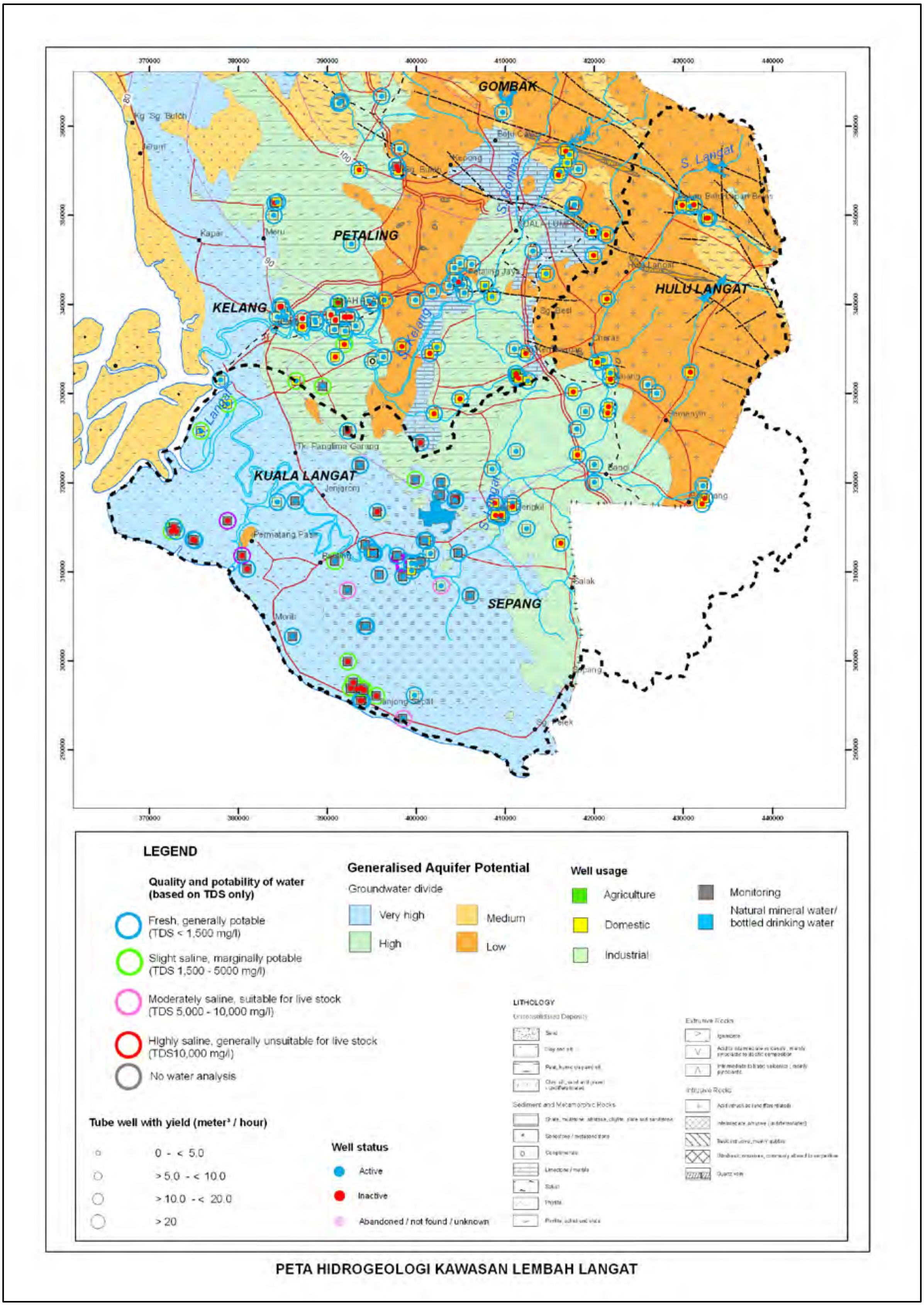

Fig. 1: Hydrogeological map of Langat Basin area

Fig. 2: Groundwater monitoring carried out by the Minerals and Geoscience Department Malaysia

The Minerals and Geoscience Department Malaysia is a custodian for mineral and geoscience data and information. They have a network of groundwater database development system. The latest groundwater data management or information system is HYDRODAT, which is part of MINGEODAT (Minerals and Geoscience Database). MINGEODAT is an integrated system centralized database that consists of 8 different systems that include HYDRODAT. The HYDRODAT stored data of a wide variety of sources and it is collection of hydrological, hydrogeological, geochemical, geophysical, geological and geotechnical data. It is automatically linked to the ArcGis map through HYDROGIS, which is part of MINGEOGIS. MINGEOGIS is an integrated, centralized and spatial database with both textural and spatial aspects. It has five (5) different spatial database systems that include HYDROGIS, which is part of GIS application. The GIS application is used in analyzing and managing geoscience data to produce useful informative maps for landuse and development planning purposes. Manap (2011) mentioned that this GIS application can be used to identify groundwater potential area and can be further used for future planning of groundwater exploration, planning and development by the related agencies, which provide a rapid method and reduce cost as well as less time consuming. These MINGEODAT and MINGEOGIS are part of MINGEOSIS (Minerals and Geoscience Information System).

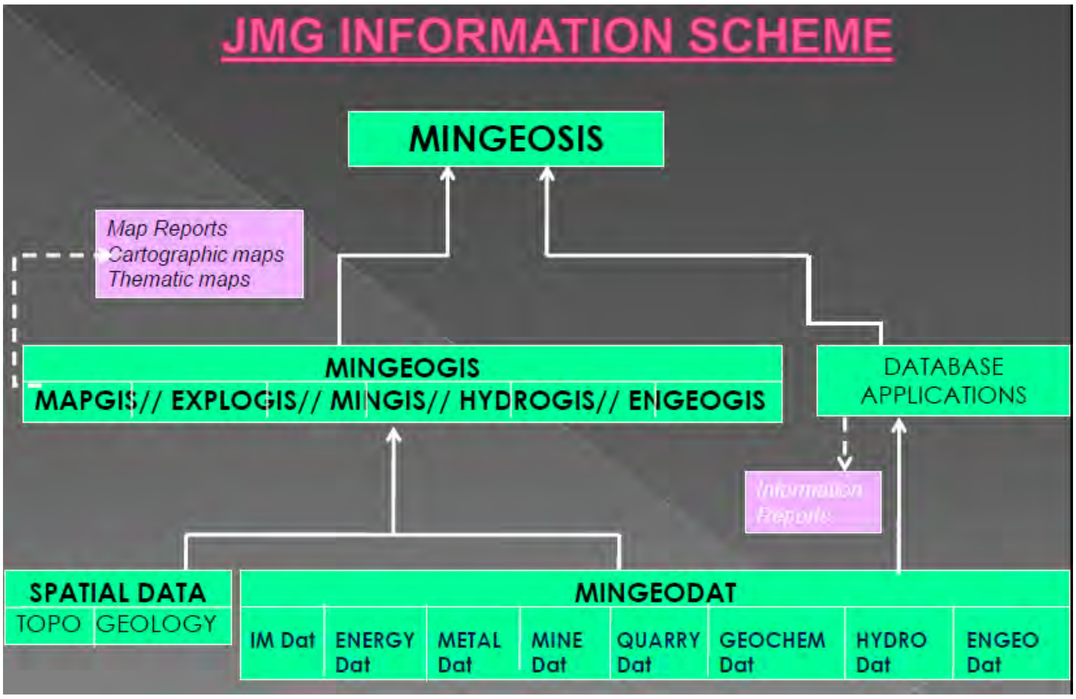

Fig. 3: The Minerals and Geoscience Department Malaysia's network of data management and information system (Source: Abd. Razak, 2012).

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

The groundwater data collected especially by the Minerals and Geoscience Department Malaysia and Megasteel Sdn. Bhd, which are stored inside the HYDRODAT system, are of large quantity. They are collected every year and are of great value to CCOP GW Project Phase III.

Data collected, which are of great important to CCOP GW Project Phase III are the water level, water quality and the survey points / benchmarks. All these data have its locations coordinate recorded, which are made known when the wells and survey points were constructed. The wells are used to collect groundwater related information data and survey points or benchmarks are used to gather information related to any possible subsidence.

The data when linked to GIS applications would be very useful through compilation under the CCOP GW Project Phase III. They can be used to produce informative maps when stored inside the proposed construction an open web based database for the development of Geoinformation Sharing Infrastructure for East and Southeast Asia. These groundwater available data can be converted to CCOP Database.

The Minerals and Geoscience Department Malaysia would help CCOP in maintaining the data quality, updating the database and to proceed to open web system in order to establish a basic geoinformation infrastructure in Asia.

We agreed to the needs of continuing intensive discussions among the member countries before, during or after the possibility of compiling GW data under CCOP GW Project Phase III in order to achieve world standard database to be used in an open Web and also to come out with world standard hydrogeological map.

4. Activity Plan for CCOP GW Project Phase III

Part of the activity plan is to map out the peat area at the Langat Basin and to come out with an isopach map of peat thickness, distributions and elevation data. These data can be used as a reference when carried out future survey to detect possible subsidence.

The present monitoring systems can be enhanced through closely monitoring any present of pollution, saline intrusion and subsidence. Part of the work can be carried out through detailed water quality study especially on the heavy metals and organic compounds. Any high level of certain materials such as for example arsenic or organic compounds will be followed up by detailed study to determine the source and caused of pollution so that immediate remediation action can be carried out to protect the groundwater quality within the Langat Basin. Any possible saline intrusion caused by overpumping could be detected through detailed chloride test on all the shallow or deep wells. An additional survey point/benchmark needs to be constructed and its depth has to be if possible to the bedrock beneath the aquifer. This survey point is needed in order to accurately detect any possible land subsidence. These all monitoring works are needed in order to establish an integrated groundwater resource and environmental management plan to achieve a sustainable groundwater resources and favorable groundwater quality for future generations and to have a healthy and clean environment.

The monitoring works can be extended through involving the collection of water samples from various locations in the vicinity of the landfill, which is as a method to determine any possible leachate distribution in the groundwater.

Geophysical survey can also be carried out through the lowlands area to determine the aquifer distribution continuity. Any possible saline intrusion or contamination can also be detected through this survey.

Constructed selected observation wells near to targeted existing well would help in further determining the aquifer properties. Long hours of pumping are needed, not only for further check on aquifer properties identification but also to enhance the determination of recharge and to further check the sustainability of the recommended pumping rate.

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Activities plan and Possibility of compiling GW data under CCOP GW Project Phase III in Myanmar

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1. Introduction

Myanmar is rich in not only natural resources but also water resources. The total utilization of the nation's water resources is only about 6 percent or 65,000 million cubic meter (52.6 million acre-ft). It is obviously seem that the physical potential for further development of water resources in Myanmar is substantial.

Myanmar is agro-basis so that the freshwater resources are mainly used by the agriculture sector with small quantities being used for domestic, industrial and other purpose. Due to the importance of the agricultural sector, the Government has accorded high priority to its development and numerous irrigation facilities have been implemented since last three decades for irrigation and water supply to monsoon and summer paddy crops.

Apart from the agricultural sector, the hydropower sub-sector is also the most important in terms of economic development and investment.

Moreover, dry-season irrigation, especially by use of river pumping project, has been successfully increased as a result of power demand is also increasing annually. In fact that, renewable hydropower generation is very important to contribute considerably to socio-economic growth in country.

Therefore, electric power generation projects are being implemented wherever possible in order to meet the demand for electricity supplies.

2. Myanmar geography

Myanmar is the second largest nation in South-East Asia. Myanmar is geographically located between 9° 32′ and 28° 31′ North Latitude and 92° 10′ and 101° 10′ East Longitude.

It is characterized by mountain ranges in the north, east and west and a long coastal strip in the south and west. Lengthwise, it stretches about 1280 miles (2060 km) north to south and approximately 587 miles (945 km) east to west thus leading to the area coverage of 67.65 million hectares (676553 sq km) for the whole country. Coastal strip is 2832 km.

The river basin characteristics in Myanmar are quite variable due to the differences in physiographic features. The principal water courses flowing separately in Myanmar comprise four major rivers, the Ayeyarwaddy (including Chindwin), Sittaung, Thanlwin, Bago and other major tributaries. All rivers with the exception of the Thanlwin river of trans-boundary nature can be considered national water assets.

Their drainage area spreads rather extensively over the country, with 1,082,000 million cubic meter (876.73 million acre-ft) of water volume per annum. The monthly distribution of river flow varies according to the pattern of rainfall, i.e. about 80 percent in rainy season and 20 percent in dry season.

3. Water Potential in Myanmar

Myanmar is endowed with abundant water resources. The surface water amounts to 1,082 Km^3 and the ground water potential is 495 Km^3. Only about 10% of the fresh water resources of Myanmar currently utilized.

The potential of water resources in Myanmar is abundant which are used not only for domestic water supply but also agriculture sector. The catchment area of Myanmar's eight principal river basins is approximately 737,800 km^2, and the average annual inflow of water is 1081.885 km^3. Current utilization totals only about 39.55 km^3.

Sr	Name of Principal River Basin	Catchment area for each stretch (thousand sq.km)	Average estimated annual surface water (km3)	Estimated groundwater potential(km3)
1.	Chindwin River	115.30	141.293	57.578
2.	Upper Ayeyarwady River (up to its confluence with Chindwin River)	193.30	227.920	92.599
3.	Lower Ayeyarwady River (From confluence with Chindwin to its mouth)	95.60	85.800	153.249
4.	Sittaung River	48.10	81.148	28.402
5.	Rivers in Rakhine State	58.30	139.245	41.774
6.	Rivers in Taninthari Region	40.60	130.927	39.278
7.	Thanlwin River (From Myanmar boundary to its mouth)	158.00	257.918	74.779
8.	Mekong River (Within Myanmar territory)	28.60	17.634	7.054
	TOTAL	**737.80**	**1081.885**	**494.713**

4. Groundwater Resources

Where a perennial supply of surface water is not available, ground water is naturally utilized and sometimes with higher costs. Nowadays, ground water is being exploited not only for domestic water supply, but also for industrial and agricultural purposes in areas where conditions are favorable.

