

Report as of FY2007 for 2007GU98B: "Hydrological modeling of atoll islands in the Federated States of Micronesia"

Publications

- Dissertations:
 - ◆ Bailey, Ryan T., 2008, Groundwater Resources of Atoll Islands: Observations, Modeling, and Management, Environmental Science MS Dissertation, College of Natural and Applied Sciences, University of Guam, Mangilao, 122 pp.
- Other Publications:
 - ◆ Bailey, Ryan T., 2008, Atoll Freshwater Lens Tool Spreadsheet, <http://www.weriguam.org/v2/reports.php>
- Water Resources Research Institute Reports:
 - ◆ Bailey, Ryan T., John W. Jenson, Donald H. Rubinstein, and Arne E. Olsen, 2008, Groundwater Resources of Atoll Islands: Observations, Modeling, and Management, Water & Environmental Research Institute of the Western Pacific Technical Report No 119, University of Guam, Mangilao, Guam, 84 pp.
 - ◆ Bailey, Ryan T., John W. Jenson, and Arne E. Olsen, 2008, An Atoll Freshwater Lens Algebraic Model for Groundwater Management in the Caroline Islands, Water & Environmental Research Institute of the Western Pacific Technical Report No. 120, University of Guam, Mangilao, Guam, 36 pp.

Report Follows

PROJECT SYNOPSIS REPORT

Project Title: Hydrological modeling of atoll islands in the Federated States of Micronesia (FSM)

Problem and Research Objectives

Problem

Atoll islands in the western Pacific Ocean can go for months with virtually no rain during El Nino events. Rain catchments, the normal source of fresh water, become unproductive when the rain stops. During prolonged drought, even fluid supply from coconuts, which normally provides a substantial amount of daily fluid intake for island residents, becomes unavailable as the trees cease to produce and the juice content of the fruit decreases in quantity and quality. At such times, groundwater becomes the only alternative to imported water. Because of the small size of the islands, however, even the groundwater reserve is vulnerable to exhaustion, as well as contamination, from surface sources, as well as sea water. In the absence of recharge, the lens becomes thinner, and the water eventually becomes brackish.

Island residents and FSM officials expressed their interest in gaining a working understanding of the conditions and processes that control the location, quality, and quantity of the fresh groundwater, especially during droughts. They also expressed interest in developing practical and reliable management tools that would aid in estimation and long-term planning for island water resources. The improved understanding of the FSM's atoll island aquifers, along with the recommendations for water development, use and conservation practices that have resulted from this project will enable residents and state officials to make more reliable water supply estimates and better use of atoll island groundwater for both routine and emergency supply.

Research Objectives

In response to the needs of the island residents and FSM officials as stated above, the principle objectives of the study were to:

1. Develop a practical and reliable management tool to estimate the quantity of potable groundwater during both average and drought conditions.
2. Provide training to FSM water resource managers on atoll island hydrogeology. This includes both basic principles of atoll island hydrology as well as training on the use of the afore-mentioned management tool.

Methodology

Field Work

We visited Ulithi Atoll, Yap State, FSM in January 2006 and January 2007, and Pingelap Atoll, Pohnpei State, FSM in July 2007. Well surveys were conducted on all inhabited islands of both atolls. The field team walked the entire perimeter of each island.



Numerical Simulations

Steady-state and transient numerical simulations were run for atoll island groundwater hydrology using the USGS finite-element code SUTRA (Bailey, Jenson, Rubinstein and Olsen, 2008). The steady-state simulations were run to investigate the influence of the principal climatic and geologic controls on the thickness of the freshwater lens (Figure 1). These controls included recharge rate, island width, Holocene aquifer hydraulic conductivity, Thurber Discontinuity depth, and the presence of the reef flat plate. Approximately 30-50 simulations were run to test the influence of each variable. Daily rainfall data and hourly tidal data from Yap and Pohnpei islands were used as boundary conditions in transient simulations. Data from 1997-1999 were used to investigate the influence of the 1998 drought on the thickness of the freshwater lens.

