Table of Contents

Item **Page**

Introduction

The purpose of the Asia-Pacific Coastal Aquifer Management Conference (APCAMM) is to provide a forum for scientists, engineers, water resource managers, and planners to share their research, ideas, and recommendations on priority issues of the region. This meeting is expected to provide a good opportunity to meet well-known and respected scientists and engineers in the field of salt water intrusion in the region as well as to identify future opportunities for collaboration in coastal aquifer management for sustainable socio-economic development. Topics covered in the Second APCAMM include the following:

- Potentials and management of groundwater in coastal cities and coastal aquifers
- Impacts of increased water demand on coastal water resources and ecosystems
- Advance in groundwater modeling
- Effects of sea level rise and climate change
- Case studies of saltwater intrusion and eco-efficient management of groundwater resources of coastal cities
- Priority issues in coastal aquifer management in the twenty-first century, including salt water intrusion
- Submarine groundwater discharge
- Tidal dynamics of coastal aquifers
- Geochemistry of coastal aquifer systems
- Aquifer storage and recovery

Program Overview

	Day -1	Day 0	Day 1	Day 2	Day 3
Day	Registration starts at 16:00	Workshop	Meeting	Meeting	Field Trip
Evening 1		Ice breaking Gathering	Governor Banquet	Happy Hour	
Evening 2		Pre-conference SC Meeting		Post-conference SC Meeting	

Opening Ceremony

Day 1:

Date: October 19th 2011

Venue: Jeju National University

Moderators: Mr. Jimmy Jiao and Mrs. Cherry Cui

9:00 – 9:05 a.m.	**Welcome Address** LOC Chair	Dr. Namsik Park
9:05 – 9:10 a.m.	**Opening Address** Steering Committee	Dr. Weixing Guo
9:10 – 9:20 a.m.	**Congratulatory Address** Jeju Special Self-Governing Province	His Excellency Mr. Keun- Min Woo
9:20 – 10:10a.m.	**Keynote Speech** UNESCO IHP UNESCO International Hydrological Programme (IHP) with special reference to groundwater activities.	Dr. Soontak Lee

Keynote Speech

UNESCO International Hydrological Programme (IHP)

with special reference to groundwater activities

Professor Soontak Lee

Yeungnam Universtiy

Prof. Dr. Soontak Lee is presently Chairperson/President of UNESCO IHP Intergovernmental Council, Governor of the World Water Council (WWC) and Presidents of the International Hydrologic Environmental Society (IHES) and the DaeGyeong Water Forum(DGWF). He is also a Distinguished Professor of Hydrology and Water Resources Engineering of Yeungnam University, Korea. Prof. Soontak Lee has extensive experiences in the field of hydrological sciences and water resources management and also served as Korean government representative to a number of water-related international conferences such as UN Water Conference, UNESCO, WMO, ESCAP and WWF. He obtained several Doctoral degrees, Ph.D., D.Sc. & Hon.D. Eng.Sc. from Korea University & University of New South Wales, Australia, University of Tsukuba, Japan and Altai State Technical University, Russia Federation.

Associated Functions

APACCCM Workshops

Date: October 18th, 2011

Venue: Seminar Room # 3 International Center Jeju National University

		From	To	Contents	Lecturer
Morning Sessions	Lecture 1	8:00	10:10	SEAWAT	Dr. Guo
	Coffee Break	10:10	10:30		
	Lecture 2	10:30	13:00		
Lunch Break		13:00	14:00		
Afternoon Sessions	Lecture 3	14:00	15:10	Optimization	Dr. Prasad
	Coffee Break	15:10	15:30		
	Lecture 4	15:30	17:00		
Evening				Ice breaking Gathering	

*Programs are subjected to change without notice.

Workshop One

SEAWAT

Dr. Weixing Guo
Schlumberger Water Services

SEAWAT is a generic MODFLOW/MT3DMS-based computer program designed to simulate three-dimensional variable-density groundwater flow coupled with multi-species solute and heat transport. The program has been used for a wide variety of groundwater studies including those focused on brine migration in continental aquifers as well as those focused on saltwater intrusion in coastal aquifers. SEAWAT uses the familiar structure of MODFLOW and MT3DMS. Thus, most of the commonly used pre and post-processors can be used to create SEAWAT datasets and visualize results. The MODFLOW concepts of "packages" and "processes" are retained in SEAWAT, which allows the program to work with many of the MODFLOW-related software programs, such as MODPATH, ZONEBUDGET, and parameter estimation programs. SEAWAT is a public domain computer program. The source code and software are distributed free of charge by the U.S. Geological Survey (USGS).

Workshop Two

Artificial Intelligence Techniques for Engineering Optimization

Dr. Devi Prasad ,
University of Salford

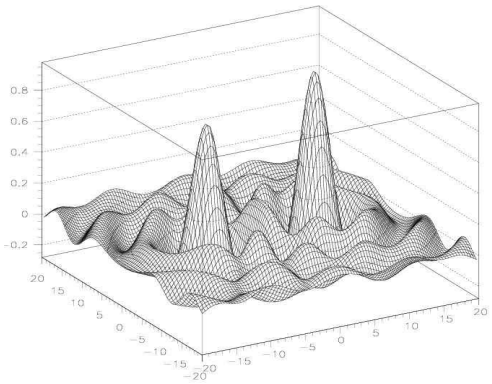
The short course will cover the fundamentals of Artificial intelligence techniques used for function optimization. It will provide an overview of the optimization techniques such as evolutionary algorithms and Monte Carlo Marko Chain models. This course will provide an insight on the type of problems that can be solved using the artificial intelligence techniques. It

will also devote to actual application of these techniques to water resources engineering optimization problems.

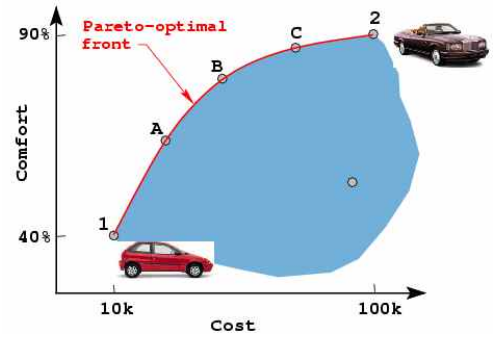
Earlier engineers and practitioners used to solve real-world problems usually by trial-and-error means. However, advancements in the latest technologies enabled us to choose not only an *optimal* solution which is best (from cost, performance, safety, etc.) compared to any other solution, but also understand the effect of parameter uncertainty on optimal solution. Artificial Intelligence (AI) techniques such as Evolutionary algorithms (EAs) have gained immense popularity in real-world engineering search and optimization. AI is a collection of several analytical tools that attempts to mimic life.

Artificial Intelligence techniques are being used in many commercial products. They are an integrated part of many new cars such as Honda and Mitsubishi. They are used to provide smooth rides in subway systems and prevent fraud in use of credit cards. They are extensively

used in the financial market to predict chaotic stock market behaviour, or optimize financial portfolios. Their application to water resources problems started in early 1990s. A number of researchers and practitioners have concentrated their efforts to provide intelligent tools for water industry. Artificial intelligence tools have been used to optimize groundwater management, aquifer parameter estimation, location of ground water sampling wells, ground water remediation design, and many other ground water related problems.



Single objective optimization



Multi-objective optimization

Evolutionary algorithms are computerized search and optimization methods that work very similar to the principles of natural evolution. Based on Darwin's survival-of-the fittest principles, EA's intelligent search procedure finds the best and fittest design solutions, which are otherwise difficult to find using other techniques. EAs are attractive in engineering design and applications because they are easy to use and they are likely to find the *globally* best design or solution, which is superior to any other design or solution. EAs are also suitable for multi-objective optimal design problems, involving multiple objectives.

This short course is designed to introduce a number of popular optimization methods used in tackling problems of water resources engineering, emphasize the importance of optimization in engineering activities, and introduce the working principles of EAs, present EA applications/case studies from a wide variety of engineering problems. Adequate hands-on exposure on computer simulations and relevant software (PC-based) will be provided so that upon completion of the course the participants can use EAs in their day-to-day activities. Participants will learn the state-

of-the-art EA techniques and will have an opportunity to have hands-on experience computer software.

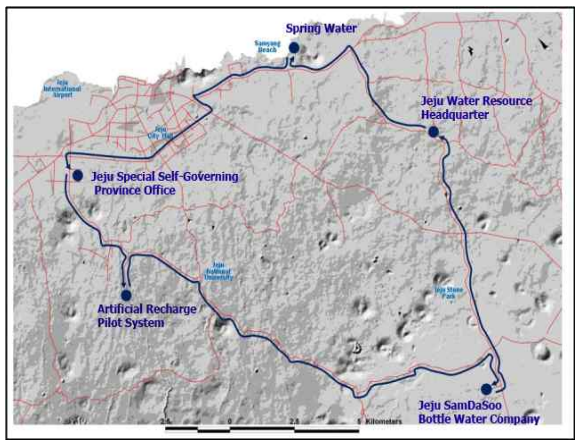
Topics to be covered

- Introduction to Optimal Solution
- Need for Optimization
- Optimization Methods
- Evolutionary Algorithms
- Advanced EA Techniques (multi-objective optimization & Monte Carlo Marko Methods)
- Water Resources Case Studies using EAs
- Tutorials/Laboratory Exercises

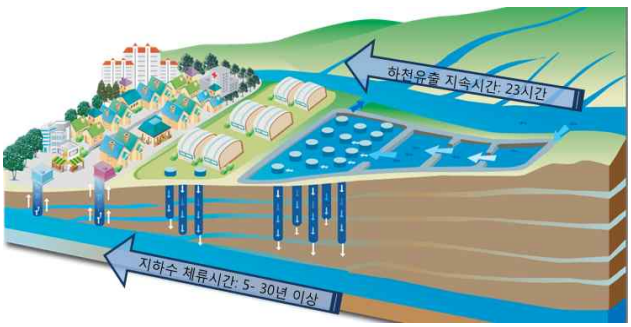
APACCM Field Trip

Date: October 21st 2011

A guided one-day field trip is planned on the 21st of October. Four sites of interests are included in the field trip. The trip starts at Jeju Special Self-Governing Province Office. Then the trip will visit, in sequence, the Artificial-Recharge Pilot System, the Jeju Samda Bottle Water Company, the Jeju Water Resource Headquarter and the Sam-Yang Big Spring (coastal groundwater discharge). The trip ends at the starting point: the Province Office. The field trip route is illustrated in the figure.



Artificial Recharge Pilot System



The construction of the Artificial Recharge Pilot system began in April 2007 and was completed in March 2011. The pilot system includes 20 artificial recharge wells (400 ㎜ diameter, depths ranging between 30 and 50m) and 5 observation wells with depths ranging from 250 to 330m. The ground level is about 300m, and the groundwater level lies 150~200m below ground level. The average injection rate for each well is about 15,000~17,000 m^3/d. It is estimated to take at least 5 years for the recharged water to reach the coast.

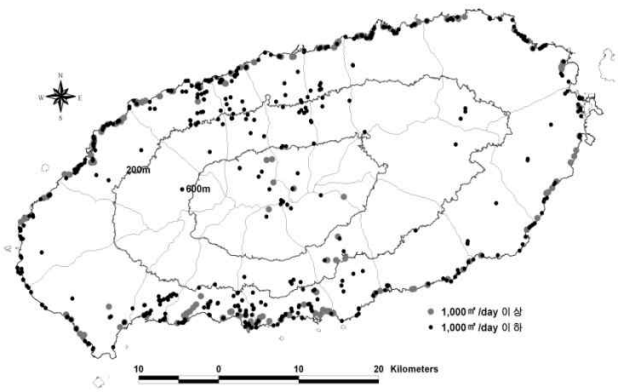
Jeju Samda Bottle Water Company

The Jeju Samda Bottle Water Company was incorporated in 1995 and began producing bottled water in March 1998. The company is permitted to withdraw up to 3,300m^3/d and operates 3 pumping wells. The company monitors groundwater conditions using 5 observation wells of 420m depth. The Samda bottle water is the most renowned mineral water in Korea. The Samda Water Company was included in the Top 100 Power Brands of Korea every year since 2005.

Jeju Water Resource Headquarter

In Jeju Water Resource Headquarter, there are three sections: Water Supply Section, Sewage Section and Groundwater Section. The Groundwater Section is in charge of 4,839 groundwater pumping wells which extracts roughly 1.8 million m^3/d. In addition there are over 1,100 wells extracting saline water and 149 observation wells.

Sam-Yang Big Spring (Coastal Groundwater Discharge)



In Jeju Island the average annual precipitation is 1,957mm. About 54% of precipitation is estimated to be lost due to evapo-transpiration and direct runoff, and the remainder is recharged. As vast amount of water is being recharged the Island has many springs, especially near the coastlines. Over 900 springs have been identified. In this field trip visit to Sam-Yang Big Spring is included. The discharge at the spring fluctuates between 15,000m^3/d to over 65,000m^3/d with the average of 40,000m^3/d.

			Number of springs	Jeju City	Seogwipo City
Elevation (m, MSL)	Sum		911	540	371
	Lower than 200m		841	489	352
	200~600m		49	37	12
	Higher than 600m		21	14	7
Discharge Rates (m^3/d)	Sum		711	410	301
	Average	Sum	1,083,333	655,279	428,054
		per site	1,524	1,598	1,422
	Maximum	sum	1,608,342	941,012	667,330
		per site	2,262	2,295	2,217

Overall Session Schedule

Session	Time	Day 1 - 19th	Day 2 - 20th
AM1	8:30~9:00	Registration	TS 1-2
AM2	9:00~10:10	Opening Ceremony	
Coffee Break	10:10~10:30		
AM3	10:30~12:00	TS 2-1	TS 2-2
Lunch	12:00~13:30		
PM1	13:30~15:10	TS 3-1	TS 3-2
Coffee Break	15:10~15:30		
PM2	15:30~17:00	TS 4-1	TS 4-2
PM3	17:00~18:00	Poster Viewing	Town Hall Meeting
Evening	18:30~	Governor Banquet	Happy Hour

Presentation Guidelines

Oral Presentations

Regular presentations: 15 minutes talk and 3 minutes Q&A

Invited presentations: 25 minutes talk and 3 minutes Q&A

Poster Presentations

Poster boards will be located in the lobby. Please feel free to approach the help desk for assistance.

Posters should be placed before 8AM on the 19th and removed after 3:30 on the 20th.

*Programs are subject to change without notice

Presentation Schedule

Date: October 19th, 2011:

TS 2-1

Time: 10:30 – 12:00 pm

Moderators: Sang Yong Chung and Hailong Li

Authors	Speaker	Institute	Country (page #)	Title
Jay F. PUNTHAKEY and Don WOOLLEY	Jay F. PUNTHAKEY	Ecoseal Developments	Australia (22)	Assessment of Groundwater Availability for Coastal Communities in the Mid North Coast of New South Wales
Sung-Ho Song, Jae-Yeon Um, Jong-Hak Choi, and Gil Zemansky	Sung-Ho Song	Rural Research Institute, KRC	Korea (25)	Assessing Climate Change Impacts on the Groundwater System of Volcanic Jeju Island
Jin-Ying Song and Hailong Li	Jin-Ying Song	China University of Geosciences (Beijing)	China (28)	Airflow in Two-layered Coastal Vadose Zone Induced by Atmospheric Pressure and Groundwater Head Fluctuations
J. SREEKANTH and Bithin DATTA	J. SREEKANTH	James Cook University	Australia (31)	Optimal pumping strategies to control saltwater intrusion in coastal aquifer
Byoung-Ryoun Koh	Byoung-Ryoun Koh	Jeju College of Technology	Korea (34)	Seawater Intrusion Prediction of Groundwater in East Coastal Basin of the Jeju Island, Korea

TS 3-1

Time: 1:30 – 15:10 pm

Moderators: E.D. PERERA and T. Devi Prasad

Authors	Speaker	Institute	Country (page #)	Title
Jiu J. JIAO and Hailong LI	Jiu J. JIAO	The University of Hong Kong	Hong Kong (35)	(Invited) Tide-induced airflow in a coastal reclamation site in Hong Kong
Takahiro Uemura, Tomonobu Nakazono and Kenji Jinno	Kenji Jinno	Kyushu University	Japan (36)	Increase of Net Groundwater Extraction from Freshwater Lens
Mohd isa Noorain, Aris Ahmad Zaharin	Mohd Isa Noorain	Universiti Putra Malaysia	Malaysia (37)	Controlling factors of hydrogeochemistry mechanism in sandy coastal aquifer at Kapas Island, Terengganu, Malaysia
Jay F. PUNTHAKEY, Nimal GAMAGE and Don WOOLLEY	Jay F. PUNTHAKEY	Ecoseal Developments	Australia (39)	Sustainable Management of Groundwater Resources and Risk of Seawater Intrusion for the Jaffna Peninsula
C. SRILERT, K.JATURON, C.SUTTHIRAT and S.THAVIVONGSE	C. SRILERT	Chulalongkorn University	Thailand (42)	Groundwater potentiality map of the coastal aquifer in Huay Sai area, Petchburi Province, Thailand

TS 4-1

Time: 15:30- 17:00 pm

Moderators: Nhan Q. Pham and Il-Moon Chung

Authors	Speaker	Institute	Country (page #)	Title
E.D.P. PERERA , K. JINNO, K. FUKAMI	E.D.P. PERERA	UNESCO-ICHARM	Japan (44)	A numerical modeling approach for biogeochemical processes of coastal aquifers
Wenli Huang, Chuanping Feng, Miao Li, weiwei Huang	Wenli Huang	China University of Geosciences (Beijing)	China (46)	Treatment of polluted groundwater in coastal area using an electrochemical method
Hoan V. HOANG, Nhan Q. PHAM, Flemming LARSEN, Long V. TRAN, Frank WAGNER and Anders V. CHRISTIANSEN	F. Larsen	Hanoi University of Mining and Geology	VietNam (47)	Processes Controlling High Saline Groundwater in the Nam Dinh Province, Vietnam
Y. WANG and J.J. JIAO	Y. Wang	Hong Kong University	Hong Kong (50)	Occurrence and geochemical behaviour of arsenic in a coastal aquifer-aquitard system in the Pearl River Delta, China
CHEH-SHYH TING	CHEH-SHYH TING	National Pintung University, Taiwan	Taiwan (51)	The Studies of Artificial Recharge of Groundwater at Pingtung Plain, Taiwan

Poster Viewing Session

Time: 17:00- 18:00 pm

Moderators: Nhan Q. Pham and Il-Moon Chung

Authors	Speaker	Institute	Country	Title
Weixing Guo, Zhongwei Li and Jefferson Giddings	Weixing Guo	Schlumberger Water Services	US (53)	Development of a Regional SEAWAT Model of the Floridan Aquifer System at the Lower West Coast Area, Southwestern Florida
F. CELICO, A. BUCCI, V. ALLOCCA, P. CELICO, and G. NACLERIO	Fulvio CELICO	University of Molise	Italy (55)	Biomolecular Analyses as a New Tool to Investigate Saltwater Intrusion
Mo Hsiung Chuang, Ching Sheng Huang and Hund Der Yeh	Mo Hsiung Chuang	Ming-Chuan University	Taiwan (57)	Analytical Solutions for Tidal Propagation in a Leaky Aquifer with Land Reclamation
NW Kim, J. Lee, I.-M. Chung, Y. S.	Nam Won Kim	Korea Ins of Construction Technology	Korea (58)	Assessment of Effects of Groundwater Abstraction near Stream on Stream flow using SWAT-MODFLOW Model
Il-Moon Chung, Jeongwoo Lee , Nam Won Kim	Il-Moon Chung	Korea Ins of Construction Technology	Korea (59)	Estimation of an exploitable groundwater in Musimcheon watershed, South Korea
Tajudeen M. IWALEWA, Mohammad H. MAKKAWI, Abdalla S. ELAMIN and Abdulaziz M. SHAIBANI	Tajudeen M. IWALEWA	King Fahd University of Petroleum and Minerals	Saudi Arabia (60)	Groundwater Management Approach in a Coastal Urban Center Using Numerical Simulation – a Case Study of KFUPM Campus
Yih-Chi Tan	Yih-Chi Tan	National Taiwan University	Taiwan (62)	Analysis of the conjunctive use scheme of the groundwater in southern Taiwan after typhoon Morakot struck
Cheng-Haw Lee, Hsin-Fu Yeh, Hung-I Lin	Cheng-Haw Lee	National Cheng Kung University	Taiwan (63)	Groundwater Recharge and Exploitative Potential Zone Mapping Using RS, GIS and GOD Approaches

Date: October 20th, 2011:

TS 1-2

Time: 9:00 – 10:00 am

Moderators: Se-Yeong HAMM and Kenji JINNO

Authors	Speaker	Institute	Country (page #)	Title
Il-Moon Chung, Nam Won Kim, Hanna Na, Seongkee Yang	Il-Moon Chung	Korea Institute of Construction Technology	Korea (64)	(Invited) Comprehensive Surface-Groundwater Analysis on the Pyoseon Region, Jeju Island
Lennox A. GLADDEN and N. PARK	Lennox A. GLADDEN	Dong-A University	Korea (65)	Evaluation of Coastal Groundwater Resources in Developing Countries: A Case Study of The Caribbean
LEI CUI and NAMSIK PARK	Lei Cui	Dong-A University	Korea (66)	Control of Saltwater Intrusion through Freshwater Injection Wells-overview of injecting plans
Lei Shi and Namsik Park	Lei Shi	The University of Hong Kong	Hong Kong (68)	Decision-Support Model for Sustainable Development of Groundwater Subject to Seawater Intrusion
BYOUNG-RYOUN KOH and BYEOUNG-CHEOL LEE	Byoung-Ryoun Koh	Jeju College of Technology	Korea (70)	Characteristics and Potentials of Springs in Jeju Island

TS 2-2

Time: 10:30 – 12:00 pm

Moderators: Byoung-Ryoun KOH and ARIS Zaharin

Authors	Speaker	Institute	Country (page #)	Title
Gil ZEMANSKY	Gil ZEMANSKY	Wairakei Research Centre	New Zealand (72)	(Invited) Seawater Intrusion in New Zealand: New Guidelines and Case Examples
T. DEVI PRASAD	T. DEVI PRASAD	University of Salford	UK (75)	The Evolution Optimising Water Resources Problems
Sang Yong Chung, Tae Hyung Kim, Namsik Park	Sang Yong Chung	Pukyong National University	Korea (76)	Identification of Groundwater Contamination Sources Using Multivariate Statistical Analysis in a Coastal Area of Busan, Korea

TS 2-2 (Continued)

Time: 10:30 – 12:00 pm

Moderators: Byoung-Ryoun KOH and ARIS Zaharin

Authors	Speaker	Institute	Country (page #)	Title
L.T. TRAN, F.LARSEN, N. Q. PHAM, A. V. CHRISTIANSEN, H.V. VAN, Long V. TRAN, H. V. HOANG and K. HINSBY	F. Larsen	Hanoi University of Mining and Geology	VietNam (78)	Scenarios for distribution of different saline groundwater types in the Red River floodplain, Vietnam
Weixing Guo and Ke Feng	Weixing Guo	Schlumberger Water Services	US (80)	Saltwater Intrusion and Coastal Aquifer Management at Western Big Cypress Basin, Florida

TS 3-2

Time: 13:30 – 15:10 am

Moderators: J. Jiao and T. Prasad

Authors	Speaker	Institute	Country (page #)	Title
Se-Yeong HAMM, Soon-Il OK, Yong-Woo LEE, Eun-Jee CHA, Sang-Hyun KIM, and In-Soo KIM	Se-Yeong HAMM	Pusan National University	Korea (81)	Characteristics of Radon Concentration in Coastal Groundwater, Stream water, and Seawater along the Coast of Busan City, South Korea
Hailong LI and Jiu J. JIAO	Hailong LI	China University of Geosciences-Beijing	China (83)	Tidal Groundwater Head Fluctuation In An Submarine Aquifer Or Aquitard
Kyung-Ho Kim, Jiyoun Shin and Kang-Kun Lee	Kyung-Ho Kim	Seoul National University	Korea (85)	Estimation of the change in fresh water quantity of coastal groundwater caused by sea level rise
W.K. Kuan, G. Jin, P.Xin, C. Robinson, B. Gibbes and L. Li	W.K. Kuan	University of Queensland	Australia (87)	Effect of tide-induced recirculation on saltwater intrusion in an unconfined coastal aquifer
Eunhee Lee, Yunjung Hyun, and Kang-Kun Lee	Eunhee Lee	Seoul National University	Korea (88)	Change in Submarine Groundwater Discharge Rate Associated with Sea Level Fluctuation

TS 4-2

Time: 15:30 – 17:00 pm

Moderators: J. Jiao and T. Prasad

Authors	Speaker	Institute	Country (page #)	Title
Namsik PARK , Lei CUI, Dong Gil KIM and Lennox A. GLADDEN	Namsik PARK	Dong-A University	Korea (90)	Preliminary Design of An ASTR System in a Coastal Aquifer
Ngo Van Quan, Gwangseob Kim	Ngo Van Quan	Kyungpook National University	Korea (91)	Impacts of spatial distribution and land use/cover change in future on the potentials of surface runoff and groundwater in coastal region Case study: Nakdong River Basin in Korea
Sunisa Smittakorn and Deanna Durnford	Sunisa Smittakorn	Thammasat University	Korea (93)	Multipurpose Underground Dam
Lim, W.Y. and Aris, A.Z	Lim, Wan Ying	Putra University	Malaysia (95)	Hydrochemistry Characteristics of the Langat River Estuary, Selangor (Malaysia)

Abstracts

Assessment of Groundwater Availability for Coastal Communities in the Mid North Coast of New South Wales

Jay F. PUNTHAKEY[1], and Don WOOLLEY[1]
[1]Ecoseal Developments, PO Box 496, Roseville NSW 2069 Australia,eco@ecoseal.com

Many coastal communities, agricultural enterprises and environmental ecosystems in coastal regions of Australia rely on groundwater resources contained in coastal sand aquifers. These aquifers require careful management and ongoing monitoring to ensure that the quality and quantity of the groundwater resource are not adversely affected. Increasing demands are being placed on many coastal groundwater resources as populations grow, and agriculture and industry intensify. To ensure that the increased demand for groundwater can be met without adverse impacts on coastal ecosystems will require effective groundwater management strategies to ensure continued use of coastal aquifers and protection of groundwater-dependent ecosystems. The issue is even more important where, as in the case of the Macleay Coastal Sands Aquifer, the borefields are within a National Park. Knowledge of the extent, characteristics, and response to pumping and climatic stresses of these aquifer systems is an important pre-requisite for management.

The project is being implemented to assist in the management of coastal groundwater resources in the Hat Head National Park. The dune system extends for some 40 km and abuts the estuarine flats of the Macleay River, and is characterized by numerous swamps and wetlands in the swales. Data from previous investigations and from the operating borefields within the study area have been supplemented by a considerable amount of new investigation. This included the construction of numerous shallow and deep monitoring bores, installation of water level and salinity loggers within several of these and pre-existing bores and vegetation surveys to characterize the differing groundwater dependent vegetation communities.

The variable density groundwater flow model SEAWAT (Guo and Langevin, 2002) was used to model regional flow conditions in the aquifers, including any impacts from the eastern seaward boundary of the aquifer. A 100 x 100 m grid was used to construct the model of the coastal aquifer in the narrow dunal strip from South West Rocks to Crescent Head. The model will be used to estimate the water balance for the Macleay Sands aquifer, to assess the potential for seawater intrusion and the impact on fresh groundwater resources. The model will be used to simulate the impacts of increased demand from the existing borefields and climate impacts such as prolonged dry periods.

The model of the dune system was constructed with five layers representing the upper, mid and lower Macleay aquifers separated by low hydraulic conductivity layers representing Coffey Rock and silty sand layers, the model grid size was 100 m. These coastal dune systems provide an

important source of good quality groundwater and are highly dependent on rainfall recharge. Due to the geomorphology, with linear ridges parallel to the coast, groundwater moves in a direction normal to the coast. Calibration was undertaken for available monitoring bores which tended to be concentrated in the three borefields in the Hat Head National Park.

The model was simulated using historical climate date from 1900 to 2010 by selecting 15 years of continuous climate records corresponding to average, dry and wet conditions. Pumping from the three borefields remained the same for each scenario which allows us to examine the impact of rainfall recharge. The three scenarios are compared in Figure 1 which shows the cumulative net storage impact for average, dry and wet conditions till 2026. The aquifer is highly dependent on rainfall recharge for replenishment, and prolonged dry periods will have a significant impact on water levels in layer 1. Although pumping causes localised drawdowns and is only taking a small amount of the resource, nevertheless, local impacts in layer 1 will need to be considered before deciding the amount of groundwater that will be available for water supply. Drying out layer 1 will have a detrimental impact on coastal dune vegetation which will not be an acceptable outcome for the community.

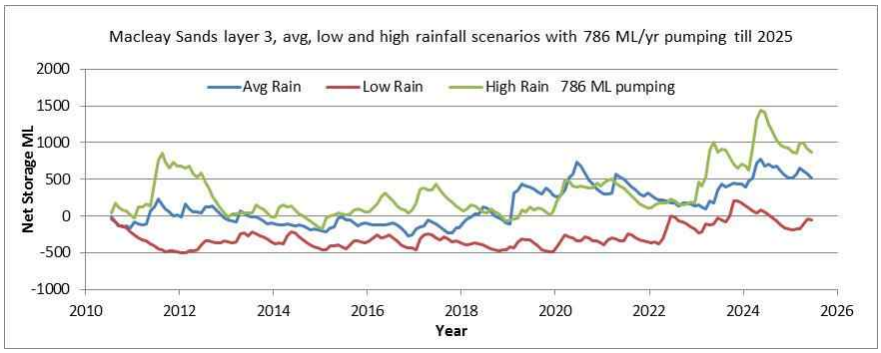


Figure 1. Cumulative net storage for three climate scenarios (average, dry and wet).

The monitoring and modelling of the borefields is being utilised to develop groundwater management strategies to enable sustainable development of coastal aquifers, concurrent with protection and preservation of the groundwater-dependent ecosystems. The model has shown the pumping the borefield at full allocation will cause large declines in water levels in the upper Macleay aquifer which would adversely impact groundwater dependent ecosystems.

A significant project outcome is the development of a framework for assessing the level of stress on the aquifer system so that it can provide guidance to Resource Managers and the community on how best to manage stressed systems (Punthakey and Woolley, 2010 The outcomes of the project will be applicable to similar high-value sand aquifer systems Australia and in many of Asia's vulnerable coastal communities that are dependent on groundwater for potable water, food security and livelihoods.

Keywords: Groundwater Management; Aquifer; Sustainable, Climate Change, SEAWAT

References

[1] W. Guo, and C.D. Langevin, Users guide to SEAWAT: Acomputer program for simulation of three-dimensional variable flow: *USGS,* Open-File Report 01-434, 77p., (2002).

[2] J.F. Punthakey and D. Woolley, Sustainable Management of Coastal Groundwater Resources and Opportunities for Further Development – A Review of Indicators - Development of a New Approach for Groundwater Management. *National Water Commission*. Ecoseal Consulting Report CR 10-1102, 66p., (2010).

Assessing Climate Change Impacts on the Groundwater System of Volcanic Jeju Island

Sung-Ho Song[1], Jae-Yeon Um[2], Jong-Hak Choi[3], and Gil Zemansky[4]

[1]*Rural Research Institute, Korea Rural Community Corporation (presenter), shsong84@hanmail.net*
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According to the IPCC SRES (Nakićenović and Swart, 2000), there are four storylines which reflect a range of changes in population and economic activity during the 21st century. The IPCC (2007) indicated multi-model averages, assessed ranges of surface warming for the A2, A1B and B1 scenarios, and showed that GCMs (General Circulation Models) have very heterogeneous characteristics. Scientists predicted that temperature rises during the 2090-2099 period related to the 1980-1999 period for the B1, A1B and A2 scenarios are 1.8°C(1.1-2.9°C), 2.8°C(1.7-4.4°C), and 3.4°C(2.0-5.4°C), respectively. Among the three scenarios, the B1 scenario predicts less warming compared to that of A1B and A2 while the A2 is more extreme and predicts more warming than the other scenarios. CCIC (Climate Change Information Center, Korea) is analyzing the impact of climate change on rainfall and temperature from downscale modeling at the 27×27 km block scale. However, modeling results are only available for A1B scenario, and although climate change in hydrology may be more affected by extreme events than averages, modeling of extreme events has not yet been considered.

This study is based on estimating the impact of climate change on groundwater systems, especially for those wells used for agricultural water supply as they constitute more than 65% of the total number of groundwater wells on Jeju Island. Long term daily weather data, consisting of both historical and simulated data for the 1971-2100 period, has been compiled for four points in the study area organized into sequential 30 year groups. Anomalies for these data have been considered by subtracting the ten year annual average (from 1971 to 1980) from annual data. Long-term results from monitoring 74 wells for seawater intrusion (Lee et al., 2007) and potential prospecting for future additional agricultural water sources (Jeju Province and KRC, 2004) were also considered.

Results and discussion

Using both historic data for the 1971-2010 period and simulation results for the A1B scenario thereafter, basic statistics for rainfall and temperature, cross correlation and trend analysis for

each 30 year time group were analyzed. In general, statistical results correspond to the A1B scenario trend. However, as simulation results were calculated by downscaling from GCMs for the regional basin, there are a several significant features to consider. Nonparametric trend analysis results for anomaly values of annual rainfall and temperature using the Mann-Kendall method for 15 modelling blocks indicated that annual rainfall patterns vary regionally in relation to Mt. Halla, at the center of Jeju Island, with higher trends near Mt. Halla and lower trends away from it, and that the total amount of rainfall became more widely distributed between the months. Therefore, estimated potential evapotranspiration increased regionally. As a whole, anomalies in annual rainfall for the whole period of from 1971 to 2100 increase slightly and vary regionally while the anomalies in annual temperature show a rising trend with no significant regional variations. However, with regard to annual rainfall, the slopes of increasing or decreasing regional trends are higher for the 2041-2070 and the 2071-2100 periods compared to the 2011-2040 period in the A1B scenario. For annual temperature, the slope of the increasing trend is the highest during the 2041-2070 period at 0.04 ^{o}C/year and the lowest for the 2011-2040 period at 0.02 ^{o}C/year without regional variation.

A groundwater monitoring well network incorporating automatic monitoring equipment has been constructed since 2001 to cover most of the low land and coastal areas of Jeju Island. Analysis of groundwater monitoring data from this system indicates that groundwater levels have decreased near the coast, especially in the northern part of the island (Lee et al., 2007). Moreover, relatively high conductivity levels and increasing trends for conductivity were observed in the eastern part of the island, which may indicate seawater intrusion by intensive pumping over several decades. Groundwater level decline and conductivity rise in the coastal area would be affected continuously by sea level rise (2.2±1.7 mm/year) near Jeju Island (Kim et al., 2009). Despite the present strict control on additional groundwater development, there is a need for further detailed studies of the impact of current development.

Keywords: Climate change; Jeju Island; A1B scenario; Groundwater.

Acknowledgement

This work is supported by a grant from KICTEP as a Jeju water circulation study.

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Airflow in Two-layered Coastal Vadose Zone Induced by Atmospheric Pressure and Groundwater Head Fluctuations

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Airflow in vadose zones is important in solving various problems in agricultural, nuclear and environmental engineering [*Shan*, 1995]. This paper presents an explicit analytical solution for describing the subsurface airflow induced by the atmospheric pressure and groundwater head fluctuations. The solution expands the previous *Li and Jiao* [2005] solution by including the atmospheric pressure fluctuations and improves the *Li et al.* [2011] semi-analytical solution which needs numerical Laplace inverse transform based on a hypothetical initial condition.

Consider the one-dimensional vertical subsurface airflow in a two-layered system. The less permeable upper layer lies in the vadose zone and the highly permeable lower layer forms an unconfined aquifer. Let the z axis be vertical, positive upward, and the intersection with the surface be the origin (elevation datum) of the axis (see Figure 1). The thickness of the lower and upper layer are b_L and b_U, respectively. Let $W(t)$ be the elevation of the water table of the unconfined aquifer (Fig. 1).

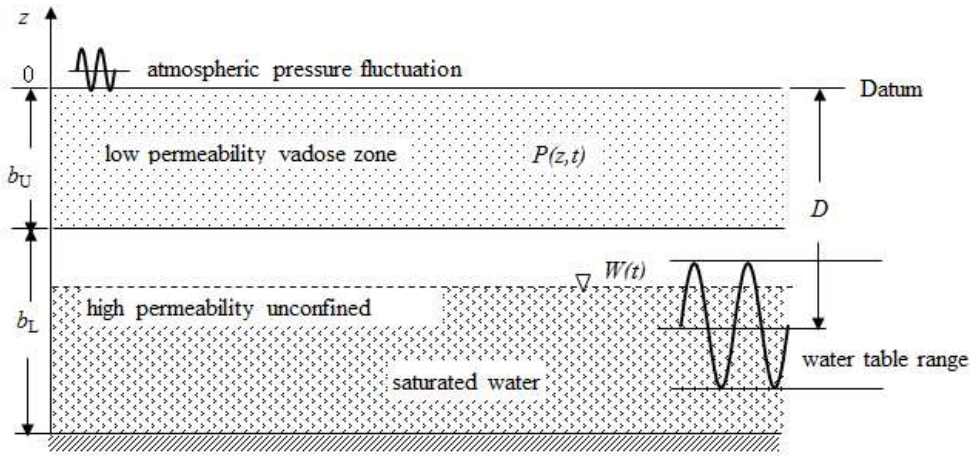


Figure 1. Schematic of subsurface airflow in vadose zone induced by atmospheric pressure and groundwater head fluctuations

Using the superposition principle, one can only consider one sinusoidal component of the atmospheric pressure and the groundwater head fluctuations, and the solution can be explicitly expressed as the sum of two terms $P = P_w + P_b$, here P_w is the air pressure induced by the groundwater head fluctuations at the lower boundary when one ignores the atmospheric pressure fluctuations on the ground surface, the expression can be found in Li and Jiao [2005], and P_b is the solution of the following boundary value problem [*Li and Jiao,*2005; *Li et al* .,2011]

$$\frac{n_U \mu}{P_{atm} k_U} \frac{\partial P_b}{\partial t} = \frac{\partial^2 P_b}{\partial z^2}, \quad -b_U < z < 0 \tag{1}$$

$$P(z,t)\Big|_{z=0} = B\cos(mt) \tag{2}$$

$$\left(\frac{\partial P_b}{\partial t} - \frac{\rho_w g k_U}{d n_L \mu} \frac{\partial P_b}{\partial z} \right)\Bigg|_{z=-b_U} = 0 \tag{3}$$

where P_{atm} is the mean atmospheric pressure [$ML^{-1}T^{-2}$], n_U and n_L are the air-filled effective porosity of the upper layer and lower layer, respectively. μ is the dynamic viscosity [$ML^{-1}T^{-1}$], k_U is air permeability of the upper layer [L^2], ρ_w is the water density [ML^{-3}], g is the gravitational acceleration [LT^{-2}]. The parameters B and m are the amplitude and frequency of the atmospheric pressure fluctuation, respectively, and the constant d is defined as $d = 1 + \rho_w g(D - b_U)/P_{atm}$, here D is the depth of the mean groundwater table from the ground surface [L].

The solution of the boundary value problem (1)-(3) is

$$P_b(z,t;d,r,\theta) = B\sigma(z/b_U;d,r,\theta)\cos[mt + \tau(z/b_U;d,r,\theta)], -b_U < z < 0 \tag{4}$$

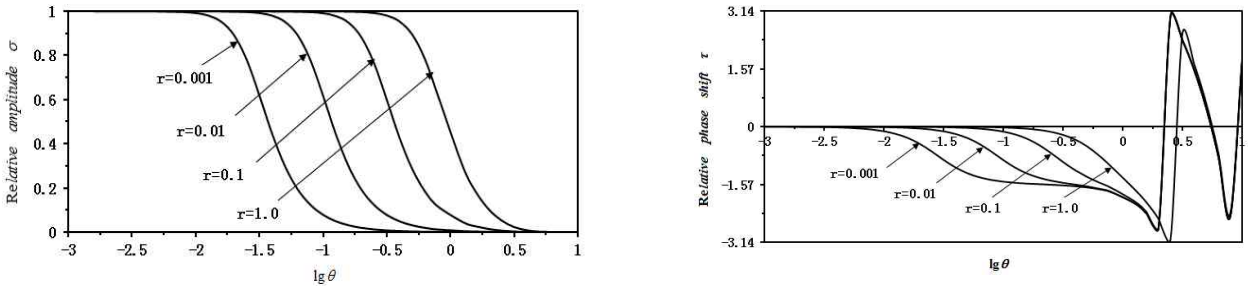
where σ and τ are the magnitude and argument of the complex function $C(z/b_U;d,r,\theta)$, respectively, with the latter given by

$$C(z/b_U;d,r,\theta) = \frac{(1+\mathrm{i})\theta d \sinh[(1+z/b_U)(1+\mathrm{i})\theta] + 2r\cosh[(1+z/b_U)(1+\mathrm{i})\theta]}{(1+\mathrm{i})\theta d \sinh[(1+\mathrm{i})\theta] + 2r\cosh[(1+\mathrm{i})\theta]} \tag{5}$$

where θ and r are two dimensionless parameters defined as:

$$\theta = b_U\sqrt{\frac{m n_U \mu}{2P_{atm}k_U}}, \quad r = \frac{\rho_w g b_U}{2P_{atm}} \cdot \frac{n_U}{n_L} \tag{6}$$

Figure 2 illustrates how (a) the relative amplitude and (b) the relative argument at the lower boundary $z=-b_U$ changes with the parameters θ and r when d is fixed at 1.266. The relative amplitude decreases as θ increases and it increases with r. The relative argument is negative and also decreases as θ increases. It increases with r. The sudden increment of 2π with the relative argument near $\lg\theta=0.25$ is merely due to its periodicity of the air pressure fluctuation.