In Myanmar, groundwater sources are the single most important supply for the production of drinking-water, particularly in areas with limited or polluted surface water sources.

For many communities it may be the only economically viable option. This is in part because groundwater is typically of more stable quality and better microbial quality than surface waters.

Groundwater often requires little or no treatment to be suitable for drinking whereas surface waters generally need to be treated, often extensively.

Groundwater has a greater advantage over surface water as it is usually free from pathogenic organisms and bacteria causing water related diseases.

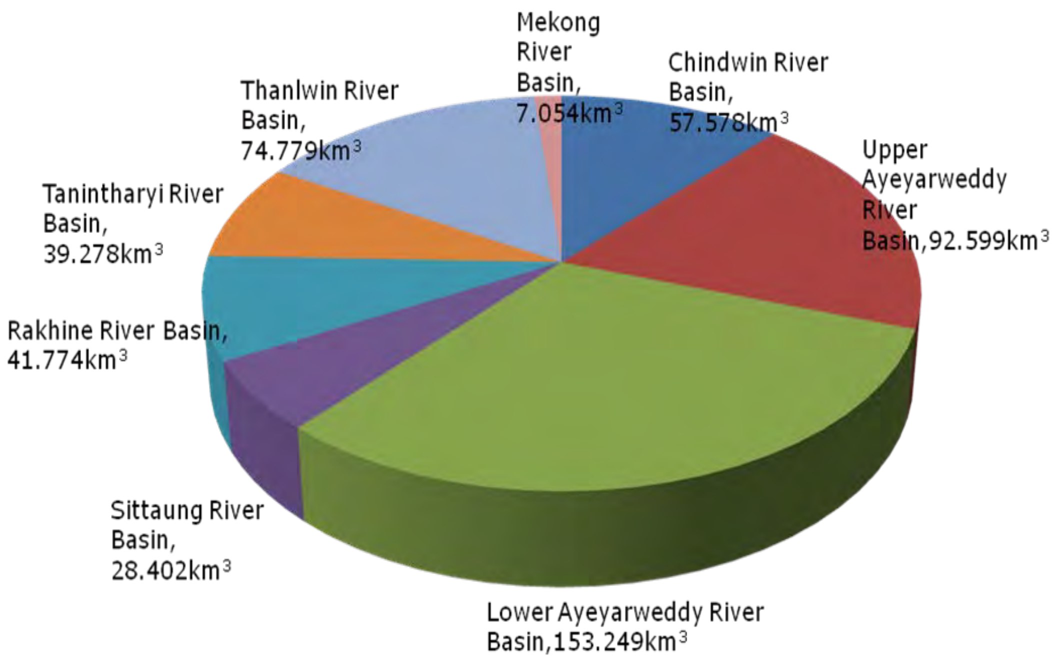
However, if the chemical quality of the water is poor, it may not be fit for drinking purposes, unless treated to acceptable levels.

The estimated groundwater potential in Myanmar is about 495 km^3 in eight principal basins in Myanmar. On the basic of stratigraphy, there are eleven different types of aquifers in Myanmar.

Depending on their lithology and depositional environments ground water from those aquifers has disparities in quality and quantity. Out of these, ground water from Alluvial and Irawaddian aquifers are more potable for both irrigation and domestic water use.

However, on the water scarcity regions, ground water from Peguan, Eocene, and Plateau Limestone aquifers is extracted for domestic use.

The annual groundwater water potential in Myanmar is as follow:-



Annual groundwater potential in Myanmar

5. Groundwater Utilization in Yangon City

People in Yangon City, the most populated area of Myanmar, have been using groundwater from hand-dug wells for centuries to the present for their domestic, livestock and agricultural needs.

Depths for surface wells dug by hand are limited, and in such cases, only the uppermost aquifer has been tapped.

Water yield is usually diminished during the dry season with the exception of a few wells from which water is available throughout the year.

In later years, drilling of deep wells by mechanical and electrical means was developed to tap groundwater from deep aquifers where a much higher and stable yield is obtained throughout all seasons of the year.

6. Groundwater Quality

The physical and chemical quality of groundwater is not always at acceptable levels.

In Yangon City, the quality of groundwater is tested periodically. The most common tests conducted are on color, turbidity, pH, hardness, iron and chloride. Bacteriological tests are rarely carried out except in cases where authorities determine it to be necessary.

Objections to groundwater quality usually arise from physical parameters such as color, turbidity, taste and odour. The presence of chemical impurities like iron and chlorides also presents problems to users.

Therefore, the water is still utilized for domestic purposes other than drinking. In such cases bottled water is used for drinking. The tests for groundwater quality were evaluated in line with the Proposed National Drinking Water Quality Standards (PNDWQS), Myanmar 2006.

7. Drinking Water and Sanitation Status

Safe drinking water supply and adequate sanitation facilities are essential elements in the protection of the environment, and improvement in health conditions and living standards.

The population of Myanmar is estimated at 60 million, of which the Yangon Metropolitan area accounts for about 11 percent of population. As greater density in urban areas and Myanmar's climate is hot and humid, the demand for water is high.

In Myanmar, several government agencies and departments under different ministries independently carry out programmes for sustainable access to safe drinking water supply throughout the country.

The government has given the priority to implementing water supply programmes in villages that have inadequate water supply in central zone area.

Myanmar strives to safely dispose of human excreta in both urban and rural areas, in order to improve sanitation conditions. In view of the importance of safe water sanitation to the well-being of the urban population, the government has initiated to set policy guidelines and oversee the performance of the sector, especially in the urban areas of the country.

It has been bilateral and multilateral parties to ensure universal access to safe drinking water and sanitation for the future development of the country.

8. Water Utilization and Challenges

The agricultural sector is the most basic economics of the state as well as the main source of livelihood in rural areas, since the rural population represents some 70 percent of the nation's population.

In order to development of the nation's economy, at present, the Government has been striving to develop the construction of dams and reservoirs throughout the country by utilizing large capital investment, man power and machineries making use of the available domestic resources and expertise in order to boost up their livelihood and economic growth.

As a result, local irrigation facilities have been constructed in respective regions throughout the country. Dams are now irrigation more than 1.7 million hectares of farmland.

Rural water supply is effective to 17 million of rural populace which is out of 41.44 million of the country.

Myanmar also faces the same kind of Global/ Regional weather changes including unusual and uneven rainfall patterns such as monsoon started about two weeks later than usual and in some parts of the country rainfall so far was less than usual.

The trend in remaining monsoon period cannot definitely be guessed. So that, the seasonal monsoon crops, main crop paddy, are mostly rain-fed crops and if rainfall is erratic, the rain dependent crops would be affected.

The storage reservoirs, rain harvesters in one way, could also be affected. In order to mitigate the impacts of climate change on water sector, the Government is trying to boost up to

(a) To strengthen the legal framework
(b) To enhance the existing systems.
(c) To function the operation efficiently.
(d) To enhance organizational capacity
(e) To aware environmental conservation.
(f) To strengthen integrated water resources management
(g) To raise cooperation among stakeholder.

9. Legislative Framework for Water Environment Management

Myanmar has no specific laws to control water pollution. There is a general provision in Section 9 of the Public Health Law of 1972, which empowers the Ministry of Health to carry out measures relating to environmental health, such as garbage disposal, use of water for drinking and other purposes, radioactivity, protection of air from pollution, and food and drug safety. However, detailed provisions do not exist to ensure more effective and comprehensive regulation of these matters.

10. Mission and Vision Statement

The mission statement of the water sector is "to establish a beneficial framework and effective mechanism for managing, developing and protecting water and related resources in an environmental and economical sound manner in order to meet the needs of the people of Myanmar."

The vision statement of Myanmar is "Sustainability of water resources to ensure sufficient water quantity of acceptable quality to meet the needs of the population in terms of health, food security, economy and environment and which clearly identified in Myanmar Agenda 21 for more efficient freshwater resources management."

11. Water Sector Profile in Myanmar

Several government agencies and departments under different ministries are operating their own programs independently without proper coordination with the principal executing agency. Provision of the agricultural water is the first priority in water resources management for the country at present and in the future as well.

It was found out that about (91) percent of the water use for agriculture, about (8) percent for domestic consumption and (1) percent for industrial purpose.

12. Pumping Station and Tube wells

Pumping station based on the availability of water resources from rivers and creeks and tube wells. 327 river pumping stations including 26 special pumping projects had been installed to irrigate some 201,095 hectares.

Groundwater facilities of 7,734 deep tube wells and 4,524 shallow tube wells (total 12,258 wells) were completed covering the beneficial area of 65,695 hectares.

Underground Water for agriculture	12,258
- Deep tube wells	7,734
- Shallow tube wells	4,524

Constructed Groundwater Irrigation Project

Sr.	State/Region	Number of Works	Beneficial Area (Hectare)
1	Kachin	44	108
2	Kayah	5	15
3	Sagaing	2,856	21,095
4	Bago	712	3,382
5	Magwe	1,298	4,271
6	Mandalay	5,957	31,577
7	Yangon	566	1,672
8	Shan	14	81
9	Ayeyarwaddy	806	3,495
	Total	12,258	65,695

13. Tube wells for domestic water supply

Shallow and deep tube wells have been digging to develop drinking water supply across the nation from 1952 to till now.

Period	Deep tube well	Shallow tube well	Total tube well	Rural Population
1952 - 2014	14,831	23,648	38,479	14,988,518

14. Sown and Irrigated Area in Myanmar

Growth in agricultural productivity has been recognized and targeted to raising the incomes of the rural poor and thus reducing poverty.

Since adequate water supply is one of the basic requirements for boosting up the production of crops, agricultural infrastructures have also been built accordingly throughout the country.

As water is fundamental requirement for agriculture, steps are being taken to ensure that there is sufficient water for the cultivation of crops at the required time.

The irrigated area and total sown area are shown in following Table.

Year	Net Sown Area (mil ha)	Irrigated Area (mil ha)	Percent
1987 - 1988	7.99	1.00	12.5
1996 - 1997	9.28	1.56	16.8
1998 - 1999	9.67	1.69	17.5
2001 - 2002	10.65	1.99	18.6
2002 - 2003	10.82	1.87	17.3
2003 - 2004	11.04	1.96	17.7
2004 - 2005	11.41	1.93	16.9
2005 - 2006	11.94	2.14	17.9
2006 - 2007	12.61	2.24	17.8
2007 - 2008	13.22	2.22	16.8
2008 - 2009	13.49	2.28	16.9
2009 - 2010	13.64	2.33	17.1
2010 - 2011	13.75	2.29	16.7
2011 - 2012	13.58	2.11	15.5
2012 - 2013	13.30	2.12	15.9
2013 - 2014	13.26	2.13	16.1

15. Watershed Protection

With the aim of ensuring sustainability of water resources of country, forests of Myanmar are well conserved and safeguarded covering 50% of the nation will contribute to fulfill the human needs.

Shifting cultivation and slash and burn practices provide significant contribution to forest loss and at the same time, it can adversely affect the environment in a number of ways such as soil erosion and degradation, deforestation, rapid silting of reservoirs, rising of river bed, causing flood at the downstream and navigation problem, etc.

Therefore, the government is making to reclaim the highlands and major watershed areas to substitute terrace farming for shifted cultivation.

In recent years a special programme has been launched by Forest Department for greening of 13 districts in central dry zone which is the most critical region in terms of degradation of land conservation of forest and establishment of forest plantation as follows:

(a) Plantation of fast growing multipurpose tree species at the rim and its periphery of the basin boundary such as 50,000 trees for high dams, 40,000 for medium dams and 20,000 trees for low dams to prevent watershed degradation as well as to restore ecological balance.

(b) Land rehabilitation and soil conservation activities in the most critical watersheds of upper Myanmar.

16. Conclusion

Myanmar being an agro-based country so that the development of agriculture sector is one of the key players to encourage the enhancement of living status, economic growth and food security.

As far as we are concerned, since the topography is favorable and fresh water resource is rich in Myanmar, groundwater development is not to be given the priority however, both of them are implementing in parallel.

It is realized that dry zone and crowded population cities are being used by groundwater for domestic and irrigation purpose, but the quality of groundwater is in limited areas in Myanmar thus groundwater developing is doing in specific areas if it is available to use.

In Myanmar, several agencies are engaged with water supply and management but it is still needed to enhance cooperation and coordination among them.

Therefore, expressing my conclusion is that all stakeholders will have to collaborate in water development process in Myanmar to run smoothly and successfully.

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Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in the Philippines

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Abstract

One of the major thrusts and programs of the Mines and Geosciences Bureau, Regional Office No. 1 is to assess and explore the potential groundwater resource in the municipalities and provinces of the country and assist the Local Government Units in locating the potential sites for the development of groundwater for domestic consumption of the populace.

Owing to the importance and usefulness of pertinent water related data collected over time, it has been recognized that there is a need to organize and systematize these data whereby not only the collecting agencies but also the general public will benefit. Although the agencies have different mandate and objectives, data sharing is one common objective that pushes for the development of water information sharing system. Information on water quality, quantity and other relevant data are managed using appropriate data format.

