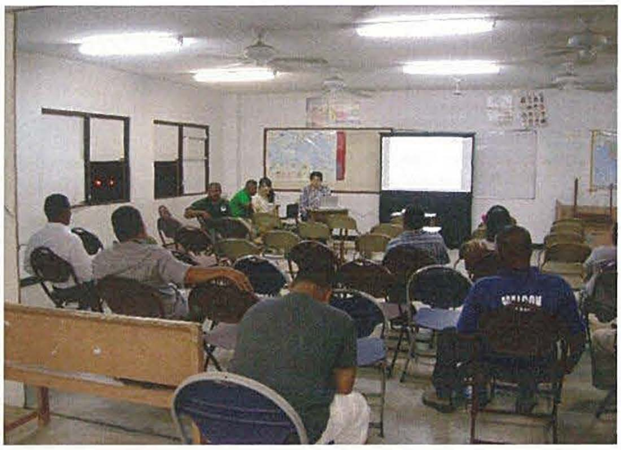
Laura Lens Conservation and Management Manual



October, 2015

JIRCAS

MRD

EPA

MWSC

Laura Island, Majuro Atoll

Summary

There are approximately 30,000 islands scattered throughout the vast Pacific Ocean, and about 1,000 of these are inhabited by humans, some of which are atolls. Atolls are small, low, flat, narrow islands, with highly water-permeable ground, thereby prohibiting the formation of rivers and lakes. On such islands, rainfall is an important source of water, and groundwater becomes an important water resource in the dry season.

Most atolls are located in a tropical or subtropical zone and experience high annual precipitation. However, the presence of El Nino can cause droughts on atolls in the Pacific region. There is also concern that climate and meteorological changes caused by global warming may expand areas of drought or cause them to shift, and such effects would be detrimental to low-latitude atolls, which depend on precipitation and groundwater for their water resources. It is therefore becoming increasingly difficult to secure water resources on atolls.

The Republic of the Marshall Islands (RMI), situated in Micronesia in Oceania, has the aforementioned problems inherent to atolls. Majuro Atoll, the capital, is inhabited by approximately half the country's population, and securing water resources is an extremely important challenge for the island. In 1998, Majuro Atoll experienced a serious drought when little rainfall was recorded for several months in the dry season, which resulted in a critical water shortage.

The freshwater lens on Laura Island is a valuable source of water for the downtown area about 50 km to the east and also for other areas of Majuro Atoll. Up-coning of the lens has now occurred as a result of excessive pumping in a drought season. Majuro Atoll needs the technology to enable as much fresh groundwater as is required to be pumped without causing up-coning, even in a drought.

In this respect, the Japan International Research Center for Agricultural Sciences (JIRCAS) has been conducting the research on the shape change of Laura lens since 2007. The report presented here outlines the research output and the groundwater observation method.

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Abbreviations

DUD	: Darrit-Uliga-Dalap
EPA	: Environmental Protection Authority
MALGOV	: Majuro Atoll Local Government
MIA	: Ministry of Internal Affairs
MRD	: Ministry of Resources Development
MWSC	: Majuro Water and Sewer Company
PALM7	: The 7th Pacific Islands Leaders Meeting
RMI	: Republic of the Marshall Islands
SPC	: Secretariat of the Pacific Community

Foreward

The *Laura Lens Conservation and Management Manual* was developed from a study of the current state of the freshwater lens on Laura Island, Majuro Atoll, Republic of the Marshall Islands. This manual describes a method for observing the shape of the upconing that has occurred in the freshwater lens; it also describes the results of observations and the results of a numerical simulation of the sustainable use of water from the lens.

The results of the study of the current state of the freshwater lens have been published every year in a seminar held in downtown Majuro. Seminar participants are informed about the current state of the freshwater lens and have developed a strong interest in changes in its shape. In past seminars, lively question and answer sessions have been held, with the participation of the Majuro Water and Sewer Company, which is in charge of water resources development, as well as representatives of SOPAC and the University of Hawaii, who came to Majuro Atoll.

A sustainable way to use the freshwater lens is yet to be achieved. I hope that the solution proposed on the basis of the results of the numerical simulation will be implemented as soon as possible.

In closing, on behalf of the Republic of the Marshall Islands, I would like to thank JIRCAS for developing this manual.

October 2015

Rebecca Lorennij, Secretary
Ministry of Resources and Development

Acknowledgement

In 2007, the Japan International Research Center for Agricultural Sciences (JIRCAS) implemented an Island Environment Conservation Project with a grant from the Ministry of Agriculture, Forestry and Fisheries. Since then, the Center has been investigating the dynamics of the freshwater lens on Laura Island, Majuro Atoll, in the Marshall Islands, as one of the Project's topics. In this topic, studies and tests are conducted to investigate the current state of the lens, and a numerical simulation is conducted to find a sustainable way to use the water.

Populations on tropical islands rely on rainwater and groundwater; they therefore have unstable water resources that are substantially affected in terms of both quality and quantity by meteorological and other conditions. Freshwater lenses on tropical islands play an important role in the stable supply of water resources. If the planned strategies prove to be effective, the sustainable use of water is expected to be useful in ensuring the supply of drinking water and stable agricultural production on tropical islands such as Laura.

This manual was developed as a final product of this project. It describes the results of a study of the current state of the freshwater lens. I hope that the manual will be useful in activities aimed at achieving the sustainable use of water from the lens through sharing of the results.

In closing, on behalf of JIRCAS, I would like to thank those in Japan and the Republic of the Marshall Islands who provided support in conducting the study of the freshwater lens.

October 2015

小林 勤

Tsutomu Kobayashi
JIRCAS Project Leader

Chapter 1 Introduction

1-1 Purpose

To promote the technology related to the use of Laura lenses to maintain or recover healthy freshwater lenses, and to contribute to the healthy economical and societal development of the Republic of the Marshall Islands etc. and the stable improvement of the quality of life of its citizens.

1-2 Definition

(1) Freshwater lens

A lens-shaped layer of fresh groundwater that floats above seawater when rainwater and seawater are in balance in an atoll island etc.

(2) Use of freshwater lens

Pumping up freshwater lenses that exist as groundwater in the Laura Island as well as other places and were formed when rainwater reached lagoons and oceans by evaporation or penetration

(3) Healthy freshwater lens

Freshwater lens in a condition such that water use and water quality/quantity are maintained appropriately based on amount of rainfall.

(4) Freshwater lens conservation and management

Healthy freshwater lenses are maintained and managed.

1-3 Basic principles

(1) Importance of use of freshwater lens

In view of the important roles played by freshwater lenses in water use, such as nurturing animals and plants of the Marshall Islands as well as contributing to the life of the citizens and industrial activities, efforts to maintain or recover the use of healthy freshwater lenses must be actively promoted.

(2) Freshwater lens as a public resource

In view of the fact that freshwater lenses are a precious public property in the Marshall Islands and are a highly valued public resource, it must be ensured that they are used appropriately and that the citizens can continue receiving the benefits of freshwater lenses in the future.

(3) Considerations for use of healthy freshwater lens

When freshwater lenses are used, it should be considered that effects on water use are avoided or minimized and the use of healthy freshwater lenses is maintained.

(4) Integrated management of the Majuro Atoll

In view of the fact that events that occur during the process of use of freshwater lenses will affect subsequent processes, the use of freshwater lenses must be managed comprehensively and integrally, not only in the Laura Island, but also downtown.

(5) International cooperation related to use of freshwater lens

In view of the fact that the maintenance or recovery of the use of healthy freshwater lenses is a common concern for the citizens of the Marshall Islands as well as for Japan and other related countries, efforts to use freshwater lenses must be promoted through international cooperation/collaboration.

Photo 1.3.1 Final manual meeting

Chapter 2 Surveys and tests needed to formulate a water utilization policy applicable to freshwater lenses

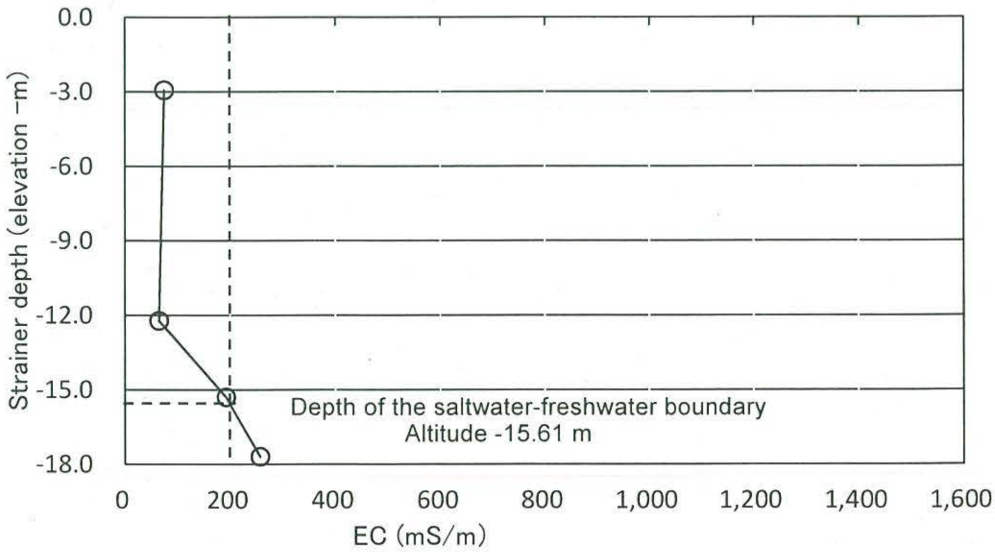
2-1 Groundwater observation

(1) Observation of electrical conductivity

Electrical conductivity is observed at strainer depth in several of the monitoring wells constructed by the United States Geological Survey in 1998. On the basis of the electrical conductivities observed at strainer depth in two of these wells, the depth at which the electrical conductivity reaches 200 mS/m is calculated by interpolation and assumed to be the depth of the saltwater–freshwater boundary of the freshwater lens. For example, Figure 2.1.1 shows the method used to obtain the depth of the saltwater–freshwater boundary of the freshwater lens on graphs depicting the depth and electrical conductivity at the two existing monitoring-well sites (No. 4 and No. 5). Figure 2.1.2 is a contour map of the depth of the saltwater–freshwater boundary of the freshwater lens on Laura Island in January 2008. The total storage volume of the freshwater lens at this time was roughly 1,800,000 t.

New monitoring wells were constructed on the same sites as the existing monitoring wells. The wells are structured in such a way that the hydraulic head and electrical conductivity can be observed at any depth. An electrical conductivity meter is used to observe the vertical distribution of the electrical conductivity. The results of groundwater observations revealed only a small change in electrical conductivity with increasing depth in the new monitoring wells. Moreover, because the time-wise fluctuations in conductivity were large, it was difficult to observe the saltwater–freshwater boundary in these wells.

