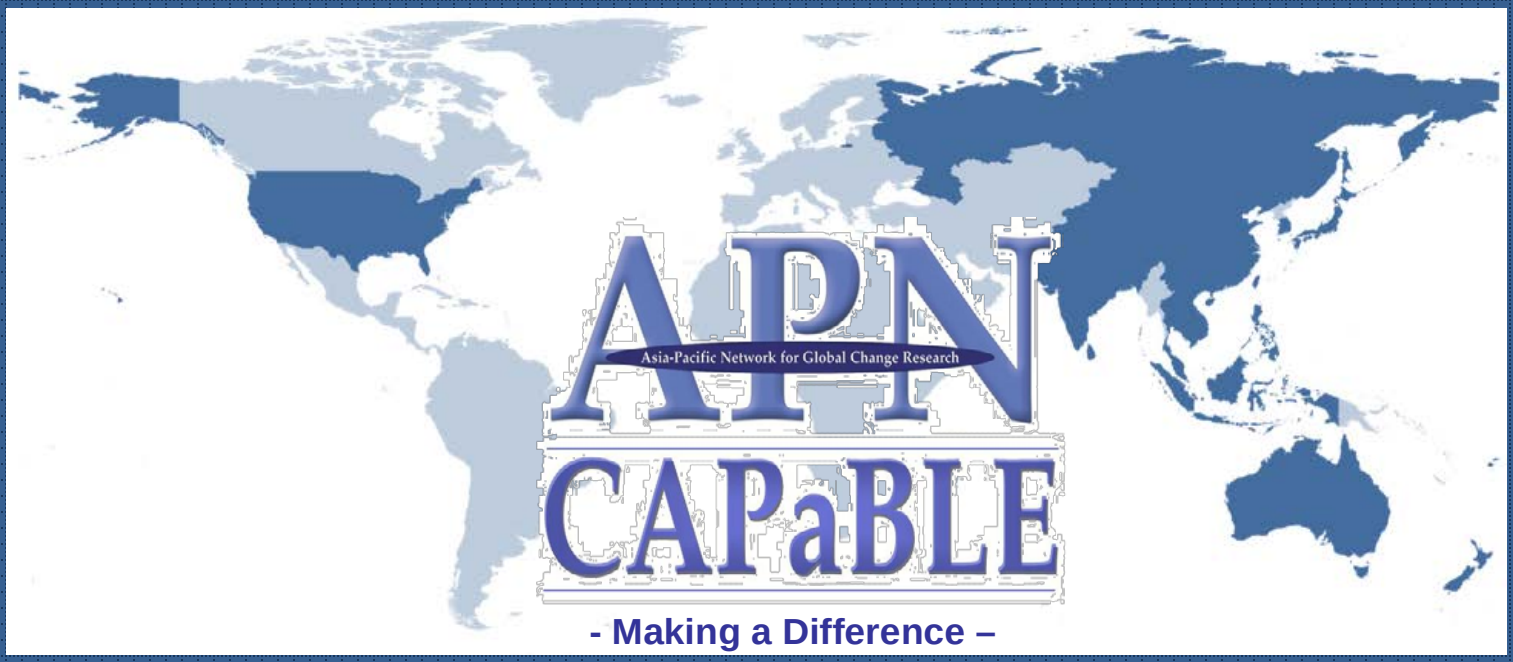
FINAL REPORT for APN PROJECT

Project Reference Number: CBA2013-06NSY-SHRESTHA

Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change



The following collaborators worked on this project:

Project Leader:

Dr. Sangam Shrestha, Asian Institute of Technology, Thailand, sangam@ait.ac.th

Collaborators:

Dr. Binaya Raj Shivakoti, Institute for Global Environment Strategies, Japan, shivakoti@iges.or.jp

Dr. Vishnu Prasad Pandey, Asian Institute of Technology and Management, Nepal, e_vishnupandey@yahoo.com

Dr. Shashidhar Thatikonda, Indian Institute of Technology (Hyderabad), India, shashidhar@iith.ac.in

Dr. Oranuj Lorphensri, Department of Groundwater Resources, Thailand, oranujl@hotmail.com

Dr. Muhammad Basharat, International Waterlogging and Salinity Research Institute,Pakistan,basharatm@hotmail.com

Dr. Rabin Malla, Center of Research for Environment Energy and Water, Nepal, rabin@creew.org.np

Mr. Haryadi Tirtomihardjo, Center of Groundwater Resource and Environmental Geology, Indonesia, haryadi_tirtomihardjo@yahoo.com

Dr. Bui Tran Vuong, Division for Water Resources Planning and Investigation, Vietnam, buitranvuong@gmail.com

Dr. Khin Kay Khaing, University of Yangon, Myanmar, khine.khinkay@gmail.com

Ms. Chindavanh Souriyaphack, Department of Water Resources, Lao PDR, chindavanh.one@gmail.com

Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change

Project Reference Number: CBA2013-06NSY-SHRESTHA
Final Report submitted to APN

©Asia-Pacific Network for Global Change Research

PAGE LEFT INTENTIONALLY BLANK

OVERVIEW OF PROJECT WORK AND OUTCOMES

Adapting to climate change impacts in water sector is one of the important agenda for sustainable development in the Asia-Pacific region. As one of the adaptation options against intensifying water scarcity especially under prolonged dry season, the need for groundwater has been increasing in recent years. Despite the significance of groundwater resource for sustainable development, it has not always been properly managed by both users and policy makers, which is a major cause of overdraft or contamination of groundwater resources. Maintaining the sustainability of groundwater resources through better management contributes not only to water security but also to increase of resilience to potential climate change in water sector.

A number of sustainability indices have been recognized for policy formulation and public communication on conveying information on water resources condition and management (Singh et al., 2009). However, indices to measure groundwater sustainability have not been developed so far. In this regard, AIT together with Institute for Global Environmental Strategies and International Research Centre for River Basin Environment with a financial support from APN developed a framework for measuring groundwater sustainability infrastructure index and applied to assess the groundwater sustainability is selected Asian cities.

Objectives

The main objectives of the project were:

1. To develop and apply groundwater sustainability index to assess the extent of use and development of groundwater resources in selected Asian cities.

2. To develop the understandings and capacity to assess groundwater sustainability of groundwater managers and relevant stakeholders including water users by involving them from the beginning of index development, customization and application to their respective cities.

Amount received and number years supported

The Grant awarded to this project was: US$ 42,000 for 1 Year and 6 months: August 2013 to February 2015.

Activity undertaken

- Prepared web-site for e-conference, virtual discussions and project output dissemination (www.apngw.ait.ac.th).
- Developed guidelines on data requirements and application of groundwater sustainability index.
- Organized e-conference and virtual discussions with country partners and experts.
- Developed background paper on groundwater resources conditions in Asian cities.

- Organized two regional workshops in Asian Institute of Technology, Bangkok.
- Prepared country report on application of groundwater sustainability.

Results

- The conceptual framework for measuring groundwater sustainability has been developed and applied in eight cities: Bangkok (Thailand), Bandung (Indonesia), Chitwan (Nepal), Ho Chi Minh City (Vietnam), Hyderabad (India), Lahore (Pakistan), Vientiane (Lao PDR) and Yangon (Myanmar).

- Reports on 'Application of Driver-Pressure-State-Impact-Response (DPSIR) and Groundwater Sustainability Index (GSI) Framework' of each city.

- Participants improved their level of understanding and capacity to assess the status of groundwater resources and management through the application of Driver-Pressure-State-Impact-Response (DPSIR) and Groundwater Sustainability Index (GSI) framework.

Relevance to the APN Goals, Science Agenda and to Policy Processes

The project and its activities are in line with APN's goals such as supporting regional cooperation, strengthening interactions between scientists and policy makers, and improving scientific and technical capabilities of the nation. The project addressed all the activities of interest of CAPaBLE program such as Scientific capacity development for sustainable development; scientific-policy interfacing; dissemination activities.

Self-evaluation

The total project duration was one year, 13 August 2013 to 14 August 2014. The project faced initial implementation delays and it actually commenced in October 2013 and was completed in August 2014. Although there was the initial delay, the project objective was successfully achieved accordance to the project plan. Furthermore, we are planning to publish the background paper on groundwater resource condition in selected Asian cities. However, the need of continued future collaboration with partners was realized during the project for the precise implementation of the sustainability of groundwater framework and capacity building in each country.