(a) (b)

Figure 2. (a) The relative amplitude σ (left), and (b) the relative argument τ (right) of the air pressure at the boundary $z=-b_U$ versus θ for different values of r.

Keywords: Subsurface airflow; groundwater head fluctuation; atmospheric pressure fluctuation; vadose zone

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Optimal pumping strategies to control saltwater intrusion in a coastal aquifer

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Over-exploitation of groundwater resources in coastal aquifers has resulted in the saltwater intrusion in to these aquifers in many parts of the world. For the continued use of these valuable resources, sustainable extraction strategies are required for groundwater management. In this work we illustrate the development and application of a multi-objective optimal management model for the management of a coastal aquifer system considering two conflicting objectives, viz, maximization of the beneficial pumping from the production wells and minimization of the pumping from barrier wells which are used as hydraulic control measure for saltwater intrusion. The model is based on coupled simulation-optimization.

The methodology applies an ensemble surrogate modeling approach (Sreekanth and Datta, 2011) to develop computationally efficient simulation-optimization framework. The three dimensional coupled flow and transport simulation model FEMWATER was used to simulate the aquifer responses to pumping in terms of saltwater intrusion levels. The data obtained from this was used to train and validate an ensemble of prediction models based on genetic programming. The ensemble surrogate models were coupled with a multi-objective genetic algorithm NSGA-II to derive optimal pumping strategies for coastal aquifers considering two conflicting objectives as mentioned above. The constraints to the optimization problem are to limit the salinity concentration levels at specified monitoring locations as a result of pumping to pre-specified limits. The functional relationship between pumping and resulting concentrations is defined by the surrogate models.

The methodology was applied to a well field in the lower Burdekin delta area in Queensland in Australia. The study area is approximately 60.2 km^2. The data required for the numerical model simulation was obtained from previously published works (Narayan *et al.*). The ensemble based surrogate modeling approach was used to obtain reliable predictions considering the uncertainty in the parameters like hydraulic conductivity and the aquifer recharge. The multi-objective optimization model evolves the optimal solutions by an organized search process where the ensemble surrogate models are called upon to evaluate the aquifer responses to each candidate solution generated by the optimization model.

The multi-objective optimization model gives a Pareto-optimal set of solutions which define a trade-off between the conflicting objectives. The Pareto-optimal solution set obtained in this study is shown in figure 1. Five solutions selected from different regions of the Pareto-optimal front are shown in table 1. The amount of barrier well pumping varies between 10-26 percent of the beneficial pumping. The simulated values of the concentrations C1 and C2 at two locations show that the imposed constraints are satisfied.

Solution	Total pumping ($\times 10^3$ m^3/d)		Constraint ($\times 10^{-3}$ kg/m^3)	
	Beneficial	Barrier	C1 < 500	C2 < 600
1	286.7	69.3	485.2	564.1
2	228.9	43.3	502.9	577.9
3	175.5	30.1	503.0	563.7
4	105.9	23.7	485.1	565.6
5	134.3	26.4	498.4	555.6

Table 1. Five optimal solutions and corresponding concentration values, at two monitoring locations

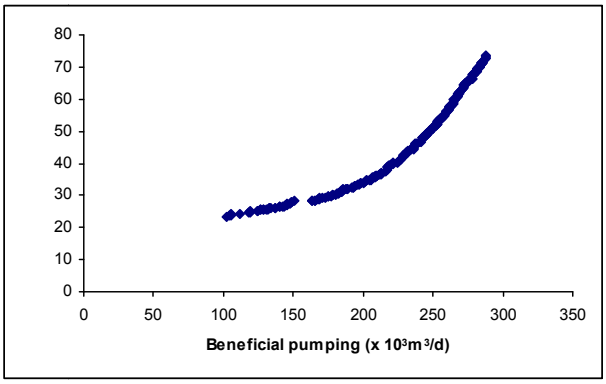

Figure 2. Pareto-optimal solutions

The front also indicates that the beneficial pumping from the coastal aquifer can be increased of the order of nearly 3 times when hydraulic control of saltwater intrusion based on barrier well pumping is utilized. From table 1 it is evident that all the solutions satisfy the imposed constraints of limiting the saltwater concentration within specified levels.

Keywords: coupled simulation-optimization; pumping; coastal aquifer;

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Seawater Intrusion Prediction of Groundwater in East Coastal Basin of the Jeju Island, Korea

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In this study, the study area is eastern part of jeju island where salinization occurs severely by seawater intrusion.

And the diffusion phenomenon by seawater intrusion is analyzed using finite difference model by the method of characteristics which is the two dimensional groundwater solute-transport model and finite element model by the Galerkin approach.

The results are as follows.

The simulation is operated most stably when the longitudinal diffusion index is 100, and velocity vector for Initial particulate consistency Of Characteristic curve shows that the pressure boundary is formed 1,500m zone from coastal basin by the density difference of seawater and freshwater.

The simulation results of MOCDENCE are appeared as 180 and 365days pumping does not show the effect of seawater intrusion but 5.10. and 20 years pumping shoe clrar and remarkable seawater are observed in SWICHA by the finite element model, and it is known that diffusion will increase as it is deeper.

It is necessary to find the way to consider the effect of tides on groundwater development, and to continue studying on salinization according to seawater intrusion because the problem of seawater intrusion in the whole jeju island may become serious.

Especially continuing study on salinity diffusion in tube well by the variation of water level which is affected by seawater according to tides must be achieved.

Keywords: seawater intrusion, salinization, MOCDENCE, SWICHA, jeju island

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Tide-induced airflow in a coastal reclamation site

in Hong Kong

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Field observation shows that significant air pressures can be generated by water level fluctuation in a coastal area capped by a low-permeability surface in Hong Kong. An isothermal, two-dimensional, cross-sectional model was built to explore the mechanism of the air pressure fluctuations in the area. Numerical simulation reveals that the significant air pressure fluctuation is due to unfavorable conditions which include the almost impermeable asphalt pavement, the less permeable fills in the unsaturated zone, the very permeable fill in the saturated zone, and rainfall during spring tides. Numerical simulation also demonstrates that the maximum air-pressure depends on the maximum rising rate of the sea level, but not necessarily on the variation amplitude of the sea level. This study provides a better understanding of the interactions among the sea tides, barometric pressure variations, groundwater and air-water flow, and rainfall. When the water table rises, the air pressure in the unsaturated zone increases, the air is pushed to escape from the ground surface, and the ground surface exhales. When the water table falls, the process is reversed and the ground surface inhales. This natural coastal breathing phenomenon has relevance to the transfer of gases across the soil-seawater-atmosphere interface and to coastal environments around the world.

Increase of Net Groundwater Extraction from Freshwater Lens

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The geology of most of Ryukyu Islands consists of extensive and thick limestone with high permeability. The surface water is scarce although abundant precipitation, since surface reservoirs to reserve rainwater are very limited due to flat topographical condition. In such areas, groundwater is only exploitable water resource.

Because the mixing zone between fresh groundwater and salt water is very variable due to the slight change of pressure head difference, pumped freshwater is easily contaminated by over exploitation.

The purpose of the present study is to discuss on the scheme by which maximization of groundwater intake with less risk of salt water contamination can implemented. The laboratory experiment was carried out using a model setup. Two cases have been investigated; in case 1, fresh groundwater was extracted by a horizontal collecting pipe installed in the fresh water region. While in case 2, a certain amount of drained freshwater was simultaneously re-injected through horizontal pipe installed at above the fresh-salt water interface.

The amount of net effective fresh groundwater in both cases has been estimated and compared. As a result, the amount of net fresh groundwater intake for case 2 was greater than that of case 1. Thus, it is shown that the simultaneous extraction and re-injection scheme, case 2, is more effective than case 1 in terms of net exploitable amount of fresh water.

In order to confirm the feasibility of this scheme, three-dimensional numerical simulations were conducted. The numerical solutions were able to reasonably represent the movement of mixing zone. However, salt water transport toward extraction pipe takes place when too much fresh water is extracted. This fact is also demonstrated by the numerical result.

As a result, approximately 10-20% of fresh water is more exploitable in case 2 in the present study.

Key words: Laboratory experiment, Fresh water lens, Discharge and re-injection of fresh water, Net fresh water exploitation, 3D-numerical simulation,

Controlling Factors of Hydrogeochemistry Mechanism in Sandy Coastal Aquifer at Kapas Island, Terengganu, Malaysia

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Small islands situated especially in tropical region are well-known as hot-spot places for eco-tourism activities and contribute a lot of economics benefit to the country. Islands management practices need to be maintained in order to sustain the ecotourism activities. Water is pivotal issue in small islands because of the limited quantity and poor quality. Generally, small islands depend largely on groundwater resource, as there is no other surface freshwater exists in an exploitable form. Increased number of visitors would likely increase the freshwater consumption and thus affects its quantity and quality. The major problem of small islands is related to its aquifers which are susceptible to anthropogenic and natural activities. Globally, small islands may experience annihilation by the movement of seawater vertically and laterally, usually caused by over abstraction of groundwater in pumping activities. In-situ parameter between EC and salinity shows strong correlation with $r=0.994$; $p<0.01$ or between EC and TDS ($r=0.995$; $p<0.01$). These relationships indicate that dissolved solid represents composition of ions in groundwater. The preliminary assessment on the hydrogeochemistry characteristics of Kapas Island aquifer shows that there are positive and strong correlation between Na and Cl ($r=0.871$; $p<0.01$) which can be identified as salinization processes. The evolution of hydrochemical facies of groundwater at Kapas Island from Ca-HCO_3 water type that later has shifted to Na-HCO_3 water type demonstrates that the water has undergone several processes such as cation exchange process, dissolution of minerals and mixing of freshwater and seawater. Saturation Indices (SI) value calculated shows that 76% of the analysed groundwater samples were in dissolution state of carbonate minerals (calcite, aragonite and dolomite). This study revealed that hydrogeochemistry of Kapas Island is dominated by the mineral dissolution and ion exchanges attributed from seawater intrusion process.

Keywords: Water Types, Saturation Indices, Small Tropical Island

Figures

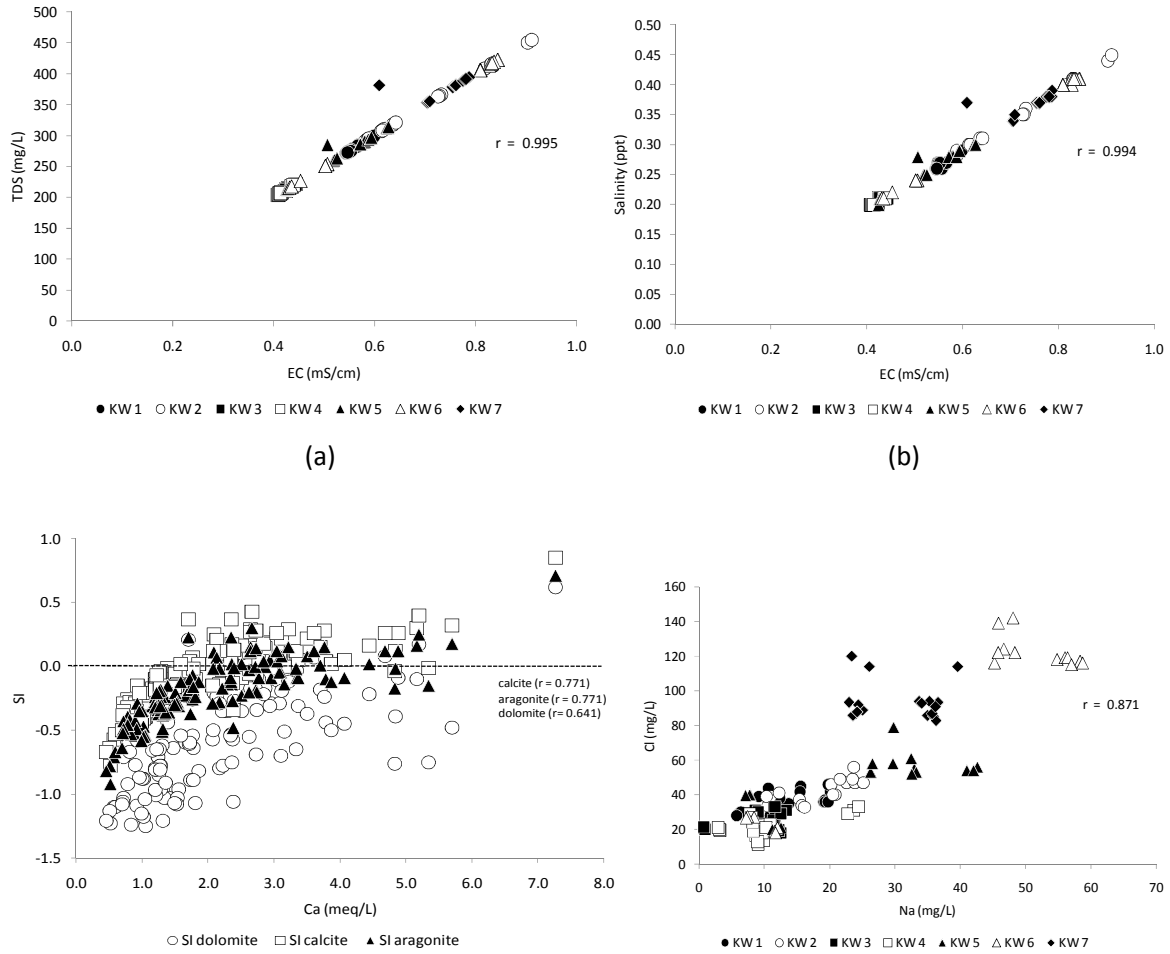

Figure 1: Insert (a) represent the correlation between EC and Salinity while Insert (b) shows the correlation between EC and TDS and Insert (c) is the correlation between Na and Cl. Insert (d) explained the saturation state of carbonate minerals (calcite, dolomite and aragonite) at Kapas Island

Sustainable Management of Groundwater Resources and Risk of Seawater Intrusion for the Jaffna Peninsula

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The Jaffna Peninsula lies in the northern-most part of Sri Lanka. The land surface is uniformly low with a maximum elevation of about 10 m, and covers an area of 1000 km^2 with a coastline of 160 km. There are several islands off the western end of the Jaffna Peninsula, of these the island of Kayts is the biggest island (Shanmuhananthan and Punthakey, 2006). The peninsula is dependent on groundwater for all its water requirements. The only surface stream, Valukai Aru, is active only during the height of the monsoon, and there are no reservoirs of a perennial nature. The low salinity groundwater lenses that constitute the Jaffna Peninsula aquifer system, (Valikamam, Chavakachcheri, and Vadamaradchi East), are the only sources of drinking water for the towns of Jaffna, Chunnakam, Chavakachcheri, Point Pedro and many smaller towns and villages scattered across the Peninsula. The freshwater lenses in the peninsula also supply a large proportion of supplementary irrigation water. As many as 100,000 shallow dug wells are used throughout the Peninsula and of these about 78 percent are used for domestic water supply and the remaining 22 percent for irrigation.

During the 1990's there was a decrease in population as people were displaced due to the continuing conflict in the region. However with the prospect of peace and refugees returning back to the peninsula and the islands, both population and development are projected to increase in the peninsula. This has raised concerns for the quantity and quality of groundwater available for drinking and agriculture in regards to an increased risk of seawater intrusion and upconing from unsustainably high extraction rates. Declines in water levels due to increased pumping would result in unacceptably high water security risks for the people of the Jaffna Peninsula as there are no alternate surface water sources. Furthermore there is no institutional or legal mechanism that prevents a person from exploiting groundwater from their own land.

The objectives of the study are to develop a groundwater flow and salinity transport model for the Jaffna Peninsula using SEAWAT (Guo and Langevin 2002), estimate the water balance for the Jaffna Peninsula, simulate groundwater responses under varying climatic conditions, simulate groundwater responses to various abstraction scenarios for present and future conditions, and assess the potential for seawater intrusion and upconing during pumping, and its impact on low salinity groundwater resources (Punthakey et al. 2006). The model for the Jaffna peninsula was constructed with 7 layers and grid cells of 500 m. The available yield predicted from the

calibration period (1999 to 2004) was 52 ML/d from the freshwater zones. However, rainfall during the calibration period was 16 percent higher than average for the Jaffna peninsula, and as such the simulated available water is expected to be higher than for average years. Model simulated dry season heads and concentrations for the Jaffna peninsula given in Figure 1a and 1b, exhibit a marked decrease in the extent of the freshwater zones in the peninsula as compared to heads and concentrations simulated during the wet season.

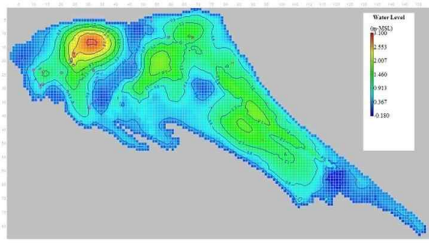

Figure 1a. Dry season heads (m MSL) in July 2003 for the Jaffna Peninsula.

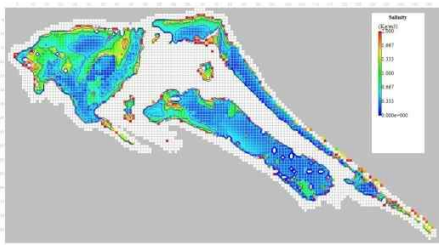

Figure 1b. Dry season concentration (kg/m3) for freshwater zone during the dry season, July 2003.

To determine the sustainable yield a number of pumping scenarios were undertaken using wells in the freshwater zones in the peninsula. Pumping from 25 high yielding production bores resulted in very high groundwater salinities with severe upconing. The use of high yielding production wells is inherently unsuitable for the Jaffna Peninsula. The most favourable scenario for the Jaffna Peninsula was pumping from 25 wells using laterals or spears as it limits the risk of upconing. The recommended groundwater extraction rate from Valikamam is 14.4 ML/d, Vadamaradchi is 6 ML/d, and Point Pedro is 4 ML/d. Additional monitoring and modelling is required to locate water supply wells for Chavakachcheri.

A number of recommendations are suggested for improving groundwater resource management for the Jaffna Peninsula. The most important of these are:

- establishment of groundwater management zones for source areas and capacity building in resource management;
- establishing a Groundwater Management Authority consisting of the relevant sector representatives to ensure the sustainable management of groundwater resources;
- design and implementation of a groundwater monitoring, data collection and management systems for Northern Sri Lanka;
- Rehabilitation of salt water exclusion schemes, introducing modern water saving technologies, and controlling the extent of irrigated agriculture during the dry season;
- Development of a risk assessment framework accompanied by modelling studies to assess the risk from climate change on security of freshwater supplies for Jaffna.
- Identifying risk, resilience and adaptation mechanism to sustainably manage groundwater resources for Jaffna as a viable source for future generations.

Keywords: Groundwater Management; Modelling; Sustainable, Climate Change, SEAWAT

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Groundwater Potentiality Map of The Coastal Aquifer in Huay Sai Area, Petchburi Province, Thailand

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Huay Sai is one of the coastal aquifers in the southern of Thailand, which has the water shortage problem in a few decades, particularly in summer seasons because most areas are agricultural areas. Due to the high growth rate of tourism industries, a number of resorts and hotels subsequently appeared to be increased water demand in recent years. In response to this increase in water demand, groundwater exploration and exploitation of the coastal sand's aquifer and a fractured granite aquifer has been carried out by both government and private sectors. Therefore, a main problem of groundwater due to over-abstraction through pumping threatens the sustainability of groundwater resources. The groundwater potentiality to plan for the sustainable is necessary to be assessed in terms of both water quality and water quantity. To simplify the assessment of groundwater potential Geographic Information System (GIS) method was used to rapid analyze before field investigation for consideration of groundwater potentiality in details. Eight GIS layers, which incorporated with were: rainfall, net groundwater recharge, lithology, lineament density, slope, drainage density, depth to groundwater and water quality, were built in a GIS system and assigned appropriate rankings according to their relative importance to groundwater potentiality.

