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ADAPTATION TO CLIMATE CHANGE:

CASE STUDY — FRESHWATER RESOURCES IN MAJURO, RMI

June 2009
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ACRONYMS

ADB	Asian Development Bank
CIA	Central Intelligence Agency
CRC	Coastal Resources Center, University of Rhode Island
CMI	College of the Marshall Islands
DOI	United States Department of the Interior
DUD	Dalap-Uliga-Darrit
EGAT/ESP	USAID Bureau for Economic Growth, Agriculture and Trade, Office of Environment and Science Policy
EPA	Environment Protection Agency of the Marshall Islands
EPPSO	Economic Policy, Planning and Statistics Office
EU	European Union
gpd	Gallons per day
GCC	Global climate change
GCMs	General Circulation Models
GTZ	Deutsche Gesellschaft für Technische Zusammenarbet (German Technical Coooperation)
IPCC	Intergovernmental Panel on Climate Change
IRG	International Resources Group
JIRCAS	Japan International Research Center for Agricultural Sciences
MWSC	Majuro Water and Sewage Company
MICS	Marshall Islands Conservation Society
OEPPC	Office of Environmental Planning and Policy Coordination
RMI	Republic of the Marshall Islands
RO	Reverse Osmossis
SCADA	Supervisory Control and Data Acquisition
SEAFRAME	Sea Level Fine Resolution Acoustic Measuring Equipment
SOPAC	South Pacific Applied Geoscience Commission
SPREP	South Pacific Regional Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change

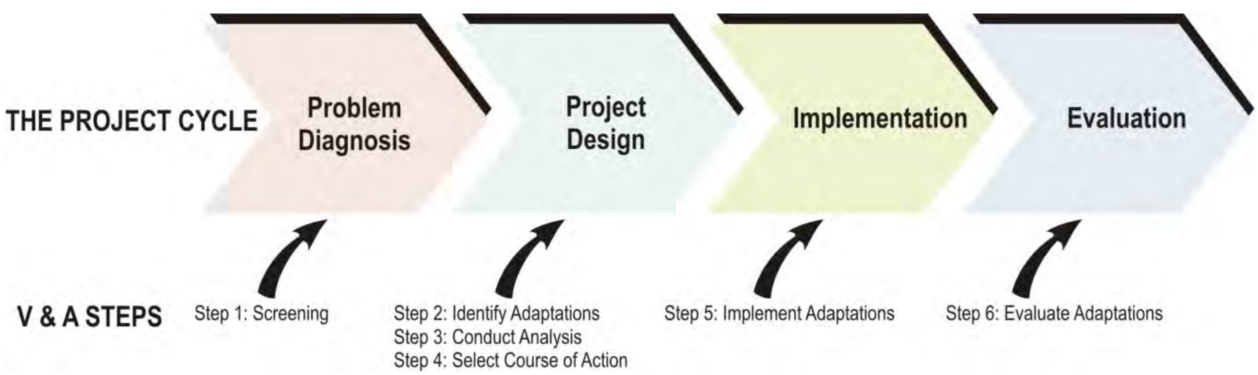
USAID	United States Agency for International Development
USGS	United States Geological Survey
V&A	Vulnerability and Adaptation
WSO	Weather Station Office

1. INTRODUCTION

1.1 BACKGROUND

With financial support from USAID and GTZ through the Micronesia Conservation Trust, International Resources Group (IRG) and the Coastal Resources Center (CRC) at the University of Rhode Island convened a two-day workshop on *Practical Approaches to Coastal Adaptation to Climate Change in the Republic of the Marshall Islands*, February 5-6, 2009 in Majuro. The objective of the workshop was to introduce practitioners and resource managers to the Vulnerability and Adaptation (V&A) Approach and provide a facilitated environment for participants to apply a climate "lens" to economic sectors in RMI.

The V&A approach is a six-step process developed by USAID to help project and program planners account for and integrate climate concerns into designs, plans and strategies. As indicated in the figure below, the V&A approach involves a similar set of sets as project cycles and policy reform processes. The major differences relate to the scope of problem diagnosis (screening) in the V&A approach, which considers the typical set of development stressors as well as vulnerability to climate change and variability.