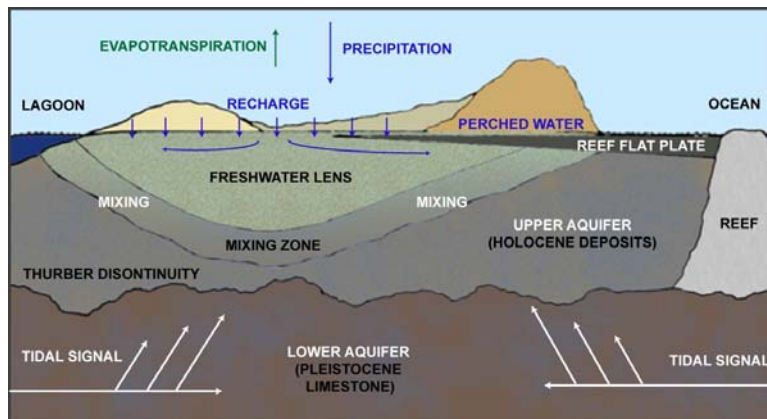


Figure 1 Conceptual Model of Atoll Island Hydrogeology, after Ayers and Vacher (1986)

Principal Findings and Significance

Insights from Field Work

A water resources survey was conducted on Ulithi Atoll (Table 1). In general, rain catchment water and coconut juice are used for drinking and cooking, while groundwater is used for washing dishes, washing clothes, and bathing.

Table 1. Water Resources Survey of Households, Falalop, Ulithi Atoll (taken August 2006)

House	Number of people	Drinking	Cooking	Wash dishes	Wash clothes	Bathing
1	3	rainwater	rainwater	well	well	well
2	4 families	rainwater	rainwater	well	well	well
3	N/A	rainwater	rainwater	well	well	well
4	11	rainwater	rainwater	Govt. well	Govt. well	Govt. well
5	5	rainwater	rainwater	well	well	well
6	N/A	rainwater	rainwater	Govt. well	Govt. well	Govt. well
7	7	rainwater	rainwater	Govt. well	Govt. well	Govt. well
8	9	rainwater	rainwater	Govt. well	Govt. well	Govt. well
9	11	rainwater	rainwater	Govt. well	Govt. well	Govt. well
10	12	rainwater	rainwater	Govt. well	Govt. well	Govt. well

Numerical Simulation Results & Development of the Algebraic Model

Using the results from the steady-state and transient numerical simulations, an algebraic model was produced which relates the thickness of the freshwater lens, in meters, to the following climatic and geologic characteristics of atoll island hydrogeology (Bailey, Jenson and Olsen, 2008):

- Annual average recharge rate (in meters per year)
- Time-variable recharge rate, through both average seasonal fluctuations and an El Nino event
- Island width (in meters)
- Holocene aquifer hydraulic conductivity (in meters per day)
- Thurber Discontinuity depth (in meters)
- Presence (or absence) of a semi-confining reef flat plate on the ocean side

This model was implemented in three ways:

1. Parameter charts, which allow for the determination of various parameters included in the algebraic model. These parameters represent island width, Holocene aquifer hydraulic conductivity, and the presence of the reef flat plate. Value for recharge rate (in meters per year) and Thurber Discontinuity depth (in meters) are input into the model directly.
2. A set of recharge curves (Figure 2), providing an estimate of the freshwater lens thickness, in meters, based on the island width and recharge rate for the island in question. These curves were produced using the algebraic model, with the Thurber Discontinuity depth set at the average depth observed in the field, and the Holocene aquifer hydraulic conductivity set at values representative of leeward and windward islands.

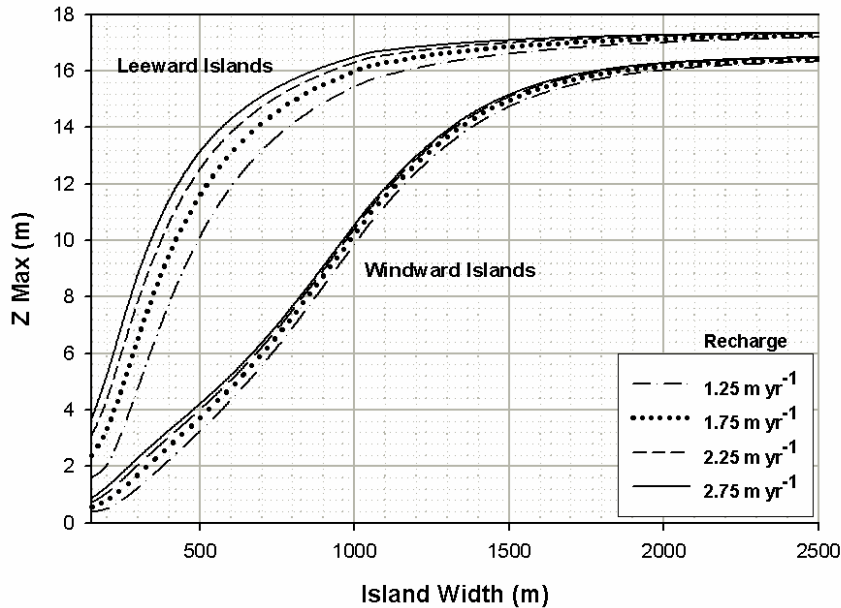


Figure 2 Recharge curves for estimating the thickness of the freshwater lens on atoll islands.