Potential for further work

The project has developed a conceptual framework and implanted it to assess the sustainability of groundwater resources in selected cities. It builds up strong partnership with groundwater managers and researchers who have a common interest to solve groundwater related problems. All the project partners realized to further improve the framework and extend its application to other cities. Therefore there is a strong potential for future work based on the common research interest, expertise and capabilities of the project team members. Furthermore, in terms of project sustainability the follow-up action would help to formulate other future programs related to groundwater management capacity in these cities.

Publications (please write the complete citation)

- Report on “Application of Driver-Pressure-State-Impact-Response in selected Asian cities”
- Report on “Application of Groundwater Sustainability Infrastructure Index selected Asian cities”
- Groundwater Environment in Asian Cities: Concepts, Methods and Case Studies (Book under preparation and to be published by Elsevier)
- Groundwater sustainability in Asian Cities (Book under preparation and to be published by CRC Press)

References

- Pandey V.P., Chapagain S.K., Kazama F (2010) Evaluation of groundwater environment of Kathmandu Valley. *Environmental Earth Sciences*, 60(6), 1329-1342.
- Pandey V.P., Shrestha S., Chapagain S.K., Kazama F (2011) A framework for measuring groundwater sustainability. *Environmental Science & Policy*, 14(4), 396-407.
- Shrestha S and Kataoka Y. (2008) Groundwater and climate change: No longer the hidden resource.
- Takizawa S. (2008) Groundwater Management in Asian Cities, Springer.

Acknowledgments

AIT gratefully acknowledges the Asia-Pacific Network for Global Change Research (APN) for providing the financial support for the project “Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change”. We would also like to extend our gratitude to the collaborating members from India, Indonesia, Lao PDR, Myanmar, Nepal, Pakistan, Thailand, and Vietnam for their active participation and support to achieve the project objectives.

TECHNICAL REPORT

Preface

The project "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change" was managed by Asian Institute of Technology in collaboration with Institute for Global Environmental Strategies (IGES), and the International Research Centre for River Basin Environment (ICRE) and with a financial support from Asia-Pacific Network for Global Network Research (APN). This project is in line with APN's goal such as supporting regional cooperation, strengthening interactions among scientists and policy makers and improving technical capabilities of the nation. This project was geared towards enhancing the importance of groundwater and its linkage to various changes for better management. The core intent of this project was to build the capacity of the groundwater managers by involving people from science/academics in one platform.

Groundwater managers and researchers from Department of Groundwater Resource, Thailand, Ministry of Energy and Mineral Resources (MEMR), Indonesia, Centre of Research for Environment Energy and Water (CREEW), Nepal, Indian Institute of Technology- Hyderabad, India, International Waterlogging and Salinity Research Institute (IWASRI), Pakistan, Department of Water Resources (DWR), Lao PDR, and Department of Geography, University of Yangon, Myanmar came together to make this project a success.

This report summarizes the overall project objective, methodologies, activities implemented and actual outcomes of the project.

Table of Contents

1. Introduction

Groundwater plays an essential role in the sustainable development of Asian cities by providing water for domestic, industrial and agricultural uses. Approximately one-third of Asia's drinking water supply comes from groundwater. In many cities, more than half of the potable water supply comes from groundwater. For instance, 60% of the rural population in Cambodia relies on groundwater, while 76% of people who do not have access to piped system depend on tube wells in Bangladesh. There are some cities which solely depend on groundwater as a source of drinking water such as Lahore and Vientiane Cities. On the other hand cities such as Bandung, Ho Chi Minh City, Hyderabad, Kathmandu, Tokyo and Yangon have piped water system but it heavily depends on groundwater as a source of drinking water supply. In urban areas, groundwater tends to be used more for industrial use than human consumption. Industrial use in total groundwater abstraction is 80% in Bandung and 60% in Bangkok.

Despite the significance importance of groundwater it has not always been properly managed, which often has resulted in depletion and degradation of the resource. Much emphasis has been given to groundwater resources development without giving careful attention to its management despite its strategic role in sustainable development. Without proactive governance, the detrimental effects of poor management will nullify (or even surpass) the social gains made so far. Many cities are already suffering from water insecurity as a result of rapid population growth and economic development. Land subsidence, depletion in groundwater table and salt water intrusion are often evident in these cities. To maintain the advantages of groundwater as an important resource for sustainable development and also as a reserve freshwater resource for current and future generations, groundwater management should be more strategic and proactive to cope with increased demand from rapid industrialization and urbanization including potential impacts of climate change.

The project 'Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change' sought to increase the understandings of policy makers and relevant stakeholders (e.g. users) in selected Asian cities and develop their capacity to assess their situation of groundwater management through customization and application of "groundwater sustainability index (GSI)". The countries and cities were namely: India (Hyderabad), Indonesia (Bandung), Lao PDR (Vientiane), Myanmar (Yangon), Nepal (Chitwan), Pakistan (Lahore), Thailand (Bangkok) and Viet Nam (Ho Chi Minh City).

"Groundwater Sustainability Index (GSI)" framework assess the sustainability of groundwater resource in which different indicators related to groundwater sustainability are integrated such as the state of scientific knowledge base on groundwater and its related problems such as land subsidence, socio-economic factors, demographic changes, institutional arrangement. In this project GSI framework has helped to examine and analyse the facts and figures of groundwater dependency; problems related groundwater over exploitation, implementation of various policy instruments and management practices and their results in selected cities.

2. Methodology

2.1 E-conference

E-conference was set up in the initial phase of the project to ensure the continuous networking and consultation with the project members and collaborators. It served as an online platform for continuous sharing and updating information on project objectives, methodologies, schedules and background paper of 'groundwater sustainability index'. At this stage, guideline on data requirements, application framework (Appendix A) was shared with all the project members and collaborators via email so that they could have draft of list of data and their sources prepared in advance for the Regional Workshop I.

The primary objective of e-conference included:

- Identifying quantifiable indicators for respective city and developing rating criteria for the indicators based on some quantitative values.
- Collecting comprehensive background information about status of groundwater environment in selected cities.
- Determining whether indicators for GSII provided in the guideline were enough for respective cities or needed more indicators.
- Determining whether indicators for DPSIR provided in the guideline were enough for respective cities or needed more indicators.

As per the expected outcome of the project the working group were able to prepare a general framework and city specific report on application of DPSIR framework which was later dealt in detail during the first regional workshop in Bangkok.

2.2 Project Website

The project website of "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", www.apngw.ait.ac.th , was constructed, which is being managed by AIT. The core idea behind setting up this website was to make an online presence among the stakeholders. The website was mainly used for sharing and uploading materials related to methodology of developing groundwater sustainability index, database of groundwater development and management of each city, application framework of groundwater sustainability. Moreover, the website contains all the project related materials.

2.3 Regional Workshop I (16-17 January, 2014)

The first regional workshop was organized on 16-17 January, 2014 at Asian Institute of Technology Bangkok (Appendix B). The workshop brought together eight groundwater managers and researchers from Thailand, Nepal, India, Vietnam, Indonesia, Japan, Pakistan and Lao PDR. The overall objective of this workshop was to present the research progress in regard to DPSIR framework and to finalize suitable the indicators and evaluating criteria for groundwater

sustainability index as well as for DPSIR analysis. The presentations were focused on the facts and issues concerning groundwater management in each cities, such as water consumption practices, the quality as well as the quantity of water resources, levels of groundwater extraction and its impact, groundwater monitoring activities and its results, production capacity of groundwater abstraction wells, status of awareness among the locals in the area, existing institutional and legal framework related to groundwater.

At the workshop participants also witnessed a detailed presentation on DPSIR Analysis of groundwater environment and groundwater sustainability framework and on how to select indicators, how to weightage/score and relationship between indices. This session was later followed by a group discussion on DPSIR technique applied for two kinds of aquifer systems [coastal (Bangkok) and inland (Lahore)]. Presentations were also made by both groups based on the outcomes of the group discussion, under the framework of Driver-Pressure-State-Impact-Response (DPSIR).

For DPSIR framework analysis following components was agreed:

Table 1 Indicators for DPSIR Analysis

Components	Indicators
Driver	Population growth Urbanization Tourism
Pressure	Inadequate surface water supply Overexploitation of groundwater resources Land cover Change
State	Well statistics Ground water extraction Groundwater quality Groundwater level Recharge
Impact	Decline in groundwater level Decline in production capacity of well Land subsidence Public health
Response	Groundwater monitoring Environmental standard guideline

At the workshop, feedbacks were gathered on Groundwater Sustainability Index (GSI) indicators based on the relevancy and data availability in the particular city but were unable to score the indicators.