In response, a double packer that blocks water by using two air tubes (on the upper and lower parts of the equipment) was developed for the new monitoring wells. Installation of a double packer can prevent saltwater intrusion from the lower part of the monitoring well. The depth of the saltwater intrusion can be identified by the changes in electrical conductivity observed at different depths in the well.



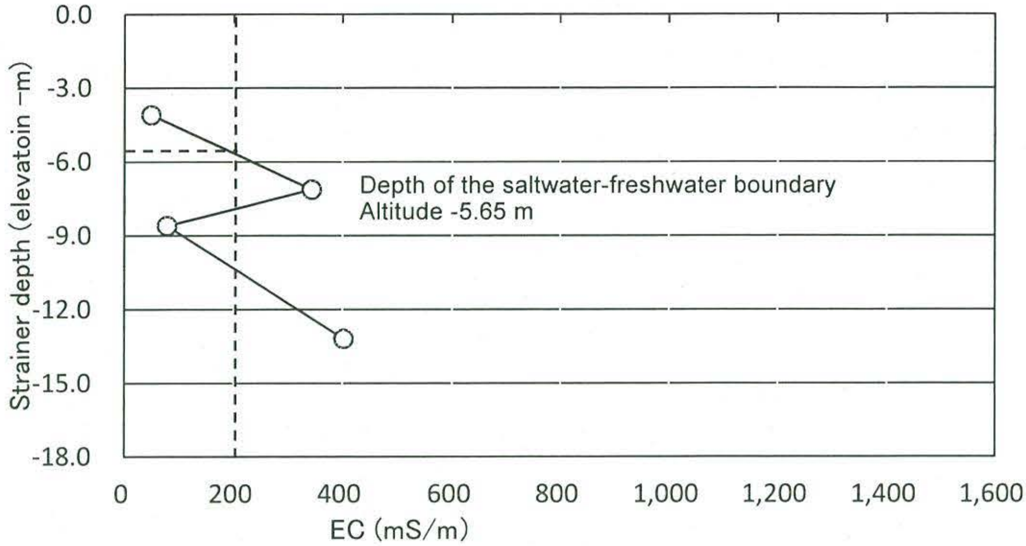


Figure 2.1.1 Strainer depths and electrical conductivities at monitoring well sites No. 4 (up) and No. 5 (down) (January 2008)

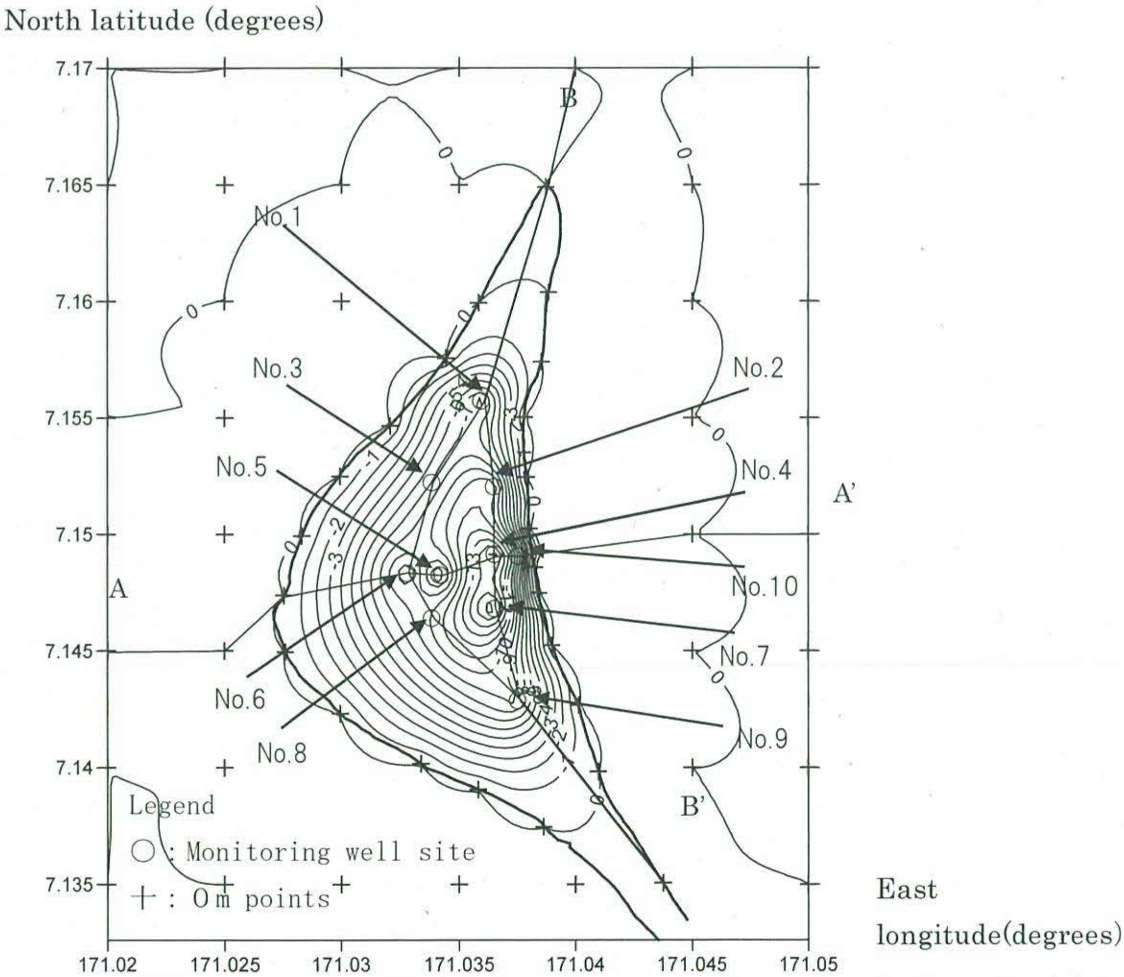


Figure 2.1.2 Contour map of the depths of the saltwater–freshwater boundary on Laura Island (January 2008)

(2) Observation of groundwater levels

Water heads are observed at strainer depth in the monitoring wells constructed by the United States Geological Survey in 1998. Groundwater flows from the monitoring wells with higher hydraulic heads to those with lower hydraulic heads. A hydraulic head contour map was created from the results of hydraulic head observations at 10 existing monitoring wells on Laura Island (Figure 2.1.3). At depths (altitudes) between –8 and –10 m on the island, higher hydraulic heads were observed on the center part of the island. Therefore, we can presume that groundwater flows from the center to the surrounding area of the island.

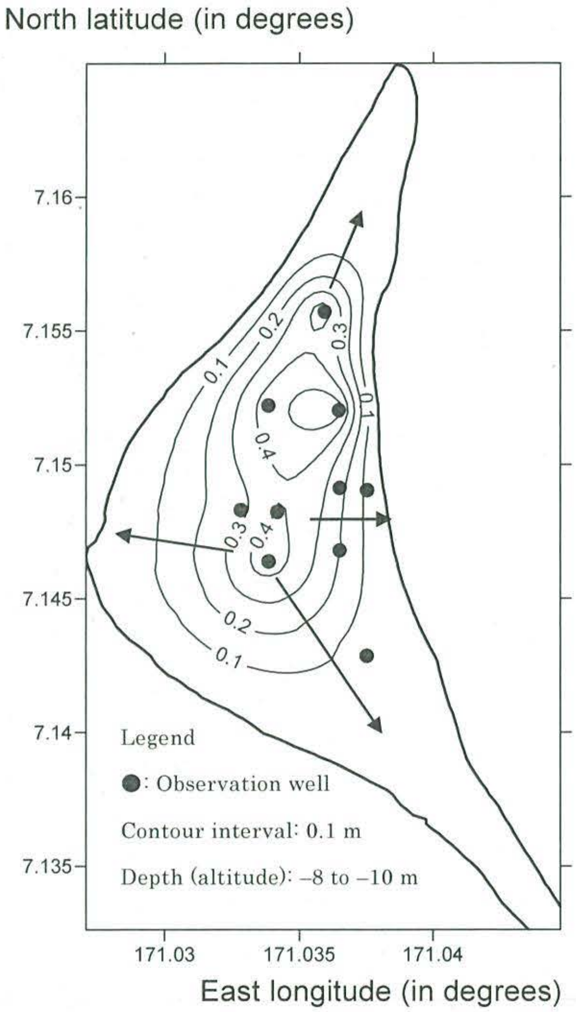


Figure 2.1.3 Water head contour map of Laura Island (April 2010)

The groundwater surface is observed in local wells in the freshwater lens. The level of the water table indicates the thickness of the freshwater lens on the surface of the sea. The water table is also observed in the new monitoring wells. A low groundwater surface, which should be consistent with the lens boundary depth, was deformed by pumpage in Laura Island (Figure 2.1.4).

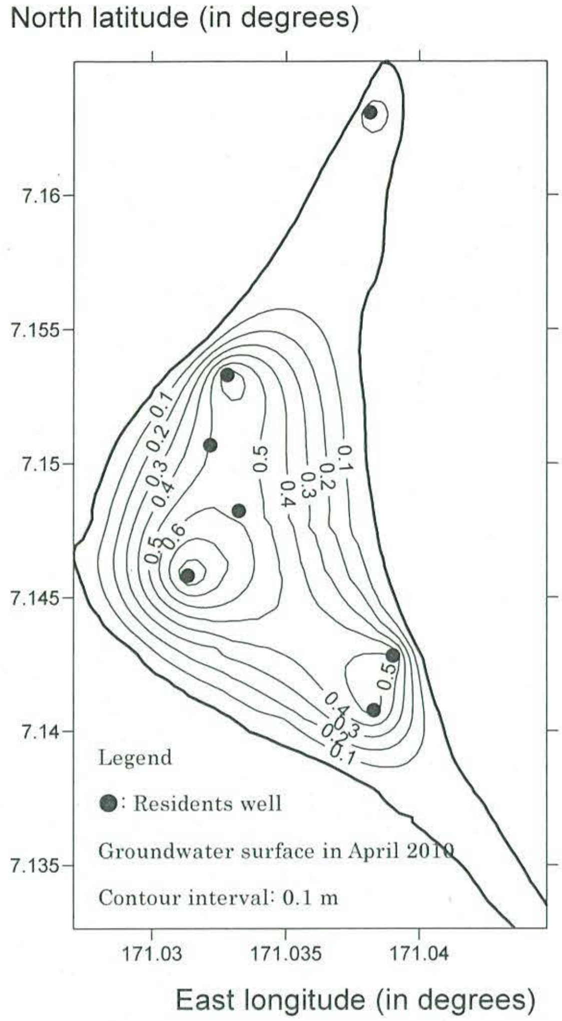


Figure 2.1.4 Groundwater surface map of Laura Island (April 2010)

2–2 Geophysical survey

Two types of geophysical survey are used: an electromagnetic and an electrical survey. In the case of the electromagnetic survey, the loop-loop method of the vertical dipole mode is used to measure the apparent conductivity of the ground by assuming that the ground consists of three layers. In the case of the electrical survey, the resistivity of the layered structure is measured by using the Wenner four-point method (Figure 2.2.1). In this method, when the survey depth increases, the distance between the electrodes also increases.