The Mines and Geosciences Bureau Regional Office No. I is equipped with sophisticated equipment to conduct hydro-geological survey, geo-resistivity survey, drilling and development of groundwater resources. The hydrogeological survey consists of collecting well data such as Static Water Level (SWL), water quality and groundwater flow. The Georesistivity Survey is conducted to investigate the physical characteristics of the subsurface earth layers and provides relatively rapid and cost-effective means of obtaining subsurface geological information, particularly in the identification of permeable layer (aquifers) and impermeable layer (clay).

Groundwater database include the index of hydrogeological maps, geological maps and georesistivity data, cross-sections and interpretations.

Keywords: groundwater, Asia, Philippines

1.0 Introduction

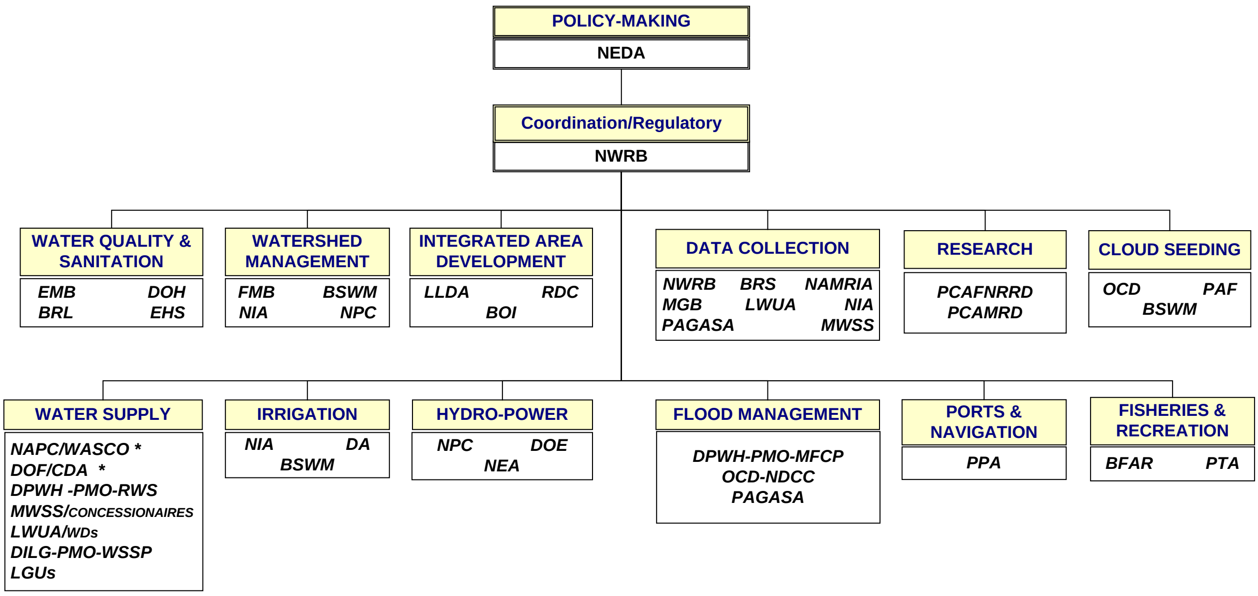
The groundwater resources is undeniably crucial in a country where rapid population and development in industry is an everyday reality thus, the need for sustainability and protection for the groundwater resources is but a vital responsibility by both the government and private person or agencies. In the past years a remarkable increase for supply of groundwater resources has been articulated by the general population both in urban and rural areas in the country. Both the government and private agencies are investing on long term program to address the gap in the supply for underground water resources and the need of the general population. Over the years however, the gap continues to remain wide indicating limited efforts resulting to reduction in supply and availability, depletion and degradation of quality to critical condition.

Efforts on the management of groundwater resources for many years have been shared by government and private agencies. Water information sharing network provided opportunities for evaluation and assessment resulting to programs to eliminate the gap. Continued efforts to find a long term solution is in place and research studies are engaged in order to scientifically identify methods to provide solution to issues in problems in groundwater management.

2.0 Situation of Groundwater Monitoring System and Database (Philippine Setting)

2.1 The Data Collection Agencies

Table 1. Functional Chart of Water Related Agencies in the Philippines
(Adopted from the Presentation of Susan P. Abano, Engineer IV, Water Resources Assessment, Policy and Program Division, NWRB)



The following are the primary data collection agencies in the Philippines with the information shared:

1. **National Water Resources Board (NWRB)**, lead agency - Water Permit, Groundwater
2. **Bureau of Research and Standard (BRS)** - Streamflow Data
3. **Environment Management Bureau (EMB) -** Water Quality
4. **Mines and Geosciences Bureau (MGB)** – Groundwater
5. **Local Water Utilities Administration (LWUA)** - Groundwater
6. **National Irrigation Administration (NIA)** – Dams, Groundwater
7. **National Economic Development Authority (NEDA)** – water policies
8. **Philippine Atmospheric, Geophysical, Astronomical Services Administration (PAGASA)** - Rainfall data

9. **Water Supply Program Management Office (WSPMO)** of the Department of Interior and Local Government (DILG)– groundwater data

2.2 Lands Geological Survey, Mines and Geosciences Bureau, Department of Environment and Natural Resources

One of the specific functions and services of the LGSD is the Environmental Geology and ***Hydrogeology Research Section.*** This Section is responsible for the conduct of ***hydrogeological assessment*** and ***geophysical survey***s in relation to ***groundwater assessment and development*** studies.

2.3 Efforts on Groundwater Database Development

The MGB and NWRB, both under the DENR have on a continuing basis conducted projects and studies on the national level. The MGB particularly conducts researches, investigations and assessment of the groundwater resources. The technical output produced had been utilized as management tools for the authorities, planners and decision makers to properly manage the groundwater resources.

2.3.1 Groundwater Resources of the Philippines (1970-1980)

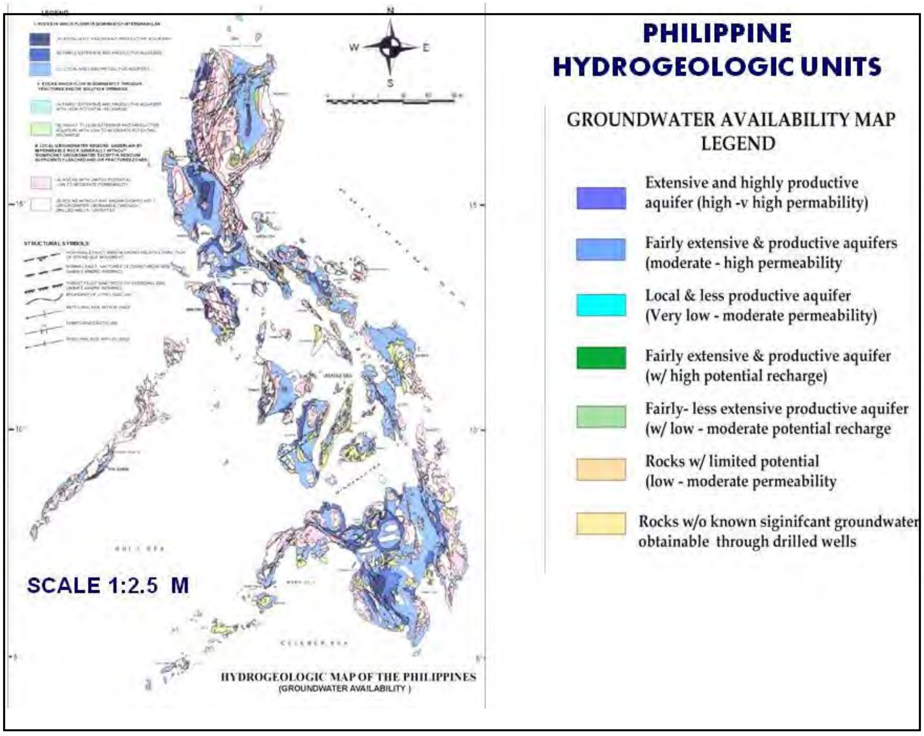


Figure 1. Groundwater Availability Map

The Groundwater Availability Map of the Philippines had been realized with the extensive hydrogeological data gathered by the early geoscientists at the MGB.

The First (1st) Edition of the Groundwater Availability Map was published by the MGB in 1982. The legends used were based on UNESCO/IAH Legend (1970) Classification of Hydrogeologic Units. The map projected the regional environment, characteristics and quantifies groundwater regimes suitably. It also represented a synthesis of all available information on geology, structure, geomorphology, climatology and hydrology relevant to the hydrogeology of the country.

The groundwater availability map of the Philippines (Figure 1) shows the availability of groundwater based on the water bearing capacity of various lithologic units covering the entire Philippine archipelago. This includes the characterization, extent, and location of groundwater sources (i.e. extensive/highly productive aquifers, fairly productive aquifer, less productive aquifers, and rocks with limited or low potential capacity to produce water) and was partly based on the hydrogeological and groundwater assessments survey, studies, and investigations made in different areas of the Philippines since the early 1960's.

2.3.2 Rapid Groundwater Assessment (1982)

In 1982, the NWRB had embarked on a project to roughly assess the country's groundwater resources at the municipal and provincial levels. This provided a comprehensive guide to water supply planners and designers and local officials.

The output of the project was a Regional Rapid Groundwater Assessment and Regional Well Classification Maps.

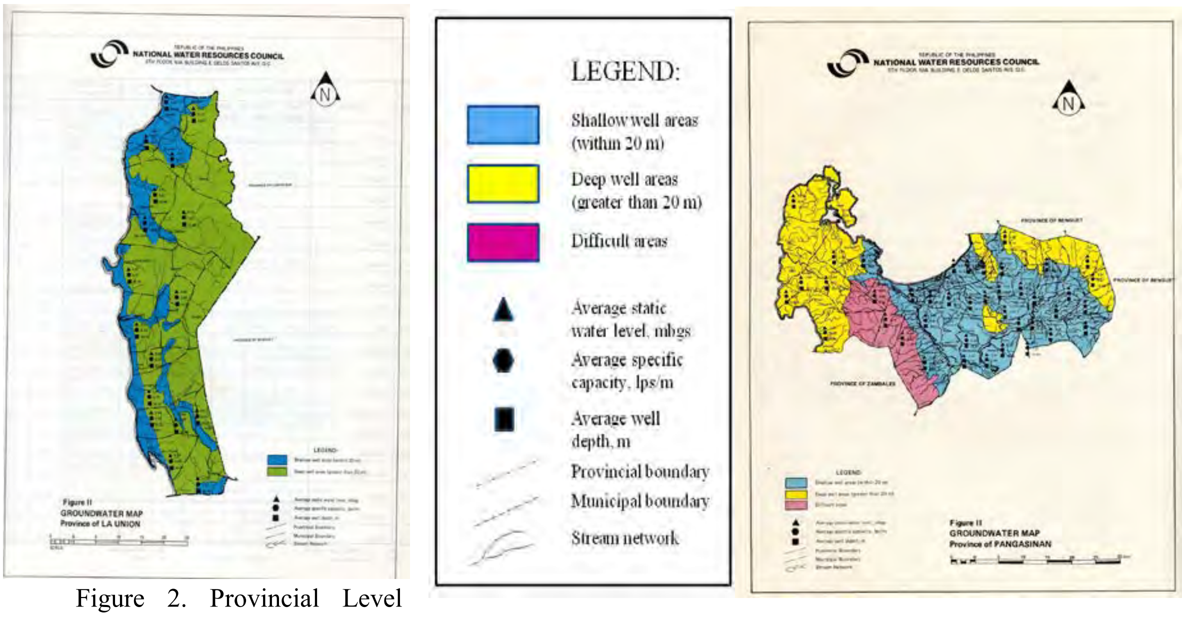


Figure 2. Provincial Level Groundwater Maps of La Union and Pangasinan Provinces

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

3.1 National Water Data Collection Network (NWDCN)

Spearheaded by the NWRB together with the MGB for groundwater, EMB for water quality and BRS/DPWH for surface water, the project is a groundwater, surface water and water quality database designed for the purpose of water resources planning.

3.2 National Water Information Network (NWIN)

The NWIN, an offshoot of the NWDCN is a computer-based system linking databases of water resources agencies. It includes stream flow data, water quality data, groundwater data, rainfall data, river systems data, water subscribers, project programs and publications. The computer data input was provided by the participating agencies.

3.3 Philippine Groundwater Databank (1991-1994)

It is the most widely used groundwater database (PGDB-GIS) developed under the UNDP Project (PHI/88/028) "Strengthening Water Sector in Groundwater Data banking and Dissemination" between the period 1991 to 1994. It was developed to systematize data collection and data banking in the groundwater sector. The database consists of well database and spring database. It was installed at the NWRB, LWUA and NIA and can still be accessed at present through the LWUA Research Division website.