2.4 Application of Groundwater Sustainability Index

Following the recommendation and comments made at the first regional workshop the project team came up with 24 indicators. The major objective of the GSII was to evaluate the sustainability of

groundwater resources using different indicators. These 24 indicators represented the following five components:

1. Monitoring of stress on groundwater: 7 indicators
2. Knowledge management: 6 indicators
3. Policy and legislation: 3 indicators
4. Stakeholder participation: 4 indicators
5. Institutions and capacity: 4 indicators

The participants were guided to calculate GSI based on the weight and ratings of indicators. Each indicator was assigned the weight (scale of 1-5) according to its importance on sustainability and rating (scale of 1-10) according to the actual value of indicators. Higher weight represented higher importance and higher ratings reflected higher sustainability. The excel file consisting of 24 indicators and their definition and example of calculation were shared with the participants through email.

Table 2 Proposed Groundwater Sustainability Index (GSI) Framework: Calculation (Example)

Component	Indicator No.	Indicator name	Weight to be assigned to indicator or component	Weights (W) (subjective) [1-5]	Ratings (R) (based on the actual value) [1-10]	WxR
Monitoring of stress on groundwater (A)	1	Per capita groundwater resources availability (m3/year)	5	5	2	10
	2	Density of groundwater observation wells	5	5	10	50
	3	Frequency of groundwater observation	5	5	5	25
	4	Total groundwater abstraction / groundwater recharge (%)	5	5	1	5
	5	Groundwater quality parameters monitored	5	5	7	35

		(physical, chemical & microbial)				
	6	Concentration of most frequently observed & significant pollution parameter [for e.g. (NO3-N) (%age of sample that comply with WHO standard)]	5	5	5	25
	7	Rate of land subsidence	5	5	10	50
Knowledge Management (B)	8	Basic hydrogeological map of aquifers layers	4	4	6	24
	9	Regularly updated groundwater budget	4	4	10	40
	10	Zonation of groundwater potential areas	4	4	10	40
	11	Delineation of groundwater critical zones (protection point of view)	4	4	10	40
	12	Status of central groundwater data compilation, storage and management department/unit	4	4	7	28
	13	Easiness to access groundwater related data/information	4	4	7	28
Policy & Legislation [C]	14	Groundwater management policy/action plan	4	4	1	4

	15	Groundwater licensing	4	4	5	20
	16	Economic instruments in place	4	4	6	24
Stakeholders' Participation [D]	17	Level of awareness	3	3	5	15
	18	Availability of community groundwater management organizations	3	3	5	15
	19	Gender inclusiveness in groundwater development and management	3	3	5	15
	20	Recognition of 'stakeholder's participation' in policy/law	3	3	6	18
Institutions & Capacity [E]	21	Groundwater overseeing authority at national level (for e.g. Ministry)	4	4	10	40
	22	Groundwater overseeing authority at sub-national/local level	4	4	10	40
	23	Availability of physical infrastructures (as % of optimal case)	4	4	6	24
	24	Technical staffs involved in groundwater development and management	4	4	8	32
				Index		647

Table 3 Proposed Groundwater Sustainability Categories

Category	GSII Index
Highly Sustainable	> 900
Sustainable	700-900
Medium Sustainable	500-700
Less Sustainable	300-500
Not Sustainable	< 300

2.5 Regional Workshop II (24-25 July, 2014)

The second and final regional workshop on groundwater management was organized at the Asian Institute of Technology (AIT) on 24-25 July 2014(Appendix C), which focussed on sharing the outputs and reports of application of groundwater sustainability index. Participants from six countries including India, Myanmar, Nepal, Pakistan, Thailand and Viet Nam, presented their work on the development and application of Groundwater Sustainability Index (GSII) to evaluate the sustainability of groundwater resources in their respective cities. Overall, the workshop focused on discussing 24 indicators of GSI which was followed by critical comments on the proposed names of components, proposed indicators and addition and/or removal of the indicators. Therefore, it was decided to revise indicator table and circulate back to the participants for preparation of final report. The following points were agreed in the workshop:

- Indicator number 1, Groundwater availability: Revision of the weightage scale was required.
- Indicator number 4, Total groundwater abstraction / groundwater recharge (%) was dropped out.
- Indicator number 6, Basic hydrogeological map of aquifers layers: Clarification of what are minimum information contents in the map.
- Indicator number 9, regularly updated groundwater budget was dropped out.
- Indicator number 10 and 11 merged and named as Delineation of groundwater zones.
- Indicator number 13, Access to GW-related data/information: Weighted as 'Access with cost =3-6; access freely 7-10, no data available =2'.

In addition, this workshop also comprised of presentations related to groundwater research by experts and researchers. Topics that were discussed were: 'Preference analysis of household groundwater use for water supply and sanitation in Asian cities' by Dr.Binaya Raj Shivakoti, 'Towards groundwater as a state-controlled resource in Kathmandu Valley: role of non-state actors' by Vishnu Prasad Pandey, Delineation of groundwater potential zone in the Comoro River Basin, 'Timor Leste using the GIS, Remote Sensing and Analytic Hierarchy Process (AHP) technique' by Domingos Pinto

and 'Model Based Estimation of Land Subsidence in the Kathmandu Valley', Nepal by Pallav Shrestha.

2.6 Editors Meeting 'Groundwater Environment in Asian Cities: Concepts, Methods and Case Studies' (17-18 January, 2015)

A two-day editor meeting was organized on 17-18 January, 2015 at the Asian Institute of Technology, Thailand (Appendix D). Four editorial members from Asian Institute of Technology and Management (AITM), Indian Institute of Technology, Hyderabad (IITH), Institute for Global Environmental Strategies (IGES) and Asian Institute of Technology attended the meeting. This meeting served as a venue to review the status of preparation of preliminary chapters and case studies, finalize the preliminary chapters and critically review and provide detail comments on chapters submitted by the contributing authors. Some of the major outputs of the meeting were as below:

- Table of Contents was revised and agreed to restructure it on geographic basis or other once the first draft of all the chapters is received.
- In terms of adding value to the book, it was agreed to structure the cases to give information on how cities are going to grow and how they affect groundwater and make each case study as a representative of a typical groundwater issues.
- It was agreed to follow up with groundwater experts/researchers for cities like Vien Tien, Beijing, Malaysia, Phnom Phen, Tianjin, Kazakhstan and some other central Asian cities.
- It was agreed to revise the DPSIR chapter on the basis of how the framework has been applied; how it can be applied in groundwater and other sectors; if the framework is readily applicable or need customization etc.
- It was agreed to keep forwards from from APN (Dr. Linda & Director) & from UNESCO (Dr. Alice) and key messages from IGRAC (Dr. Neno); IGES (Dr. Mori or Prof. Hamanaka), as a Groundwater Knowledge hub); ICIMOD (Dr. Molden); UNESCAP (Dr. Shalma); Dr. Tussar Shah

3. Results & Discussion

The main output of this project was conceptual framework to evaluate groundwater environment of selected Asian cities through application of DPSIR and GSI framework. The brief summary of the results from these application are as follows:

i) Status of Groundwater as a result of application of application of Driver-Pressure-State-Impact-Response (DPSIR)

- In Bandung city of Indonesia, increase in urban population during the last two decades, and development of industrial areas acted as driving forces to exceed groundwater abstraction over recharge in some areas of the basin, decrease in groundwater levels in industrial areas (Leuwigajah, Dayeuhkolot, Rancaekek, and Banjaran), deterioration in groundwater quality, and lowering of land elevation due to land subsidence in some industrial areas. Management intervention have been and still being carried out by establishing map of

groundwater conservation zone, modeling approach for groundwater utilization plan, decreasing abstractions for groundwater permit in dangerous and critical zones, and stop groundwater pumping in damage zone. Therefore to obtain the positive impacts of these efforts a continuous monitoring of groundwater condition (quantity and quality) should be performed. Groundwater database and information system of local governments which is linked to the Central Government (CGREG) should be established soon in order to exchange groundwater data and information for better management of the Bandung-Soreang GB.