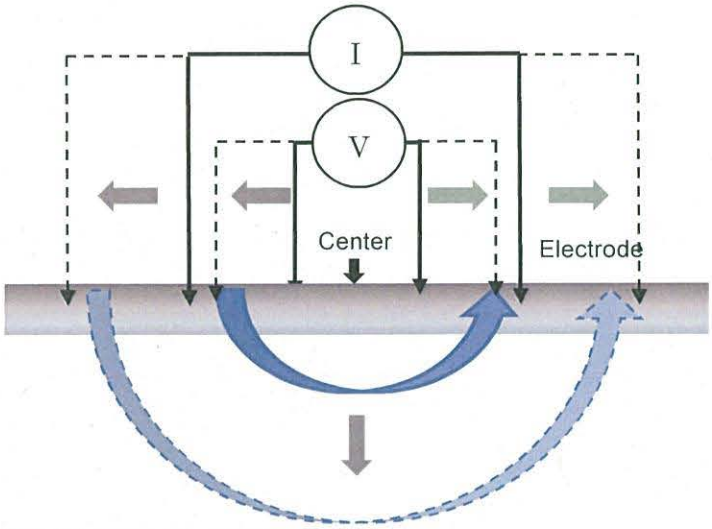


Figure 2.2.1 Wenner electrode array

The depths of the saltwater–freshwater boundary of the freshwater lens are obtained from the results of the electrical conductivity measurements performed in the existing monitoring wells. By making use of these measurement results in the geophysical survey, the cross-sectional shape of the central part of the freshwater lens can be obtained (Figure 2.2.2).

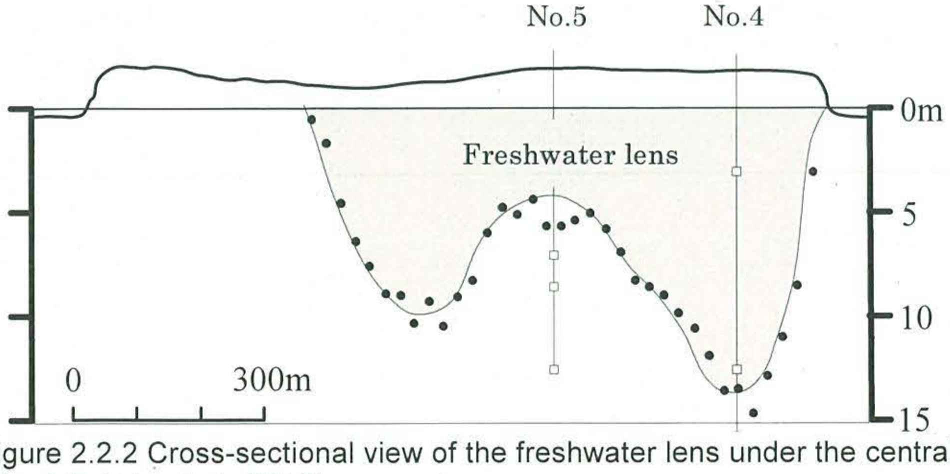


Figure 2.2.2 Cross-sectional view of the freshwater lens under the central part of Laura Island (Ishida et al., 2010)

As a result of the geophysical survey, the up-coning that was observed in 1998 was observed again in 2009, showing that it is difficult for the freshwater lens to return to its original shape.

Photo 2.2.1 Electrical survey

2–3 Pumping test

Pumping tests that change the flow rate of pumping from a well to measure time variations in the relationship between flow rate and water level are performed to obtain flow characteristic parameters. When pumping tests are performed along the seashore, a range of temporary pumping wells or monitoring wells are created so that tidal fluctuations can be taken into consideration. Whether or not the groundwater beneath the pumping test area is in an unconfined aquifer or a confined aquifer is determined on the basis of a tectonic map. AquiferTest Pro software is used to analyze the test results. If the groundwater is in an unconfined aquifer, the Boulton method is used to analyze time variations in the water level.

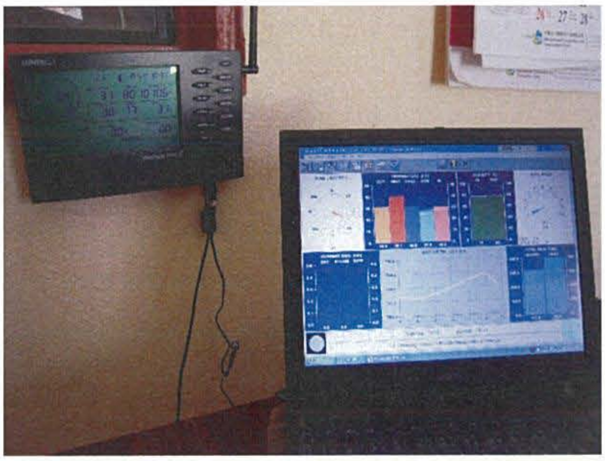
The observed data (i.e. the relationship between water level and time and electrical conductivity and time, as well as the water level corrected for tide level and time) are shown in graphic form. The relationship between electrical conductivity and the amount of water pumped is checked to confirm that an up-coning is not occurring during the pumping test. The relationship between the distance from a pumping well to a monitoring well and the equilibrium water level of the monitoring well is also checked to confirm that the influence of the water pumping reaches only to the area where the water-level monitoring wells are located.

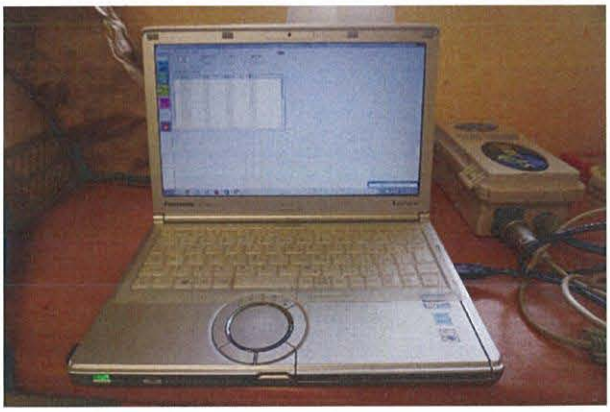
The specific production rate, coefficient of permeability, and others are calculated from the above process. The storage volume of the freshwater lens is calculated on the basis of the volume of the freshwater lens aquifer and the specific yield.

Photo 2.3.1 Pumping test performed at the time of high tide

2–4 Weather observation

Weather observation instruments are placed in the field on Laura Island to collect and organize weather observation data. The types of weather observation data collected include temperature, humidity, and precipitation. These data are saved on a recording device at a fixed time interval, for instance, precisely every hour. Roughly about four times a year, these data are downloaded on a personal computer to plot them into a graph. The observation instruments—especially those that collect the most important data of all, namely the amount of rainfall—need to be duplicated to prepare for malfunctions of the weather observation instruments. These instruments are placed in clearings at least 5 m from the nearest palm tree (Photo 2.4.1).



(Upper left) Outdoor weather observation sensor
(Upper right) Indoor weather information console
(Lower left) Rain gauge sensor
(Lower right) Data logger
Photo 2.4.1 Weather observation instruments placed in the field on Laura Island

Chapter 3 Promotion of adequate and effective use of water and preservation and management of water quality

The freshwater lens is important common property of the people of Majuro Atoll and is thus also highly public property. In light of this fact, efficient use of water and other efforts to ensure adequate and effective water use need to be promoted. In addition, restrictions and other appropriate measures need to be implemented on water uses that may affect the freshwater lens by, for example, increasing or decreasing water volume or causing a deterioration in water quality.

For sustainable use of the freshwater lens on Laura Island as a freshwater resource, it must be maintained, preserved, and passed down to the generations to come in a condition that is not only safe and secure in terms of water volume and water quality but also stable. Saltwater up-coning is the target in efforts to preserve the freshwater lens: the objective of preservation is to prevent the up-coning from reaching the shaft (see below); moreover, the saltwater–freshwater boundary is watched to preserve the freshwater lens. Creation of a pumping standard and implementation of water utilization methods such as distributed pumping (based on the pumping amount determined by numerically simulated experiments as the amount that should not cause up-coning) are recommended in this regard.

3.1 Numerical simulation

The SEAWAT model is used to perform the above-mentioned numerical simulations and to develop a preservation and management method applicable to the freshwater lens on Laura Island. The water in the freshwater lens is pumped from a shaft, which in the SEAWAT model is described as a drain. Boundary conditions, such as the non-flow boundary, groundwater recharge rate, water pumping volume, and constant head boundary, can be assigned. An area 100 m deep, 1900 m long, and 220 m wide and centered on the cross-section of the central part of Laura Island where up-coning into the freshwater lens was observed was chosen as the calculation area and subjected to spatial discretization (Figure 3.1.1). The results of the pumping tests are used to decide on the flow parameters of the strata. The flow parameters of the ocean are such that it has some flowability. Average precipitation is input to create a freshwater lens over seawater. The initial shape of this freshwater lens is almost the same as that of the freshwater lens in 1985 (the last recorded shape of the freshwater lens before the up-coning) as shown in Figure 3.1.2.