Groundwater potentiality map was then created by overlay technique and has shown groundwater potentiality classes ranging from very high (in Rai Mai Pattana area) to very low (in Sam Praya area). Moreover, the validity of this map was correlated with the published hydrogeological map carried out by Department of Groundwater Resources (DRG), where a concordant justification was reached. These will be the fundamental database for groundwater exploration planning and sustainable management by groundwater budget technique.

Keywords: Groundwater potentiality; Huay Sai Area; Coastal aquifer; Petchburi Province; GIS

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Acknowledgement

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A numerical modeling approach for biogeochemical processes of coastal aquifers

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Bio-geochemical reduction processes play a major role in alluvial aquifers because of the abundant availability of organic carbon which is indispensable for bacteria growth. As a result of reduction process, significant changes of groundwater chemistry take place; denitrification, reductions of MnO_2, $Fe(OH)_3$, SO_4^{2-}, AsO_4^{3-}, and CH_4 which are well known as reduction processes in an anaerobic groundwater condition. Therefore, the prediction of redox environment in an aquifer is a key subject in order to understand how the groundwater chemistry is affected. If the groundwater chemistry changes mechanism in an aquifer is systematically understood, impacts caused by natural or anthropologic factors could be predicted and subsequently appropriate management practices for aquifers would be established.

In the present study, qualitative understanding of above mentioned processes were achieved for a coastal aquifer by developing a two dimensional bacteria mediated redox model. The model explains the utilization of O_2, NO_3^-, MnO_2, $Fe(OH)_3$, and SO_4^{2-} as electron acceptors for the oxidation of available organic carbon (CH_2O) under the aerobic and anaerobic conditions. The conceptual model consists of three different phases named as bio phase, mobile phase and matrix phase as shown in Figure 1. Bacterial growth is assumed to follow double Monod kinetic equations. Four bacterial groups (X1, X2, X3 and X4) are considered.

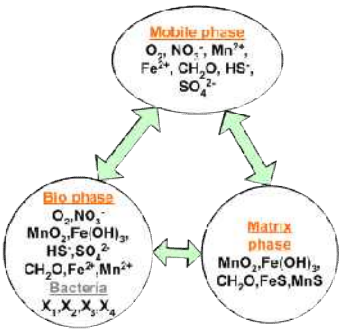

Figure 3. Chemical species considered in the redox model and species exchange between different phases.

Table 1 explains the sequence of bacteria mediated reduction processes which were considered in the simulation. Bacteria group X_1 uses O_2 under aerobic conditions and NO_3^- under anaerobic conditions as electron acceptor. Anaerobic bacterial groups X_2, X_3 and X_4 use MnO_2, $Fe(OH)_3$ and SO_4^{2-} as electron acceptors respectively. Organic carbon which acts as the electron donor is considered as the most important factor for the bacteria mediated reduction processes.

Table 2. Sequence of reduction reactions.

Reactions	ΔG^0 (kcal/mol) at pH = 7
Aerobic respiration (*bacteria* X_1)	
$CH_2O + O_2 \rightarrow CO_2 + H_2O$	- 22
Denitrification (*bacteria* X_1)	
$CH_2O + 4/5NO_3^- + 4/5H^+ \rightarrow CO_2 + 2/5N_2 + 7/5H_2O$	- 114
Manganese dioxide-reduction (*bacteria* X_2)	
$CH_2O+2MnO_2 \rightarrow 2Mn^{2+}+3H_2O+CO_2$	- 81
Iron hydroxide-reduction (*bacteria* X_3)	
$CH_2O+4Fe(OH)_3+8H^+ \rightarrow 4Fe^{2+}+11H_2O+CO_2$	-28
Sulphate reduction (*bacteria* X_4)	
$CH_2O+1/2SO_4^{2-}+1/2H^+ \rightarrow CO_2+1/2HS^-+H_2O$	- 25

ΔG^0 is the change of free energy

The results show that it is generally possible to simulate the formation of reduced environments and behaviors of different bacterial groups in coastal subsurface environments. The parameters used in the present simulation were obtained from scientific literature and previous research works. However necessary adjustments were carried out to obtain meaningful results. Due to the practical constraints, in the present study the verification of the model was not carried out. Instead, a systematic numerical explanation for aerobic/anaerobic bacterial growth and to simulate the reduction processes in a selected coastal aquifer was shown. Obtained results clearly display the potential of the developed model for further research on coastal biogeochemical environment. Despite the importance, this type of numerical simulations is still very limited though such numerical study can provide an insight for the occurrence of reduced species in the subsurface aquifers and their effects on the groundwater chemistry.

Keywords: Bacterial growth; coastal aquifer; numerical model; redox reactions

Treatment of polluted groundwater in coastal area using an electrochemical method

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In China's coastal areas, excessive exploitation of groundwater has resulted in seawater intrusion. Moreover, the high salinity of groundwater has caused soil salinization and fertility decline of farmland. On the other hand, nitrate contamination of groundwater has become an increasing problem due to the extensive use of nitrogen fertilizers. A high level of nitrate in drinking water can cause methemoglobinemia in infants and gastrointestinal cancer in adults. A maximum limit of 45 mg/L NO_3^-(15 mg/L for infants) in drinking water were recommended by the World Health Organization.

In this paper the treatment of polluted groundwater in coastal area by electrochemical method was studied. At the cathode, nitrate was completely reduced to harmless nitrogen and no by-product was formed due to Cl^- was existed in groundwater. Simultaneously the treated solution changed to weak alkali, In which, HCO_3^- become to CO_3^{2-} and the precipitate of $CaCO_3$, $Ca(OH)_2$, $MgCO_3$ and $Mg(OH)_2$ were produced, achieving the purpose of both decrease salinity and completely removal nitrate from coastal groundwater.

Keywords: Electrochemical; Nitrate; Salinity; Groundwater.

Processes Controlling High Saline Groundwater in the Nam Dinh Province, Vietnam

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The coastal zone of Nam Dinh province in Vietnam is hydrogeologically characterized by a regional Pleistocene sandy aquifer and shallow relatively thin Holocene sandy aquifers, and these aquifers are interbeded by low permeable clays and sands in a Holocene marine sequence [1]. Larger abstractions of groundwater from the Pleistocene aquifer were initiated some 30 years ago, which has caused a decrease in the water table from approximately +1 masl (1995) to -8 masl (2010). Increased salinities have been observed in the Pleistocene aquifer, and concerns have been raised that a saltwater intrusion from the South Chinese Sea could hamper a future use of this groundwater resource. Other sources of salty groundwater have, however, also been identified in this area, being saltwater intrusion along rivers and residual saltwater in the low permeable Holocene marine sediments [2]. The aims of this work are to investigate the risk of a regional saltwater intrusion in the Nam Dinh province from the sea and delineate the risks of saltwater intrusions from other sources. The project is under implementation and is expected to be finalized during 2013.

The methods used in the study include geological and hydrogeological investigations in 14 National Groundwater Monitoring boreholes and 02 newly drilled boreholes. Pore water from the low permeable marine sediments were squeezed out using a N2 pressure and the water was analyzed in the laboratory. In addition, the data from transient electromagnetic soundings (TEM) conducted in four survey lines and saltwater intrusions in the rivers were measured by leafing from a boat. Hydrogeological modeling is ongoing using the code SEAWAT in the Visual MODFLOW interface.

Salty bottom water is observed in the Red River as far inland as 35 km from the South Chinese Sea, with concentrations as high as 60 % that of oceanic water. The inland transport of seawater is controlled by the discharge of freshwater in the river, tidal effects and storm events. This observation shows that where high permeable layers are present, saltwater may intrude the shallow aquifer system, driven by a density controlled flow or by advective flow during high water stands in the rivers.

The borehole logging and the TEM soundings results show elevated concentrations of salty pore water in the aquiclude separating the Holocene and Pleistocene aquifer. The TEM

soundings (Fig.1) show low resistivity layers, with resistivities as low as 0.5 to 4.2 ohm*meters, in the Holocene sediments.

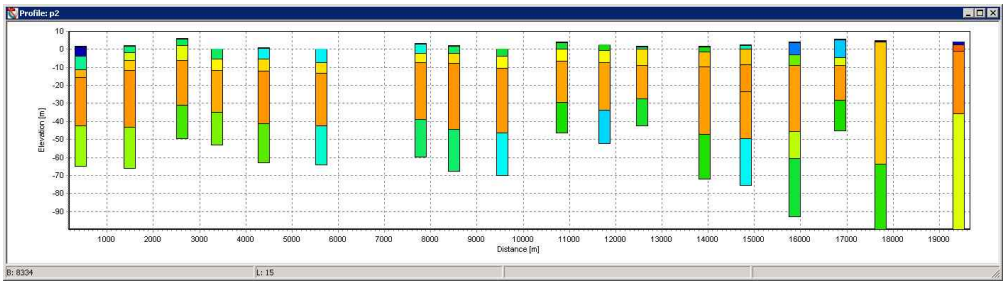

Fig. 4. TEM profile 2 showing a 4 layer resistivity model

The result of borehole logging in 16 boreholes confirms the elevated formation resistivities in the low permeable Holocene sediments, and in addition these results provide information about high salinity in the shallow aquifer from saltwater intrusions from rivers (Fig. 2). This is seen as low resistivity layers in the bottom of the shallow aquifer indicating a density driven transport on the underlying aquiclude (Fig. 2). The results from the squeezed pore water from the low permeable layers shows a good correlation between formation and water resistivities with an average formation factor of vv. Measured electrical conductivities shows values as high as 50 % that of sea water.

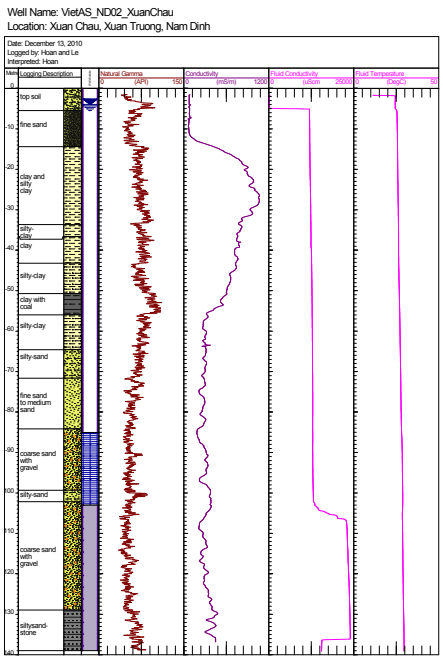

Fig. 2. Results from borehole geophysical logging

The sediments in this part of Nam Dinh province is approximately 5,000 years [1], and conceptual 1D and 2D modeling with SEAWAT in this time span show a predominantly downward transport of saline pore water driven by diffusion, which is contributing to elevated salinities in the Pleistocene aquifer.

Keywords: Saltwater intrusion, TEM sounding, squeezing pore water, USGS SEAWAT.

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Occurrence and geochemical behaviour of arsenic in a coastal aquifer-aquitard system in the Pearl River Delta, China

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Elevated concentrations of arsenic (ranging from 3.3 to 161.4 μg/L) were identified in groundwater samples from the confined basal aquifer of the Pearl River Delta (PRD), which is still intensively influenced by paleo-seawater intrusion. This study treated the coastal aquifer-aquitard as an integrate system and aimed to understand the occurrence and behavior of arsenic in such a coastal groundwater system. This study identified concentration distribution of aquatic arsenic in the basal aquifer and the vertical arsenic profile in the aquitard at MZ4 site, and investigated the transfer of arsenic in the coastal aquifer-aquitard system on the basis of characteristics of water chemistry as well as geochemistry and mineralogy of the sediments. It was found that arsenic enriched groundwater was characterized by devoid dissolved oxygen, negative Eh values, slightly alkaline environment, abnormally high ammonium, and dissolved organic carbon (DOC) concentrations, but low nitrate and nitrite contents. Geochemical analysis as well as the results of sequential extraction experiments suggested that reductive dissolution of FeOOH could be one of the major processes that mobilized solid arsenic. Geochemical analysis combined with positive correlations between arsenic and ammonium and between arsenic and DOC in groundwater suggested that mineralization of the sedimentary organic matter could release adsorbed arsenic to groundwater. Abundant authigenic pyrite in such a reducing environment indicated that co-precipitation of arsenic with authigenic pyrite was one of the major processes controlling concentrations of aquatic arsenic in such a coastal aquifer-aquitard system.

The Studies of Artificial Recharge of Groundwater at Pingtung Plain, Taiwan

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Pingtung Plain (Fig. 1) has abundant precipitation under a sub-tropical climate, and more than 90% of total annual precipitation occurs during the wet season. The hydrological characteristics of the plain are unique with short, steep gradient rivers (Fig.2). As a result, it takes only a few hours from upstream rainfall to downstream runoff. Due to the current lack of reservoirs surface water cannot be preserved during wet periods, and groundwater therefore becomes the main source of water supply. Groundwater tables consequently decline, the problem being most severe in the coastal areas.

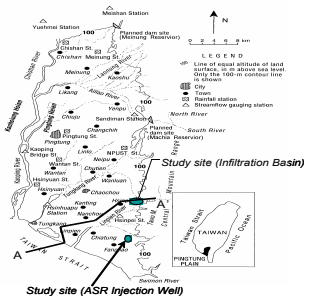

Figure 1 Location map pf Pingtung Plain

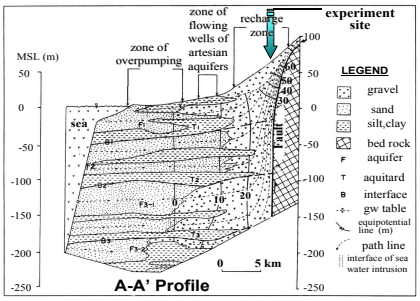

Figure 2 Schematic section of the hydrogeological conceptual model

Due to rapid economic development and associated changes of societal attitudes to the environment, the construction of large reservoirs capable of preserving runoff during wet periods is at a standstill. A water supply alternative, therefore, is to apply eco-engineering methods such as smaller Infiltration Basins (i.e. artificial lakes) or ASR (Aquifer Storage and Recovery) groundwater injection well of Artificial Recharge (AR) of Groundwater in high permeability aquifers. These not only retain surface water during wet periods, but also conserve the groundwater resource and can thus achieve the goal of sustainable water resources development.

The two field studies presented in the paper are located in the Wanlung Farm Infiltration Basin experimental area (Fig. 3) and Changlung Farm ASR Well demonstration facility site (Fig. 4). The aim of a serious years studies is to investigate the basin area, the thickness of filter layer design, the biological clogging factors, and the direction of flow of the recharge water for Infiltration Basin and performed in maintaining and managing the ASR well and carry out pumping and injection tests in order to establish the hydrogeological conditions of the ASR local area.The present paper reports on results from an artificial recharge pilot study in these Infiltration Basin that was initially performed over the period 8-16 October, 2001. Infiltration velocity, measured using observation wells and a micro-groundwater flow meter, was found to be ca. 20 m/day.

Figure 3 Infiltration Basin for experiment at Wanlung Farm, Pingtung, Taiwan

Figure 4 ASR (Aquifer Storage Recovery) groundwater injection well at Changlung Farm, Pingtung, Taiwan

In the of 2003-2004, to propose the filter layer design, two test instruments were presented and commonly used geo-texture materials were to developed as a source of reference for future studies to understand and solve clogging factors. Regarding the biological blocking factors, bacillariophyta was confirmed as the dominant algae species and Oedogonium sp. was identified as the main type of silk shaped algae species. However, their growth did not appear to have a serious affect on the injection efficiency. The recharged water was found to flow from the north-east towards the south-west from these two years studies.

The field study presented in the years of 2005-2007, the aim of study was to investigate the lake area, infiltration quantity, infiltration rate, the clogging factors, H-O isotope analyzed the direction of flow of the recharge water. The observation of average infiltration quantity was 6,466CMD and average infiltration rate is 8.55m/day. The large-scale alga may be in order to cause clogging one of the influence factors. The aquifer (1) of Pingtung Plain used to be observed for the artificial recharge and flow for the Northeast to the Southwest by contour of water level and H-O isotope showed the same results.

The aim of the present study is to evaluate the feasibility of developing the ASR technique as a means of managing the water resources in Taiwan. An ASR demonstration facility had been established at Fangliao township in Pingtung County. The equipment at this facility includes one ASR well, two observation wells, and one clean water storage tank in 100 m^3. Previous research projects had been surveyed the local area and have been performed preliminary injection and pumping cycle tests. These in-situ tests had been provided a fruitful information. This paper presents the work which had been performed in maintaining and managing the ASR well in the years of 2004-2007. The damaged parts of the ASR well and its peripheral equipment had been maintained and replaced as required in order to restore the ASR to full working order. The ASR well had then been used to carry out pumping and injection tests in order to establish the hydrogeological conditions of the local area.

From the current studies through years, T (Transmissivity) and S (Storage Coefficient) values were calculated ca. 1,700 m^2/day and 6.30×10^{-7} respectively. Well efficiency was reduced ca. 90% by the year of 2007. Long-term sustainable water resources development in Pingtung Plain is made possible by the fact that total water resources are much large than total demand. However, sustainability can only be achieved with demand management and conjunctive use of the surface and groundwater resources through Managed Aquifer Recharge.

Keywords: Artificial recharge of groundwater, Recharge basin, Recharge well, Taiwan

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Development of a Regional SEAWAT Model of the Floridan Aquifer System at the Lower West Coast Area, Southwestern Florida

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Due to the substantial growth of population in southwestern Florida, demands for potable and irrigation water are significantly increased. To meet water demands while maintaining economic and environmental sustainability of the area, future water supply will shift its major source from the shallow surficial aquifer or intermediate aquifer system to the Floridan Aquifer System (FAS) that contains water from freshwater to brackish or sea water.

The Florida Aquifer System extends from Georgia and dips to south. It underlies the whole Florida peninsular. In many parts of Georgia and Florida, the FAS is major source of groundwater supply. The southern portion of the FAS receives recharge through the vertical leakage from the shallow aquifers in central Florida area. This project covers the FAS under southwestern portion of Florida as shown on Figure 1.

A conceptual model was developed based on previous studies (Stewart 1980; Myers, 1989). No-flow boundary conditions were assumed along imaginary flow lines generally parallel to the northern and eastern model borders. Constant head and seawater concentration boundary conditions were assumed along the Straits of Florida to the south and far west to the Gulf of Mexico. A no-flow boundary was also assumed on the top of the FAS based on the field data that indicate there is little hydraulic connection between the FAS and overlying shallow aquifers. Constant head and constant concentration conditions were also assumed for the Boulder Zone that is at the bottom of the FAS. The recharge area was delineated based on the study by Stewart (1980) and others. The recharge rate was based on the previous studies and was adjusted during model calibration.

A numerical model was constructed and calibrated first under steady-state and transient conditions. During the steady-state model calibration, averaged rates of groundwater withdrawals of all permitted wells tapping the FAS were applied. Transient calibration was performed following the steady state calibration. Time-variant pumpage and rainfall were used during the transient model calibration.

The model simulation results show the patterns of groundwater flow from the recharge area divergently to the Florida Strait and the Gulf of Mexico. The model flow patterns are in general agreement with the conceptual model.

This model will provide the water managers of South Florida Water Management District a useful tool in future water resource management when brackish water from the FAS becomes more important.