- Increase in population density (3566 to 4983 person/km^2), urbanization (increase in urban population from (5.14 million to 7.20 million) and increase in number of industries acted as main drivers exerting pressure on the groundwater environment in the Lahore city of Pakistan. The groundwater extraction is exceeding the recharge (extraction =1161 and recharge = 1013 MCM), decline in groundwater level is 0.65 m during 1980-2000 and 0.79m during 2000-2011, and deterioration of groundwater quality has led to dug up deeper well in search of relatively good quality groundwater. On the other hand, recharge to the aquifer (the sole source of water supply) is decreasing, both in quantity and quality, due to onset of urban housing development, since 1980s onwards. Thus, per capita water availability from the safe yield of the aquifer system is decreasing with the passage of time. In the absence of groundwater management policy and plans situation of groundwater environment in Lahore are expected to deteriorate further.
- In case of Bangkok city of Thailand the DPSIR analysis revealed that increasing population density, urbanisation and industrialization acted as a driving force for over exploitation of groundwater resources, decrease in groundwater levels and land subsidence. Land subsidence was over 10 cm/year in the eastern suburbs and 5 to 10 cm/yr in central Bangkok between 1978-1981. However, the remedial measures for controlling the groundwater uses were introduced in 1983 which had contributed to the decreasing rate of land subsidence. At present the overall area subsidence rate is 1-2 cm/yr. Even though the groundwater crisis situation has been recovered in Bangkok, the quantitative measurement of groundwater sustainability has not been adopted yet.
- Rapid population growth, urbanization and increase in tourism (due to development of Information Technology (IT) industries acted as the main drivers which has raised structural, environmental, social and economic challenges in Hyderabad city of India. Aquifers are being mined faster than being recharged in the absence of groundwater management policy and plans, management intervention and meaningful public participation. The government seemed ignorant towards implementation of the Water, Air, Land and Trees Act (WALTA) although administrative revenue offices still do not have sufficient information on the figures of the total number of bore wells in their jurisdiction. Knowledge generation and institutional capacity are relatively good and government is in the process of initiating several measures to improve storage and dissemination at national level.
- The application of DPSIR analysis in Yangon city of Myanmar revealed that increasing population density (13,494 persons/km^2); urbanisation (increase in area from 165 to 793 km^2) and increasing number of hotel due to tourism (204 to 300) acted as a driving force to exceed groundwater extraction over recharge. Overexploitations of groundwater have led to lowering groundwater level and decrease in production capacity. Therefore, groundwater

monitoring on extraction amount, water quality, well statistics and on land subsidence needs to be developed in Yangon City.

- Increase in population density (3,315 in 2008 to 3,779 person/km^2 in 2012), urbanization and increase in number of hotels (1,400-2,772) acted as driving forces in Ho Chi Minh City of Vietnam which exceeded groundwater extraction over recharge (extraction= 669,091m^3/day and recharge = 536,540 m^3/day), decrease in ground level, increase level of land subsidence ranging from 5-15 mm/year in 2010. (Although the groundwater policies and plans were in existence, it lacked in terms of management. Furthermore, the priority should be placed on implementing economic instruments for groundwater abstraction and quality protection in the city.
- The DPSIR analysis showed anthropogenic sources (such as population growth, urbanization, agriculture and tourism industry) acted as a driving force to exert pressures on the groundwater environment as result of changing land use, changes in agricultural cropping pattern and practices in Chitwan valley of Nepal. As a result, number of wells and corresponding extraction has increased which have affected the static water level and quality of the groundwater. In the present scenario groundwater quantity are not affected as the recharge is higher than abstraction. However as indicated by shallow groundwater quality of Mangalpur Village Development Committee (VDC), nitrate contamination has already begun and attributed to anthropogenic and agricultural practices. The government of Nepal has already drafted an act to better investigate, study; formulate plans, policies and strategies; and manage and regulate groundwater resource of Nepal.

ii) **Status of groundwater sustainability as a result of application of Groundwater Sustainability (GSI)**

Following the constructive suggestions from the collaborators for the development and application of GSI, it was revised accordingly and project team came up with 22 indicators (Appendix G). The GSI index were also classified in different categories i.e.: highly sustainable, if the index values > 800; sustainable if index ranges from 600-800; medium sustainable if index falls within 400-600; less sustainable when the value ranges from 200-400; and non-sustainable when the GSII is less than 200. The summary of the groundwater sustainability index in Asian cities is illustrated below:

- The overall situation of groundwater in Lahore city of Pakistan can be rated as 'sustainable' with the value of 651. Although the city has sustainable groundwater condition, significant efforts are needed to achieve the goal of 'groundwater sustainability'. The main improvement in sustainability can be achieved by addressing two out of five components of the GSI i.e 'Policy and Legislation' and 'Stakeholder's Participation'. To be more specific, lack of groundwater management and policy actions, no practice of groundwater licensing, lack of economic instruments and out-dated water budget are the main weakness in Lahore city.
- The overall situation of groundwater in Hyderabad city of India can be rated as 'medium sustainable' with the value of 590. Although the citizens are well aware about the decreasing level of groundwater, they seemed ignorant on the fact which might be due to lack of economic instruments for groundwater abstraction regulation and quality protection and no

provision of legal/social provision/mechanism for public participation. Therefore, this study area needs extensive improvements in terms of stakeholders' participation, institutional and capacity building.

- Overall situation of the groundwater in the Chitwan valley of Nepal can be considered as 'sustainable' with the index value of 790. The availability of water is not the problem but the ineffective implementation of the policies and economic instruments, inadequate research and documentation and inadequate instruments for water quality monitoring are some of the major factors hindering sustainability of groundwater resources. Therefore, more attentions are required to strengthen the sustainability infrastructures and subsequently achieve groundwater sustainability in the valley. Results of the GSI application demonstrated the areas for improvement and ultimately guide appropriate policy-actions towards sustainable groundwater management.
- The overall score of GSI in Bangkok city is 552 and classified as 'medium sustainable'. The study result showed the ratio of groundwater abstraction/groundwater recharge (%) is 109 % which has been classified as "High Stress" situation. The groundwater monitoring, knowledge management, policy and legislation practices are relatively good in the city. After the implementation of Groundwater Act in 1983 the groundwater resource condition has now been improved. However, the level of awareness among the stakeholders, immediate management intervention at community level and gender inclusiveness in groundwater development and management are the areas that needed significant attention. Although the stakeholders are quite aware of the situation of groundwater but their involvement is fairly commendable, lacked in terms of community groundwater organization, and gender issues are not normally discussed in the groundwater development and management field.
- The total index for Ho Chi Minh City of Vietnam is estimated as 612, all the components of the index are relatively good hence the overall situation of groundwater sustainability in HCMC city can be rated as 'sustainable'. The result showed that the ratio of groundwater abstraction/groundwater recharge (%) is 106%; therefore, the general situation of groundwater in HCMC can be considered as heavily stressed. It also showed that the coverage of monitoring (groundwater level, extraction, land subsidence and quality) is inadequate and knowledge deficiencies among stakeholders are poor. Thus, it reflects the need of attentions to strengthen these two indices in order for achieving groundwater sustainability.
- Overall situation of groundwater sustainability in Yangon City of Myanmar can be rated as 'medium sustainable' category with a value of 550. Although the indicators are satisfactory, the result showed that the information on monitoring (groundwater level, extraction, and quality and land subsidence) is inadequate and data quality, storage and dissemination aspects are very poor. Absence of groundwater management policy and plans, management interventions and meaningful public participation are some of the factors hindering the sustainability of the groundwater.

iii) Capacity Building Workshop

The project was able to develop the understandings and capacity of groundwater managers and researchers to assess groundwater sustainability by involving them from the beginning of index development, customization and application in their respective cities. The collaborators showed their keen interest through their active participation in all the project activities, most importantly proposing the names of components, proposing indicators and addition/modification/ removal of the indicators, rating criteria based on their expertise and experience in their cities. The project collaborators from each country could assess the sustainability of groundwater use not only in the selected city but also in other cities of their country with the comprehensive and practical expertise developed during this project.

4. Conclusions

This project achieved its objective of developing the conceptual framework for measuring groundwater sustainability and successfully implemented the framework to assess the sustainability of groundwater resources in selected cities. Furthermore, this project has enhanced the understandings of groundwater sustainability concept. In addition the project also enhanced the capacity of groundwater managers and researchers to use the framework by providing an opportunity to share groundwater sustainability issues, problems and opportunities in their respective cities.

Overall the groundwater sustainability of selected Asian cities can be rated as 'medium sustainable to sustainable'. In most of the studied city condition of groundwater is under risk because the groundwater level is declining, aquifers volumes are decreasing and water quality is deteriorating. To cope with these situation city like Bangkok have taken measures to restrict groundwater exploitation such as introduction of licensing/permission system and groundwater charging scheme. However, cities such as Chitwan, Ho Chi Minh, Hyderabad, Lahore and Yangon lack such kind of policies and its implementation. Therefore, higher priority must be given to formulate groundwater policies and regulations for achieving groundwater sustainability in these cities. Furthermore, to enable the application of groundwater sustainability tool in future we recommend engaging respective groundwater managers with the relevant stakeholders regularly and developing updated groundwater database.

Although the project objectives have been achieved feedback and follow-up with groundwater managers would be helpful to formulate other future programs related to enhancing groundwater management capacity in respective cities.