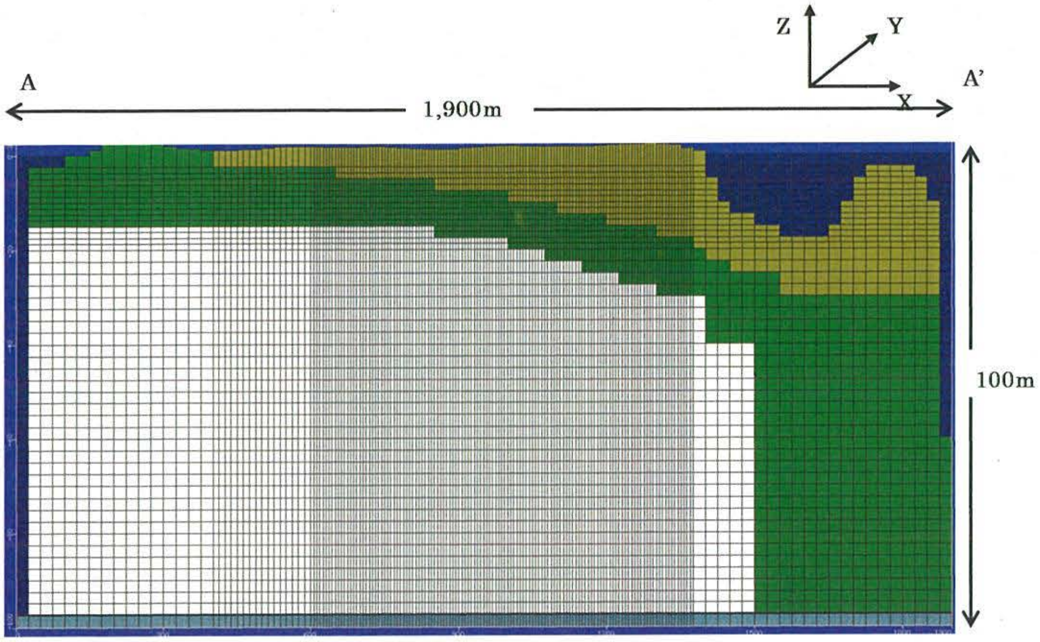
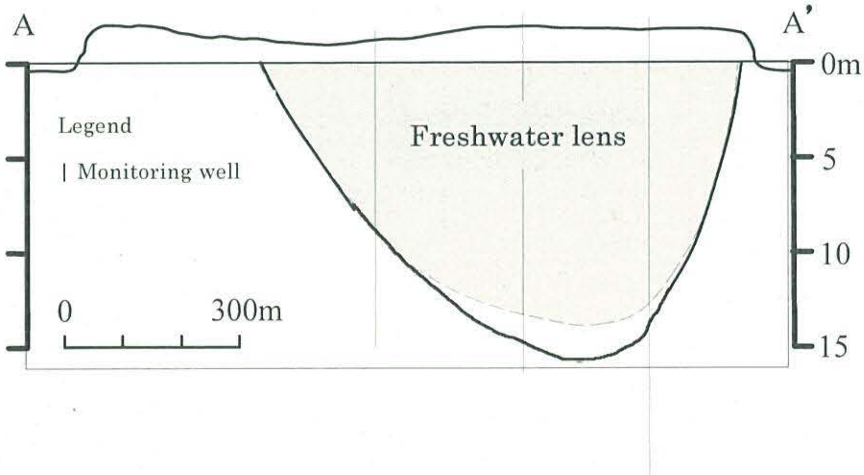


Figure 3.1.1 Spatial discretization model in Laura island



Black dash line shows the observation result of Laura lens boundary in 1985 (Presley, 2005) , and black solid line the numerical simulation result. Vertical solid line displays location and depth of observation wells. Location of A-A' is almost same as the survey line of physical prospecting.

Figure 3.1.2 Cross Sectional View of Freshwater Lens in 1985 in the central parts of Laura Island

3.2 Calculation method of a water pumping standard

To try to preserve the freshwater lens by targeting up-coning, a numerical simulation is performed to estimate the daily water-pumping volume (i.e. the output), in contrast to the groundwater recharge rate (the input), by parametrically changing the monthly precipitation and daily water-pumping volume. A safe water-pumping volume is calculated in relation to precipitation and will be the baseline for preservation of the freshwater lens. By using a linear approximation formula, the safe water-pumping volume based on a past average monthly precipitation of 271 mm was calculated and the result of 168.1 m^3/day was obtained. The average monthly daily water-pumping volume for 1998 was smaller than the safe pumping volume. Therefore, Laura Island was found to be in a critical condition in which an up-coning may occur in the freshwater lens if the monthly precipitation turns out to be even slightly lower than that in normal years but the daily water-pumping volume is not reduced accordingly. The average water-pumping volume at the time of water pumping in 1998 somewhat exceeded the safe water-pumping volume. The linear approximation formula in Figure 3.2.1 shows the safe baseline for pumping water from the freshwater lens. If the pumped volume is below the line, then the volume is on the safe side; if it is higher than the line, the volume is on the danger side.

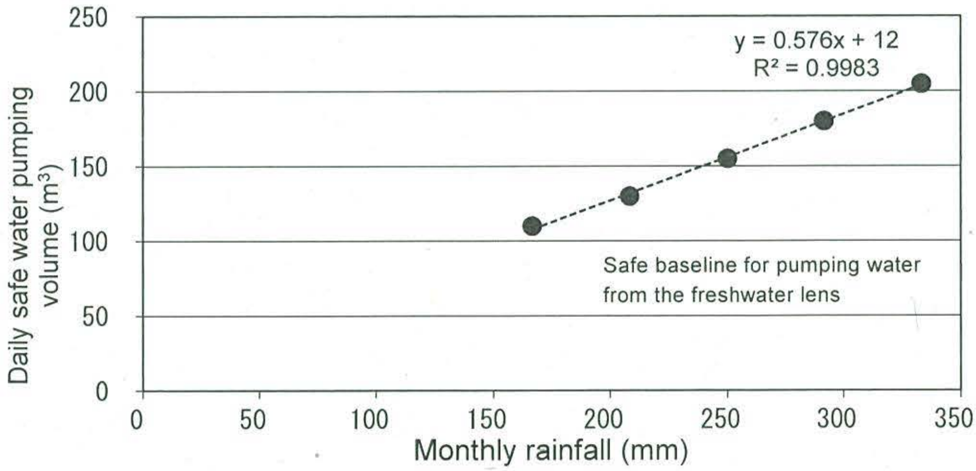
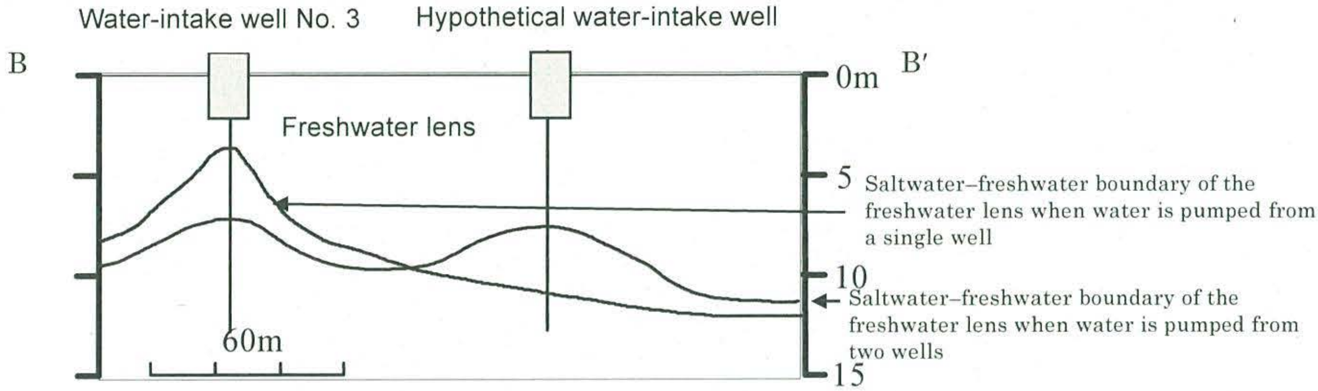


Figure 3.2.1 Monthly rainfall and daily safe water-pumping volume

3.3 Method to reduce the water pumping intensity

If one extra hypothetical water-intake well is constructed and the volume of water pumped from that well is halved to lessen the water-intake rate, then the depth of the up-coning caused by the pumping of water from that single intake well is also reduced to about half the original depth (Figure 3.3.1).



Note: B–B′ is a transverse line that passes north and south through water-intake well No. 3.

Figure 3.3.1 Saltwater–freshwater boundary of the freshwater lens when water is pumped from two intake wells

The results of the numerical simulation showed that, to preserve the freshwater lens, it is important to increase the number of water-intake wells so as to be able to reduce the pumping volume at each well. In light of this finding, the revival of abandoned wells or the creation of new wells in places where two existing wells are widely spaced is recommended (Figure 3.3.2).

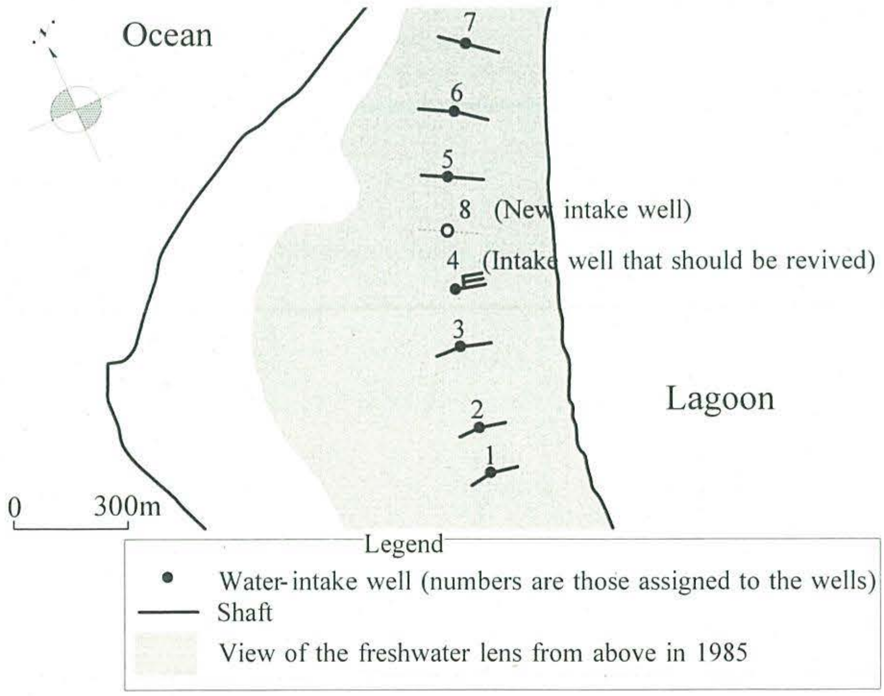


Figure 3.3.2 The new groundwater-intake system for Laura Island

Chapter 4 Conservation and Management System for Laura Lens

EPA, MWSC, MALGOV and MRD should intensely and comprehensively promote the policies relating to the Laura Lens use in the Republic of the Marshall Islands.