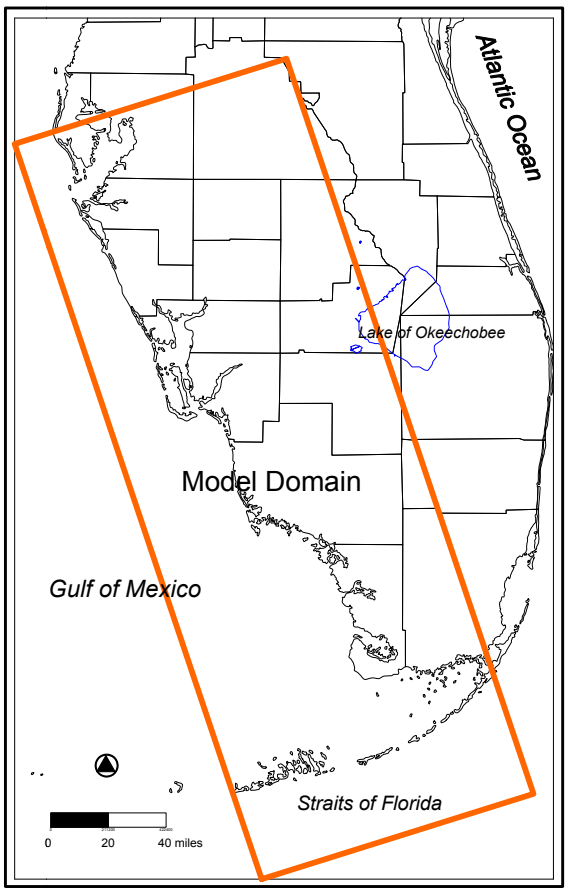

Figure 5. Model Domain

Keywords: Floridan Aquifer System; Coastal Aquifer management; SEAWAT;

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Biomolecular Analyses as a New Tool to Investigate Saltwater Intrusion

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Microbial communities are influenced by the physico-chemical features of the habitat where they persist. This means that, from the theoretically point of view, they represent a valuable natural tracer of interactions between different water types, such as groundwater and seawater in coastal aquifers, and biomolecular investigations could be a new effective tool to investigate such interactions. The effectiveness of such an approach has been experimentally verified recently in other environments to analyze, for example, mixing processes between the lower saline infiltration water and the higher saline groundwater [1].

Here, the results of a first study in a volcanic island (Ischia, Italy) are presented. The effectiveness of the proposed approach has been verified by comparing the results of biomolecular investigations with those of hydrogeological, hydrochemical and isotopic ones.

Ischia Island is the westernmost active volcanic complex of the Campania area and belongs to the Phleagrean volcanic district of southern Italy. Ischia is composed mainly of volcanic rocks and subordinately of sediments. The volcanic rocks belong to a low potassium series and consist of shoshonite and alkalitrachyte.

Biomolecular analyses have been carried out according to described methods [2], using water samples collected in a well (HP) located where seawater intrusion has been documented through hydrogeological, hydrochemical and isotopic investigations [e.g., 2, 3].

Microbial strains detected in well HP are closely related to uncultured mesophilic and thermophilic bacteria. Therefore, no detailed information is given concerning physiology and metabolism of these microorganisms. Nevertheless, homologues of different strains detected in this well (Table 1) were detected in hypersaline water (e.g. at the Axel Heiberg Island, Canada; [4]), and in coastal areas where a mixing between terrestrial hot (T 78 °C) water and seawater has been hypothesized (e.g. at Lesvos Island, Greece; [5]) or associations of marine and terrestrial microorganisms has been detected (e.g. at Reykjanes peninsula, Iceland; [6]).

Thus, the association of microorganisms typical of different aquatic habitats, which was detected in the investigated well, further supports the hypothesis that seawater intrusion can affect the part of Ischia where the investigated well has been drilled. In a broader context, the same results confirm that microbial community investigations can represent a valuable tool to analyze the

interaction between groundwater and saltwater in coastal aquifer, such as in other aquatic environments where water bodies with different salinities can interact.

Table 3. 16S rDNA gene sequences recovered from well HP and their closest phylogenetic affiliations. (*) This sequence has the same similarity with more than one sequence deposited in the EMBL Nucleotide Sequence Database, therefore only one homologue is reported as an example.

Sequence	Accession number	Classification / Closest affiliations	Accession number	Similarity
HP1-2 (*)	FM242514	Uncultured *Firmicutes* bacterium clone PL07-22	FJ844313	99%
HP2-1	FM242515	Uncultured bacterium clone p760_b_9.29	AB305438	84%
HP2-3 (*)	FM242516	Uncultured organism clone MAT-CR-P2-H06	EU246076	100%
HP3-1	FM242517	Uncultured bacterium clone Pol_B_60	EF444682	100%
HP4-2	FM242518	Uncultured bacterium clone Pol_B_41	EF444700	95%
HP4-14	FM242519	Uncultured bacterium clone CSR-26	AY699376	100%
HP4-23 (*)	FM242520	Uncultured *Chloroflexi* bacterium clone pMARB10_30	AB496521	92%

Keywords: Island aquifer; Microbial community; Saltwater intrusion.

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Analytical Solutions for Tidal Propagation in a Leaky Aquifer with Land Reclamation

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Recently, the issue of land reclamation, especially the impact of reclamation on groundwater resources, becomes one of research interests to the hydrogeologists. To our knowledge, the research on the land reclamation for a tidal aquifer with multi-layer formations has never before been presented. This paper is devoted to developing an analytical model for describing the groundwater fluctuation in a reclaimed aquifer system composed of the aquitard between the upper unconfined and confined aquifer. The impacts of the aquifer parameters are thoroughly investigated in this paper. In addition, the effect of the leakage on the groundwater fluctuation is examined graphically for the cases with different reclamation lengths and reclamation materials.

Keywords: Land reclamation, Analytical solution, Tidal effect, Aquifer system.

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Assessment of Effects of Groundwater Abstraction near Stream on Streamflow using SWAT-MODFLOW Model

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The decline of groundwater levels around pumping wells located near streams captures some of aquifer discharge to the streams, and moreover, if large enough water is pumped out of the aquifer, induces infiltration of stream water into the aquifer. Extensive groundwater abstraction near streams for irrigation and industrial water supply may result in concerns about the reliability of streamflow threatened by stream depletion. Therefore, the rate and volume of stream flow depletion due to groundwater pumping need to be estimated for effective water resources management. Estimates of streamflow depletion are often obtained using analytic models of the stream-aquifer system. However such models are greatly simplified representations of reality, so the groundwater numerical models have been effectively used for understanding and quantifying stream-aquifer interaction. However, most previous studies based on numerical models have focused on regional scale problems without sufficient consideration for hydrological characteristics such as long term variation of precipitation and the corresponding variations of groundwater recharge and water influx from upland areas. Particularly, to predict the impacts of upstream flow changes due to pumping on downstream flow duration, a watershed scale approach is required. In this study, a watershed based integrated surface water and groundwater model, SWAT-MODFLOW is used to quantify stream-aquifer interaction and estimate the stream flow depletion due to groundwater pumping. The integrated model was applied to the Sindooncheon watershed, South Korea to assess the effects of various groundwater abstraction scenarios including current usage pattern on stream flow. The simulated results showed the groundwater pumping at current status has induced the decrease of 14% in streamflow at the outlet of the watershed, which was attributed to pumping wells located within the distance of 100m from the stream. The simulated results also revealed that vast water withdrawals have dramatically changed water budgets of aquifer and stream.

Estimation of an exploitable groundwater in Musimcheon watershed, South Korea

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In Korea, groundwater management is conducted based on the estimation of annual average of groundwater recharge. The traditional concept of safe yield, which equates safe yield with natural recharge, is flawed and has been widely discredited. It has now been replaced with sustainable yield. Since groundwater recharge and surface-groundwater interactions show spatial temporal variation, continuous monitoring and distributed hydrologic modeling with groundwater abstraction must be carried out to evaluate the sustainability of groundwater resources. In this study, an integrated surface-groundwater analysis by using SWAT-MODFLOW was conducted considering various groundwater pumping scenarios in Musimcheon watershed. When current usage is applied, baseflow reduction and annual averaged storage reduction were thought to be reasonable. Consequently, exploitable groundwater in a region should be determined by physically based analysis as well as social compromise in a community.

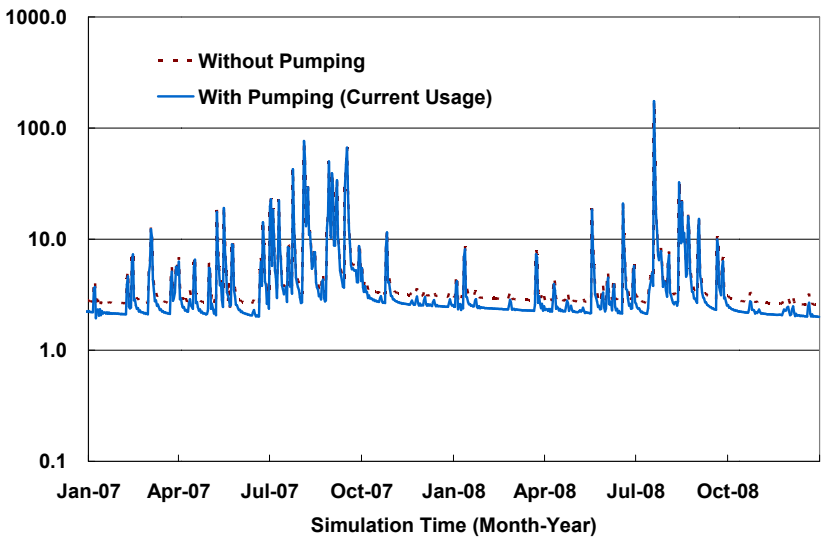

Fig. 1 Stream flow change due to well pumping ($Q=Q_0$)

Groundwater Management Approach in a Coastal Urban Center Using Numerical Simulation – a Case Study of KFUPM Campus

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King Fahd University of Petroleum and Minerals (KFUPM) is located on the east coast of Saudi Arabia. The Umm Er Radhuma (UER) aquifer is the source of over 90% of KFUPM water demand. Rapid development and growing population in KFUPM in the past four decades have led to major increase in water consumption for domestic uses and landscape irrigation, as well as sanitation services. As a result, increase in groundwater pumping from the UER aquifer has led to increase in salinity level. This study focused on qualitative assessment of groundwater resources in KFUPM campus and evaluation of the aquifer system's sustainability for three long-term pumping alternatives. A solute transport model was developed and calibrated to predict future Total Dissolved Solid (TDS) levels of the UER aquifer in the study area using numerical simulation. The simulation spanned 21 years; from 1990 to 2010. The results indicated an increase in TDS level from an average of 3,100 mg/l in 1990 to an average of 4,050 mg/l in 2010. The calibrated model was subsequently utilized to predict the TDS levels of the aquifer over a planning horizon of 20 years (2011-2030) under the prescribed pumping alternatives. The results revealed that Alternative Scheme II, which assumed conservative measures, is the best alternative for long-term sustainability of the groundwater resources in the area. The findings presented in this study would help KFUPM Community in implementing better management of the available and non-renewable groundwater resources. Similar approach can be used to improve groundwater use and management in rapidly growing urban centers in other coastal regions.

Keywords: Coastal aquifer; salinity level; numerical simulation; groundwater management; KFUPM.

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Analysis of the conjunctive use of groundwater in southern Taiwan after typhoon Morakot struck

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Typhoon Morakot struck Taiwan during August 8-10, 2009. Government statistics indicate 617 casualties, 76 missing persons, and 24,950 evacuees.. The long period of heavy rainfall also triggered many debris flows and landslides. One major landslide in Xiaolin Village, Kaohsiung County resulted in 431 dead or missing persons. That landslide wiped out the entire village. In addition, the southern part of Taiwan faced a serious problem of high water turbidity because of the heavy rains. The uneven spatial and temporal distribution of rainfall and growth in the use of water resources in southern Taiwan has resulted in water shortages in southern Taiwan becoming more serious.

To solve water shortage problem in southern Taiwan, a conjunctive scheme to make four artificial lakes or reservoirs will be used to augment groundwater recharge. In this study, we adopted a MODFLOW numerical model to simulate different scenarios in this area.

First, we performed pumping tests to obtain data to characterize hydrogeological parameters of the study area. Then we applied MODFLOW, a numerical computer model, to simulate four artificial lakes with pumping from two different regions. The model was calibrated and validated. A sensitivity analysis was also conducted.

We analyzed a total of eight cases of water level changes in the experimental area, and applied the Hill method to analyze the safe yield of groundwater. Finally, we calculated that it has 20.5 million tons water can provide for dome tics use.

Keywords: MODFLOW, Groundwater, Safe yield, Sensitivity Analysis, Hill Method, Conjunctive Scheme

Groundwater Recharge and Exploitative Potential Zone Mapping Using RS, GIS and GOD Approaches

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Abstract

Two-thirds of the total area of Taiwan is the mountainous terrain which is the main groundwater recharge sources of plain region. The purpose of this study is to assess groundwater recharge and exploitative potential zone in central division of mountain area (the middle reaches of Jhuoshuei River basin). The basic information from remote sensing (RS) and satellite phantom are collected to set up the basic data maps, includes elevation, Formosa-II images, NDVI, drainage distribution, slope, aspect, lineament distribution, and land cover etc. The geographical information system (GIS) is used to integrate five contributing factors: lithology, land cover/land use, drainage, slope, and lineaments. The procedure criteria of recharge potential assessment are established to demarcate the groundwater recharge potential zone.

The resultant map of the groundwater potential zone demonstrates that the highest recharge potential areas are located towards the downstream regions of the Chingshui River, between the Chichi Weir and the Changyun Bridge, and the eastern mountain of Chenyuland River. The spatial distribution map of groundwater recharge indicates the recharge controlled by precipitation. The main recharge zones are located at eastern and southern mountain of study region. The Jhuoshuei River is the medium recharge zone and the lowest are in Chingshui River and Tungpuna River.

Finally, GOD rating system is adopted to evaluate the exploiting potential zone that the three main parameters are considered: the groundwater occurrence, the lithology of the overlying layers, and the depth to groundwater. The results show in the middle reaches of Chenyuland River are the large exploitative potential zones due to plentiful rainfall. The west of Jhuoshuei River and downstream regions of the Chingshui River are the medium areas because of the high infiltration rates and shallow groundwater level.

Keywords：Groundwater recharge, exploitative potential, Jhuoshuei River, RS, GIS, GOD

Comprehensive Surface-Groundwater Analysis on the Pyoseon Region, Jeju Island

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The integrated SWAT-MODFLOW model was applied for the comprehensive investigation of the hydrologic components of the Pyoseon region in the Jeju island. The SWAT-MODFLOW model simulated water budget components reasonably well compared with observed data. The pumping module in the SWAT-MODFLOW model was used to simulate water pumping from the present 198 wells in the island by increasing pumping amount up to 20 folds relative to current pumping amount in order to investigate the impact on hydrologic components. When groundwater pumping rate increases by ten and twenty folds, then groundwater discharge decreases 17 and 45 %, respectively. Considering topographical characteristics of the island, most of recharged groundwater is shown to be discharged to the sea. Thus, appropriate groundwater extraction in the Jeju island could reduce the loss of deep aquifer into the sea and subsequently be effective in securing additional water resources. Since many pumping wells in the watershed are located near the sea shore where landscape is near flat, excessive pumping may cause salt water intrusion to aquifer due to reverse gradient of groundwater toward inland direction. Groundwater level drops down to more than 10 meters in the scenario of 20 folds increase from the reference pumping rate (Fig. 1). Actually, over 20 folds increase, the reverse gradient of groundwater happened. The possibility of salt water intrusion should be taken into account for this kind of study.

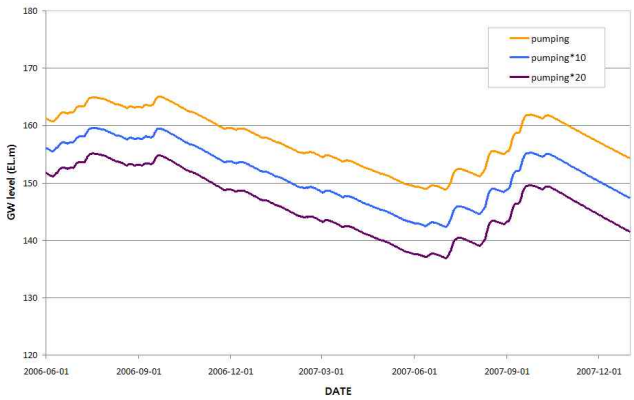

Fig. 1. Groundwater level change depending on aquifer pumping levels

Evaluation of Coastal Groundwater Resources in Developing Countries: A Case Study of The Caribbean

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Coastal groundwater is an important resource for countries which belong to the Caribbean. The Caribbean is divided into two regions known as the Greater and the Lesser Antilles. With some Small Islands of Developing States (SIDS) of the Lesser Antilles having virtually no freshwater ecosystem for example the Virgin Islands and the Netherland Antilles and to some extent Barbados. As a result of a high population density in coastal areas, the practice of over abstraction of coastal aquifers is prominent on most of these islands. This is known to eventually cause seawater intrusion to occur and thus limiting the amount of potable water, available to the respective coastal communities. The study reviews the availability of coastal groundwater in this region and highlights the variation from island to island in regards to abstraction and utilization. Where it was observed that although abstraction and usage may vary from between the islands the common reason for inefficient management of the groundwater resource is insufficient knowledge of hydrological conditions due to limited data collection.

Keywords: Caribbean, groundwater, coastal aquifer, management, island

Control of Saltwater Intrusion through Freshwater Injection Wells-overview of injecting plans

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Nowadays, more and more coastal areas are facing seawater intrusion problems due over-pumping and poor management. Injecting freshwater into underground is one of several strategies to mitigate seawater intrusion.

This option works in two ways: one generally focuses on artificial recharging underground basin, increasing the infiltration of water to reduce the biggest inducement of seawater intrusion: over extraction. Therefore, the effect of controlling seawater intrusion in this way is most likely indirect. Many related researches were interested in how to build a successful undersurface reservoir and recover groundwater from it.

Another way focuses on raising groundwater level to a necessary hydraulic gradient that prevent seawater intrusion directly. To achieve that, injection wells were built along the coastline as seawater barriers, or located nearby contaminated area where required protection. In 1960s, three barriers projects were constructed in Los Angeles County to mitigate seawater intrusion and they protect this area successfully for 50 years. However, raising cost of barrier system and the aging infrastructure requires better management or alternatives (Ted Johnson 2007). Simulation optimization methods were used to either identify useful improvement of injection policy (Benjamin and Willia 2008) or offer a possible alternative as in-lieu delivery (Eric and Theodore 2005). Another seawater intrusion barrier that was built in the mid-1970s by The Orange County Water District was facing similar situation, and they easy the problem by using reclaimed wastewater from a water purification system (GWRS) to reduce the pressure of maintenance costs. Even with these problems, seawater barrier is still constructed in field (F. Ortuno et al. 2010) or recommended as a useful tool to prevent seawater intrusion (Tsanis and Song 2001). Moreover, analytical approach, numerical simulations and laboratory-scale experiments were done to investigate the effect of seawater barriers on saltwater/freshwater interface movement without considering any extraction (A. Mahesha 1996a&1996b; Roger Luyun .et al. 2011).

As so far, it is clear that injecting freshwater into aquifer can be an effective option for preventing saltwater intrusion, however, clearly relationship between extraction rates and injection rates is barely mentioned in any research.

Herein, a simulation-optimization model (SIOP) is used to calculate both optimal injection rate (Q_{in}) and well location subject to preventing an extraction well from being intruded by seawater

in a hypothetic coastal aquifer. The extraction well was contaminated because of excess pumping rate Q_{ep}. A conception called net injection efficiency (R_{nb}) is defined as $[(Q_{ep}-Q_{in})/Q_{ep}]$, and if the efficiency is larger than 0, we can have net benefit from injecting. After series of scenarios, there are cases with R_{nb} higher than 50% and more cases with no benefit at all ($R_{nb}=0$). More simulations and studies are needed to identify sensitive parameters on affecting the value of R_{nb}.

Keywords: Saltwater intrusion; Injecting freshwater; Simulation-optimization model; net injection benefit.

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Decision-Support Model for Sustainable Development of Groundwater Subject to Seawater Intrusion

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In this study, a decision-support model is proposed for sustainable development of groundwater subject to seawater intrusion. The proposed model consists of a sharp-interface model and genetic algorithm (GA) coupled with physical creep mutation (PCM) method for developing wells of satisfying the sustainable demand of freshwater in coastal areas. The primary objectives of the model include maximizing freshwater pumping rates for freshwater production wells, minimizing saltwater pumping rates from freshwater production wells and minimizing freshwater injection rate for freshwater injection wells. Negative impacts of pumping or injection are also considered.

The sharp-interface model was verified against the analytical solution (Strack, 1976) on a hypothetical semi-infinite homogeneous aquifer. Laboratory experiments were conducted in sand tanks to investigate if the sharp-interface model could estimate freshwater-saltwater interface and saltwater contents at pumping wells. The scenarios of the experiments involved not only excessive pumping from freshwater wells but also saltwater pumping and freshwater injection.

The PCM method was developed to improve the performance of GA which the convergence speed is fast at early stage but becomes very slow afterwards. PCM allows GA to search for the best solution in a much smaller parameter space for one generation, so that the optimization efficiency can be improved greatly.