5. Future Directions

This project focused on only selected Asian cities for the assessment; however it is anticipated that members from each country can assess the sustainability of groundwater use also in other cities of their country which will be useful for better groundwater development and management. Furthermore, in terms of project sustainability perspective the follow-up action/project would help

to formulate other future project and programs related to groundwater management capacity in these cities.

References

- Basharat, M. (2014). Groundwater environment and long-term sustainability of the aquifer under the Lahore (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Basharat, M. (2014). Groundwater environment and long-term sustainability of the aquifer under the Lahore (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)
- IGES (2007) Sustainable groundwater management in Asian cities, p 157
- Khaing, K.K. (2014). Groundwater situation in Yangon city (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Khaing, K.K. (2014). Groundwater situation in Yangon city (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)
- Lorphensri, O., Ladawadee, A., Netthas, T. (2014). Evaluation of groundwater environment of Bangkok and vicinity (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Lorphensri, O., Ladawadee, A., Netthas, T. (2014). Groundwater sustainability of Bangkok aquifer system (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)
- Malla, R. (2014). Assessment of groundwater environment of Chitwan, Nepal (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Malla, R. (2014). Study on development and application of groundwater sustainability index (GSI) to evaluate the sustainability of groundwater resource in Chitwan, Nepal (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)

- Pandey V.P., Chapagain S.K., Kazama F. (2010) Evaluation of groundwater environment of Kathmandu Valley. Environmental Earth Sciences, 60(6), 1329-1342.
- Pandey V.P., Shrestha S., Chapagain S.K., Kazama F. (2011) A framework for measuring groundwater sustainability. Environmental Science & Policy, 14(4), 396-407.
- Shashidhar (2014). Groundwater status at Hyderabad, India (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Shashidhar (2014). Groundwater sustainability of Hyderabad, India (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)
- Tirtomihardjo, H. (2014). Groundwater status of Bandung Indonesia (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Vuong, B.T. (2014). Groundwater on Ho Chi Minh city (Submitted at First Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January, AIT, Thailand)
- Vuong, B.T. (2014). Groundwater sustainability of Ho Chi Minh city (Submitted at Second Regional Workshop "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 24-25 July, AIT, Thailand)

Appendix A: Background Paper for APN CAPaBLE Project

Background paper on Groundwater sustainability in Asian cities

Note: Please see the attached copy of paper for reference.

Appendix B: Regional Workshop on "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change", 16-17 January 2014

A two-day workshop on "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change" was successfully completed on 17 January, 2014 at Asian Institute of Technology (AIT) in Bangkok, Thailand. The main purpose of this workshop was to share the knowledge of groundwater environment of selected Asian cities; to discuss on the framework of Driver-Pressure-State-Impact-Response (DPSIR) and Groundwater Sustainability Index (GSII).

The first day of the workshop started with the introduction of the project and objectives of the workshop by Dr. Sangam Shrestha. He briefed the workshop as a platform to enhance understanding among policy makers on Groundwater Sustainability Index and Driver, Pressure, State, Impact, Response (DPSIR) framework as the analytical framework for reaching the goal of achieving good groundwater status.

Prof. Sivanappan Kumar, Vice President for Academic Affairs (VPAA) of AIT inaugurated the first regional workshop. In his welcome speech, he stated that AIT is dedicated to Sustainable Development issues, and its two academic programs of Water Engineering and Management (WEM) and Urban Environmental Management (UEM) are closely linked with the topics under discussion at the workshop.

Following his inaugural speech, Dr. Akio Takemoto, Director, Asia-Pacific Network for Global Change Research (APN), provided an overview of the activities of APN. Dr. Jariya Boonjawaat, Scientific Planning Group, APN (Thailand) also informed the participants about the activities of APN. The workshop also included a keynote speech entitled "Save Groundwater Secure Future" delivered by Prof. Mukand S. Babel, Water Engineering and Management (WEM), AIT.

The first day of the workshop witnessed presentations from selected participants from eight countries including Thailand, Nepal, India, Indonesia, Japan, Lao, Vietnam and Pakistan. Delegates from each country focused their presentation on the facts and issues concerning groundwater management in their countries, such as water consumption practices, the quality as well as the quantity of water resources, levels of groundwater extraction and its impact, groundwater monitoring activities and its results, production capacity of groundwater abstraction wells, status of awareness among the locals in the area, existing institutional and legal framework related to groundwater.

On the second day, Dr. Vishnu P. Pandey of AITM delivered a presentation on DPSIR Analysis of groundwater environment and groundwater sustainability framework. Some of the areas covered in his presentation are summarized as follows:

DPSIR Analysis

-Causes of problem (Impact) are Drivers, Pressure, State of the system and Solution is given by Response to all the causes.

-Information on generation of this technique was also provided

-Details of the entire framework applied at Kathmandu valley was also provided

-Indicators of D-P-S-I-R used were shown

-Conclusion of the study and the recommendations provided

Groundwater Sustainability Index (GSII) Framework

-Introduction to the conceptual framework

-Five dimensions of sustainability and groundwater sustainability infrastructures

-Indicators for GSII in Nepal context from the study

-Demonstration of various indicators for Kathmandu valley

The session was followed by a group discussion on DPSIR technique applied for two kinds of aquifer systems [coastal (Bangkok) and inland (Lahore)]. Presentations were made by both groups based on the outcomes of the group discussion, under the framework of Driver-Pressure-State-Impact-Response (DPSIR) provided. Participants are as follows:

Group-1 (Coastal Aquifer)		**Group-2 (Inland Aquifer)**	
Case study: Bangkok City		**Case study: Lahore City**	
Name	**City**	**Name**	**City**
Dr. Oranuj Lorphensri	Bangkok	Dr. Muhammad Basharat Chaudhary	Lahore
Dr. Bui Tran Vuong	Ho Chi Minh City	Dr. Rabin Malla	Chitwan
Dr. Shashidhar	Hyderabad	Dr. Haryadi Tirtomihardjo	Bandung
Dr. Tussanee Netasana	Bangkok	Ms. Chindavanh Souriyaphack	Vientiane

Program Schedule

Day 1: Thursday, 16 January

Venue: Room B 202, AITCC

	Opening Session	
8:30 – 9:00	Registration	
9:00 – 9:05	Objective of the workshop	Dr. Sangam Shrestha, AIT, Thailand
9:05 – 9:10	Welcome Remarks	Prof. S. Kumar, Vice President-Academic Affairs, AIT, Thailand
9:10-9:30	Introducing Asia Pacific Network for Global Change Research (APN)	Dr. Jariya Boonjawat, Scientific Planning Group, APN, Thailand
9:30 – 9:35	Group Photo	
9:30 – 10:00	Keynote Speech	Prof. Mukand S. Babel, AIT, Thailand
	10:00-10:20(Coffee/Tea Break)	
Technical Session -1: Groundwater Status in South-East Asia **Chair: Dr. Bui Tran Vuong**		
10:20 – 10:45	Presentation on 'Groundwater status in Bangkok, Thailand'	Dr. Oranuj Lorphensri, Director, Ground Water Control Bureau, Department of Groundwater Resources, Thailand
10:45 – 11:10	Presentation on 'Groundwater status in Bandung, Indonesia"	Dr. Haryadi Tirtomihardjo, Senior Hydrogeologist, Central of Groundwater Resources and Environment Geology, Indonesia
11:10 – 11:35	Presentation on 'Groundwater status in Vientiane, Laos'	Ms. Chindavanh Souriyaphack, Chief, Groundwater Management and Planning Sector, Ministry of Natural Resources and Environment , Lao PDR
11:35 – 12:00	Discussion	All
	12:00-13:30(Lunch Break)	

Technical Session -2: Groundwater Status in South-Asia **Chair: Dr. Oranuj Lorphensri**		
13:30 – 13:55	Presentation on 'Groundwater status in Chitwan, Nepal'	Dr. Rabin Malla, Executive Director, Center of Research for Environment and Water, Kathmandu, Nepal
13:55 – 14:20	Presentation on 'Groundwater status in Hyderabad, India'	Dr. Shashidhar, Assistant Professor, Indian Institute of Technology, Hyderabad, India
14:20 – 14:45	Presentation on' Groundwater status in Lahore, Pakistan'	Dr. Muhammad Basharat Chaudhary, Director, International Waterlogging and Salinity Research Institute, Lahore, Pakistan
14:45 – 15:10	Discussion	**All**
15:10-15:30(Coffee/Tea Break)		
Technical Session -3: Groundwater Status in South-East Asia **Chair: Dr. Shashidhar**		
15:30 – 15:55	Presentation on 'Groundwater status in Tokyo, Japan'	Yatsuka Kataoka, Senior Coordinator, Institute for Global Environmental Strategies, Japan
15:55 – 16:20	Presentation on 'Groundwater status in Ho Chi Minh City, Vietnam'	Dr. Bui Tran Vuong, Deputy Director General, Division for Water Resources Planning and Investigation, Vietnam
16:20 – 16:45	Presentation on 'Groundwater status in Yangon, Myanmar'	Dr. Khin Kay Khing, Lecturer, Department of Geography, University of Yangon, Myanmar
16:45 – 17:10	Discussion	All
17:10 – 17:30	Closing of Day-1	All
18:00	Welcome dinner	All