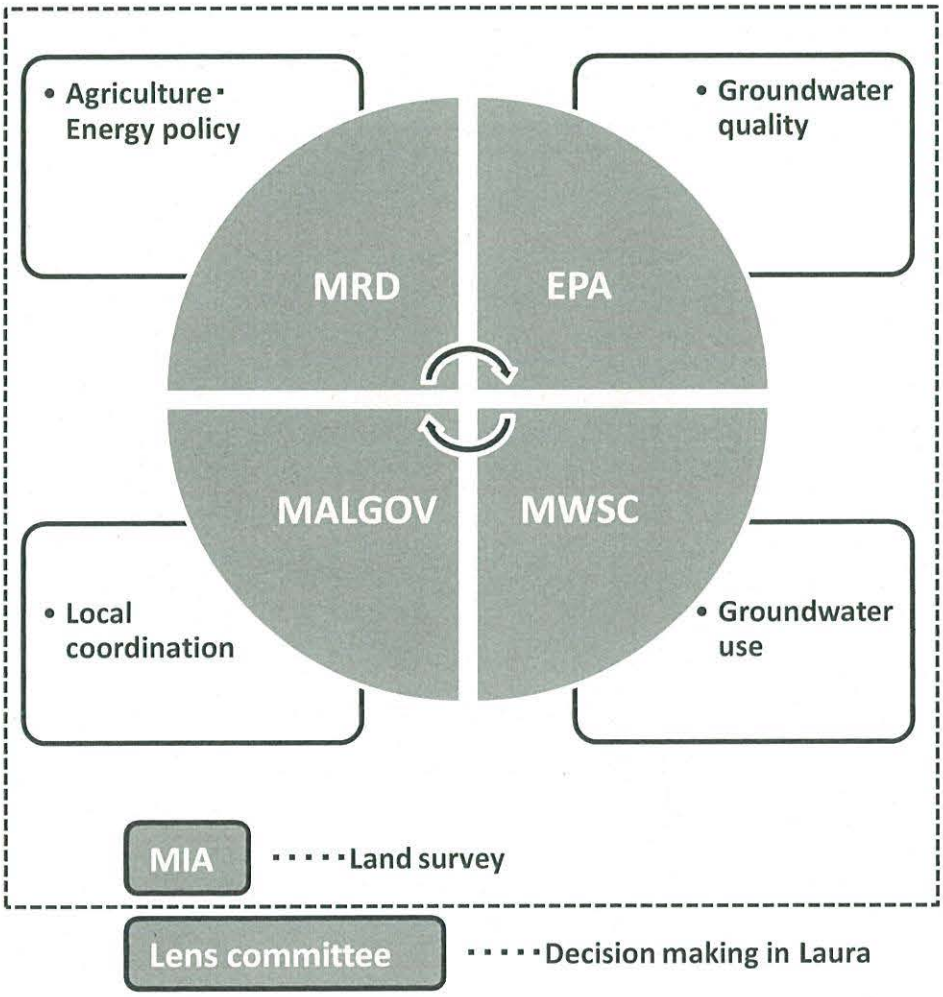


Figure 4.1.1 Conservation and Management System for Laura Lens

Appendix

Chapter 5 Maintenance and improvement of retention and recharge functions

To maintain and improve groundwater storage and recharge functions in groundwater storage areas such as freshwater lenses, JIRCAS takes measures to develop civil engineering structures capable of recharging water resources, along with other necessary measures.

5-1 Horizontal impermeable layer

Installing a horizontal impermeable layer between an intake well and the saltwater–freshwater boundary of the freshwater lens reduces vertical flow of the groundwater due to water pumping from the intake well. This delays the occurrence of up-coning. However, despite the delayed up-coning in the freshwater lens, water pumping creates horizontal flow of groundwater and consequently the freshwater lens shrinks horizontally. This causes agricultural water and water for human consumption taken from shallow wells near the intake well to be become salinized earlier than the water in the intake well. As a result, a freshwater lens that was usable before installation of the horizontal impermeable layer is likely to become unusable.

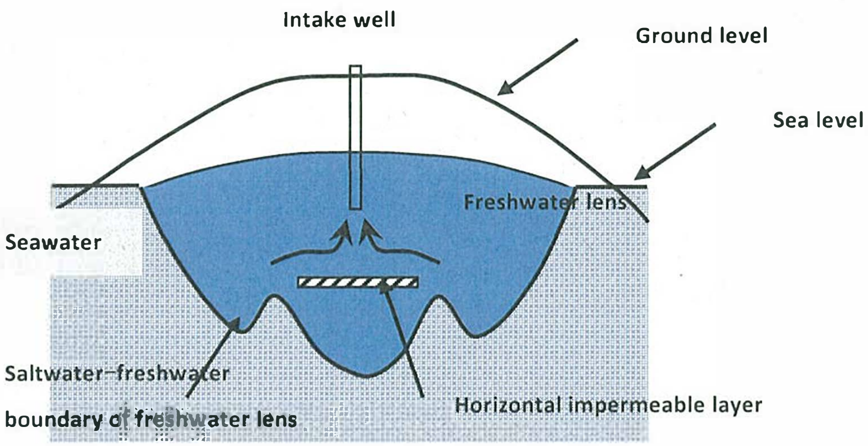


Figure 5.1.1 Conceptual diagram of a horizontal impermeable layer adapted from Masuoka and Horikoshi (2014), with revision

5-2 Vertical double water pumping

To further mitigate up-coning, vertical double water pumping was proposed by Wolthek (2013) and Masuoka, Yamamoto, and Aoki (2010). In this method, both freshwater and saltwater are simultaneously pumped, so that the saltwater–freshwater boundary of the freshwater lens is expected to rise in a shape similar to that before pumping. However, because water pumping can be achieved only under conditions of 1 atmosphere of pressure and up to about 10 m deep, this method is subject to depth restriction. Because the saltwater–freshwater boundary of the freshwater lens on Laura Island is deeper than 10 m, only the water above the boundary can be pumped. In addition, on Laura Island, which has no rivers, even if saltwater is pumped it has to be discharged back into the sea through a pipeline. To cope with these problems, sizable saltwater drainage facilities will be required. Furthermore, saltwater taken in from deep areas may form new underground water flow paths. Consequently, vertical double pumping is not suitable for mitigating up-coning in the freshwater lens on Laura Island.

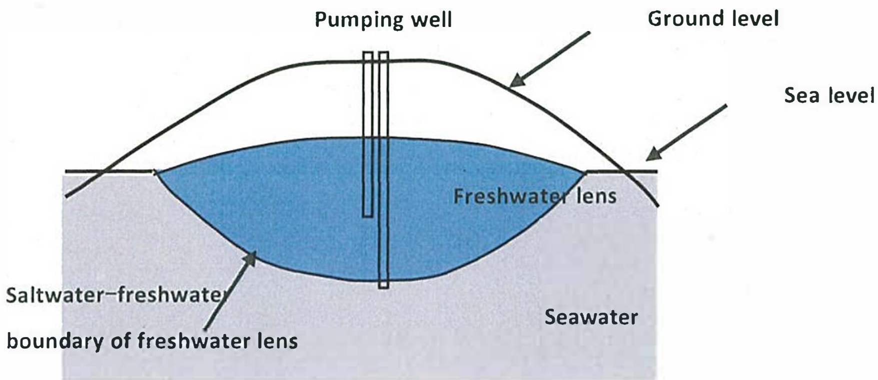


Figure 5.1.2 Conceptual diagram of vertical double pumping

5-3 Underground dam

In terms of water income and expenditure on Laura Island, the volume of recharged groundwater surpasses that of pumped water. Water-pumping from the intake well generates a water surface gradient in a concentric pattern on the groundwater surface, thus creating lateral flow of groundwater. Recharged precipitation water other than that close to the wells and the intake well flows into the ocean without being used. If an underground dam were to be constructed for efficient use of the groundwater, outflow of the freshwater into the ocean would be prevented. This would likely thicken the freshwater lens and mitigate the up-coning. An underground dam usually stores groundwater by blocking an underground valley that is composed of impermeable bedrock and sits above sea level; the dam has a cut-off wall that holds back the groundwater that would otherwise flow into the ocean. A boring survey has yet to confirm the presence of impermeable bedrock on Laura Island. This geological structure is suitable for an underground dam called a floating-type underground dam (Masuoka, Yamamoto, and Aoki: 2010). This type of dam is thus a water intake facility that increases the freshwater storage volume by placing the cut-off wall along the plane boundary of the freshwater lens. Installing a floating-type underground dam along with an intake well on the coast enables underground freshwater to be pumped before it wastefully flows into the ocean. To achieve the function of a floating-type underground dam or underground freshwater storage, the freshwater lens on Laura Island needs to be encircled by a cut-off wall. However, the underground dam that would need to be constructed along the plane boundary of the freshwater lens on Laura Island would be so sizeable that it would not be practicable. In addition, an underground dam would prevent nitrate-nitrogen derived from piggeries, chemical fertilizers, and sewage from flowing into the sea. Overall, on the one hand, an underground dam would be expected to act as a mitigation measure for up-coning, whereas on the other hand efforts to conserve the quality of water (excluding saltwater) are highly likely to be needed. Therefore, cost and water quality management would be challenges for the application of an underground dam on Laura Island.

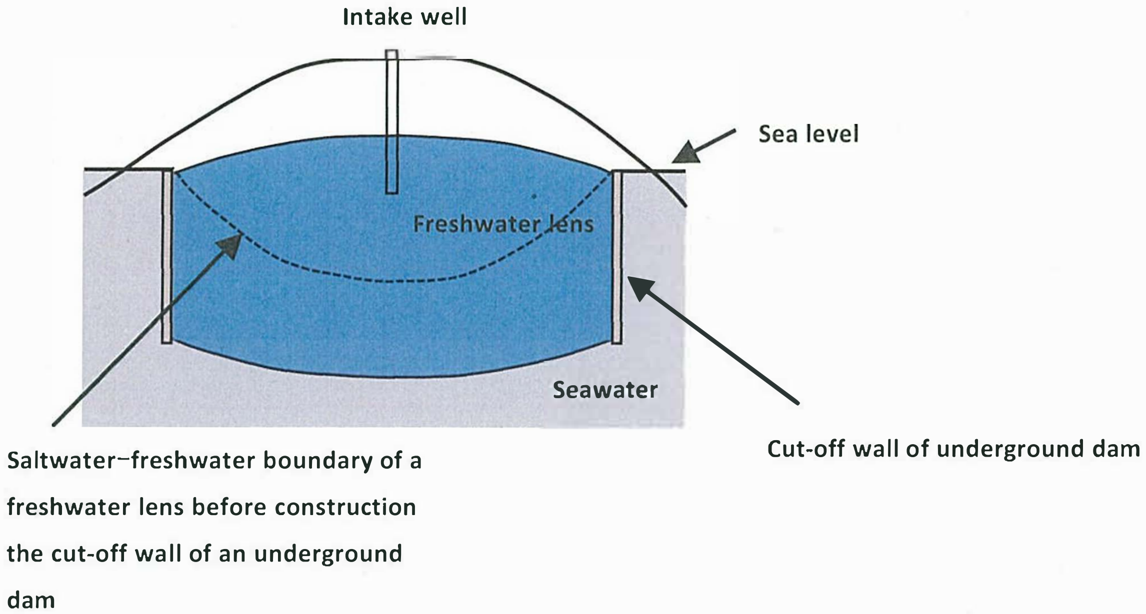


Figure 5.1.3 Conceptual diagram of a floating-type underground dam adapted from Masuoka et al. (2010) with revision

Appendix

Chapter 6 Promotion of coordination within atoll (downtown and Laura Island)

With the aim of achieving comprehensive and integrated management within the atoll, JIRCAS is developing a system to promote collaboration and cooperation. We are also taking the measures needed to reflect local residents' opinions of management measures within the atoll.