3.4 MGB Regional Offices Data Collection

3.4.1 Hydrogeological Survey (Well Inventory)

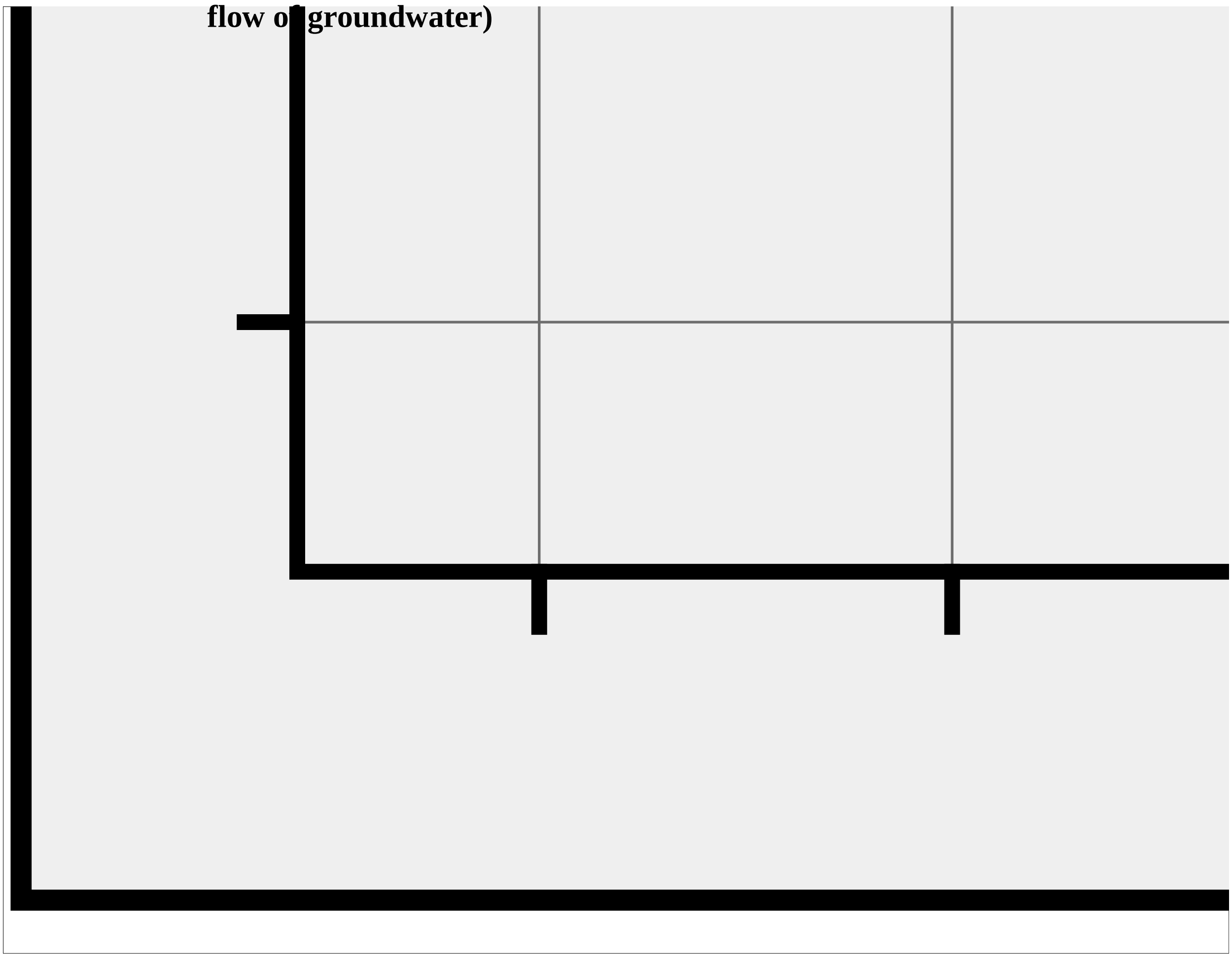
- Well inventory of Static Water Levels (SWL)

WELL NO.	COORDINATES N Latitude	E Longitude	GROUNDWATER LEVEL (GWL) (Dry Season)	(after rainy)	RECHARGE (in meters)
1	17⁰39' 51.9"	120⁰22' 13.4"	1.5 m.	3.6 m.	2.1 m.
2	17⁰37' 54.2"	120⁰22' 36.1"	0.7 m.	1.1 m.	0.4 m.
3	17⁰37' 53.5"	120⁰25' 53.5"	8.6 m.	9.7 m.	1.1 m.
4	17⁰37' 41.9"	120⁰25' 57.2"	19.2 m.	19.5 m.	0.3 m.
5	17⁰37' 35.9"	120⁰26' 22.9"	25.0 m.	27.9 m.	2.9 m.
6	17⁰37' 20.2"	120⁰27' 04.2"	26.0 m.	43.3 m.	17.3 m.
7	17⁰37' 12.1"	120⁰27' 04.2"	41.2 m.	55.4 m.	14.2 m.
8	17⁰37' 40.0"	120⁰26' 46.0"	43.1 m.	55.2 m.	12.1 m.
9	17⁰38' 00.0"	120⁰26' 24.4"	22.2 m.	23.2 m.	1.0 m.
10	17⁰38' 21.8"	120⁰26' 29.5"	28.3 m.	29.3 m.	1.0 m.
11	17⁰38' 32.6"	120⁰26' 11.5"	23.7 m.	23.8 m.	0.1m.
12	17⁰38' 44.8"	120⁰26' 50.9"	28.6 m.	29.5m.	0.9 m.
13	17⁰39' 09.9"	120⁰27' 05.6"	Dry Well	38.0 m.	
14	17⁰38' 50.2"	120⁰26' 17.5"	22.5 m.	23.3 m.	0.8 m.
15	17⁰39' 19.0"	120⁰26' 22.9"	20.2 m.	23.0 m.	2.8 m.
16	17⁰39' 35.9"	120⁰26' 41.7"	30.3 m.	31.4 m.	1.1 m.
17	17⁰39' 12.2"	120⁰25' 30.7"	12.2 m.	13.2 m.	1.0 m.
18	17⁰39' 39.5"	120⁰25' 03.3"	11.9 m.	13.2 m.	1.3 m.
19	17⁰39' 28.6"	120⁰25' 39.7"	13.9 m.	14.8 m.	0.9m.
20	17⁰39' 16.0"	120⁰24' 51.7"	12.2 m.	13.0 m.	0.8 m.
21	17⁰38' 06.7"	120⁰24' 39.1"	7.9 m.	8.4 m.	0.5 m.
22	17⁰38' 14.1"	120⁰24' 52.9"	7.4 m.	8.1 m.	0.7 m.
23	17⁰38' 29.8"	120⁰25' 16.4"	8.7 m.	9.1 m.	0.4 m.
24	17⁰37' 56.0"	120⁰24' 06.1"	5.9 m.	8.8 m.	2.9 m.
25	17⁰37' 58.3"	120⁰23' 46.9"	4.7 m.	7.1 m.	2.4 m.
26	17⁰38' 26.0"	120⁰24' 18.4"	7.6 m.	9.1 m.	1.5 m.
27	17⁰38' 46.3"	120⁰23' 57.9"	6.8 m.	6.8 m.	0 m.
28	17⁰39' 36.6"	120⁰24' 01.6"	7.9 m.	7.9 m.	0 m.
29	17⁰39' 58.5"	120⁰24' 16.3"	8.0 m.	9.0 m.	1.0 m.
30	17⁰39' 21.8"	120⁰23' 37.7"	3.9 m.	8.1 m.	4.2 m.
31	17⁰39' 36.1"	120⁰22' 59.4"	5.1 m.	8.6 m.	3.5 m.
32	17⁰39' 59.5"	120⁰22' 26.6"	4.5 m.	7.7 m.	3.2 m.
33	17⁰39' 26.5"	120⁰22' 27.1"	3.6 m.	3.7 m.	0.1 m.
34	17⁰38' 54.7"	120⁰23' 08.9"	4.4 m.	5.5 m.	1.1 m.
35	17⁰38' 39.4"	120⁰23' 31.4"	4.3 m.	4.9 m.	0.6 m.
36	17⁰39' 05.0"	120⁰22' 29.9"	2.6 m.	4.1 m.	1.5 m.

37	17^{0} 38’ 57.2”	120^{0} 22’ 04.2”	0.4 m.	3.0 m.	2.6 m.
38	17^{0} 38’ 25.6”	120^{0} 22’ 04.0”	4.1 m.	4.5 m.	0.4 m.
39	17^{0} 38’ 22.7”	120^{0} 22’ 31.1”	2.0 m.	4.0 m.	2.0 m.
40	17^{0} 38’ 15.4”	120^{0} 23’ 10.5”	2.9 m.	3.6 m.	0.7 m.

MGB-1 Personnel Conducting Well Inventory and Measurements in Barangay Nagbettedan, Sto. Domingo, Ilocos Sur

3.4.2 Piezometric Contouring of SWL (Showing potential area and relative flow of groundwater)



3.5.0 Georesistivity Survey

3.5.1 Instrumentation

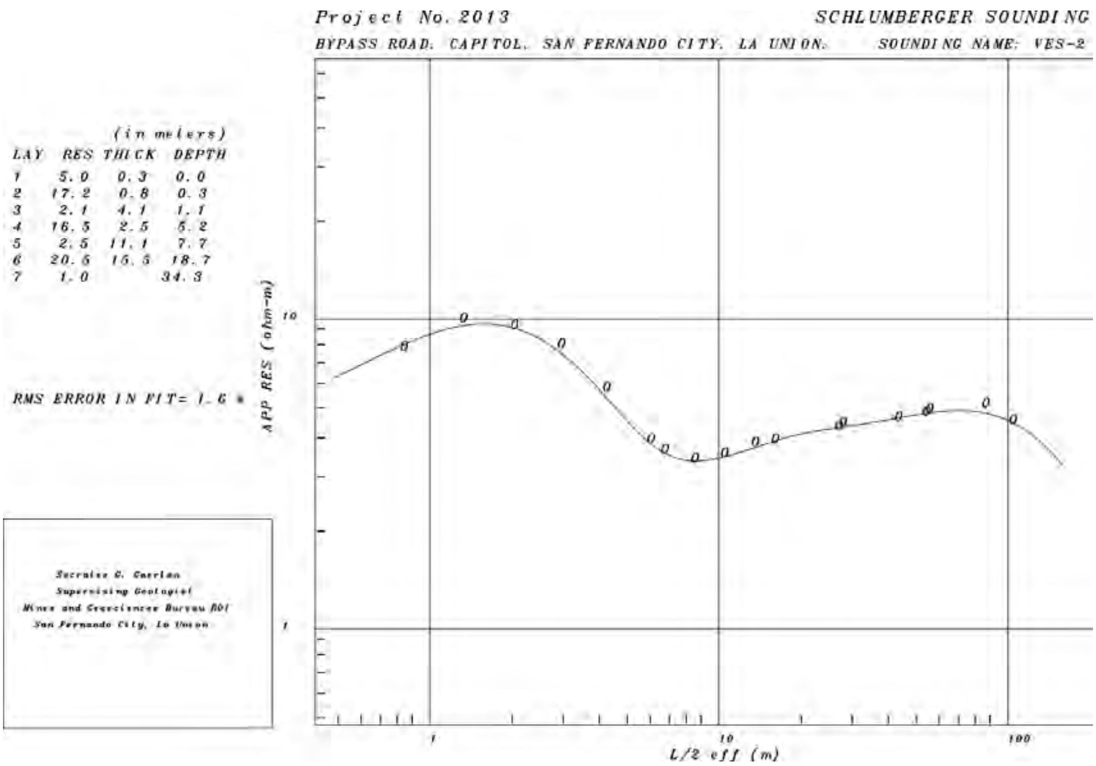
Photos 1 and 2 - The OYO McOHM Mark-2 Model 2115A resistivity instrument used during the geo-resistivity survey with MGB-RO1Team.

3.5.2 Data Acquisition

No.2013 San Fernando city, La Union, March-May, 2013

VES-1	Location:	Provincial Capitol					VES-2	Location:	By Pass Road (Capitol)			
	Azimuth			16°36'47.6"	120°19'02.0"			Azimuth			16°36'48.1"	120°19'05.4"
AB/2	MN	GF	V/I	Leff	App Res		AB/2	MN	GF	V/I	Leff	App Res
1.0	1	2.36	21.522	0.8	50.71	1	1.0	1	2.36	3.3715	0.8	7.94
1.4	1	5.50	8.5719	1.3	47.13	2	1.4	1	5.50	1.782	1.3	9.80
2.0	1	11.78	2.7256	1.9	32.11	3	2.0	1	11.78	0.7498	1.9	8.83
2.8	1	24.35	0.7816	2.8	19.03	4	2.8	1	24.35	0.3486	2.8	8.49
4.0	1	49.48	0.2145	3.9	10.61	5	4.0	1	49.48	0.1184	3.9	5.86
5.7	1	99.75	0.0776	5.6	7.74	6	5.7	1	99.75	0.0382	5.6	3.81
8.0	1	200.28	0.0328	8.0	6.57	7	8.0	1	200.28	0.0173	8.0	3.46
11.3	1	401.34	0.0152	11.3	6.10	8	8.0	8	18.85	0.2241	6.3	4.22
11.3	16	12.57	1.2968	6.5	16.30	9	11.3	8	43.98	0.0902	10.1	3.97
16.0	16	37.70	0.1936	12.6	7.30	10	16.0	8	94.25	0.0407	15.1	3.84
22.6	16	87.96	0.089	20.2	7.83	11	22.6	32	25.13	0.1793	12.9	4.51
32.0	16	188.50	0.0518	30.3	9.76	12	32.0	32	75.40	0.0582	25.1	4.39
45.3	16	389.56	0.031	44.0	12.08	13	45.3	32	175.93	0.026	40.4	4.57
64.0	16	791.68	0.0173	63.1	13.70	14	45.3	64	50.47	0.0933	25.9	4.71
						15	64.0	64	150.80	0.0306	50.3	4.61
						16	90.5	64	351.77	0.0148	80.8	5.21
						17	90.5	128	100.49	0.0336	51.7	3.38
						18	128.0	128	301.51	0.0146	100.5	4.40
						19	181.0	128	703.55		161.6	0.00
						20	256.0	128	1507.62		242.2	0.00

3.5.3 Data Interpretation



4.0 Activity Plan for CCOP GW Project Phase III

Current Programs and Initiatives

The Groundwater Resources and Vulnerability Assessment Program had been initiated by the MGB pursuant to Republic Act No. 9275 or the Clean Water Act of 2004. Chapter 3, Section 19, Item (d) thereof required "the preparation and publication of a national groundwater vulnerability map incorporating the prevailing standards and methodologies…" (MGB News Item, September 12, 2011).