Day 2: Friday, 17 January

Venue: Room B 202, AITCC

Session		Resource Person
9:30 – 9:35	Registration	
9:35 – 10:00	Summary of the 1st day's sessions and objective of the 2nd day's program	Dr. Sangam Shrestha, AIT, Thailand
Technical Session -4:Theoritical framework on Driver-Pressure-Sate-Impact-Response		
10:00 – 10:30	Presentation on ' Driver-Pressure-State-Impact-Response'	Yatsuka Kataoka, Institute for Global Environmental Strategies (IGES)
10:30 – 11:30	Discussion on presentation and e-Conference	All
11:30-12:30 (Lunch Break)		
Technical Session -2:Theoritical framework on Groundwater Sustainability		
12:30 – 13:00	Presentation on 'Groundwater Sustainability Framework'	Dr. Vishnu Prasad Pandey, Asian Institute of Technology and Management (AITM), Nepal
13:00 – 14:00	Discussion on presentation and e-Conference	All
14:00-14:20 (Coffee/Tea Break)		
14:20 – 14:50	Moving forward	All
15:00 – 15:10	Closing Remarks	Dr. Sangam Shrestha, AIT, Thailand

List of Participants

S.N.	Name	Field of Study	Email
1	Akio Takemoto	Asia Pacific Network for Global Research (APN)	atakemoto@apn-gcr.org
2	Prof. Sivanappan Kumar	Asian Institute of Technology	kumar@ait.ac.th
3	Dr. Jariya Boonjawat	Asia Pacific Network for Global Research (APN)	jariya@start.or.th
4	Dr. Sangam Shrestha	Asian Institute of Technology	sangam@ait.ac.th
5	Prof. Mukand S. Babel	Asian Institute of Technology	msbabel@ait.ac.th
6	Dr. Oranuj Lorphensri	Department of Groundwater Resources (DGR)	oranujl@hotmail.com
7	Dr. Tussanee Nettasana	Department of Groundwater Resources (DGR)	n_thassanee@yahoo.com
8	Dr. Shashidhar	Indian Institute of Technology Hyderabad (IIT Hyderabad, IITH)	shashidhar@iith.ac.in
9	Dr. Bui Tran Vuong	Division of Water Resources Planning and Investigation for the South of Vietnam (DWRPIS)	buitranvuong@gmail.com
10	Dr. Muhammad Basharat	Pakistan Water and Power Development Authority (WAPDA)	basharatm@hotmail.com
11	Dr. Rabin Malla	Centre of Research for Environment Energy and Water (CREEW)	rabin@creew.org.np
12	Dr. Vishnu P. Pandey	Asian Institute of Technology and Management (AITM)	Vishnu.pandey@gmail.com
13	Mr. Haryadi Tirtomihardjo	Centre of Groundwater Resources and Environmental Geology (CGREG)	haryadi_tirtomihardjo@yahoo.com
14	Ms. Chindavanh Souriyaphack	Division of Groundwater in Department of Water Resources (DWR)	chindavanh.one@gmail.com
15	Prof. Avishek Datta	Asian Institute of Technology	

16	Smriti Malla	Asian Institute of Technology	smritim@ait.ac.th
17	Proloy Deb	Asian Institute of Technology	debproloy@gmail.com

List of Observers

S.N.	Name	Field of Study	Email
1	Ajay Ratna Bajracharya	WEM	ajay.ratna.bajracharya@ait.ac.th
2	Anshul Agrawal	WEM	st111582@ait.asia
3	Aung Myo Khaing	WEM	aungmyokhaing.77@gmail.com
4	Dickson Semkuyu	WEM	Dickson.john.semkuyu@ait.ac.th
5	Domingos Pinto	WEM	st114528@ait.ac.th
6	Duong Thanh	WEM	st115653@ait.ac.th
7	Emal Wali	ASE	emal.wali@ait.ac.th
8	Huang Zhirong	NRM	st116009@ait.ac.th
9	I Putu Santikayasa	WEM	st111717@ait.ac.th
10	Jeewanthi Gangani Sirisena	WEM	t.a.j.gangani.sirisena@ait.ac.th
11	Kshitij Parajuli	SERD	kshparajuli@gmail.com
12	Medha Khatiwada	SERD	medhakhatiwada@gmail.com
13	Mohammad Hassan Hassanyar	WEM	hasanyar84@hotmail.com
14	Muhammad Babur	WEM	muhammad.babur@ait.ac.th
15	Nguyen Thi Thuy Trang	WEM	st115455@ait.ac.th
16	Nisha Maharjan	WEM	st115610@ait.ac.th
17	Nurrohman Wijaya	UEM	st113371@ait.ac.th

18	Palpasa Prajapati	WEM	palpasaprajapati@gmail.com
19	Ranjana Kafle	WEM	st115600@ait.ac.th
20	Sainglong Kaing	RS-GIS	sainglong.Kaing@ait.ac.th
21	Sajan Jung Pandey	WEM	sajan.nitw@gmail.com
22	Saroj Adhikari	WEM	saroj.adhikari@ait.ac.th
23	Saroj Chapagain	EEM	saroj@ait.ac.th
24	Sneha Sandhliya	WEM	st115595@ait.ac.th
25	Sohaib Baig	WEM	st115603@ait.ac.th
26	Suwash Chandra Acharaya	WEM	suwash.Chandra.Acharya@ait.ac.th
27	Tran Viet Bach	WEM	st114339@ait.ac.th
28	Victor Shinde	WEM	victorshinde@ait.ac.th

Appendix C: Regional Workshop on "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change"

A two-day workshop on "Enhancing the groundwater management capacity in Asian cities through the development and application of groundwater sustainability index in the context of global change" was successfully completed on 25 July, 2014 at Asian Institute of Technology (AIT) in Bangkok, Thailand. The main aim of this workshop was to share the outputs/reports of application of groundwater sustainability index using different indicators which was derived based on the suggestions and comments from our first workshop. Based on the outputs/report, a set of recommendations were formulated in the workshop for the improved groundwater management in each city.

Delivering the welcome remarks, Prof. Voratas Kachitivichyanukul, Dean, School of Engineering and Technology of AIT highlighted the role played by AIT in capacity building projects and thanked Asia-Pacific Network for Global Change Research (APN) for their support to the project.

Following his inaugural speech Dr. Jariya Boonjawaat, Scientific Planning Group, Asia-Pacific Network for Global Change Research (APN), provided an overview of the activities of APN. The workshop also included a keynote speech entitled "Towards scientific and methodological innovation in trans-boundary groundwater management" delivered by Prof. Mukand S. Babel, Water Engineering and Management (WEM), AIT. In his speech he stressed the importance of using scientifically proven method to assess the groundwater availability, use and vulnerability state.

The first day of the workshop witnessed presentations from selected participants from six countries including Thailand, Nepal, India, Myanmar, Vietnam and Pakistan. Delegates from each country focused their presentation on the development and application of groundwater sustainability infrastructure index (GSII) to evaluate the sustainability of groundwater resources in their respective cities. Some of the areas covered in their presentation were social, environmental, economic, institutional and mutual trust dimensions which were represented as public participation, groundwater monitoring, regulatory intervention, institutional responsibility and knowledge generation and dissemination.

The second day, which marked the conclusion of the workshop, saw presentation from researchers like Dr. Binaya Raj Shivakoti of Institute for Global Environmental Strategies (IGES), Dr. Vishnu Prasad Pandey of Asian Institute of Technology and Management (AITM), Mr. Domingos Pinto and Mr. Pallav Shrestha of Asian Institute of Technology (AIT).

Dr. Sangam Shrestha thanked all the participants and sponsors for making the event successful and expressed his hope that this workshop would contribute towards strengthening future collaboration.