6-1 Public relations and education activities

An article on the JIRCAS seminar on October 26, 2012 was published in the November 9, 2012 issue of the local weekly newspaper, the *Marshall Islands Journal* (photo 6.1.1).


18 Friday, November 9, 2012 — The Marshall Islands Journal

Watching over our water

GIFF JOHNSON

A comprehensive report on conservation and management of the Laura fresh water lens was delivered Friday by a combination of Japan and Marshall Islands officials.

The presentations were organized by the Japan International Research Center for Agriculture Sciences (JIRCAS), which has been working closely over the past three years with the Ministry of Resources and Development, Majuro Water and Sewer Company, RMI EPA, the Office of Environmental Planning and Policy Coordination and residents of Laura.

Laura's water lens is estimated to be 1.9 million cubic meters in volume, presenting a huge resource of fresh water for Laura and Majuro residents.

Over the past three years of an extended five-year research project, JIRCAS officials working with their RMI counterparts have studied the dimensions of the lens, its susceptibility to contamination by salt water and pollution, overall water usage in Majuro Atoll, and are experimenting with a low-cost home desalination unit they hope can be put into use for island residents after further testing.

MWSC water monitor staff Linda Konou-Kobaisi delivered a presentation on MWSC's two-year action plan for improving and fixing water issues.

Some of the reports were highly technical and, to the average person, quite boring. But the information provided by the multiple Japanese researchers who are involved underline the importance of the lens well as a key resource for Majuro Atoll.

Kunihiro Doi, the Director of JIRCAS, lightened the mood following several technical presentations. "I'm the boss of all the researchers here," he said. "The reason I'm here is because researchers often forget their purpose." His job was to check all the reports to ensure that it is not only research that is accomplished, but that there is a result from it all.

As he was about to make his presentation using a powerpoint, it turned out it hadn't been loaded to the computer that was connected to the projector, and it would take a minute to copy it off his computer to the other one. "Japanese technology is proceeding but human beings are not keeping up," he said in announcing a short delay to his talk. When he was restored to the podium, Doi offered an overview of water issues affecting Majuro looking at the four main sources of fresh water — the airport reservoir and runway catchment, the Laura lens well, desalination equipment and home tanks. He spoke about the need for reservoir management, fixing leaks in the distribution system, and looking at operations and maintenance costs of any equipment used to ensure it is sustainable in the long-term.

Key issues to be answered by the ongoing Laura lens well research, he said, including: How much water can be safely pumped out daily, and how to maintain the water quality of the lens so that it does not get polluted by activities of local residents such as farming and raising pigs.

Among the various people attending the presentation, Laura resident and Majuro Atoll Waste Company Manager Jorelik Tibon raised the point that he wanted to receive easier to understand material so that it can be translated and provided to Laura residents to learn more about the fresh water resources there.

Research Project Leader Tsutomu Kobayashi responded by saying there are two more years to go in the project and as it moves to its final phases, reports will be written for broad public use in easy-to-understand language so that the conclusions reached by the researchers can be passed along to the community and government leaders.

Director of JIRCAS Kunihiro Doi.

The Japan International Research Center (JIRCAS) for Agriculture Sciences has been studying the Laura water lens for over three years. Last Friday JIRCAS Director Kunihiro Doi delivered his report.

2009

2010

2011

2012

Illegal hook-ups and leaks a huge problem

The eye-opening information that as much as 50 percent of MWSC's fresh water is "unaccounted for" was part of a presentation last week that focused on the water company's action plan for improvement.

Majuro Water and Sewer Company faces three main challenges to keeping residents supplied with fresh water, according to MWSC water monitor Linda Konou-Kobaisi. These include loss of half of the water during distribution, deteriorating pipe network, and increased demand. She gave the talk during the Laura water lens seminar on Friday.

She said illegal hook ups and leaks account for most of the "missing" water.

MWSC has launched a major leak detection program, and is installing "block meters" around the island that will help identify where water is going once it leaves the airport reservoir.

Konou-Kobaisi also said MWSC needs enforcement action against people who connect illegally to the system to get free water.

The company also has plans to upgrade its water distribution network by replacing cast iron and concrete pipes with PVC.

Should we make our own H20?

In addition to studying the Laura lens well, Japan water researchers have been engaged in designing a home desalination unit to produce up to 50 gallons of fresh water daily.

Scientist Tsutomu Kobayashi said he and others in his organization, Japan International Research Center for Agricultural Sciences (JIRCAS), have spent the last two years coming up with a design for a small, affordable desalination unit. As currently designed, the approximately five-foot long by three-foot wide unit can produce 21 gallons of fresh water daily. The estimated cost for the unit is $500.

Kobayashi said the unit has gone through trials in Japan and is now being tried here. At first, it took more than five hours to boil water, which was not efficient. The scientists improved the boil time to less than an hour and can maintain it during the day for up to six hours. The further aim is to increase water production to 50 gallons a day (200 liters).

"We plan to continue design work in 2013, and we are applying for a patent on the technology," he said. Once this work is done, a more detailed explanation of the design will be provided to RMI officials, Kobayashi said.

Photo 6.1.1 Article in the *Marshall Islands Journal*

6-2 Holding seminars

Every October for the past 6 years, JIRCAS has held seminars on "Conservation and Management of Freshwater Lenses" in downtown Majuro Atoll. The aim of the seminars has been to share the results of our research investigations with relevant project organizations. Several tens of people participated in each seminar. They represented, from government organizations, the Ministry of Resources Development (MRD), the Environmental Protection Authority (EPA), the Water Task Force of the Republic of the Marshall Islands (RMI), the Majuro Atoll Local Government (MALGOV), and Majuro Atoll Waste Company (MAWC); from educational institutions, the College of the Marshall Islands (CMI) and the University of Hawaii; and from international organizations, the South Pacific Applied Geoscience Commission (SOPAC). Also present were members of the Freshwater Lens Committee, consisting of representatives of landowners in designated project areas; the manager of the Majuro Water and Sewer Company (MWSC); the project coordinator of the MAWC; the Chargé d'Affaires ad interim of the Japanese Embassy in the RMI; and representatives of the JICA/JOCV Marshall Islands Office.

After sessions on Q & A and the exchange of views at the seminar, a trainee from RMI who had attended JICA's training course in Okinawa, titled "Conservation and Management of Water Resources in Small Island Regions," reported on an action plan based on the training experience.

The participants commented, "Now we understand the importance of the conservation and management of freshwater lenses. We want JIRCAS to continue its activities and proactively share information about the current status of freshwater lenses."

Photo 6.2.1 Seminar on "Conservation and Management of Freshwater Lenses" on October 26, 2012, at the Marshall Islands Resort Hotel

6-3 Interview Survey

JIRCAS assessed the impacts of the giant tsunami after the 2010 Chile earthquake on the freshwater lens. We selected 18 private homes located near Laura Island's lagoon beach; on March 15 and 16, 2010, we interviewed the occupants and evaluated the quality of water from their wells.

Photo 6.3.1 Laura beach after the 2010 Chile earthquake (left: northern part, right: southern part)

We interviewed occupants about changes in tide levels, flows, and well-water levels. The results showed that the electrical conductivity of the well water was only about 120 mS/m at the highest. The well water was therefore not salinated, suggesting that the tsunami had not affected the freshwater lens. According to the interviewees, an ocean current had formed, running from the beach at Laura Park on the northern part of Laura Island into the lagoon and raising the entire local sea level. On northern Laura Island, erosion of coastal areas by the ocean current destroyed concrete structures and tore up palm trees by their roots. In central and southern Laura Island, garbage was strewn everywhere. The tsunami was estimated to have reached the height where the damage occurred.

6-4 Briefing session for local residents

In April, 2014, JIRCAS held a briefing session for residents in the Laura district to explain the current status of the freshwater lens. Participants included the Integrated Water Resources Management (IWRM) team from SOPAC, as well as representatives of the EPA, MWSC, MRD, and others. We explained the current status and problems of the freshwater lens to the residents by using the results of the geophysical survey and of field investigations, such as observations of underground water levels and quality that had been performed in collaboration with the EPA. At the end of the session, we felt that we had won the understanding of the residents.

Photo 6.4.1 A briefing session for residents of Laura Island

6-5 Joint investigation

JIRCAS needs to form a cooperative system that will help to promote independent development. Through simultaneous observations of water levels and quality, as well as water quality analysis, all of which were performed in collaboration with EPA, we have implemented human resource development programs for local young administrators.

Photo 6.5.1 A joint investigation of groundwater on Laura Island

Appendix

Chapter 7 Use of consultant

Necessary measures should be implemented to facilitate activities relating to the maintenance and recovery of water cycle, which are conducted by technology consultant etc.

7-1 Boring survey

7-1-1 Outline

1) Objective

to install two observation holes to obtain basic information on the movement of the freshwater lens in Laura, Majuro, Marshall Islands

2) Place

Laura, Majuro Atoll, the Republic of the Marshall Islands

3) Period

June 23 to July 5, 2009

4) Contents

- Boring :φ86mm Site No. 6: Excavation Length = 15 m Site No.10: Excavation Length = 16 m
- Pipeline: VP50 with strainer Site No.6: Length = 16 m Site No.10: Length = 17 m
- In-situ Permeability Test: Casing method: once in each hole

7-1-2 Methods

1) Preparation

Boring scaffold, boring machine, and excavation machine tool are transported from Japan by ship according to the ship schedule. Local site conditions are inspected before the works start.

2) Access and Safety Management

Getting access to the site etc. were conducted after the land owners approve the entering to their lands at the land owners' meeting. Safety cones and a traffic control personnel were arranged to make sure the pedestrian safety during the works.

3) Installation and removal of scaffold

Boring scaffold system was temporarily installed by single pipes. The minimum space, which was necessary for the installation of the boring machine, was occupied and used. After the inspection of the excavation depth was conducted by JIRCAS, the boring machine etc. were removed and the working space was recovered as it was.

4) Boring (excavation works)

Oil-feed Boring Machine was used for the excavation. Non-core boring whose diameter of the excavation was 86 mm was conducted. Not only a casing pipe was inserted but also the thickner was used for the protection of the wall of the excavated hole as the collapse of it was extremely recognized.

5) Pipe works

After the excavation of the ground in 86mm was finished, PVC pipe was installed in the hole. Then, filtering materials were inserted between the pipe and the excavated soil wall. They are compacted not only by shaking the pipe but also by adding water when they were inserted. The height of the pipe from the ground is about 20 cm. The ground around the hole was covered by mortar. To remove the slime and the mud cake attached inside the pipe, water cleaning was conducted. After the cleaning was finished, the recovery of the permeability is expected.