- The spreadsheet, wherein the use of the algebraic model is automated, is shown in Figure 3. The user inputs the characteristics of the island, from which the values of the parameters within the algebraic model and the resulting freshwater lens thickness are computed. This spreadsheet performs average, seasonal rainfall, and El Nino conditions.

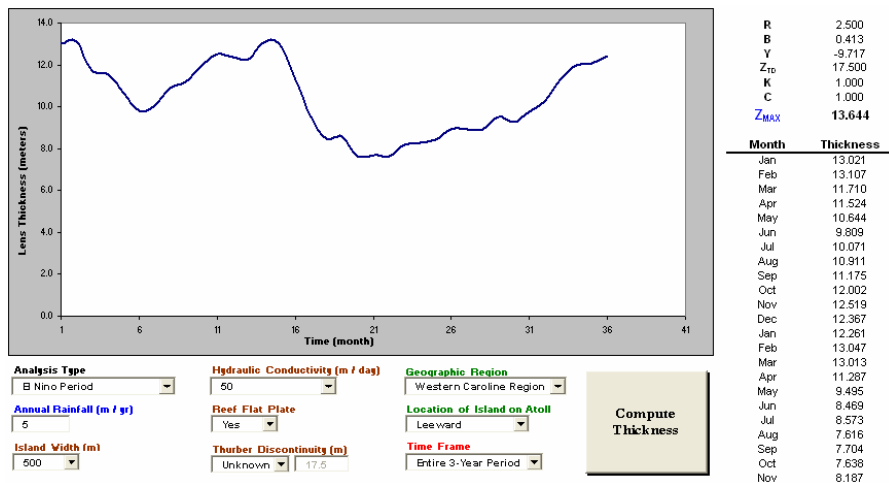


Figure 3 Spreadsheet wherein the use of the algebraic model is automated

Training sessions on Pohnpei and Yap

Training sessions and educational presentations were given on Pohnpei (16-19 April 2008) and Yap (April 30 – May 2 2008). On Pohnpei, we met with the employees of the Pohnpei

Environmental Protection Agency as well as a member from the Conservation Society of Pohnpei. The session consisted of training on basic principles of atoll island hydrogeology, followed by training on the use of the algebraic model and its three methods of implementations (see previous section). On Yap, we met with the council of outer-island chiefs (Council of Tamol) to teach basic principles of atoll island hydrology and provide suggestions on the management of atoll island water resources. Conservation of groundwater from surface contamination was stressed, as well as the development of rain catchment storage. This meeting was followed by two sessions with managers and employees from the Yap State Public Corporation Service (YSPSC) to provide training on basic principles of atoll island hydrogeology and the use of the algebraic model. These meetings were extremely fortuitous, as they dovetailed with ongoing proposals and projects featuring water resources within the Federated States of Micronesia. We also visited the Yap satellite campus of the College of Micronesia to discuss reports needed for their classes and the college library.

Two technical reports have been published. The first (Bailey et al., 2008a) summarizes the methods, results, discussion, conclusions and recommendations from the project. The second (Bailey et al., 2008b) is a user's manual for the algebraic model. Once these reports are printed they will be mailed to the government agencies and public officials of the FSM states. A short manual on water conservation on atoll islands will be in press shortly, and will be given to government agencies, public officials, and school teachers throughout FSM. This manual will provide basic understanding of atoll island hydrology and enable the residents of the atoll islands to conserve their water resources.

References

- Bailey, R.T., Jenson, J.W., Rubinstein, D.H. and Olsen, A.E., 2008a. Groundwater Resources of Atoll Islands: Observations, Modeling, and Management. *WERI Technical Report no. 119*, Water & Environmental Research Institute of the Western Pacific, University of Guam, Mangilao.
- Bailey, R.T., Jenson, J.W. and Olsen, A.E., 2008b. An Atoll Freshwater Lens Algebraic Model for Groundwater Management in the Caroline Islands. *WERI Technical Report no. 120*, Water & Environmental Research Institute of the Western Pacific, University of Guam, Mangilao.