Program Schedule

Day 1: Thursday, 24 July

Venue: Room B 202, AITCC

	Opening Session	
9:00 – 9:30	Registration	
9:30 – 9:40	Objective of the workshop	Dr. Sangam Shrestha, AIT, Thailand
9:40-9:50	Welcome Remarks	Prof. Voratas Kachitvichyanukul, Dean, School of Engineering and Technology, AIT, Thailand
9:50-10:10	Key note: Towards scientific and methodological innovation in transboundary aquifer resource management	Prof. Mukand S. Babel, Professor and Director, Center of Excellence on Sustainable Development in the context of Climate Change (SDCC),AIT, Thailand
10:10-10:30	Briefing on Asia Pacific Network for Global Change Research (APN)	Dr. Jariya Boonjawat, Scientific Planning Group, APN, Thailand
10:30 – 10:35	Group Photo	
	10:35-10:55 (Coffee/Tea Break)	
Technical Session -1: Groundwater Environment and its Sustainability in South-East Asia Chair: Dr. Muhammad Basharat		
10:55 – 11:25	Groundwater Sustainability of Bangkok, Thailand	Dr. Oranuj Lorphensri, Director, Ground Water Control Bureau, Department of Groundwater Resources, Thailand
11:25-11:55	Groundwater Sustainability of Ho Chi Minh City, Vietnam	Dr. Bui Tran Vuong, Deputy Director General, Division for Water Resources Planning and Investigation, Vietnam
11:55 – 12:25	Groundwater Sustainability of Yangon, Myanmar	Dr. Khin Kay Khaing, Lecturer, Department of Geography, University of Yangon, Myanmar

12:25 – 12:45	Discussion	All
12:45-14:10 (Lunch Break-AITCC)		
Technical Session -2: Groundwater Environment and its Sustainability in South-Asia Chair: Dr. Oranuj Lorphensri		
14:10 – 14:40	Groundwater Sustainability of Chitwan, Nepal	Dr. Rabin Malla, Executive Director, Center of Research for Environment and Water, Kathmandu, Nepal
14:40 – 15:10	Groundwater Sustainability of Hyderabad, India'	Dr. Shashidhar, Assistant Professor, Indian Institute of Technology, Hyderabad, India
15:10 – 15:40	Groundwater Environment and Long-term Sustainability of Lahore Aquifer, Pakistan	Dr. Muhammad Basharat Chaudhary, Director, International Waterlogging and Salinity Research Institute, Lahore, Pakistan
15:40 – 16:00	Discussion	All
16:05 – 16:15	Closing of Day-1	All
18:00	Welcome dinner (AITCC)	All

Day 2: Friday, 25 July

Venue: Room B 202, AITCC

Session		Resource Person
9:00 – 9:10	Summary of the 1st day's sessions and objective of the 2nd day's program	Dr. Sangam Shrestha, AIT, Thailand
Technical Session -4: Sharing Groundwater research		
9:10 – 9:30	Preference analysis of household groundwater use for water supply and sanitation in Asian cities	Dr. Binaya Raj Shivakoti , Institute for Global Environmental Strategies (IGES)

9:30-9:50	Towards groundwater as a state-controlled resource in Kathmandu Valley: role of non-state actors	Dr. Vishnu Prasad Pandey, Asian Institute of Technology and Management (AITM), Nepal
9:50-10:10	Delineation of groundwater potential zone in the Comoro River Basin, Timor Leste using the GIS, Remote Sensing and Analytic Hierarchy Process (AHP) technique	Domingos Pinto, Asian Institute of Technology
10:10-10:30	Model Based Estimation of Land Subsidence in the Kathmandu Valley, Nepal	Mr. Pallav Shrestha, Asian Institute of Technology
10:30-10:45	Discussion	All
10:45-11:00 (Coffee Break)		
Technical Session -5: Comparative Analysis of Groundwater Environment and its Sustainability		
11:00 – 11:20	Presentation on 'Comparative analysis of Groundwater Sustainability Index'	Dr. Sangam Shrestha, AIT, Thailand
11:20 – 12:20	Moving forward (Proposal preparation for next phase)	All
12:20 – 12:25	Closing Remarks	Dr. Sangam Shrestha, AIT, Thailand
12:25-13:25 (Lunch Break-AITCC)		

List of Participants

S.N.	Name	Affiliation	Email
1	Dr. Jariya Boonjawat	Asia Pacific Network for Global Research (APN)	jariya@start.or.th
2	Dr. Sangam Shrestha	Asian Institute of Technology	sangam@ait.ac.th
3	Prof. Mukand S. Babel	Asian Institute of Technology	msbabel@ait.ac.th
4	Dr. Oranuj Lorphensri	Department of Groundwater Resources (DGR)	oranujl@hotmail.com
6	Dr. Bui Tran Vuong	Division of Water Resources Planning and Investigation for the South of Vietnam (DWRPIS)	buitranvuong@gmail.com
7	Dr. Muhammad Basharat	Pakistan Water and Power Development Authority (WAPDA)	basharatm@hotmail.com
8	Dr. Rabin Malla	Centre of Research for Environment Energy and Water (CREEW)	rabin@creew.org.np
9	Dr. Vishnu P. Pandey	Asian Institute of Technology and Management (AITM)	vishnu.pandey@gmail.com
10	Dr. Binaya Raj Shivakoti	Institute for Global Environmental Strategies (IGES)	shivakoti@iges.or.jp
11	Dr. Khin Kay Khaing	University of Yangon	khine.khinkay@gmail.com
12	Domingos Pinto	Asian Institute of Technology	St114528@ait.ac.th
13	Pallav Shrestha	Asian Institute of Technology	Pallav3.14@gmail.com
14	Smriti Malla	Asian Institute of Technology	smrtim@ait.ac.th
15	Dr. V. Sridhar	Virginia Tech University	vsri@vt.edu

List of Observers

S.N.	Name	Field of Study	Email
1	Palpasa Prajapati	WEM	palpasaprajapati@gmail.com
2	Ranjana Kafle	WEM	st115600@ait.ac.th
3	Nisha Maharjan	WEM	Nisha.maharjan065@gmail.com
4	Nguyen Thi Thuy Trang	WEM	Nttrang.us@gmail.com

Appendix D: Editors Meeting Minutes

Book Title: **Groundwater Environment in Asian Cities: Concepts, Methods, and Case Studies**

1) Table of Contents: The TOC was revised in the following form. Whether to go for geographic basis or other will be decided once the first draft of all the chapters as well as comparative analysis is ready.

Section-I: Concepts and Methods

1. Introduction → Dr. Sangam [10 pages]
2. DPSIR Framework → Dr. Vishnu [8 pages]- 2nd draft by 16th Feb

Section-II: Groundwater Environment in South Asian

3. Introduction South Asia: general description of the region (map, context, socio-economic, groundwater use scenario, then go for case studies of selected cities in the subsequent chapters)
4. Chitwan (Dr. Rabin): 1st draft received
5. Hydarabad (Agreed: Dr. Sashidhar): by end of JAN, 2015
6. Lahore (Dr. Basharat):1st draft received
7. Khulna (Agreed; Ref: Dr. Binaya): by end of JAN, 2015
8. Colombo (Agreed; Ref: IWMI): in the worst case, we may go with Candy case study available in IGES report; we may ask someone else
9. Delhi, India (Agreed: Prof. Shashank Shekhar; Ref: Shashidhar)

Section-III: Groundwater Environment in Southeast Asia

10. Introduction of Southeast Asia: general description of the region (map, context, socio-economic, groundwater use scenario, then go for case studies of selected cities in the subsequent chapters)
11. Bangkok (Dr. Oranuj Lorphensri): 1st draft received on 15th Jan
12. Ho Chi Minh (1st Draft received: Dr. Bui)
13. Bandung (Need to write by ourselves based on report submitted to the project; Mr. Haryadi): we may write by ourselves keeping him as first author
14. Vien Tien (Agreed but a bit confused; Mr. Paul; Dr. Binaya will talk with him soon)
15. Yangon (Dr. Khin Kay Khaing): 1st draft received
16. Phonm Penh (Rejected due to data unavailability; Dr Sangam will talk again with him on JAN 22-23 when he will be visiting AIT)
17. Dili, East Timore (Mr. Domingos Pinto): 1st draft received; Needs revision
18. Cebu, Philippines (very preliminary draft or report is received & requesting for feedback to streamline it; Ref: Dr. Binaya will follow up)
19. Malaysia: Dr. Binaya will try to contact

Section-IV: Groundwater Environment in Central and East Asia

20. Bishkek, capital of Kyrgyzstan (Agreed: Dr. Rafael Litvak; will provide chapter by middle of March)
21. China: Beijing (Dr. Binaya will follow-up)
22. China: Tianjin (Dr. Sangam will follow up)
23. Kazaksthan: Dr. Sangam will follow up)

24. Japan: Tokyo (Agreed: Dr. Binaya)
25. Japan: Osaka (Dr. Sangam will follow up with Dr. Hara)
26. Russia and/or some other country: Dr. Sangam will follow up
27. Seoul, Korea: (Agreed: Dr. Jin-Yong Lee; will provide chapter by April, 2015; Ref: Dr. Sangam)

Section V: Summary and Conclusion

28. Comparative analysis

2) Ways to add value to the book:

- Decide the criteria to select the cities (climatic; agro-climatic regions; mega cities; etc.). Some ideas could be:
    - Mega cities; growing cities; stagnant cities??
    - Current level of dependency groundwater?
- Enrich the cases with the most basic details of those cities
- Try to make each case study as a representative of a typical groundwater issues (e.g. land subsidence, salinity intrusion, economic instruments, etc.) so that the reader can visualize what happens for different kinds of aquifers if GW dependency increases from the case of other cities.
- We may structure the cases to give information on how cities are going to grow and how they affect groundwater

3) Forewords: We will keep forewords and key messages.