The Program aims to generate critical information and database on groundwater resources availability and vulnerability in the various regions and areas of the country, and make the information available to authorities responsible for water resources management and development, physical framework and land use planning, land classification and allocation by Local Government Units, and regional as well as developmental projects.

The main activities for the Program had been data compilation, remote sensing studies, geologic and water well inventory, resistivity surveys and the identification, characterization and assessment of groundwater reservoirs and aquifers. The expected outputs are hydrogeological maps and groundwater vulnerability maps at 1:50,000 and 1:10,000 scales, and groundwater resources inventory database.

Groundwater Vulnerability Mapping

The Groundwater Vulnerability Mapping had be a contribution to the implementation of a provision of the clean water act stipulated in Chapter 3, Section 19-D, to wit: prepare and publish a national groundwater vulnerability map, monitoring and remediation of areas seriously affected by groundwater degradation and depletion.

Conclusion and Recommendation

Database development in the Philippines faced many challenges including outdated hardware, software and network technology. Database developed for stream flow data, groundwater and water quality had not been properly maintained and updated.

The computer hardwares for NWIN are already unserviceable and the servers are outdated. Fiber optic network is very expensive and there are already new network technologies available in the market. The website is not available most of the time due to the problems on webhosting services.

There was no clear cut policy on the propriety of data. Data generating agencies were not able to update and upload the data. Personnel/staff trained are already gone, had either transferred, been promoted or retired.

There had been identified overlaps and gaps in the management system. Duplication of entry had been common. But mostly, the lack of fund and institutional weaknesses had been blamed as the common reason in attaining sustainability, continuous operation and maintenance of the database.

There is a need for a National Database for Groundwater Resources to be able to:

- Develop an effective planning and management tool for an informed policy and decision making strategies.

- Improve data management to ensure sustainability of data collection and processing of data and information
- Generate data for sharing of information through the use of science based models and tools
- Improved capacity in terms of water resources assessments by concerned institutions/ agencies
- An integrated data management system should be made operational. The use of a common database for easy sharing should be developed.
- Various stakeholders are also encouraged to visit the web portal of the MGB to be able to appreciate and understand the various hazard maps and other information/data available for the public.

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Activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Thailand

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Abstract

Groundwater development in Thailand has been initiated for almost 60 years by the responsibility of Groundwater Division, Department of Mineral Resources (DMR). Borehole information was systematically recorded as year-books. Well records included well number, well location, drilled depth, developed depth, type of aquifers as well as lithologic logs. After twenty years from that starting point, the Groundwater Division, DMR by the assistance and advice of professional people on systematic groundwater database has setup the powerful database system of groundwater well information and names it as Pasutara. The Pasutara has been further developed for several times due to there have more essential fields to fill in to create the most perfect groundwater database in Thailand as well as the Hydrogeological Geographic Information System (HYGIS) had been developed under the compilation of 1:100,000 Provincial Groundwater Maps. After Groundwater Division, DMR has become to the Development of Groundwater Resources by the Government Reformation Scheme in 2002, more database of groundwater have been created qualitatively and quantitatively as products of more research studies have been carried on, including detailed study for the preparation of 1:50,000 Groundwater and Hydrogeological Maps following the standards of the International Association of Hydrogeologists (IAH) within the year 2022.

Keywords: groundwater database, HYGIS

1. Introduction

Currently, groundwater is widely used in Thailand since it is a dependable water source and generally has a better quality than surface water. The total amount of groundwater consumption is 3,446 million cubic meters per year (Mm^3) in 2010 (DGR, 2010). Almost half of that is used for agriculture while the use of water for domestic consumption is about one-third. The rest, approximately 700 Mm^3, is use in industrial segment. The demand of groundwater use has increased steadily each year. The increment of groundwater well development and groundwater use cause the difficulty in tracking and monitoring both quantity and quality of groundwater resources. As a result, some resources are affected by the use of groundwater in excess of existing potential and water quality changes from the saltwater intrusion. So use data from past to present. And higher demand for groundwater in the future. Therefore, the record of chronological groundwater use and predicted demand of groundwater use in the future are necessary to be utilized as guidelines for groundwater management

The Department of Groundwater Resources (DGR), Ministry of Natural Resources and Environment is the only agency that is responsible for the implementation of exploration, development and management of groundwater resources in Thailand since the reform of civil service in 2002. The mission of various departments: Department of Mineral Resources, Department of Public Works, Department of Accelerated Rural Development and the Department of Health, regarding groundwater development and management were transferred to DGR. Since then, all information of groundwater wells including well development, lithologic log data, pumping test data, water level, and water quality has been stored in database called “Pasutara” while all hydrogeological data has been stored as GIS layers in database named Hydrogeological Geographic Information System (HYGIS).

2. Situation of Groundwater Monitoring System and Database

Groundwater levels and groundwater quality in all 27 groundwater basins in Thailand has been monitored since 2004. A network of observation wells, 775 monitoring stations with 1,408 wells (DGR, 2014), has been conducted in some important basins which does not cover the entire area and groundwater systems in Thailand (Figure 1). The groundwater levels are tracked twice a year as representatives of wet and dry periods. The groundwater samples are collect at least once a year to observe change of water quality. Water level data is stored in Pasutara while the quality data is stored in a database of Division Groundwater Analysis named “eLab”.

Application for drilling and groundwater abstraction is under authorization of Bureau of Groundwater Control. Information of 36,439 private wells and groundwater use across the country is stored into an information system for groundwater management called “GCL”

To summarize, the information of groundwater resources in Thailand are stored in three databases: Pasutara, eLab, and GCL, according to types of data. Well development and groundwater level data is stored in Pasutara. Groundwater quality data is kept in eLab. The last one, GCL, possess private well data and groundwater use.

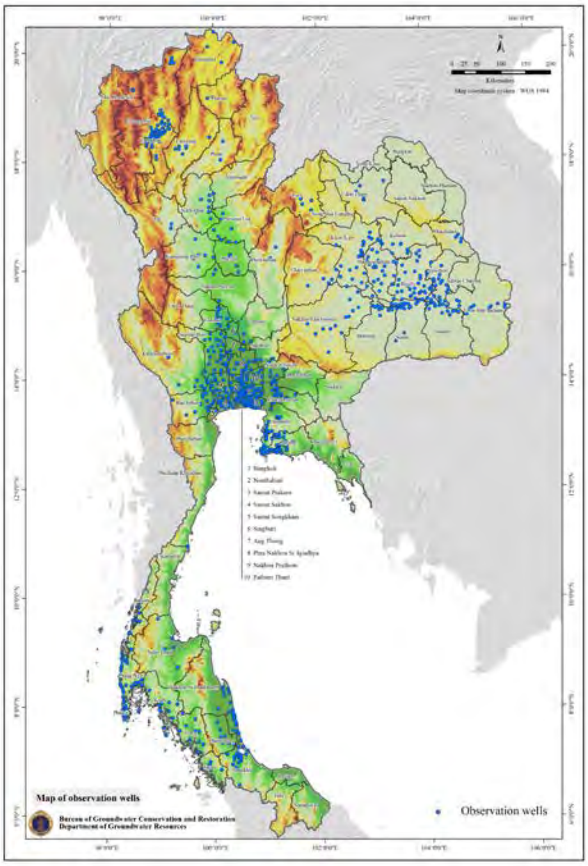

Figure 1 Groundwater monitoring station in Thailand

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

It is highly possible under the following situation:

- The current database system is improved to the international level with English language encoding.
- All database systems are linked together including Pasutara Database (Figure 2a), national groundwater quality, water usage as well as geophysical exploration from newly-researches studies being run by DGR itself.
- Internet database display is developed as Web based and/or Mobile apps.
- The most interesting software about database system that is under the preparation of the Project on the study of compilation of detailed groundwater and hydrogeological mapping, which is called Geocene3D (Figure 2b) developed by Denmark & Greenland Geological Survey.

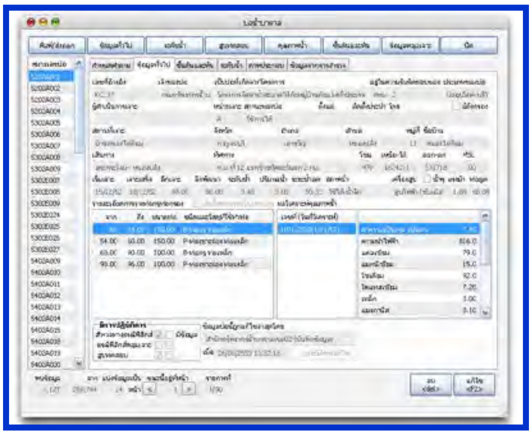

Figure 2a Pasutara Database

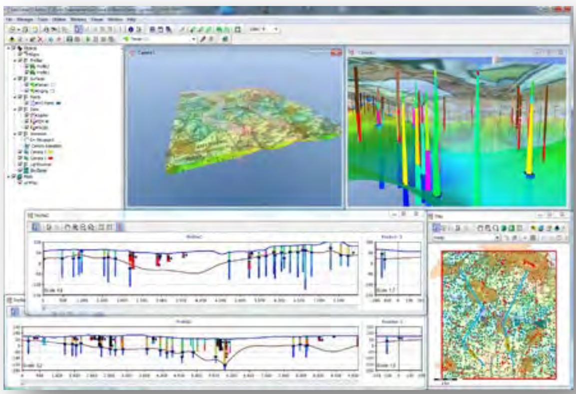

Figure 2b Geocene3D Software

4. Activity Plan for CCOP GW Project Phase III

- Extend monitoring wells and networks to 2,549 stations 6,120 wells within 2014.
- Setup the automatic monitoring systems in monitoring network and employs real-time reporting.
- Complete the nationwide Detailed Groundwater and Hydrogeological Mapping, by doing this DGR will have new HYGIS Database and Geocene3D images covering the nation areas.

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Country Report of Timor-Leste on CCOP Groundwater Project Meeting in 2015

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1. Introduction

Timor-Leste forms the eastern half part of the island of Timor, sitting adjacent to Indonesia and separated from Australia by the Timor Sea. The country is about 14,922 km^2 and includes the island of Atauro and the enclave of Oecussi (latitude 8° 00' to 9° 30' south and longitude 124° 00' to 127° 30' east, (see figure 1).

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

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

The climate of Timor-Leste is characterised by the Asian tropical monsoonal system due to its topographic relief and geographical location. The climate of Timor-Leste can largely be divided in to two distinct seasons: the 'Wet season' (December to May) with the wettest month January, February or May depending on the region; and the 'dry season' (June to November) with September-October generally the driest months, also depending on the region, (source: Wallace et all, 2012).

Rainfall varies from as low as 500 mm/annum along the northern coast to as high as 2000 mm/annum in mountains. Most areas receive maximum rainfalls during the northwest monsoon in December or January extending to April in some years. Areas in the east and southeast also have a secondary wet season during the southwest monsoon in May or June. There is limited seasonal variation in temperatures in most areas in Timor-Leste. The average temperature during rain season ranges from 29°-35°C. Dry season temperatures between May and November average around 20°-33°C. Day time temperatures are warm to hot, but are cool to cold at night specially in mountainous areas, (source: Anonymous).

Timor-Leste (The Democratic Republic of Timor Leste), population in 2010 an estimated population of 1,066,582 (source: Direcção Nacional de Estatística, Timor-Leste, 2010), half of them were female and two thirds were less than 25 years old. The population is growing rapidly and the fertility rate (7 children per woman) is nearly the highest in the world.

The population is distributed in 2,300 villages and divided into 34 ethno linguistic groups. The majority of the population lives in rural areas (73.5 per cent), draws its livelihood from subsistence agriculture and is poor with a low standard of living, (source: Pedro D. S. Henriques et all, 2011).

Timor Leste has several types of aquifer as show in Hydrogeological map, on figure 3.