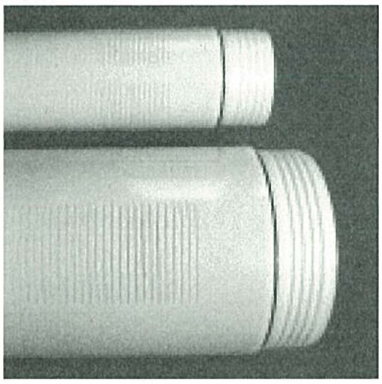
6) In-situ Permeability Test

In-situ permeability test was conducted By using the casing through non-steady method at the observation holes.

7-1-3 Installation of observation holes

1) Materials

PVC pipe, whose opening rate is 10.8 %, was used for the strainer. The reason why this pipe was used is that the pipe never uses the poisonous and artificial coloring materials, which do not include zinc.



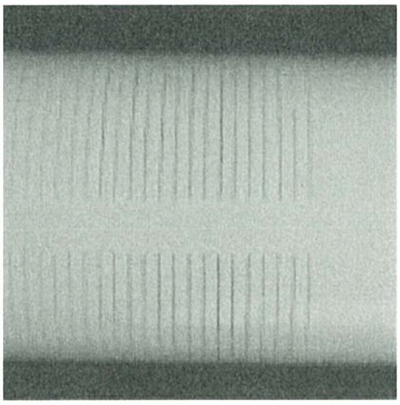


Photo 7.1.1 Joint of PVC pipe (left) and Slit of PVC pipe (right)

Table7.1.1 Pipe Size

Nominal Diameter	Outer Diameter	Inner Diameter
50 mm	60 mm	51 mm

2) Schematic view of the structure of the observation hole

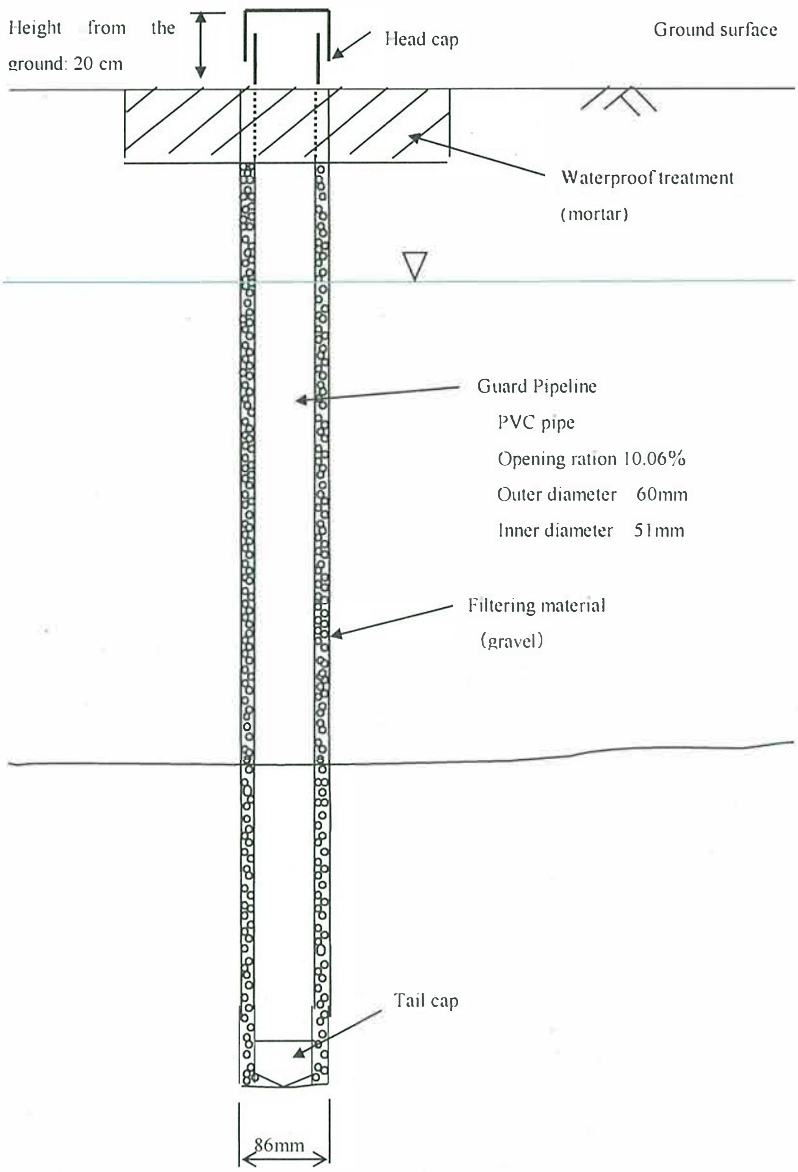


Figure 7.1.1 Structure of Observation Hole

7-1-4 Boring and in-situ test

1) Boring

The soil found in Laura is such a special one that the classification is not clearly established in Japan. However, according to JGS 0051-2000 established by the Japanese Geotechnical Society, the stratum could be analyzed as follows.

2) Stratum Organization

Table 7.1.2 Stratum Organization

Site No.	Thickness (m)	Stratum Classification	Main Characteristics
No.6 GL: 1.83m	11.35	Sand stratum	From the ground surface to the depth of 1.7 meters, there are sands whose particles are uniformly-sized. From 1.70 to the depth of 11.35 meters, water content ranges from small to medium, soils mainly consist of fine sands with small amount of angular gravels (diameter of about 2 to 10 mm). Heavy water leakage and soil collapse can be observed.
	3.65	Gravel stratum	Distribution of the gravel stratum can be observed at the depth than 11.35 meters. Sand and gravel with large water content whose diameter is about 50 to 60 mm (collapse ground) can be observed. Diameter of main gravel is about 2 to 10 mm among which loose sand is mixed with silt. Medium-compacted as a whole but densely compacted below the depth of 15 meters.
No.10 GL: 2.17m	9.7	Sand stratum	Buried soil mixed with rubble can be observed from the ground surface to the depth of 1.10m. Fine sands with small to medium water content can be mainly observed from the depth of 1.10 m to 6.60 m, in which wood roots are mixed. Loose and soft silty sands mixed with humic matter (mainly wood block) can be observed from the depth of 6.60 m to 9.70 m. Bad and putrid smell can be recognized
	6.3	Gravel stratum	This stratum is distributed below the depth of 9.7 m. Loose sand and gravel with large water content (collapsed ground) with coarse gravel whose diameter is about 50 to 60 mm. Diameter of main gravel is about 2 to 10 mm, among which loose sand are mixed with silt.

3) In-situ Permeability Test

The result of the test shows that in terms of the permeability the soil property is classified into medium category according to the permeability coefficient of 3.02E-05～8.57E-05 (m/s).

Table 7.1.3 Results of the Permeability Test

Number	Depth (GL-m)	Soil Property	Permeability k (m/s)
No.6	6.0 to 6.3	Sand with gravel	3.02E-05
No.10	6.0 to 6.3	Sand with gravel	8.57E-05

Appendix

Chapter 8 Promotion of science and technology

To promote science and technology directed at restoring and maintaining the health of freshwater lenses, JIRCAS improves its system of experimentation and research; promotes R & D and disseminates the results; trains researchers; and takes any other measures needed.

8-1 Development of a double packer

To investigate the cause of increased electrical conductivity (EC) of groundwater in monitoring wells and to consider ways of combating it, EC in the monitoring wells must first be measured by depth to identify the depth of saltwater intrusion. Tracers are generally used to detect the groundwater flow layer. However, because the freshwater lens on Laura Island is a water supply source, tracers cannot be used. We therefore considered alternatives to the use of tracers; as a result, we produced a double packer in Japan and transported it into the field to apply to the monitoring well on Laura Island.

A packer is an air-tube-integrated device that stops the vertical flow of groundwater in the monitoring well. There are two types of packer, namely, single and double. A single packer is a small device with one air tube, whereas a double packer is a large device with two air tubes.

The structure of the double packer is shown in Figure 8.1. To observe EC variations due to groundwater intrusion from outside the monitoring well, an EC sensor is installed in the part where the water is blocked by the air tubes. EC measurements taken by changing the depth of the double packer allow us to identify the depth of saltwater intrusion and to estimate the condition of the monitoring well when the well is partially blocked up to the monitoring depth.

Photo 8.1.1 Detection of water leakage from the double packer

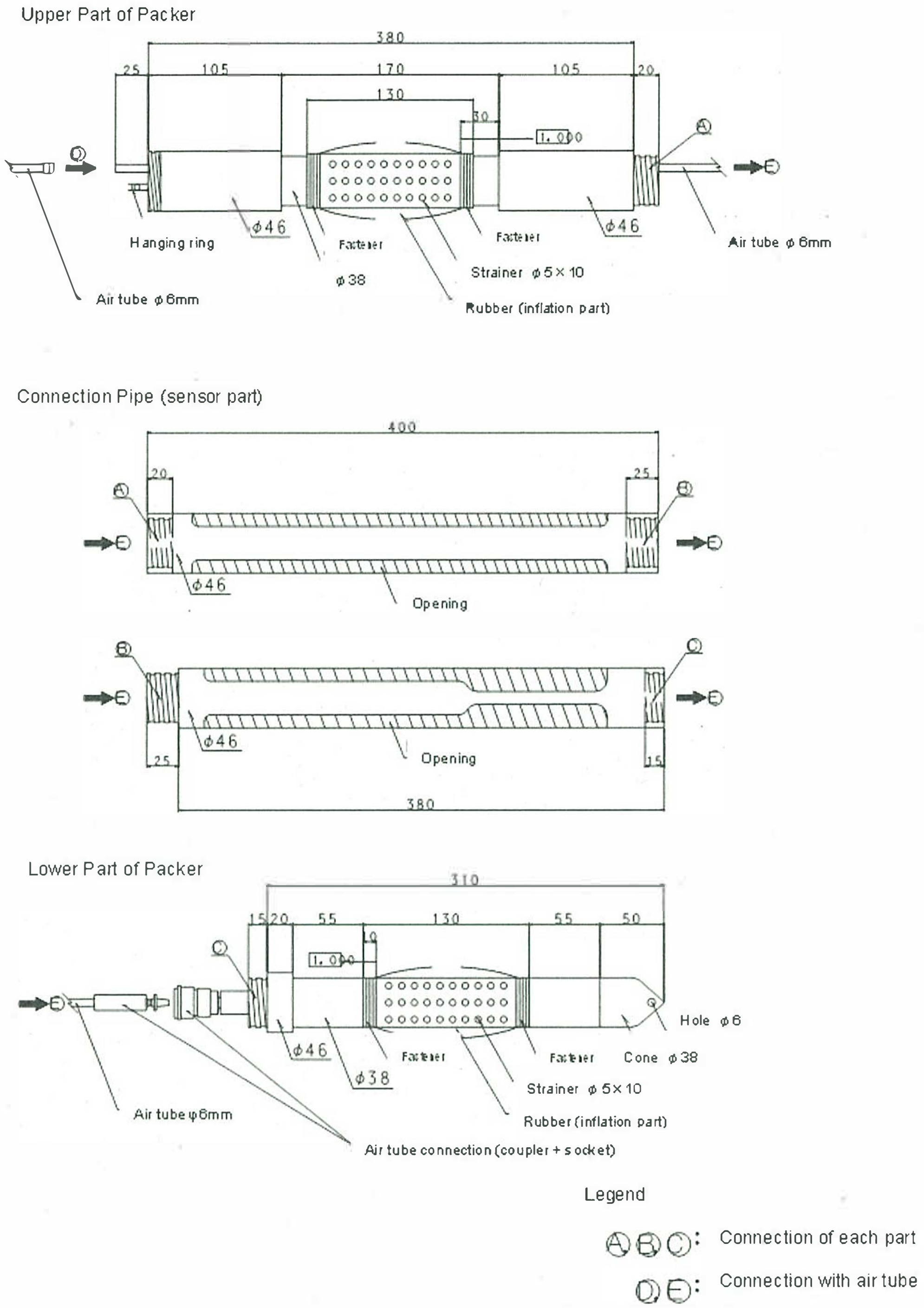


Figure 8.1.1 Structure of a double packer (units: mm)

8-2 Development of a solar desalination system

See the report on the development of a solar desalination system (http://www.jircas.affrc.go.jp/english/program/pdf/Development_of_solar_desalination_device_en.pdf).