- **FOREWORDS**: from APN (Dr. Linda & Director) & from UNESCO (Dr. Alice)
- **KEY MESSAGES**: IGRAC (Dr. Neno); IGES (Dr. Mori or Prof. Hamanaka), as a Groundwater Knowledge hub); ICIMOD (Dr. Molden); UNESCAP (Dr. Shalma); Dr. Tussar Shah

4) Follow up for case studies:

- Dr. Binaya will follow up for Vien Tien (Dr. Paul), Beijing, and Malaysia
- Dr. Sangam will follow up for Phnom Penh, Tianjin, Kazakhstan and some other central Asian cities, Russia, and Osaka

5) Comments on Preface, Introduction, Style of Case Study Chapters

- Preface: Should focus on overall regional scenario instead of being city specific.
- Introduction chapter: Is okay. It was suggested to move the city specific examples from Preface to Introduction.

6) Comments on DPSIR Chapter: it is advised to address following comments

- Introduction may include: What is DPSIR itself? Why is its importance (referring to different kind of applications of DPSIR)? How has it been applied in other sectors? How can it be customized (if needed) to apply in subsurface environment?

- Framework: present the framework in an attractive way and describe the components
- Indicators for the framework: Indicators may vary with case studies; present indicators used are various types of studies; then come up with a recommended set of indicators for evaluating groundwater environment. Some discussion could be:
    - Which indicators should be given more emphasis? Example: how can we evaluate state of groundwater if we don't have groundwater level data?
    - What are the most basic indicators necessary? Depending upon climatic regions, impacts may vary, drivers may vary, level of information available, etc, different kinds of response strategies can be prepared; what one city can learn from other city? If groundwater is highly stressed/exploited, they must use very comprehensive set of indicators → depending upon level of groundwater development
    - How indicators vary depending upon level of groundwater development?
- Structure review in a form of table and discuss/comment on commonalities and differences and come up with selected set of indicators?

7) Action Plans & Timeline

Action Plan (What?)	Deadline	Responsible person
Collecting all the comments (Comment sheet + Paper)	25th Jan, 2015	All Editors
Compiling them and communicating to Authors	1st Feb, 2015	Dr. Sangam & Smriti
Response from Authors	16th Feb, 2015	Authors
DPSIR chapter	16th Feb, 2015	Dr. Vishnu
Reorganizing the completed chapters by Editors	15th Mar, 2015	All Editors
Contacting potential authors	20th Jan, 2015	Dr. Sangam & Dr. Binaya
Submission of remaining chapters from Authors	30th Mar, 2015	Authors
1st review	15th Apr, 2015	Editors
Communicate comments to the Authors on remaining chapters	22 Apr, 2015	Dr. Sangam & Smriti
Response from Authors	7th May, 2015	Authors
Comparative analysis chapter	15th May, 2015	All Editors
Reorganizing those chapters	21st May, 2015	Editors
Request for Forewords and Remarks	30th May, 2015	All editors
Final draft of the book	7th June, 2015	Editors

Meeting Schedule

Day 1: Saturday, 17 January

9:30-10:00	Review of the status of submitted chapters and potential contributing authors	Dr. Sangam and inputs from all
10:00-11:00	Review of ToC Review of Preface Review of chapters: Introduction, DPSIR framework	All
11:00-11:10	**Coffee/Tea Break**	
11:10-12:10	**Review** Bangkok: Sangam Cebu: Binaya Bandung: Vishnu Dili: Shashidhar	
12:10-13:30	**Lunch**	
13:30-15:00	**Review** Chitwan: Sangam Yangon: Binaya Hyderabad: Vishnu Lahore: Shashidhar	
15:00-15:10	**Coffee/Tea Break**	
15:10-17:00	**Review** Yangon**:** Sangam Ho Chi Minh City: Binaya Dili: Vishnu Cebu: Shashidhar	

Day 2: Sunday, 18 January

9:30-10:00	Selection of foreword providers	All
10:00-11:00	**Review** Dili: Sangam Khulna: Binaya Chitwan: Vishnu Bandung: Shashidhar	
11:00-11:10	**Coffee/Tea Break**	
11:10-12:10	**Review** Hyderabad: Sangam Chitwan: Binaya Lahore: Vishnu Yangon: Shashidhar	
12:10-13:30	**Lunch**	
13:30-15:00	**Review and way forward** **Action points (who, what and when)**	All

Appendix E: Proposed indicators for groundwater sustainability components. The components are also briefly described

Index	Component	Indicator	Description
Groundwater Sustainability Infrastructure Index (GSII)	1. Groundwater monitoring (GwM)	1.1 Groundwater level 1.2 Groundwater extraction 1.3 Groundwater quality 1.4 Land subsidence	GwM enable a long-term understanding of groundwater availability and anthropogenic effects on groundwater resources. It helps protect groundwater environment
	2. Knowledge generation and dissemination (KgD)	2.1 Knowledge generation 2.2 Knowledge/data CSM 2.3 Provision for KID	KgD help facilitate groundwater resources evaluation, planning and management. KgD also help build 'mutual trust' among the stakeholders to achieve the goal of sustainability
	3. Regulatory interventions (ReI)	3.1 Groundwater rights 3.2 Groundwater licensing 3.3 Economic instruments	ReI aim to ensure sustainability through interventions like licensing, tax/subsidy, trading groundwater rights, etc.
	4. Public participation (PuP)	4.1 Awareness 4.2 Interest to participate 4.3 Availability of mechanism	PuP help safeguard social wellbeing through sustainable use of the resource. It helps for informed decision making, conflict prevention and maximizing benefits (social, economic and technical)
	5. Institutional responsibility (InR)	5.1 Availability of authority 5.2 Legal framework 5.3 Institutional capacity	InR empowered with clear mandate, sufficient resources and legal framework increases strength of institutional leadership in groundwater management

CSM' is compilation, storage and management; 'KID' is knowledge integration and dissemination

Appendix F: Proposed indicators for DPSIR analysis

Components	Indicators
Driver	Population growth Migration (urbanization) Agricultural and industrial development (Economic Growth) Climate change
Pressure	Inadequate surface water supply Increase in extraction of groundwater Land use changes Occupational Shift (to be confirmed from field)
State	Well statistics Ground water extraction Water quality Water level Recharge Legal framework and organization
Impact	Groundwater quality deterioration (groundwater contamination) Decline in groundwater level Decline in production capacity of well Human health risk Impact in river discharge
Response	Groundwater monitoring (Quality, level) Alternative water sources Application of advance technology

Glossary of Terms

AIT	Asian Institute of Technology
AITM	Asian Institute of Technology and Management
APN	Asia- Pacific Network for Global Change Research
CGREG	Central Groundwater Resources and Environmental Geology
CGREG	Centre of Groundwater Resources and Environmental Geology
CREEW	Centre of Research for Environment Energy and Water
DGR	Department of Groundwater Resources
DPSIR	Driver, Pressure, State, Impact and Response
DWR	Division of Groundwater in Department of Water Resources
DWRPIS	Division of Water Resources Planning and Investigation for the South of Vietnam
GSEMR	Government Services on Energy and Mineral Resources
GSII	Groundwater Sustainability Infrastructure Index
ICRE	International Center for River Basin Environment
IGES	Institute for Global Environmental Strategies
IT	Information Technology
Km^2	Square Kilometer
MCM	Million Cubic Meter
VDC	Village Development Committee
VPAA	Vice President of Academic Affairs
WALTA	Water, Air, Land and Trees Act
WAPDA	Pakistan Water and Power Development Authority
WEM	Water Engineering and Management