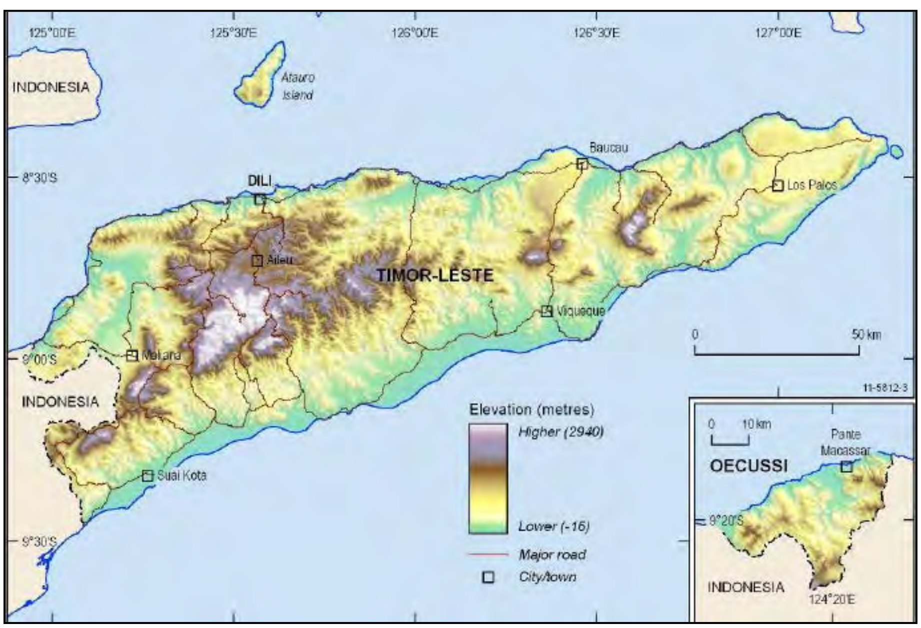

Figure 2. Topography of Timor-Leste (Wallace et all, 2012)

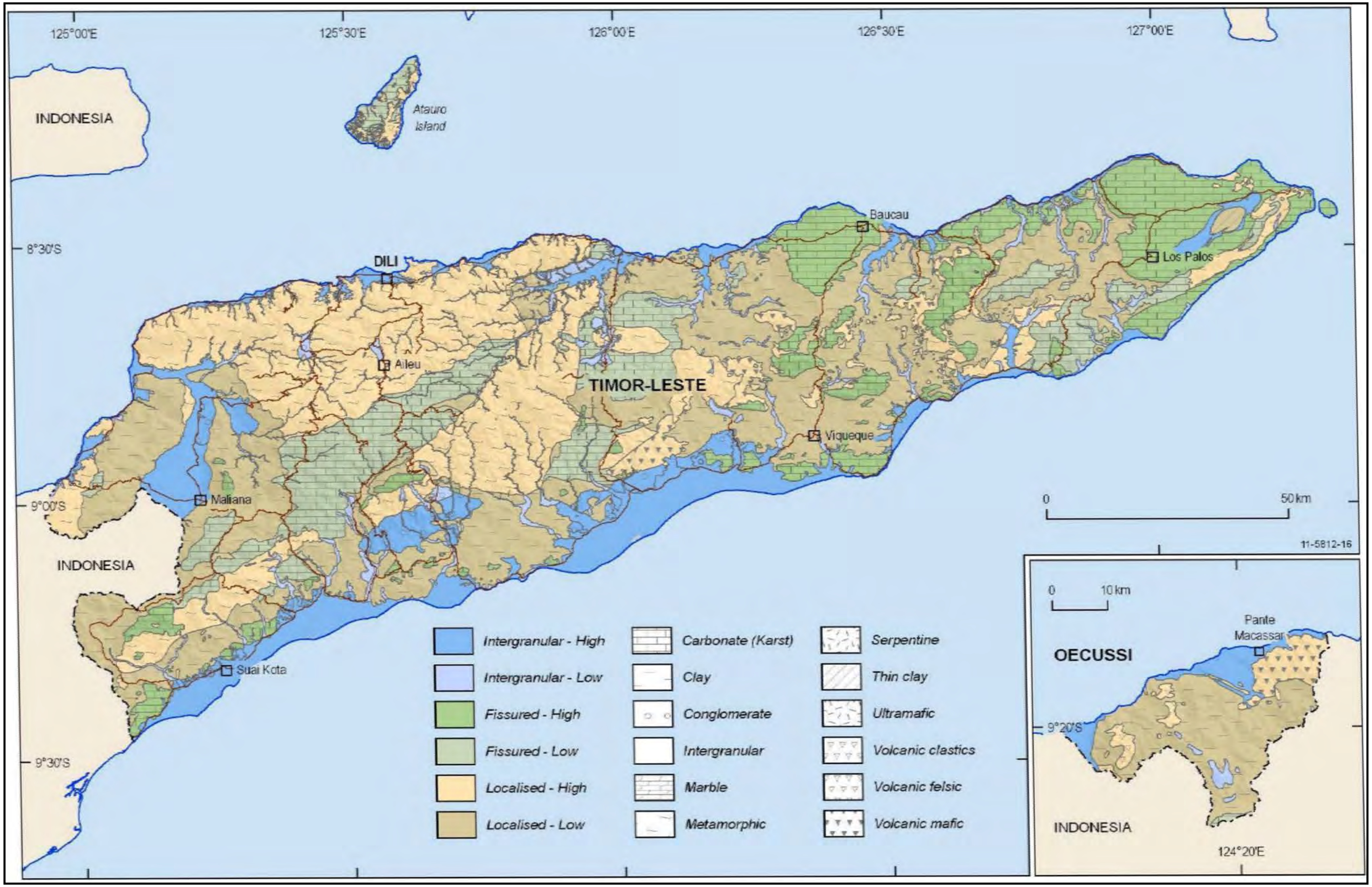

Figure 3. Regional hydrological map of Timor Leste (Wallace et all, 2012)

2. Situation of Groundwater Monitoring System and Database

Before discussing the situation of groundwater monitoring system and database in Timor Leste, first of all we should know the water resources and groundwater aquifers in timor-leste, as described below.

2.1 Water Resources

Almost all of surface water supplies rivers, lakes, wetlands and estuaries connect with groundwater. This means that using water from rivers and lakes can affect groundwater supplies and similarly, using groundwater can impact water supplies in rivers, lakes or wetlands. The perennial rivers in the area Loes, Laclo and Clere are the most significant hydrological units that are currently providing water for domestic use and irrigation.

Surface water is also vulnerable to faster evaporation during warmer temperatures and extreme heat days. The climate in Timor-Leste is predicted to become 1.5 ºC warmer by 2050 and have more extreme heat days, (source: Australian AID in Timor Leste, 2013).

2.2 Groundwater Aquifers in Timor-Leste

Groundwater resources of Timor-Leste have been classified into three principal aquifer types consistent with international classifications (UNESCO, 1983): sedimentary porous rock aquifers with intergranular porosity associated with the river valleys and coastal lowlands; fissured aquifers of karst formations within limestone rocks; and rocks with localised flow comprised of fractured rocks and clay sediments.

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

Groundwater in Timor-Leste is recharged by rainfall during the wet season to maintain enough storage for use during the dry season. Without regular recharge, the stored groundwater decreases.

Increased demand of water caused by population growth, industry and agriculture also have the potential to reduce the amount of stored groundwater. Both groundwater recharge and pumping need to be understood, and in the case of pumping, managed in Timor-Leste to ensure enough the groundwater avalability, (see figure 3).

2.3 Situation of Groundwater Monitoring System and Database In Timor Leste (Dili)

The Timor Leste National Laboratory (The Direcção Nacional de Controle e Qualidade da Água) was established in 2004 by the Secretary State of Water and Sanitation under Ministry Of Public Works. The Direcção Nacional de Controle e Qualidade da Água (DNCQA) has instaled groundwater monitoring wells in Dili, Timor-Leste. The location of monitoring wells shown on figure 4 below.

At this time, the monitoring system of the groundwater level is only establised in Dili because Dili is the capital city of the country that has a population density reached in 234,331 and total area 372 km^2 (source: Direcção Nacional de Estatística, Timor-Leste, 2010) and most of the population and industrial consume water from groundwater. The location of monitoring wells (DM1-4), water supply wells (P Com, P Bec, P Bid) and Dili aquifer (Blue Boundary).

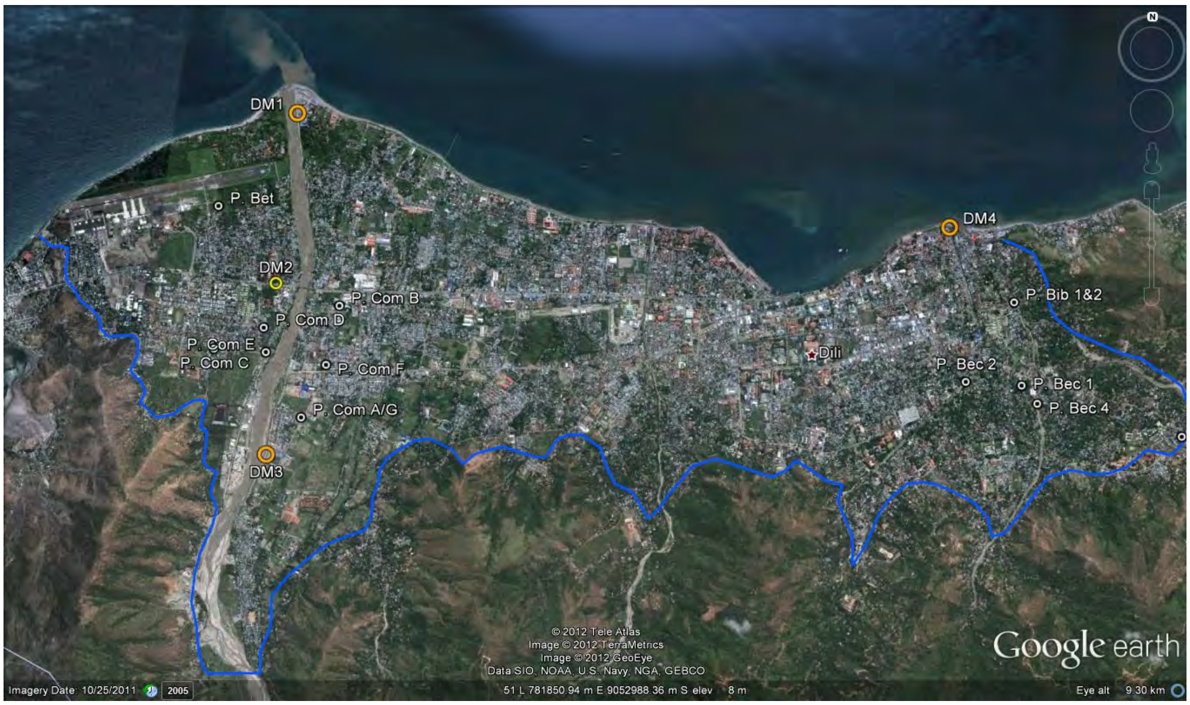

Figure 4. Location of monitoring wells in Dili, (Source: Lindsay Furness, 2012)

The four groundwater monitoring wells were installed between 1 November, 2011 and 27 March, 2012 in Dili to observe groundwater levels and water quality in shallow (around 30 meter) and deep (around 140 meter) aquifers. The wells are situated along the Comoro River and near to the mouth of Bidau River as shown in Figure 4. The groundwater monitoring in Dili was first documented by Lindsay Furness (2012). The purposes of monitoring wells are to observe any changes in groundwater levels and quality (salinity) in response to climate change and in response to groundwater extraction for Dili water supply.

2.3.1 Well Design

The construction and design of the monitoring wells was based on an understanding of the nature of the aquifers in the Dili area and geophysical studies which will be discussed in sub title 3.1 and based on the location of production wells as one of the aspects of monitoring is to provide an early warning of salt water intrusion due to sea level rise, or over-pumping, monitoring was based on the geophysics predictions of salty water at a depth of about 140 metres near the coast line.

Along the Comoro River, which crosses the Dili aquifer from south to north, three sites were chosen to measure the hydraulic gradients from the mountains to the sea. DM1 is located close to the mouth of the Comoro River and downstream of the Comoro production well. DM2 is located near the Comoro River bridge and DM3 is located upstream of the well.

DM4 monitoring well is located next to the sea near the mouth of the Bidau River on the eastern side of the Dili aquifer. The site was chosen at the estimated middle of an ancient drowned river valley indicated by the hills to the east and rock outcrop in the sea to the west, (Lindsay Furness, 2012).

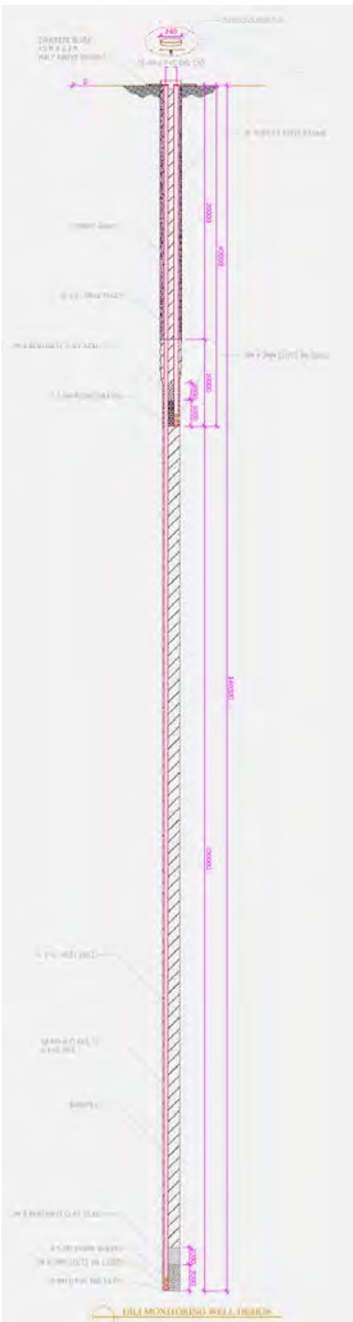

Figure 5. Monitoring Well Design, (Source: Lindsay Furness, 2012)

Base on the report of Lindsay Furness (2012), the design includes 30 meter of 200mm diameter steel casing installed from the surface and cemented in place in a nominal 320mm diameter drilled hole. The purpose of the casing is to prevent contamination from surface water and to stabilise the hole during deeper drilling. The drill hole was then planned at 150mm diameter to 140m depth (or bedrock) and then completed with two monitoring pipes of 50mm diameter PVC with 3 meter of slotted screen at nominal 40 meter depth and 140 meter depth. Final construction depths are given in Table 1. The slotted screens were packed with gravel filter and the drill hole backfilled with cuttings.

The two monitoring pipes are protected with 1 meter of 200mm diameter steel pipe above the ground encased in a 1.5 by 1.5 meter by 0.3m thick concrete block and fitted with a locked cap.