Some examples solved with analytical solution (Park and Aral, 2004; Cheng et al., 2000) were studied for testing the capability of the proposed model. Examples on a heterogeneous aquifer demonstrate the model's applicability in complex aquifers and boundary conditions.

Keywords: saltwater intrusion, decision-support model, genetic algorithm, physical creep mutation method, maximizing freshwater pumping.

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Characteristics and Potentials of Springs in Jeju Island

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Jeju island has an area of 1,810 km^2 and is considered the largest island in South Korea. Historically springs and puddles were the island's primary sources of water. However, after 1970 all sectors, including the urban and industrial sectors depended solely on groundwater as their water resource. As a result of this most springs have either been destroyed or been in the state of neglect. In some cases it has been observed that springs were preserved by nature, however majority of the cases saw springs losing their own nature as a result of abandonment. It was recorded that there were 911 springs in Jeju Island (Figure 1) with most of them being distributed along the coast, which consequently increases their susceptibility to seawater intrusion. The objective of this study was therefore to analyze characteristics of springs in the island, highlighting its past utilization and reestablishing its potential as a source of freshwater.

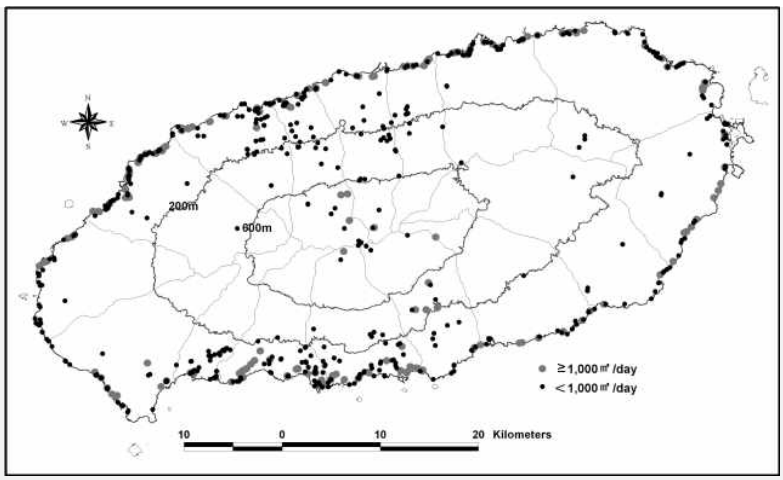

Figure 1. Spring Distribution of Jeju Island

Tables 1 and 2 present Meinzer's classification based on size and the ratio of the discharge of spring was analyzed on the Jeju Island.

Table 1. Meinzer's classification of springs according to size

Magnitude	Discharge	koh(1987) 1)	Jeju (1999) 2)
		233 points	690 points
First	100 cfs or more	-	-
Second	10 to 100 cfs	-	-
Third	1 to 10 cfs	37	35
Fourth	100 gpm to 1 cfs	74	176
Fifth	10 to 100 gpm	63	278
Sixth	1 to 10 gpm	49	129
Seventh	1 pt to 1 gpm	-	72
Eighth	Less than 1 pt/min	-	-

Variability of a spring is defined by Meinzer'sas the ratio of the discharge fluctuation to its average discharge within a given period: V= 100(a-b)/c. V is the variability (%), a is the maximum, b is the minimum, and c is the average, discharge. Koh (1987) analyzed variability of 37 springs (Table 2).

Table 2. Classification according to variability and permanence of discharge

Constant (V < 25%)	Subvariable (V<100%)	Variable (V> 100%)
11 springs	25 springs	1 springs

The results of this study can be summarized as follows:

1) The magnitude of springs and variability show fourth and subvariability a point on the average according to Meinzer's classification.
2) A variation in distribution from the third to the sixth magnitude was observed within the entire basin.
3) The magnitude of spring and variability phenomena depends on topographic and geologic influence, based on varying weather conditions.

Keywords: Jeju Island, springs, water resources, value, classification of spring

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Seawater Intrusion in New Zealand: New Guidelines and Case Examples

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New Zealand is an island nation ranking tenth in the world for national length of coastline. It has about 15,100 km of coastline surrounding a land area of 268,000 km^2. The Republic of Korea, in contrast, has only about one-sixth of the length of coastline New Zealand has and one-third the land area (National Foreign Assessment Center, 2006). Groundwater is also very important in New Zealand, accounting for about 50% of consumptive water use and 80% of the water used for agricultural purposes. These facts underscore the potential importance of seawater intrusion for New Zealand.

New Zealand is divided into 16 Regional Councils. All of these Regional Councils have some amount of coastline within their jurisdiction. These Regional Councils are responsible for environmental management, including the protection of groundwater from seawater intrusion, under the country's Resource Management Act of 1991. Technical guidelines have recently been prepared to help Regional Councils in New Zealand in the analysis of risks to groundwater from seawater intrusion. These technical guidelines consist of a report and a companion Excel spreadsheet. Their preparation was funded by the New Zealand Ministry of Science and Innovation (MSI) through its Envirolink programme. The Envirolink programme is an environmental research knowledge transfer programme. Therefore, both the report and the spreadsheet are available at the Environlink programme internet site (www.envirolink.govt.nz/ Envirolink-tools).

The guideline report, identified as Callender, et al. (2011), provides the following information:

1. "a review of coastal groundwater monitoring currently… undertaken… in New Zealand;"
2. "a classification of the type of sea water intrusion risk(s)… that occur in New Zealand;"
3. "predictive methods for identifying situations where there is… potential for sea water intrusion to adversely effect groundwater usage:"
4. "a description of chemical indicators of sea water intrusion;"
5. "a consideration of the effects of sea level rise on sea water intrusion risks;"

6. "recommended approaches for monitoring sea water intrusion risks;" and
7. "recommended approaches for management of sea water intrusion risks."

Callender, et al. (2011) is more of a summary of some of the relevant information available in standard textbooks such as Domenico and Schwartz (1990) and Todd and Mays (2005) than guidelines per se. In addition it contains brief general summaries of the scope of existing Regional Council seawater intrusion monitoring programs and monitoring and management approaches. This summary indicates that half of the 16 Regional Councils have wells in their groundwater monitoring networks intended to provide information of one kind or another regarding coastal groundwater issues (this would typically be water level and ground water quality). However, other Regional Councils may focus their seawater intrusion monitoring efforts on specific consent issues rather than via their broader monitoring programmes.

The Excel spreadsheet has worksheets providing the following analytical solutions for predicting or assessing the seawater-fresh groundwater interface:

1. Ghyben-Herzberg depth under static conditions;
2. Glover equation when the hydraulic gradient is known;
3. Schmorak and Mercado (1969) and Dagan and Bear (1968) equations for upconing of the interface when pumping a groundwater well;
4. Strack (1976) equation (critical well discharge) to assess the effect of well pumping;
5. Werner and Simmons (2009) equation (constant head) to assess the effects of sea level rise on seawater intrusion; and
6. Werner and Simmons (2009) equation (constant flux) to assess the effects of sea level rise on seawater intrusion.

Case examples of seawater intrusion concerns near the New Zealand coast are discussed. These are:

1. Seawater intrusion related to quarry dewatering near Manukau Harbor (Auckland area);
2. Seawater intrusion related to quarry dewatering near the Bay of Plenty;
3. Seawater intrusion related to private water supply well pumping near the Bay of Plenty; and
4. Seawater intrusion in Dunedin related to sea level rise.

Keywords: New Zealand, seawater intrusion guidelines, spreadsheet solutions, case examples

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The Evolution Optimising Water Resources Problems

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Water resources systems present many interesting and challenging optimization problems. For example in the ground water monitoring well location problem, the interactions between decision variables are complex and not always easily understood. Also, assumptions or simplification of the problem alter its structure and permit a range of methods to be applied. Constraints and objective(s) can be linear or nonlinear. Some problems can be posed in a stage-wise structure. Thus, a number of optimization methods are found in the literature for the range of problems related to water resources systems. This work attempts to provide an overview of the maturity of optimization techniques applied in the area over time.

With the availability of fast computers, the improvement of methodologies and solutions to more complex problems is now possible. From the initial consideration of simple systems (linear models) to considering complex systems is now a reality. The development of fast hydraulic simulation models led to the linking of optimization and simulation models. The emergence of water quality as a central issue in water engineering and the movement of water resources oriented optimization software from research to practice through commercialization have also contributed to the development of this area.

In this work, timelines of advances in the application of optimization methods to water resources problems are presented. They relate the types of problem considered over time, the methods applied, and the general formulation structures with the changes listed in the previous paragraph and others that altered the way problems were posed and solved.

Identification of Groundwater Contamination Sources Using Multivariate Statistical Analysis in a Coastal Area of Busan, Korea

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Multivariate statistical analyses of groundwater quality data were carried out to identify the groundwater contamination sources in a coastal area of Busan City. The groundwater quality of the study area generally indicated $Ca(HCO_3)_2$ type of common groundwater in Korea. However, it was contaminated mainly by seawater, and partly by heavy metals. The groundwater around the Suyeong River was contaminated by the salinized river water, and contained the high concentration of NaCl. Cluster analysis (Fig. 1) classified the groundwater of the study area into Group 1 for fresh groundwater in 63% ratio of the total groundwater, Group 2 for a little contaminated groundwater by seawater or by sewer leakage in 30% ratio, and Group 3 for seriously contaminated groundwater by seawater in 7% ratio. Factor analysis (Table 1) found five groundwater contamination sources, i.e. several chemical components derived from seawater, nitrate from sewage, manganese from factories or waste landfills, fluoride from geology, and iron from borehole casings. Discriminant analysis showed that three groups determined by cluster analysis gave 100% correct assignation for the standard, forward and backward stepwise modes. It was concluded that multivariate statistical analysis was very indispensable to the identification of groundwater contamination sources.

Keywords: multivariate analysis, cluster analysis, factor analysis, discriminant analysis

Acknowledgement

This research was supported by a grant (code# 3-3-3) from Sustainable Water Resources Research Center of 21st Century Frontier Research Program (Korea).

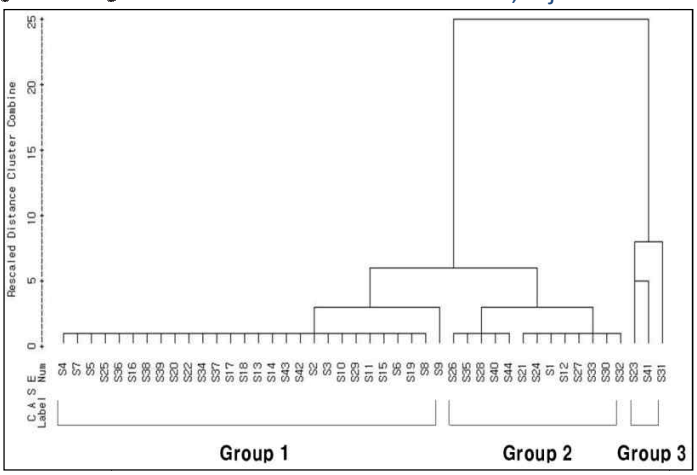

Fig. 1. Dendogram of groundwater samples classified by cluster analysis

Table 1. Factor matrix for groundwater quality variables by factor analysis.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality
Temp.	-0.009	0.158	**-0.755**	0.249	-0.231	0.711
pH	0.170	**0.842**	-0.130	0.101	0.013	0.766
EC	**0.979**	0.078	0.062	0.137	-0.039	0.989
Na^{+}	**0.977**	0.035	0.175	0.025	-0.038	0.989
K^{+}	**0.825**	0.074	0.372	0.347	-0.112	0.958
Ca^{+2}	**0.961**	0.028	-0.116	-0.131	0.00003	0.954
Mg^{+2}	**0.958**	0.024	0.167	0.206	-0.031	0.990
Cl^{-}	**0.984**	0.017	0.153	0.040	-0.032	0.995
SO_4^{-2}	**0.957**	0.033	0.052	0.227	-0.025	0.973
HCO_3^{-}	0.082	**0.847**	0.133	0.099	-0.097	0.761
NO_3^{-}	0.473	**-0.588**	0.367	0.199	-0.093	0.752
F	0.112	0.115	-0.151	**0.907**	0.037	0.873
Br	**0.737**	0.064	0.418	0.408	-0.130	0.906
Fe	-0.066	-0.040	0.114	0.025	**0.965**	0.951
Mn	**0.608**	0.217	**0.553**	0.120	-0.141	0.757
Sr	**0.986**	0.016	-0.084	-0.082	-0.010	0.986
Eigenvalue	8.483	1.879	1.503	1.386	1.059	
Percent of variance	53.016	11.742	9.395	8.659	6.616	
Cumulative percent of variance	53.016	64.758	74.153	82.813	89.429	

Scenarios for distribution of different saline groundwater types in the Red River floodplain, Vietnam

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Groundwater is a key source for drinking water in the Red River floodplain, where over 16.6 million people are living. However, extensive groundwater abstractions impose a risk of altwater intrusions. In additional to that, salty paleowater is present in aquitards, which may deteriorate the water quality at the distance up to 75 kilometers from the sea.

The aim of this study is to establish a conceptual hydrogeological model for the origin and extension of fresh groundwater, salty paleo groundwater and recent salty water intrusion in the Pleistocene and Holocene aquifers in the floodplain in Vietnam. This was done with geological and hydrogeological data from 83 National Monitoring boreholes, geophysical borehole logging in 34 of these boreholes and 170 geophysical soundings using the transient electromagnetic method (TEM). The model was compared with reported water compositions from samples collected in 49 and 244 boreholes screened in Holocene and Pleistocene aquifers, respectively.

The established conceptual hydrogeological model shows that fresh groundwater (TDS < 1 g/L), salty paleowaters (1 g/L < TDS < 5 g/L) and salty water from recent intrusions (TDS > 5 g/L) occur as follows: Fresh groundwater in the Holocene aquifer presents from the northwest margin of the plain to 50-75 km down gradient the capital Hanoi (Fig. 1A). In the underlying Pleistocene aquifers, fresh water is more widespread, but this water becomes salty towards the coastline (Fig. 1B).

Salt paleowaters present in the Holocene aquifers at distances up to 50-75 km from the present coastline and its extent is primarily controlled by the spatial distribution of the Holocene marine sediments. A density driven leaching of salty porewater has occurred from high permeable Holocene sediments into underlying Pleistocene deposits, whereas in low permeable Holocene layers the main mechanism of saltwater leaching is by diffusion. In the Pleistocene aquifer, the highest content of dissolved solids is found below the two valleys with Holocene marine sediments and along the coastline. A recent intrusion of saltwater from the South Chinese Sea is observed in shallow groundwater as far inland as 35 km from the coastline. The saltwater intrusion may be caused by surface water-groundwater interactions, where salty water at the bottom of rivers affects the salinity of connected shallow aquifers.

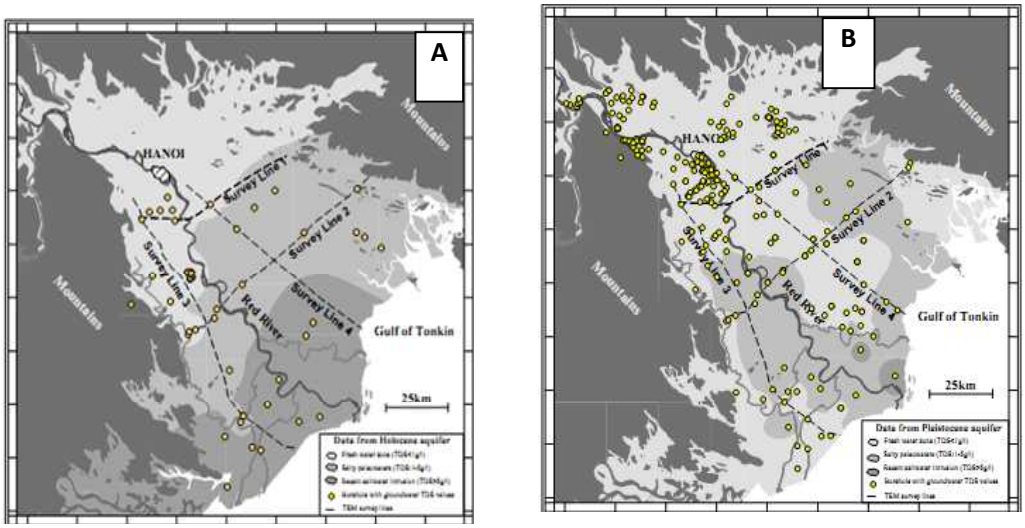

Figure 1: Maps showing the distribution of different saline groundwater types in: (A) Holocene aquifers and (B) Pleistocene aquifers

Keywords: Saltwater intrusion; Salty Paleowater; Red River floodplain; TEM

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Saltwater Intrusion and Coastal Aquifer Management at Western Big Cypress Basin, Florida

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Potential global warming and sea level rise add extra pressure for coastal aquifer management and sustainable water supply in the coastal areas. Big Cypress Basin, as part of South Florida Water management District (SFWMD), is located in the coastal area in southwest Florida, USA. Rapid increase of population in this area in the past years has put pressure on the water managers.

A variable-density flow and solute transport numerical model was developed using SEAWAT to study the potential impact due to sea level rise and increase of groundwater withdrawal in the coastal area. The model covers the western portion of the Big Cypress Basin. The model consists of 7 layers representing the Water-table aquifer, the Lower Tamiami aquifer and the Sandstone aquifer, as well the semi-confining units between these aquifers. The Lower Tamiami aquifer, the major water supply aquifer in the area, was divided into three sub model layers in order to get better vertical resolution. Transient model calibration was performed for the time periods from January 2005 to December of 2006. The results of model calibration indicates the model calculated water and water quality are in close agreement with field observed data.

After model calibration, this model was used to evaluate the potential impacts of future sea level rise and increase of pumpage of groundwater in a wellfield near coast. In the first scenario, the sea level is expected to rise 1 foot over the next twenty years at a rate of 0.1 ft every two years. The results of model simulation indicate the saltwater intrusion will occur mainly the low land area south of US-41. The encroachment of saltwater in the deeper aquifer is expected to be slower and it takes longer time for the equilibrium between the freshwater and saltwater to be established.

In the second scenario, the current pumping rate at the City of Naples Coastal Wellfield will be doubled in next twenty years. The simulation results clearly indicate that the saltwater will move landward quickly in response to the increase of groundwater withdrawals, especially at the southern end of the wellfield where the coastal ridge is absent.

Characteristics of Radon Concentration in Coastal Groundwater, Stream water, and Seawater along the Coast of Busan City, South Korea

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Groundwater that infiltrated into the recharge area outflows from the subsurface through evapotranspiration, baseflow, groundwater abstraction, and finally coastal and submarine discharges. Groundwater discharge to the sea amounts to one tens or maximum one third of the total river discharge (Duaiova et al., 2010). Radon and radium isotopes made by radioactive decay of uranium and thorium are conservative and widely used for estimating submarine groundwater discharge (SGD) (Duaiova et al., 2006). Groundwater contains a higher concentration of Rn-222 than seawater and stream water do. This study estimated Rn-222 concentration in coastal groundwater discharge (CGD), well groundwater, Ilkwang Stream water, and sea water along the eastern and southern coasts of Busan City, South Korea during the years of 2009-2011. Rn-222 concentration of the groundwater (an arithmetic mean of 17.73 Bq/L) showed ~8 times higher than that of the stream water (an arithmetic mean of 2.217 Bq/L). The Rn-222 concentration in the stream water becomes lower to downstream. The median of the radon concentration is highest in the well groundwater (18.36 Bq/L) and then the CGD (15.92 Bq/L), stream water (2.217 Bq/L), and seawater (0.030 Bq/L) in the order. This indicates that most well groundwaters have a longer pathway and a longer residence time in the subsurface than the CGD excepting a few groundwaters that showed a lower concentration of Rn-222 (<10 Bq/L) probably affected by the stream water. The relationships between radon concentration and electrical conductivity (EC) in the well groundwater, CGD, stream water, and seawater were different: (a) the CGD demonstrated two groups which represent groundwater and seawater origins, respectively, (b) the well groundwater showed a higher negative relationship between radon concentration and EC with a correlation coefficient r = -0.6554, (c) the stream water displayed almost no relationship with two groups (one group linked with fresh water and the other group connected with seawater), and (d) the seawater showed a comparatively high relationship with a rapid decrease of radon concentration relative to EC increase.

Keywords: Radon; coastal groundwater; stream water; seawater; Busan City.

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Tidal Groundwater Head Fluctuation In An Submarine Aquifer Or Aquitard

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The tide-induced groundwater head fluctuation in a submarine aquifer/aquitard with impermeable bottom is considered. The aquifer/aquitard is assumed to be directly connected with the seawater and to extend horizontally infinitely. Such a configuration is commonplace in reality (e.g., Moore, 2005). A vertically one-dimensional mathematical model is used to describe the problem.