Appendix

Chapter 9 Ensure international collaboration and promote international cooperation

Restoration and maintenance of the health of freshwater lenses are important issues in atoll islands. From this perspective, JIRCAS ensures international collaboration in restoring and maintaining healthy freshwater lenses; promotes technological cooperation on adequate and efficient use of water; and promotes other types of international cooperation.

9-1 The Pacific Islands Leaders Meeting

The Pacific Islands Leaders Meeting (PALM) is held every 3 years in Japan. Leaders from 14 countries around the Pacific Ocean gather in Japan and, together with the Prime Minister of Japan, discuss regional cooperation. The 7th PALM was held in the city of Iwaki in Fukushima Prefecture in May, 2015. JIRCAS participated in a side event, Pacific Festa 2015, which was held at the ARK Karajan Plaza in ARK Hills in Tokyo. We exhibited posters, distributed brochures, played videos, and exchanged views and information with participants.

Photo 9.1.1 PALM (top, participants viewing the displays; bottom, a participant chats with an exhibitor)

9-2 The World Water Forum

JIRCAS participated in the 7th World Water Forum held in Korea in April, 2015. In the Japanese pavilion, under the theme "Water for Food," we explained the activities of the project "Environmental Conservation of Small Islands" to 949 participants from 72 countries and organizations via both a slide presentation on a monitor and leaflet distribution. In a lecture at the side event "Communal Water Management for Cohesive and Resilience," we presented a numerical simulation showing that utilizing existing wells in such a way as to reduce water intake intensity was an adequate method of freshwater lens conservation.

Photo 9.2.1 JIRCAS booth at the 7th World Water Forum

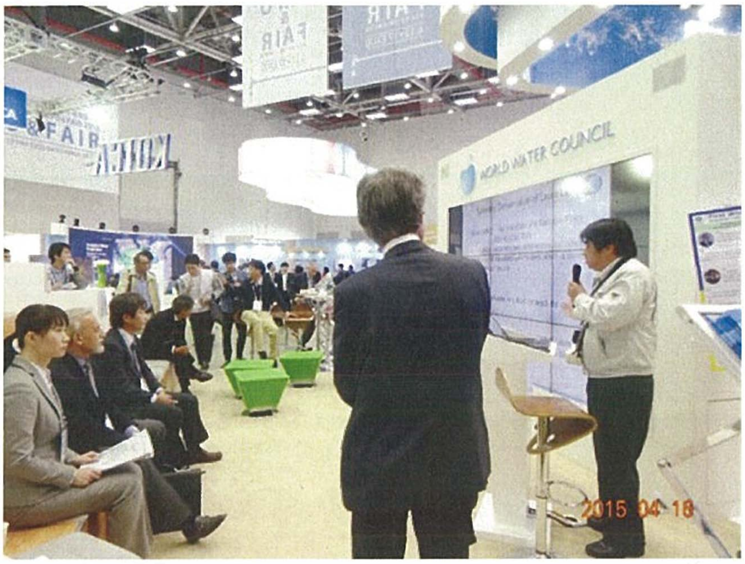


Photo 9.2.2 A side event at the 7th World Water Forum

Appendix

Chapter 10 Others

10-1 Papers

・Koda, K., Kobayashi, T., Ishida,S., Yoshimoto, S. (2014.11) Numerical Simulation of freshwater Lens in Laura Island, Geotechnical Engineering Magazine of the Japanese Geotechnical Society, Vo.62, No.11/12, pp.30-33. (in Japanese)

・Koda, K., Kobayashi, T., Ishida, S., Yoshimoto, S., Kondou, Y., Kawamitsu, Y., and Ueno, M.,(2013.10) Drought Impact on Freshwater Lens and the Countermeasures for Sustainable Irrigation, 1st Irrigation Forum, pp.63.

・Koda, K., Manpuku, Y., Kobayashi, T., Ishida, S., Yoshimoto, S., and Okubo, M.,(2013.7) A Study of Sealing Effect in the Observation Well of the Freshwater Lens at Laura Island, Republic of the Marshall Islands, JARQ, Vo.47, No.3, pp.257-272.

・Koda, K., Kobayashi, T., Ishida, S., Yoshimoto, S. (2013.7) Estimation of Hydraulic Parameters of Freshwater Lens Aquifer in Laura Island, Water, Land and Environmental Engineering of the Japanese Society of Irrigation, Drainage and Rural Engineering, Vol.81, No.7, pp.541-545. (in Japanese)

・Ishida, S., Yoshimoto, S., Kobayashi, T., Koda, K., Nakazato, H. (2013.6) Application of Geophysical Exploration for Investigation of Freshwater Lens in Small Island, Geotechnical Engineering Magazine of the Japanese Geotechnical Society, Vo.61, No.6, pp.32-35. (in Japanese)

・Kobayashi, T., Koda, K. (2012.10) Development of Survey Method for Freshwater Lens in Marshall Islands JIRCAS Working Report 77

・Ishida, S.,, Yoshimoto, S., Kobayashi, T., Koda, K., Tsuchihara, T., Nakazato, H., Masumoto, T., and Imaizumi, M. (2011.3) Measurement of freshwater-saltwater interface depths using geophysical prospectings, Technical Report of the National Research Institute of Agricultural Engineering, No.211, pp.9-20. (in Japanese)

10-2 Exhibition

Exhibition and presentation were conducted at the opportunities of Global Festa Japan (Tokyo), Public Exhibition in Tsukuba, The 6th World Water Forum, The 6th Pacific Islands Leaders Meeting, and the 1st World Irrigation Forum etc.

10-3 Participants list

This manual was completed in cooperation with the following participants.

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10-4 Brochures

Project brochures, which describe the outline of research output, have been published in both Japanese and English since 2011.

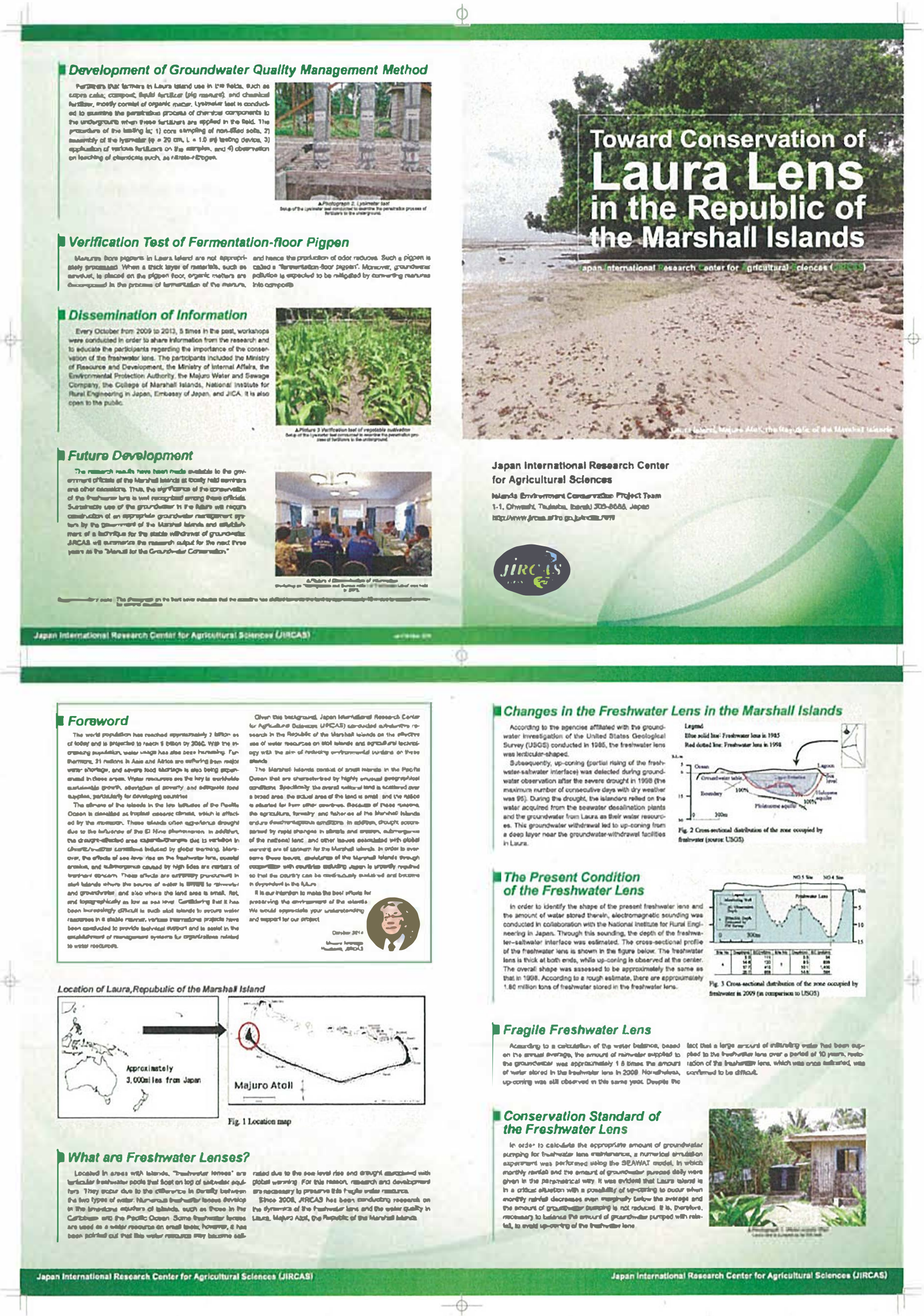

Photo 10.4.1 Brochure in 2014

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