2.3.2 Monitoring

Lindsay Furness (2012), reported that using the above construction, it is possible to independently monitor the groundwater level and quality at each site at two different depths. The two monitoring pipes are designated (DM1S and DM1D) for Dili Monitoring Shallow and Deep screens. Each pipe is fitted with CTD diver to automatically monitor the groundwater. They are programmed to measure water level, water conductivity (salinity) and temperature at hourly intervals. The divers have sufficient memory for about 5 years' of data and a battery life of approximately 10 years.

The CTD divers will continually monitor water level, temperature and conductivity every hour to store the data. The data can be regularly downloaded (preferably at 3 month intervals) using the E+Control field computer and displayed and stored using Diver-Office software by Schlumberger Water Services. A separate Baro diver recording barometric pressure changes is located at Comoro B production well and can be used to make barometric correction changes in each set of CTD diver data. This is necessary as the divers record to combined water pressure and atmospheric pressure. By subtracting the barometric pressure from the diver pressure gives the water pressure only. Analysis should include Barometric corrections using the Comoro-B Baro Diver data and comparison made between well records, Comoro-B water and conductivity as well as Bidau-2 data. During analysis, reference should be made to Dili rainfall and Comoro River gauging data to see if there is a correlation in the shallow and deep aquifers. Should any trends be observed of changing water levels or salinity this should be assessed as to the likely causes. The water levels and final construction details are indicated in Table 1.

Table 1. Monitoring Well Construction Details (Source: Lindsay Furness, 2012)

Site	DM1		DM2		DM3		DM4	
Elevation	+3m		+22m		+37m		+3m	
Monitoring	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Screen Depth	30-33	137-140	30-33	134-137	29-32	125-128	27-30	123-126
Diver elevation	-7	-2	+12	+5	+21	+21	-7	-7
Water Level*	1.91	3	19.46	11.75	27.14	22.89	0.34	0.78
Conductivity*	419	634	390	590	492	579	3,600	11,900

*Measurements at the end of monitoring well construction

The water levels indicate that DM3 is in an area of recharge from the Comoro River, as is DM2 where the shallow aquifer water pressure is higher than the deep aquifer level. Groundwater levels near the sea fluctuate with tide levels as shown in the following Figure 5.

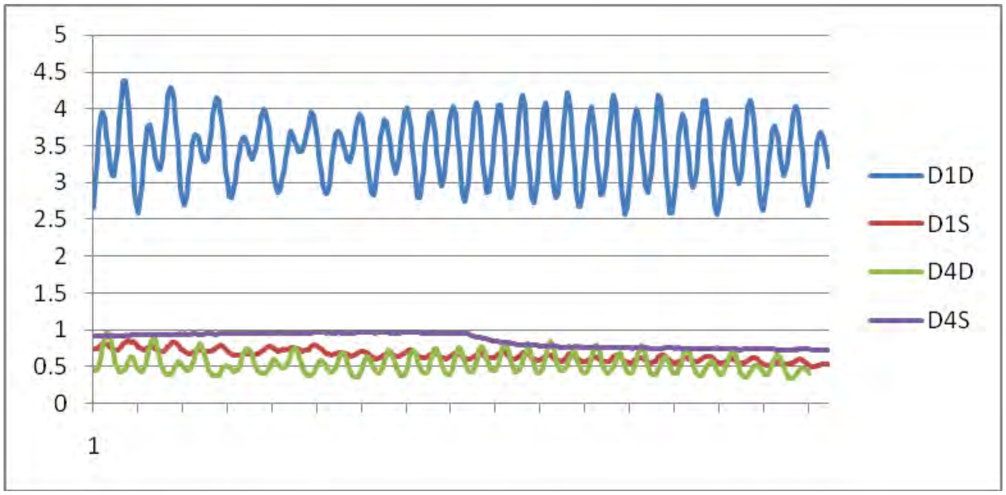

Figure 6.Water level fluctuations at sites D1 (S&D) and D4 (S&D) from 13 to 29 March, 2012 water levels in metres above mean sea level, (Source: Lindsay Furness, 2012).

At the DM1 the site is in an area of potential discharge as the deep aquifer which is under artesian pressure of about 3 to 4 meter above sea level and the shallow aquifer about 0.5 meter above sea level. The deep aquifer water level is controlled by the tides in the sea and fluctuates diurnally, about 90% of the tidal range. The shallow aquifer water level is slightly tidal but mostly appears to be affected by the Comoro River level. Both aquifers have fresh water with the salinity slightly higher in the deep aquifer.

The DM2 is located in recharge area from the Comoro River, with the shallow aquifer having a water level where close to the river level and the deep aquifer about 9 meter deeper. The water levels fluctuate slowly in response to rainfall conditions. Both aquifers have fresh water with the deeper aquifer slightly higher in salinity than the shallow. DM3 is in an area of recharge from the Comoro River with the shallow aquifer water level close to the river level and the deep aquifer water level slightly deeper. Both aquifers have fresh water with the deep aquifer slightly higher in salinity.

DM4 is very close to the sea and the two monitoring screens are within the mixing zone between the fresh water and salt water in the aquifer. The deep aquifer shows a tidal response in water levels with the fluctuations about 20% of the sea tide levels. The shallow aquifer water level is influenced by the level of the nearby Bidau River. The deep aquifer salinity is about 29,000uS/cm (based on diver records) or about half of sea water. The shallow aquifer is about 3,000uS/cm or 10% sea water. Any further sea water intrusion to the aquifer, either by sea level rise and/or over pumping will be quickly detected at this site, (Source: Lindsay Furness, 2012).

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

There are some activities were done over the period of 2011 to 2014, such as below.

3.1 Geophysics

A geophysics study was carried out by CSIRO, in 2011.The method that use was the Time domain Electro-Magnetic (TEM) where an electromagnetic field generated in a coil of wire causes a secondary EM field in the ground that can be interpreted as a response of the strata and groundwater. The measurements of the response are turned into model of the strata properties by an inversion process.

The following figure 7 shows that the location of measurements ST1 to ST5 along the Comoro River looking towards to the north.

Fig 7. Location of TEM measurements at ST1 to ST5 on the Comoro River to the north, (Source: Lindsay Furness, 2012).

The results of the TEM inversions are shown in Figure 8 for sites ST2 to ST5 in depth versus conductivity profiles. Low conductivities, to the left indicate fresh water, sand, gravel and fresh rock, whereas higher conductivities to the right indicate clay, salty water and weathered rock.

ST2 predicts about 25 meter of sand and gravel overlying silt or clays to 50 meter and then sand and gravel or bedrock to 110 meter (or more). ST3 indicates 10 meter of silty sand and then sand and gravel to 43 meter, then silt and clay to 130 meter and then likely rock. ST4 and ST5 have almost the same profile of 10 meter s of silty sand and then sand and gravel to 38 meter, then silty sand to 141 meter overlying salty water. This interpretation is illustrated in the following Figure 8.

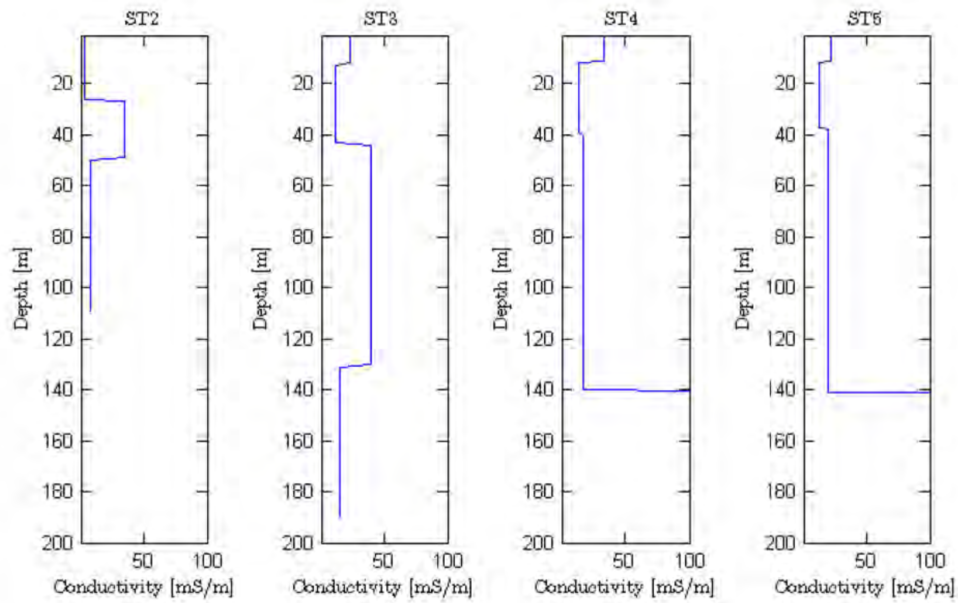

Figure 8. Conductivity profiles for sites ST2 to ST5, (Source: Lindsay Furness, 2012).

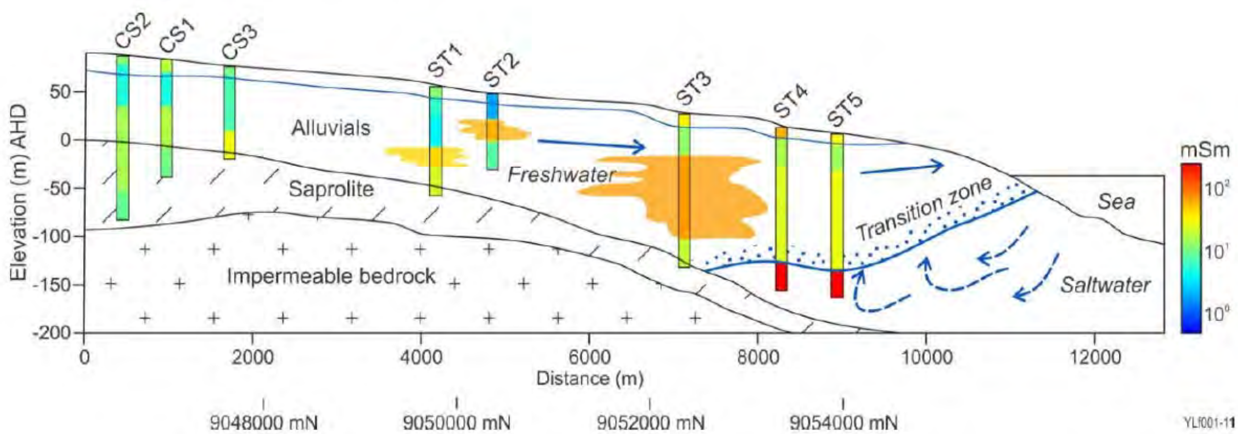

Figure 9. Interpreted geological section along the Comoro River (Source: Lindsay Furness, 2012)

3.2 Hydrological data collection system (Stream and rainfall)

Figure 10. Meter installation or stream gauge in Balubo river-Maliana District. (source: DNCQA,

Figure 11. Laptop which use to download rainfall at Railako-Ermera District, (source: DNCQA, 2011)

Figure 12. Spring observation in Oecusse area, (source: IPG-IP, 2014)

Table 2. Form for monitoring well in Dili, Timor Leste, (source: DNCQA, 2014)

No	DATE	TIME	LOCATION OF PUMP	DATA BEFORE CORECTION			DATA AFTER CORECTION			DESCRIPTION
				Pump on	Pump Off	Depth of cassing	DEPTH OF WATER LEVEL		Drawdown	
				(Meter)	(Meter)	from (m)	Pump on	Pump Off	(m)	
1			SB Comoro A/G			0.46				
2			SB Comoro B1			0.36				
3			SB Comoro B2							
4			SB Comoro C (Juaquim)			0.63				
5			SB Comoror D (Fernando)			0.30				
6			SB Comoro E (Sidonio)			1.00				

Table 3. Form for discharge intake (surface water) in Dili, Timor Leste, (source: DNCQA.,2014)

No	DATE	TIME	NAME OF INTAKE	MESUREMENT		FOR WATER SUPPLY		Comment
				BEFORE INTAKE	AFTER INTAKE			
				(m^3/s)	(m^3/s)	(m^3/s)	(l/s)	
1			Inteke Benanamauk					
2			Intake Mutudare					
3			Intake Lakoto					
4			Intake Nahaek					
5			Intake Maloa					
6			Intake Bemos					

4. Activity Plan for CCOP GW Project Phase III

There are two plans that will be done by the Geohazard division of Institute of Petroleum and Geology-Public Institute., i.e.

- ☞ For long period, the investigation and assessment of groundwater potential in all district in Timor Leste are will be done.
- ☞ In the period from 2015 to June 2016, the groundwater investigation will be done in Maliana District. The location of study area is shown on figure below.

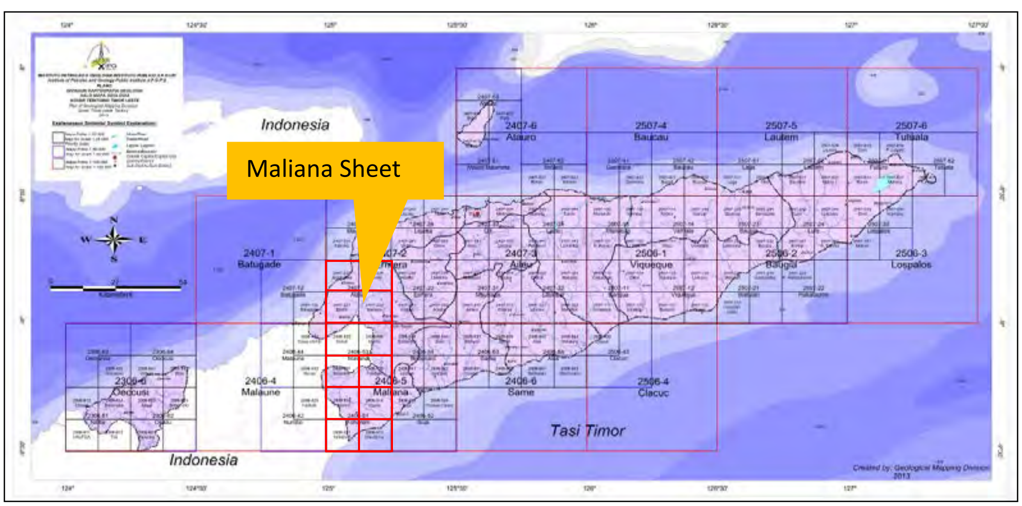

Figure. 13 Location of mapping area for period 2015-2016

5. Summary

The monitoring points for each station are chosen to be representative of the geology (aquifer). The selection of a monitoring point also considers other factors such as well construction, well depth and groundwater flow directions.