Let the z axis be positive upwards and perpendicular to the seabed (Fig. 1). It is further assumed that the density difference between the groundwater and the seawater is negligible due to its slight impact on groundwater level fluctuation (Li and Jiao, 2001). Based on these assumptions and the theories of elastic aquifers proposed by Jacob (1950), the mathematical model to describe the groundwater fluctuations in Fig. 1 is as follows.

$$S_S \frac{\partial H}{\partial t} = K \frac{\partial^2 H}{\partial z^2} + S_S T_e \frac{dH_s}{dt}, \quad -\infty < t < +\infty, \ 0 < z < b \qquad (1)$$

$$H(b,t) = H_s(t) = A\cos(\omega t) \qquad (2)$$

$$\left.\frac{\partial H}{\partial z}\right|_{z=0} = 0 \qquad (3)$$

where $H(z, t)$, S_S, K and b are hydraulic head [L], specific storage [L^{-1}] vertical hydraulic conductivity [LT^{-1}], and thicknesses [L] of the aquifer, respectively; T_e is the tidal efficiency (dimensionless) (Jacob, 1950); $H_S(t)$ is hydraulic head of the sea tide [L]; A is the amplitude [L] of the tidal change; ω is the tidal angular velocity (or frequency) [T^{-1}]. The elevation datum is at the bottom of the aquifer.

Eq. (1) indicates that the groundwater level fluctuation in the submarine aquifer under the sea is caused by its elastic compression and expansion due to the tidal loading rate of the sea water above seabed (the term related to the tidal efficiency), in addition to the tidal fluctuation at the seabed boundary as expressed by eq. (2). Eqs. (3) states the no-flow boundary condition on the upper surface of the impermeable bottom.

The solution to the boundary value problem (1)-(3) reads

$$H(z,t) = A\,\mathrm{Re}\left\{e^{\mathrm{i}\omega t}\left[T_e + (1-T_e)\,\mathrm{sech}\left((1+\mathrm{i})ab\right)\cosh\left((1+\mathrm{i})az\right)\right]\right\},\quad 0 < z < b \qquad (4)$$

where Re denotes the real part of the followed complex expression, and the parameter *a* is the tidal wave number defined as

$$a = \sqrt{\omega S_S/(2K)}\,. \qquad (5)$$

From (4), the head at the bottom $z = 0$ is

$$H(z=0,t) = A\,\mathrm{Re}\left\{e^{\mathrm{i}\omega t}\left[T_e + (1-T_e)\,\mathrm{sech}\left((1+\mathrm{i})ab\right)\right]\right\} \qquad (6)$$

When *ab* tends to infinity, sech[(1+i)*ab*] tends to zero. So $H(z=0,t)$ will tend to $AT_e\cos(\omega t)$. This means that even for a very thick aquitard with very small hydraulic conductivity K (i.e., very large value of *ab*), the groundwater head at the bottom of the aquitard will not vanish due to the tidal loading effect.

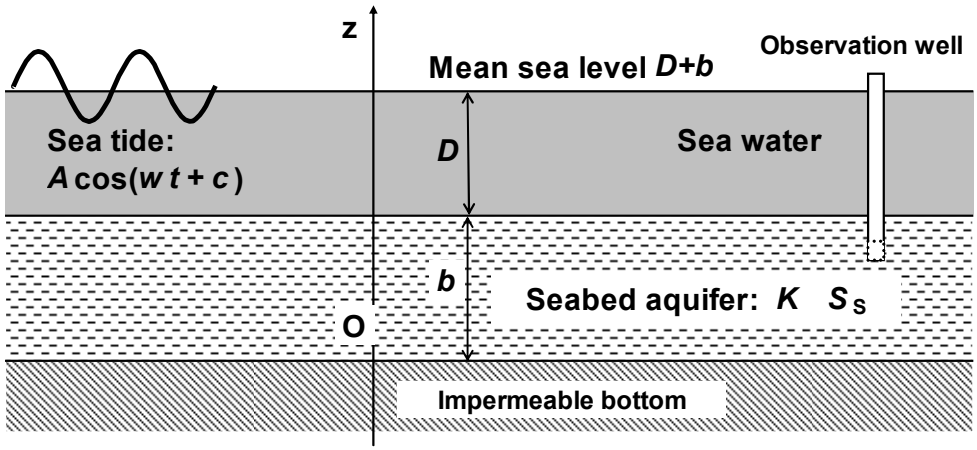

Figure 6. A submarine aquifer extending horizontally infinitely under the sea

Keywords: Submarine aquifer/aquitard; tides; groundwater head fluctuation; tidal loading; tidal efficiency.

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Estimation of the change in fresh water quantity of coastal groundwater caused by sea level rise

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Global warming is being accelerated due to the increase in global fossil fuel consumption. Sea level rise is one of the representative phenomena of climate changes caused by global warming. It may be harmful to many people who live in coastal areas and use local groundwater.

The rising trend of sea level caused by global warming is reported to be about 3 mm/year for the most recent 10 year average (IPCC, 2007). The rate of sea level rise around the Korean peninsula is reported to have been 2.30±2.22 mm/yr during the 1960-1999 period (Cho, 2002) and 2.16±1.77 mm/yr (Kim K., et. al, 2009) during the 1968-2007 period. Both of these rates are faster than the 1.8±0.5 mm/yr global average for the similar 1961-2003 period (IPCC, 2007).

In this study,we first found the most effective parameters of groundwater quantity change using an analytic methodology in order to estimate the change in fresh water quantity in coastal groundwater caused by sea level rise. From the results calculated, topographic slope and hydraulic conductivity were the most sensitive factors. In steep places where the slope is larger than 2.5 degree or so, the quantity of fresh water in a coastal area increases as sea level rises. On the other hand, when sea level drops, its quantity decreases. This is because the groundwater level also rises with sea level rise in steep areas. In relatively flat places, where the slope is smaller than around 2.5 degrees, the quantity of coastal fresh water decreases when sea level rises because the area flooded by rising sea water is increased. The volume of aquifer containing fresh water in this circumstance is greatly reduced in proportion to the flooded area with sea level rising. Since relatively flat areas where the slope is less than 2.5 degree are much more common along actual coasts, the quantity of fresh groundwater in most of the coastal region will be greatly reduced with sea level rise.

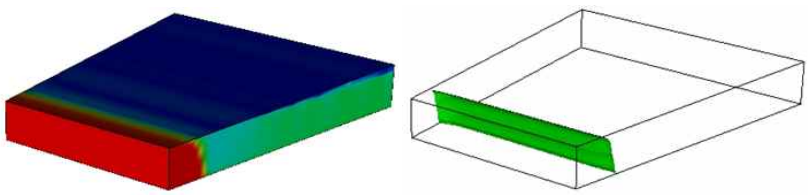

Figure 7. Groundwater salinity and seawater-freshwater interface distribution simulated with using SUTRA.

To calculate the change in groundwater quantity caused by sea level rise, a given coastal area was divided by a number of block domains. A module that can simulate the distribution of fresh-saline groundwater along the coast and calculate a change in groundwater quantity was developed by using the variable-density groundwater flow and solute or energy transport model SUTRA.

In an example domain represented in Fig. 1, which was calculated by the module developed, if sea level rises by 0.5m, the amount of freshwater is expected to decrease by roughly 8 percent in a coastal area where the elevation is lower than 10 m. This result is limited to the example case of Fig. 1. In order to apply this method to an actual site, the calculation should reflect the geologic and hydraulic characteristics of the site. This is because there is a wide range of possible values for the local slope, the depth of the domain, hydraulic conductivity, etc. Using the module developed in this study, it is expected that the change in coastal groundwater quantity with sea level rise along the coast of the Korean peninsula can be calculated in further study.

Keywords: sea level rise; groundwater quantity; climate change.

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Effect of tide-induced recirculation on saltwater intrusion in an unconfined coastal aquifer

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Studies of seawater intrusion in unconfined coastal aquifers typically assume a static seaward boundary condition defined by the mean sea level, neglecting oceanic oscillations including tides and waves. These studies have been focused on the saltwater wedge. In the presence of tidal oscillations, an additional saline water zone has been observed below the beach surface within the intertidal zone at natural coasts. The changes in sea level induced by tidal oscillations lead to changes in the hydraulic gradients, subsurface flow velocities and directions within the near-shore aquifer. In this study, a field-scale numerical model was developed to investigate the behavior of the saltwater wedge under the influence of tidal oscillations. The simulation results demonstrated that the tide-induced circulation acted as a 'recharge' into the aquifer system. The tidally induced inflow modulated significantly the extent of seawater intrusion. Neglect of such tidal influence was found to result in over-estimation the seawater intrusion and incorrect prediction of the location of fresh groundwater discharge.

Keywords: Upper saline plume; Tide; Submarine groundwater discharge; Subterranean estuary.

Change in Submarine Groundwater Discharge Rate Associated with Sea Level Fluctuation

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The time scale dependent change in submarine groundwater discharge rate associated with the periodic fluctuation of sea level was investigated by numerical analysis. Numerical code FEFLOW (Diersch, 2005) was used to evaluate the effect of sea level fluctuation on the recirculated submarine groundwater discharge rate (RSGD) with various time scales from diurnal to glacial cycle. To measure the increase of recirculated submarine groundwater discharge rate in response to the seal level fluctuation, RSC is defined as

$$RSC = RSGD(t) / RSGD(i) \times 100 \qquad (1)$$

where RSGD(i) indicates the amount of steady flux of RSGD with no periodic forcing from seabed, and RSGD(t) is the amount of RSGD considering the fluctuation of sea level. Simulation results show that the submarine groundwater discharge rate is generally proportional to the amplitude of sea level change (A) and specific storage of the aquifer (S_s), while inversely proportional to the hydraulic conductivity of the aquifer (K) and period of sea level change (P). Based on the simulation results, nondimensional number, P* was proposed to represent the increase in submarine groundwater discharge rate due to the periodic forcing of sea level.

$$P^* = \sqrt{A^2 S_s / KP} \qquad (2)$$

Figure 1 shows the relationship between P* and RSC. Overall, RSC are relatively well fitted by the simple curve when the dimensionless inland recharge rate, which divides recharge rate by hydraulic conductivity, is same. It also can be seen that, RSC begins to increase only when P* exceeds a critical number. It implies that all sea level fluctuation does not lead to the increase in RSGD rate especially when aquifer has large hydraulic conductivity or small specific storage or both. However, P^* can provide a consistent criterion whether the given hydraulic gradient change leads to the increase of RSGD or not. The differences in inland recharge rate and P^* are expected to cause the discrepancies in the effect of sea level oscillation on the increase of SGD rates.

Keywords: submarine groundwater discharge rat, FEFLOW, sea level

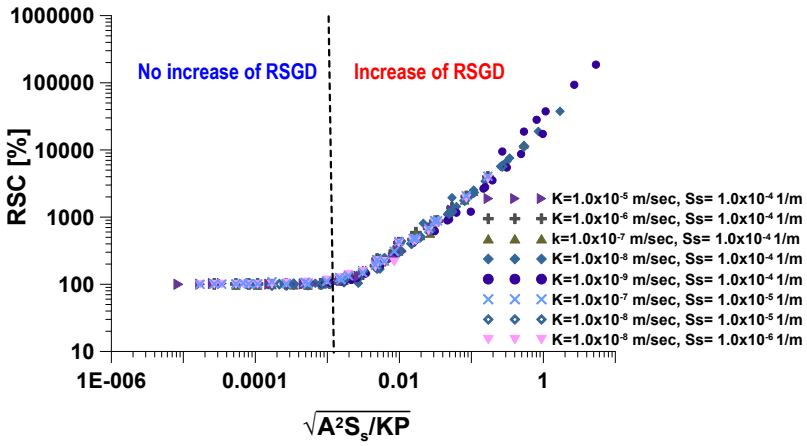

Figure 8. Theoretical relation between P* and RSC

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Preliminary Design of An ASTR System in a Coastal Aquifer

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Aquifer storage, transfer and recovery (ASTR) method may be used to augment groundwater resources. The method involves artificial injection, flow through aquifer and pumping. The ASTR method differs from the aquifer storage and recovery (ASR) method in that the former method uses different wells for injection and recovery wells whereas the latter method uses the same well for injection and recovery. Advantages of the ASTR method over the ASR method include: the former method may allow more control of injected water and may provide recovery water of more uniform age compared to the latter method.

An ASTR system is proposed at a large delta area developed near the estuary of Nakdong River in Southeastern Korea. The delta expands over 100km^2 of area, and the thickness of alluvium layers ranges between 70~100m thick. The alluvium contains alternating layers of clay and sand/gravel. There are two major aquifer layers of sand and gravel. The upper layer is confined from below and from above with clay layers. The lower confined sand/aquifer layer is bound from above by a clay layer and lies over bedrock. The top portion of the bedrock is severely weathered, but the extent of weathering in the vertical direction is not known at this moment. The alluvium layers contain groundwater of high salinity; the electric conductivity is around 10 milliS/cm.

In this study a pilot ASTR system is being planned to investigate the feasibility of the method. The target capacity of the pilot system is 3,000m^3/d. In addition, a large volume of potable groundwater stored in the aquifer is also sought. In this presentation approaches and results of a preliminary design of the pilot ASTR system are introduced.

Keywords: ASTR, brackish aquifer, design

Impacts of spatial distribution and land use/cover change in future on the potentials of surface runoff and groundwater in coastal region
Case study: Nakdong River Basin in Korea

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Abstract: Groundwater and surface water resource are important issues for water supply, and water resources management in region. Recent, groundwater table depth and surface runoff oscillation over time are significantly affecting on human activities by land use/cover change, which is a major issue of hydrological process changes. There are many causes of land use/cover change, one of the main factors were indicated by the combination of rapid population growth coupled with industrial and urban development and their impacts on disaster and water balance are the most vigorous research in the international hydrological fields. The Nakdong river basin was not out of these effects, which influenced by above variability and its impacts directly influenced to potentials of hydrology regime as surface runoff and groundwater in region. The objective of this study to investigate how to assess the potentials of surface runoff and groundwater will be affected by spatial distribution and land use/cover changes scenarios in the future with combination of land use model and a hydrologic model.

Two models as CA-Markov model and SWAT (the Soil and Water Assessment Tools) model were used integrated to achieve the goal of study. After the SWAT model set up which was calibrated and validated with observation using monthly streamflow for the period (1995-2004) and (2005-2009) respectively. Then based on the regression statistical as Nash-sutcliffe coefficient (E_{NS}), the Coefficient of determination (R^2) values were evaluated for model, and the results showed that except several years which simulated peaks are greater than observed ones, most of the years have a very good agreement between the simulated and observed streamflow. In particular, the low flow was simulated very well. The validation period statistics were stronger than those computed for the calibration period (validation R^2 and E_{NS} values of 0.90 and 0.81 while values of 0.82 and 0.76 for the calibration period). Then future land use scenarios for the year 2020, 2050, 2080 are forecasted using the CA-Markov model based on the land use of history from 1980 and 2000. Finally, the calibrated SWAT model was used to simulate groundwater depth and surface runoff by climate data during of (1995-2010) under different land use/cover change of baseline year 2000 and future land use/cover scenarios in the watershed.

Results determined that under spatial distribution and land use/cover change scenarios in future were influenced by significantly increasing on surface runoff while reduced on the groundwater depths. In addition, results also indicated under different characteristic spatial distribution in urban area growth rate are also different effects on surface runoff and groundwater in each sub-basin in region.

In this study, the results showed the effects of spatial distribution and land use/cover change on the potentials of surface runoff and groundwater depths and their impacts on hydrologic process as showed more extreme events of disaster as flood in summer season, drought in winter season in future. In addition, research can provide new method and useful support for the sustainable water resources management strategies and policy in this study area.

Key words: Surface runoff, groundwater, land use change, streamflow, SWAT model, CA_Markov.

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Multipurpose Underground Dam

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An underground dam was constructed as a mean to store water underground since the ancient times in the Roman Empire and in North Africa [1]. Simple underground dams with similar purposes to the old times were subsequently constructed in many countries, for example India [2], Brazil [3] and Somaliland [4]. More elaborate underground dams were constructed in Korea [5] and Japan [6] for water supply. In China, the average depth of 26.7 m underground dam with the 5,842 m long of concrete wall was utilized mainly as a protection of the sea water intrusion [7]. Nakakima subsurface dam in Japan was constructed for both goals; the water supply and the defense against the saltwater intrusion. [8].

An underground dam is an important water management tool used to mitigate drought and saltwater intrusion problems in semi-arid or coastal areas. Compared to surface-water dams, an underground dam can also be used for multiple purposes. A surface-water dam may not be feasible due to insufficient land area for islands experiencing shortage of fresh water, floods and saltwater intrusions. An underground dam can be used to alleviate these problems. In this study, a combination of aquifer storage and recovery along with an underground dam was proposed to achieve the objectives of increased fresh water availability, saltwater intrusion prevention and flood alleviation.

Among these objectives, the flood control has posed a challenge. Storage of flood water underground would have been ideal. However, forcing all flood water underground within a short time span is difficult. Normally, a retention pond should serve as pre-storage before the aquifer storage action actually proceeds. Again, a vast surface reservoir is needed, but may not be suitable given the insufficient land availability. Therefore, a network of lateral perforated pipes connected from the river bed and along side of the road to the underground reservoir was proposed. The effectiveness of the perforated pipe network in recharging groundwater and in reducing flood discharge was evaluated as part of the storm water management system in Canada [9]. In their 20-year performance evaluation of this system, it showed that peak flows from the outlet of the perforated pipe were 14 to 53% of those of the conventional drainage system. The total runoff volumes were only 14 to 27% of those for conventional systems. It implied that part of the water was in fact recharged to the groundwater. From video inspections inside the pipe, it found no evidence of collapse or signs of tree-root intrusion. Some debris was observed in the pipe.

Using perforated pipes to recharge the aquifer has advantages over a pumping system because there is only the construction cost without the operating expense and the recharge area would be

widespread. However precautionary measures should be taken while using this method since the water quality in the rivers should meet groundwater standards. In summary, an underground dam has already proven to be an excellent solution to the water supply and the saltwater intrusion problems. The additional feature of flood alleviation would serve as a great source of groundwater recharge to the aquifer, making the combination of an underground dam and aquifer storage and recovery a plausible solution to other parts of the world with similar problems.

Keyword: Underground dam, Aquifer storage and recovery

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Hydrochemistry Characteristics of the Langat River Estuary, Selangor (Malaysia)

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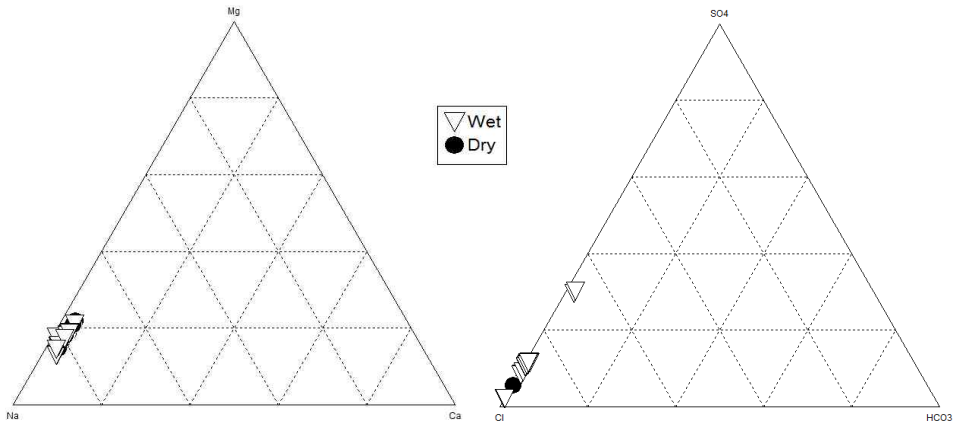
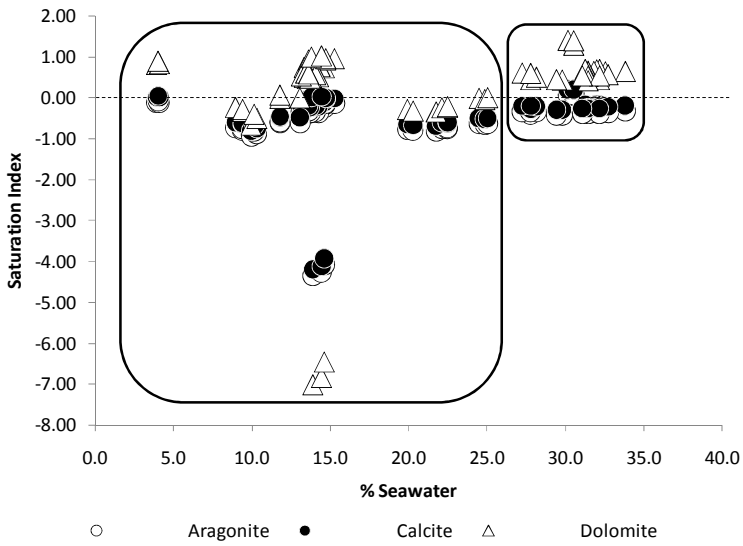
Estuary is important assets based on their immense biological diversity and subject to high demand for a variety of uses. The hydrochemical characteristics and constituents' variation were assessed. Major ions chemistry (bicarbonate (HCO_3), chloride (Cl), sulphate (SO_4), nitrate (NO_3), calcium (Ca), sodium (Na), potassium (K), magnesium (Mg)) and physico-chemical parameters (dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), salinity, redox potential (Eh) and pH) in the river water derived from the estuary in Langat River were investigated in the present study The factors that influenced the ionic composition of the water samples were also determined. Twelve sampling stations were chosen and the study was conducted on both wet and dry seasons. The water samples analyzed have relatively high concentration values in EC, TDS, Na, Mg and Cl, which are the common indicators for the seawater influence. The major ions chemistry of Langat River in the study area were dominated by Na > Mg > Ca for cations and Cl > SO_4 > HCO_3 for anions. The water type for samples from the stations at Langat estuary was known as Na-Cl water type. Simple statistical analysis and ternary diagrams were presented to illustrate the major ion constituent and their differences in water chemistry between seasons and stations. The results revealed that the Langat River estuary which affected by the seawater intrusion had impact toward the study area and it may be of a public health concern in the area.

Keywords: Estuary, hydrochemistry characteristics, seawater intrusion



Figure#: Ternary diagram for major ions in Langat River estuary



Figure#: Distribution of saturation index for aragonite, calcite and dolomite in 12 sampling stations at Langat River estuary for dry and wet season

Withdrawn

Assessment of seawater intrusion at an ex-promontory land, Langat Basin Malaysia

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Freshwater lens in the island may easily be influenced by seawater intrusion due to shoreline physical changes on an island of coastal-area. The present study is concerned with using a two-dimensional geo-electrical method for studying the effect of seawater intrusion to freshwater lens morphology and distribution due to large-scale deforestation of mangrove areas that lead to severe coastal erosion at the ex-promontory land, Carey Island area in Malaysia. Earth resistivity was measured by ABEM Terrameter SAS4000 and ES10-64 electrode selector. The relationship between earth resistivity and total dissolved solids (TDS) was derived, and with resistivity images, used to identify water types (fresh, brackish and saline). The contour resistivity maps results show that the area facing severe erosion exhibits thinned freshwater lens ranging from 5 to 10 m compared to the area still intact with the mangrove area, with the thickest freshwater at about 40m (Figures 1 and 2). Estuarine, main canal and drains also affected the salinity of shallow subsurface at depths of 2.5m to 5m (Figure1). The results therefore suggest that the seawater more effectively intruded at barren and open areas such as the erosion area and the hydraulic structure for agriculture, respectively, rather than the area still intact with natural mangrove habitat. The findings of this study are particularly useful for understanding the freshwater lens condition for domestic and agriculture water supply status at a limited recharge area.

Keywords: Freshwater lens · severe erosion · morphology · seawater intrusion · 2-D geo-electrical method

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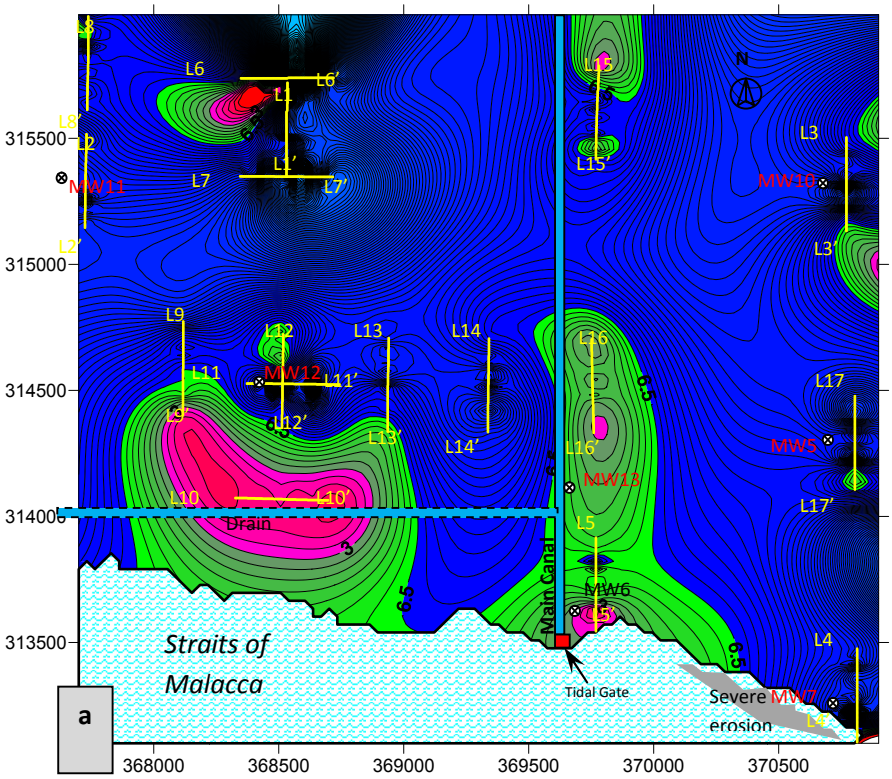

Figure 1: Contour maps of electrical resistivity at depth 5.0m. The freshwater lens (blue) covers about 60%-70% of the study area

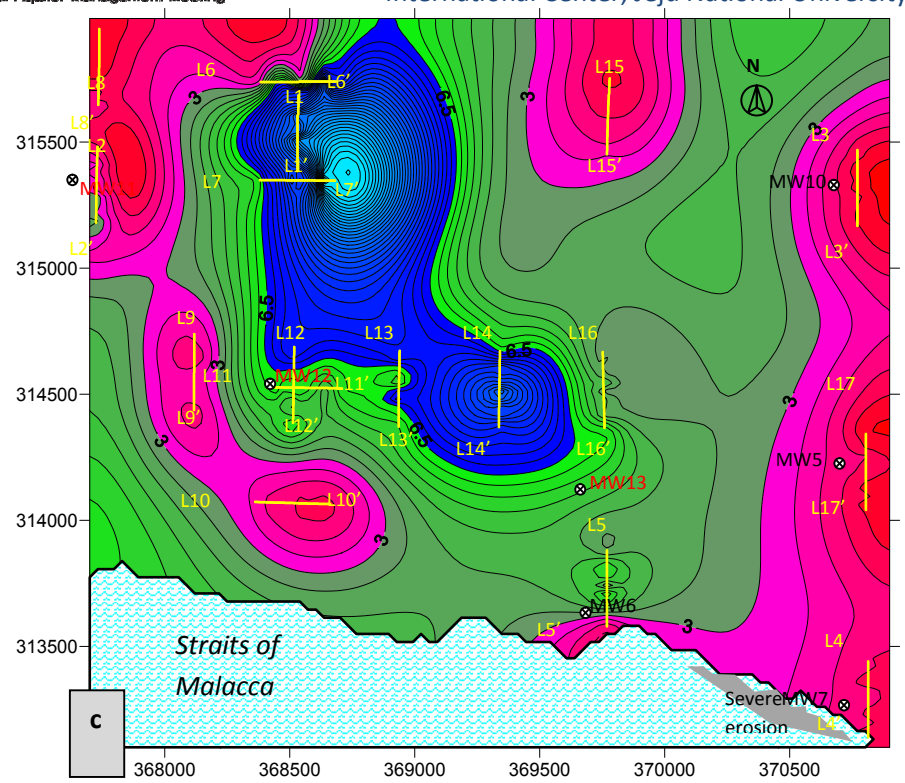

Figure 2: The brackish (green) and saline (red) water covers about 60% and 70% at depth of 20.0m

The Application of Poroelastic Theory to Monitor the Use of Soil and Water Resources

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The change of dynamic earth system and the overuse of resources cause significant impacts on the environment and ecology. For example, result in the rise of sea level due to global warming to reduce the availability of land resources. Another example is the excessive use of groundwater to cause land subsidence and seawater intrusion. Utilizing scientific methods is useful and challenge for the reduction of environmental impacts from the resource interactions. Poroelastic theory is a well constructed physical model, which uses displacement and change in pore water pressure as the variables to explain the coupled behavior between soil deformation and water flow. In this study, analytical solutions of poroelastic theory subjected to different boundary conditions were derived. Changes in pore water pressure and displacement were analyzed under pumping and injection conditions. The results show that subsidence caused by the drainage at lower boundary is significant when compared to the top of the load. In the injection case, a balance point exists for the interaction of the loading at top and injection at bottom. Poroelastic theory was shown to be a useful tool for monitoring the use of soil and water resources. It can be applied to environmental monitoring, such as carbon dioxide geological sequestration and land subsidence control.

A New Solution for Constant-head Test in a Leaky Aquifer with a Finite-thickness Skin

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Abstract: Constant-head test is commonly used for aquifer parameters estimation in groundwater hydrology. A mathematical model for a constant-head test in leaky aquifers with a finite-thickness skin was developed in this study. Three different aquifer-aquitard systems were considered and the corresponding Laplace-domain solutions were obtained and then inversed numerically to the time-domain solution with the Stehfest method. The well discharge was analysed for different cases and a sensitivity analysis was also performed. The results indicated that the dimensionless transmissivity of the aquitards has little effect on the well discharge at early times; while a larger transmissivity of the aquitard leads to a larger well discharge at late times. The well discharge for the positive skin is smaller than that without the skin, while the well discharge for the negative skin is larger than that without the skin, where positive or negative skins refers to the cases in which the permeability values of the skin zones are less or greater than that of the formation zone, respectively. A larger skin thickness results in a smaller well discharge for the positive skin case but leads to a larger well discharge for the negative skin case at late times. It was also found that the drawdown for the positive skin case is less than that of the negative skin at the same time, and a positive skin might result in a delayed response of the aquifer to pumping. The sensitivity analysis indicated that the well discharge is sensitive to the properties of the skin zone, not sensitive to the properties of the aquitards.

Key words: constant-head test; skin effect; leaky aquifer; Laplace transform; sensitivity analysis

Effectiveness of Underground Dams in Coastal Area of Shandong Peninsula, China

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Seawater intrusion problems have been caused by over-exploitation of unconsolidated alluvial aquifers in the vicinity of several streams near the coast of Shandong Province. To address this problem by increasing groundwater storage six underground dams have been built. These consist of grout walls beneath surface water dams that extend out into adjacent valley alluvium from above sea level down to the underlying hard rock basement, creating underground reservoirs protected from seawater ingress. This paper analyses characteristics of six dam sites in Shandong Peninsula, including topography, geology, hydrology, hydrogeology, main groundwater source types and distribution, as well as their effectiveness and techniques that have been used to enhance recharge due to accumulation of clay and silt upstream of dams. . Site selection principles and construction technology in building complete bidirectional cut-off walls are discussed.

In order to solve the problem of low leakage rates in natural beds of ephemeral rivers due to the relatively short period of time in the flood season compounded by surface layers of clay, a combination of surface water impoundments and aquifer recharge enhancement projects were selected and the effect on quantity of recharge was observed using wells. Comparing observational data before and after the construction of a cut-off wall, the changes in groundwater recharge and discharge as well as changes in groundwater quality were analyzed, and a numerical model was calibrated to simulate the observed effects and help inform management of the recharge enhancement. The underground barriers have been proven to play important roles in increasing groundwater supplies and preventing sea water intrusion. However they have not been able to solve all the problems of groundwater quality protection upgradient of the dam and exacerbated problems on the downstream side. Finally, social, environmental and economic benefits of the construction of underground dams were evaluated, occurred problems of underground barrier were summed up; and measures of protecting groundwater sources of supplies and improving groundwater quality in the reservoir area were proposed.

Keywords: Coastal plain; Underground reservoir; Managed aquifer recharge.

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Social Dimensions of Climate Change : A case study from India

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Global warming is here to stay. No one can deny it any longer. Climate Change is most talked about subject all over the world including India. Changes in the global climate can have national and global implications, particularly on environmental and economic structures. Rising sea levels, desertification, extreme storms, loss of farmland and food sources and salinization of fresh water etc. Six per cent, or 63.2 million, of India's population live in low elevation coastal zones that are vulnerable to sea-level rise. The Sundarbans, a vast tract of forest and saltwater swamp forming the lower part of the Ganges Delta, extending about 260 km along the Bay of Bengal from the Hooghly River Estuary (India) to the Meghna River Estuary in Bangladesh, is part of the world's largest delta formed from the sediments deposited by three great rivers, Ganges, Brahmaputra and Meghna. The whole tract reaches inland for 100-130 km. Along the coast the forest passes into a mangrove swamp which is one of the most unique ecosystems in this part of the world. Sunderban covers an area of 4262 Km^2 in India. The core area is 1330 Km^2 and is a national forest and UNESCO world heritage site. Mangrove forests not only act as a barrier against tsunamis, cyclones and hurricanes, but also provide society with a range of other 'ecological services' such as preventing coastal erosion, protecting coral reefs from silting up, and providing a source of timber, food and traditional medicines. This unique coastal tropical forests are among the most threatened habitats in the world. Mangrove forest in Sunderban delta is declining at an alarming rate-possibly even more rapidly than inland tropical forests. On one hand, it is due to Global Warming, because of which the Himalayan glaciers are retreating affecting six per cent, of India's population who lives in low elevation coastal zones that are vulnerable to sea-level rise. The Intergovernmental Panel on Climate Change says the rate of warming was quite high during 1993-2007. Two islands of Sunderban delta have already vanished from the map, displacing 7000 people. Twelve more islands are likely to go under owing to an annual 3.14 sea level rise, which will make 70,000 refugees. Five villages in Orissa's Bhitarkanika National Park, famous for the mass nesting of Olive Ridley turtles, have been submerged, and 18 others are likely to go under. On the Gujarat coast, sea level rise is displacing villages, as it is many more places along India's 7,500 km-long coastline. The expected danger of the melting down the glaciers is the widespread flooding followed by irreversible droughts, threatening the livelihood of millions of people. It is anticipated that due to existing pattern of climate change low-lying lands of the country would further go under water within the next 50 years. The climate pattern change is bringing in the variability in monsoon and seasonal rainfall is leading to 10-40% fall in agricultural food production as the water balance is disrupted leading to droughts in traditionally fertile zones. This would not only mean

unprecedented food shortage but also a massive water crisis. Also an increase in global temperature will likely enhance the ability for severe weather, which could mean stronger and more frequent storms. Warmer temperatures cause more evaporation of water, which, as part of the water cycle eventually leads to increased precipitation and further increasing the potential for flooding.

However, India as one of the major economy in the world cannot abdicate its responsibility in fighting global warming and, therefore, following the mitigation measures such as - Energy efficiency improvement and energy conservation ; Promotion of renewable energy - Setting a goal of using renewable energy for 10% of new power generating capacity by 2010 ; Transportation - Reduction of vehicular air pollution by converting from gasoline and diesel to compressed natural gas (CNG) and use of bio-diesel ; Carbon sequestration - Afforestation policy is planned to increase from existing 23 % to 33 % by 2012 ; Technology initiatives - Coal gasification, beneficiation and liquefaction for value addition to domestic coal, and recovery of coal bed methane ; Nuclear energy – it emits no CO_2, though the dangers of radioactive waste has to be addressed. Replacing incandescent light bulbs with compact fluorescent bulbs - compact fluorescent produce the same amount of light as normal bulbs, but use about a quarter of the electricity and last ten times as long. Each switch we make helps clean the air today and curb global warming.

Keywords; saltwater swamp, delta, mangrove, global warming, mitigation measures

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Coastal Aquifer Management in South-East Asia: Recent Approaches Towards Better Water Security for Social Economic Development

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The paper provides an overview of ground water utilization in South-East Asia, including the coastal areas, with emphasis on coastal aquifer management for economic growth and urbanization. It discusses the existing persisting issues and trends in the coming years to meet the emerging challenges of water resources management. The paper also discusses possible application of recent efforts in the development of water insecurity index initiated by the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) in collaboration with other international organizations within the framework of the Asia-Pacific Water Forum for more effective policy options development and policy formulation. Within this context, a brief summary of ongoing efforts in dealing with various aspects of water security, including water supply and sanitation; food, water and energy nexus and water-related disaster reduction, will be presented within the context of regional cooperation. The paper also presents ongoing efforts of the Da Nang University to promote inter-sectoral collaboration for more effective human resources development and the formulation of integrated water security policies. Finally, the paper identifies opportunities to further strengthen intra and inter-national cooperation on this subject and outlines the plan of Da Nang University to establish an Integrated Water Security Research Center to mainstream national and international cooperation on water resources to support sustainable development in Central Part of Viet Nam as well as the country.

Keywords: water security, groundwater management, South-East Asia, socio-economic development

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Guarantee Capacity Analysis of Conventional Water Resources in Coastal area: A Case Study at Caofeidian Area in The Bohai Sea Fjord, China

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In recent years, the government of China is developing energetically economic new area in the costal areas, such as Pearl River Delta area, the Yangtze River Delta area, and Bohai sea fjord etc. Because of the large-scale urban exploitation, the requirement of water resources has a substantial increase. Therefore, geological environment problems have become increasingly prominent because of the imbalance between the water supply and demand.

In order to make reasonable use of water resources and to guide the deployment of conventional water use in economic new areas，this paper takes the Caofeidian area in the Bohai sea fjord as an example to analyze the guarantee capacity of conventional water resources for new area development. Firstly, we analyzed the impact factors of conventional water resources and constructed the evaluation index system of water resources' guarantee capacity. Secondly, we analyzed the available water resources and water consumption in Caofeidian area under the current condition. Through analogy water consumption standards of costal cities, we predicted the demand of water resources in next 10 years. Finally, we constructed the index of the guarantee capacity of water resources, analyzed guarantee capacity of water resources at present and in the next 10 years, and provided some suggestions of conventional water resources safe use.

The results indicate that : (1)In the analysis of the guarantee capacity of water resources, we should consider four indexes, i.e., water availability，population of area, industry structure and modulus of water consumption. (2)At present, the amount of available water resources in Caofeidian area is between 3.83 $\times 10^8$ $m^3$and 4.63$\times 10^8$ m^3, which mainly come from external water transfer.(3)we predicted that the demand quantity of water in the next 10 years is about 8.57$\times 10^8$ m^3. The consumption of conventional water is unsafe with the available quantity of water resources at present.(4)The main methods of solving the shortage of water resources in the future are the development of desalination，the use of recycled water and the increase of external water transfer.

The results obtained in this study will be of great use in water resources management and guaranteeing the sustain development of water resources in Caofeidian area.

Keywords: Conventional Water Resources; Guarantee Capacity; Coastal area.

Groundwater Quality Characteristics and the Potential Health Risk to Kinmen Residents

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Kinmen is located in the southwest of Mainland China and mainly has two islands, large Kinmen and Leiyu. Residents of Kinmen islands consume groundwater over the long period as surface water resources are limited. This work characterizes the groundwater quality in Kinmen using factor analysis. Salinization, redox and organic pollution factors were identified from 17 hydrochemical measurements made from 18 monitoring wells. Factor scores calculated from 18 monitoring wells were plotted spatially to illustrate the groundwater quality. Acidic and oxidizing groundwater with nitrate-N pollution was distributed primarily in the west of large Kinmen island. Saline groundwater was distributed to the northeast of large Kinmen island and in the south of Leiyu island. Organic-polluted groundwater was observed throughout Leiyu island. Groundwater is polluted with nitrate-N in the west of large Kinmen island, which supplies 50% of the domestic water used on the island. The chronic health hazard quotient (HQ) associated with the potential noncarcinogenic risk of drinking nitrate-N-polluted groundwater was assessed. The HQ was observed to be 2.74 at 95th percentile, indicating that exposure to waterborne nitrate-N poses a potential noncancer risk to the residents of the island. Corrective measures, including protecting groundwater recharge zones and reducing the amount of agricultural and non-agricultural nitrogen sources that enter the aquifer, should be implemented in the western part of large Kinmen island.

Keywords: Kinmen; groundwater quality; factor analysis; risk assessment; nitrate-N.

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