Sites DM1 to DM4 were drilled over the period of 1 November, 2011 until 27 March, 2012. The DM1 and DM2 located at elevation +3m, DM2 is +22m and DM4 is +37m. The position of screen of DM1 and DM2 for shallow aquifer is located at depth 30-33m, DM3 is located at depth 29-32m and DM is situated at 27-30 m. At the deep aquifer, DM1 is screen is at depth 137-140m, DM2 is screen is located 134-137m, DM3 is situated at depth 125-128m and screen of DM4 is in depth 123-126m. The elevation of divers are diverse, from -7m to +21m for shallow aquifer an -2 to +21 for deep aquifer.

The well data recording system is use CTD divers, the CTD divers will continually monitor water level, temperature and conductivity and store the data every hour. The data should be downloaded at 3-monthly intervals using the E+control field computer, analyzed using the Diver-Office software and archived. In this analysis should include Barometric corrections using the Comoro-B Baro Diver data and making comparison between well records. During analysis, reference should be made to Dili rainfall and Comoro River gauging data to see if there is a correlation in the shallow and deep aquifers. Any changes in water salinity trends that were observed very useful for analyzing the possible causes.

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Vietnam activity plan and Possibility of compiling GW data under CCOP GW Project Phase III in Thailand

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Abstract

The Vietnamese Government is always interested in advancing the natural resources and environment monitoring network, including water resources monitoring network. In Viet Nam, the Ministry of Natural Resources and Environment (MoNRE) is the state institution, responsible for managing all natural resources sectors, including water resources monitoring system. National Center for Water Resources Planning and Investigation (NAWAPI) is the organization assigned to manage and operate this national network within Vietnam territory.

Groundwater monitoring network is being operated in 5/7 the observation regions of Vietnam, including: Northern, North Central, South Central, Highlands and Southern. However, the Northeast and Northwest regions still do not have network monitoring. The networks in Red River delta, Mekong River delta and Highlands have been constructed and worked since 1988. The total number of works under observation is 638. Over the years, NAWAPI is always attentive in international cooperation to develop the network of groundwater monitoring in Vietnam and shares experiences to the neighbors. Joining the CCOP is also in view to enhancing international cooperation of the Center. The groundwater monitoring sharing; in addition to contribute the overall success of the CCOP in achieving the objectives matching with copperative periods, also enhances monitoring quality to meet the requirements of water resource management. With that goal, the Center will complete the responsibilities to ensure successful cooperation in complying with the laws of Vietnam.

Keywords: Groundwater, monitoring, Vietnam.

1. Introduction

National water monitoring network in Vietnam is invested by the Government and is annually funded for maintenance and operation. The main objective is to acquire regional, inter-regional and watersheds' water resources information to process and provide data serving national integrated water resources management. Monitoring data are set to assist the water resources planning, forecasting and warnings; and to become inputs of regional socio-economic development planning.

Regarding the groundwater monitoring, there are 5 out of 7 the observation regions are invested. In particular, the networks in Red River delta, Mekong River delta and Highlands have been built and functioned since 1988. The total number of structures under observation is 638. Monitoring density in the Red River Delta is 1 station/ 80km^2, Mekong River delta is 1 station/ 280km^2 and Highland is 1 station/ 260km^2. Since 2009, 46 new groundwater monitoring works in the North Central region and 46 others in the South Central Coast region have been freshly built. Vietnamese Government intends to extend national groundwater monitoring to ensure all 7 hydrogeological regions, and basins are under observation during 2016-2020 and finalize the national automatic network before 2025. The capital is mainly from domestic sources. Details can be found in Figure 1 and Figure 2.

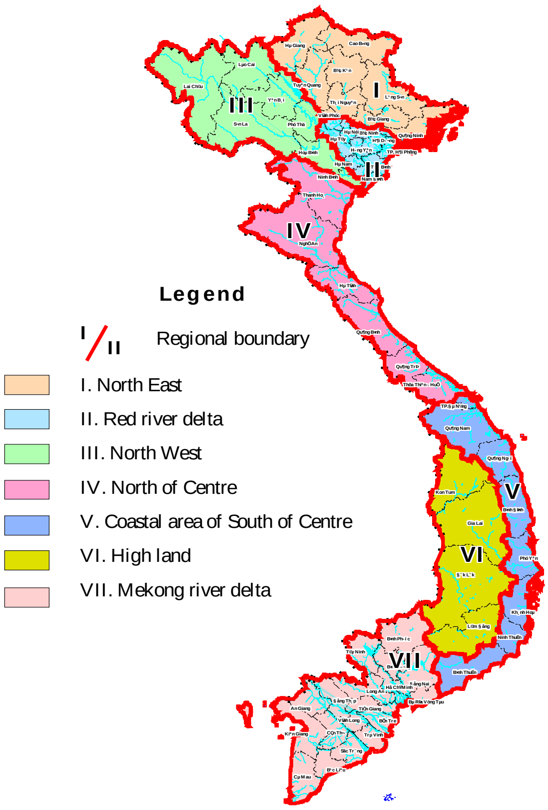

Figure 1. Groundwater region of Vietnam

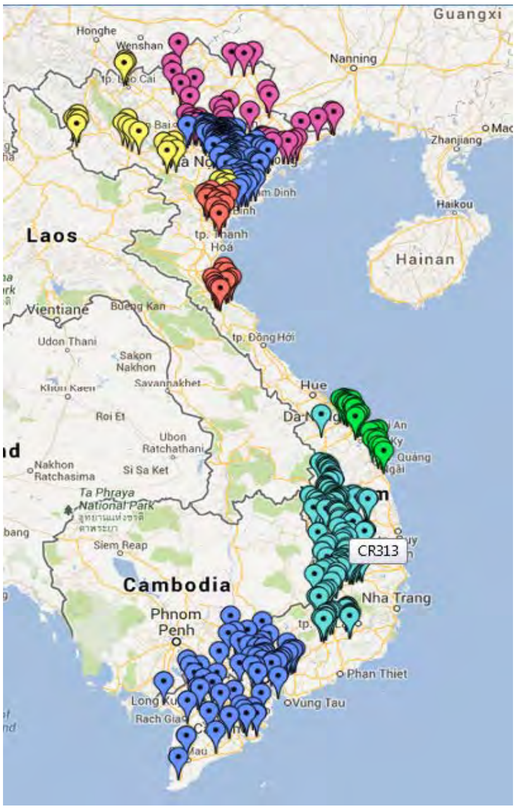

Figure 2. Groundwater monitoring network of Vietnam

2. Situation of Groundwater Monitoring System and Database

2.1. Situation of groundwater monitoring network in Vietnam

As stated above, the groundwater monitoring network in Vietnam is currently operated in five regions, comprising Northern, North Central, South Central, Highlands and Southern. The observation of groundwater in Vietnam is mainly implemented by advanced technologies: Water level measurement with mechanical self-recording machine, automatic data transmission machine, semi-automatic self-recording machine; Monitoring works wasing and water sampling; Water quality monitoring in the field by field analyzer. Goundwater monitoring factors are water level and temperature; water samples are annually extracted for analyzing water quality twice a year. The indicators of water quality analysis are mainly the basic physical and chemical indicators of water and contamination indicators as follows:

Indicators for comprehensive sample analysis in the observation regions: Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{-2}, HCO^{3-}, CO_3^{-2}, CO_2, NH^{4+}, Al^{3+}, NO^{3-}, NO^{2-}, drying sediment, pH, hardness, physical properties.

- Analysis of iron samples in the monitoring areas: Fe^{+2}, Fe^{3+}.

- Analysis of micro samples:

+ Red River delta and North Central: As, Hg, Pb, Cu, Zn, Mn, Se, Be, Cd, Cr, Ni.

+ South Central Coast and Highlands: F, As, Hg, Cu, Cr, Mn, Zn.

+ Mekong River delta: As, Cd, Pb, Cr, Cu, Zn, Mn, Hg, Se, F.

- Analysis of contamination sample: NH^{4+}, NO^{3-}, NO^{2-}, PO^{4-}, pH, Eh.

2.2. Groundwater database

The database is product of monitoring activities, processing the data and updating the national water resources data. The process of updating the database is as follows: observers conduct measurements in the field and record in a log or update data automatically (Figure 3) via a computer. The monitoring data are written in a monitoring log with measured results at the time of data collection. Observers enter monitoring data into regional database, representative of the regions will transfer data (Microsoft excel file) 01 time/month to the monitoring office corresponding administrative regions in the North, Central and South. The products of this stage are the monitoring log, monitoring notebook and database at the monitoring points and stations.

Data from the observers are sent to monitoring departments in the North, Central and South monthly are checked and entered into the regional database (Microsoft access file). Regional monitoring departments transfer the databases monthly to Center for Water Resources Warning and Forecasting to keep and update the national database throughout the territory. Data quality is assessed and evaluated following defined processes again before being stored as national level database. The data met the quality assessment are entered into the national monitoring database.

Time to perform all stages from data entry to data testing of hydrologists, regional departments to national database updating is 10 days. These databases (Table 1) are initially used to announce the information message, forecasting and warning of water resources. The information is available online and is broadcasted on television every month. The entire monitoring data and reports are delivered monthly to the Department of Water Resources Management and the authorities to serve the license managment of exploiting and using groundwater resources.

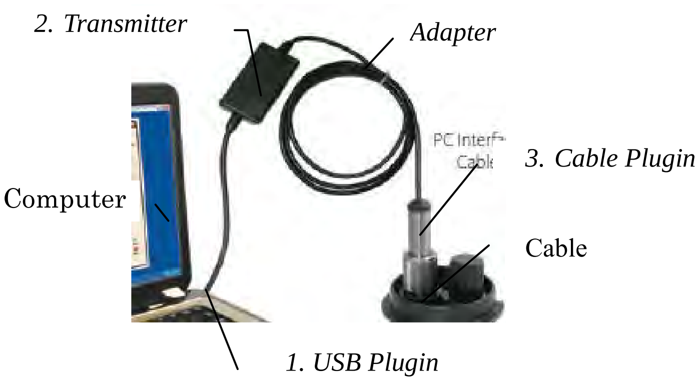

Figure 3. Parts of device transition

Table 1. Groundwater monitoring database

DateMonitor	P.30a	P.31a	P.33a	P.33b	P.34a	P.34b	P.41a
15/01/03	-13.04	-9.22	3.47	4.27	-2.82	3.54	-20.79
15/02/03	-13.93	-9.56	2.99	5.22	-3.07	3.37	-21.63
15/03/03	-13.99	-9.22	3.25	5.07	-3.13	3.52	-21.61
15/04/03	-14.00	-9.44	3.27	4.21	-3.46	3.15	-21.96
15/05/03	-13.79	-8.71	3.60	4.46	-3.30	3.15	-21.63
15/06/03	-13.46	-8.99	5.56	6.63	-2.67	3.18	-22.10

Table 2. Water quality monitoring database

No.	Well name	Elevation (m)	Well Depth (m)	EC(mS/m)	pH	Cl	Br	NO3
11	P30a	48	44	62	7.1	11.24	0.04	1.24
2	P31a	36	60	39	7.35	0.9	0.0	0.3

3. Possibility of Compiling GW Data under CCOP GW Project Phase III

As stated above, the national water resources monitoring system in Vietnam is built and operated by the Government under the state management of the MoNRE and operation of NAWAPI. Thus, the entire database is under management of the Government represented directly by MoNRE and can be shared to the third party for research or development cooperation based on written agreement. NAWAPI, in addition to manage and operate the monitoring system, is tasked to investigate and establish the basic planning of water resources in Vietnam as well as the initiative in collaboration with relevant domestic and world-wide partners. Therefore, NAWAPI manages not only the entire monitoring database but the entire baseline survey database of water resources in Vietnam. Since NAWAPI is tasked to use the entire database, NAWAPI is ready to sign contracts in terms of scientific research cooperation in phase III of CCOP project. Then, carrying out joint research, monitoring data sharing, and experts exchange to complete the Phase III's goals of CCOP project and gradually linking information regarding transboundary waters within the borders of the Southeast Asia and Asia countries to serve the management purpose of regional water resources sector.

4. Activity Plan for CCOP GW Project Phase III

To accelerate the implementation of Phase III of the CCOP project, Vietnam proposes to involve the North Central, South Central, including provinces: Nam Dinh, Thanh Hoa, Ha Tinh, Quang Nam, and Quang Ngai into study areas of salinity intrusion research in Vietnam. These selections are made since the important groundwater resources in the Holocene and Plestocen deposits are being exploited and these provinces have national underground monitoring works. NAWAPI proposes contribution of Vietnamese side as well as the ASEAN countries in the phase III of CCOP study is implemented through contracts signed by CCOP and representatives of the countries, with which Vietnam is NAWAPI. By doing this way, members of CCOP project will be mounted and the objectives can be solved.

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