Workshop participants were divided into five small groups and tasked to apply the first four steps of the V&A approach to one of the following sectors: 1) education; 2) health; 3) fisheries and mariculture; 4) environment and biodiversity, and 5) freshwater resources. Workshop proceedings are provided in Appendix 1.

As part of USAID's support for climate change in the Marshall Islands following the initial workshop, IRG and CRC proposed three sets of activities: 1) V&A training-of-trainers for RMI governmental staff and other practitioners and climate change training for the College of the Marshall Islands' Natural Resources Certificate Course for resource managers from the outer islands; 2) assistance in mainstreaming climate change into planning frameworks and area plans; and 3) case studies focused on practical adaptation options. On the strength of the small group exercises, discussions with USAID and RMI practitioners, and the potential replication value, IRG selected freshwater resources for one of the RMI case studies.

1.2 CASE STUDY OBJECTIVES

This report presents the results of the case study on freshwater resources management for Majuro. The case study involved the collaboration between IRG and the Marshall Islands Conservation Society (MICS) based in Majuro. The objective of the proposed case study is to develop recommendations for an adaptation strategy for managing freshwater resources in Majuro, in view of climate change and variability. The case study builds on the results of the workshop and is designed to examine the current situation in greater detail, define adaptation measures in precise terms in relation to effectiveness and implementation costs, evaluate candidate measures and make recommendations for integrating adaptation measures into an adaptation strategy.

The report is structured according to the steps of the V&A approach. Chapter 2 describes the current situation in Majuro related to the quantity and quality of freshwater and management of water resources and pricing of water services. Chapter 3 provides a diagnosis of problems related to provision of freshwater resources in Majuro and includes a discussion of non-climatic and climate stressors and assessment of vulnerability to climate variability and change. Chapter 4 provides a list of adaptation options for coping with climate change and variability that were identified during the V&A workshop in February and refined as a result of the case study. Chapter 5 includes an assessment of adaptation options and Chapter 6 presents recommendations for prioritizing adaptation options and integrating them into a freshwater resources strategy.

2. FRESHWATER RESOURCES IN MAJURO: CURRENT SITUATION

2.1 WATER RESOURCES OF MAJURO

The following section presents a brief overview of freshwater resources in Majuro. Background information is presented on the topography, geology, and climate which contribute to the availability of freshwater resources of the island. In addition, current water infrastructure is described and basic information provided on water pricing.

2.1.1 TOPOGRAPHY AND DEMOGRAPHICS

The Republic of the Marshall Islands (RMI) is a nation of 29 atolls and 5 individual islands. The atolls trend along two island chains, and are spread over an area of about 750,000 mi^2. The capital of the RMI is on Majuro Atoll. The Majuro Atoll is near the southeastern end of the nation and is composed of 64 sand and coral islets, none higher than 15 feet (ft) above sea level. The islets to the east, south, and west are connected by coral fill and a road to form a thin, 30-mi long island. Islets to the north are not connected. The total land area of the atoll is about 4.3 mi^2 (Presley, 2005).

According to Presley (2005), most of the population of Majuro resides on the eastern end of the atoll, known as the Dalap-Uliga-Darrit (DUD) area). This urban area is the center of business, houses governemnt, and the largest concentration of residences in Majuro. The western end of the island, called Laura, is rural and agricultural, and has an area of about 450 acres. Most landowners in Laura grow coconut, bananas, breadfruit, and/or taro. A few landowners are engaged in larger scale cultivation consisting predominantly of vegetable crops for commercial sale.

Population growth rates in Majuro as well as the Marshall Islands have been quite variable over time. Between, 1980 and 2000, there was an increase in population in Majuro of around 67% (Overmars, 2000). This rapid increase was believed to be a result of reduced infant mortality, increased fertility rates and immigration from the outer islands. In 1988, the population of Majuro was 19,664 with approximately 1,450 people living in the Laura Area (Anthony et.al., 1989). Since 2000, the growth rate has significantly decreased and as of 2004 the population was around 25,400. This slower growth rate is due to emigration of residents to pursue economic opportunities elsewhere. Recent estimates indicate a population growth rate of around 2.7% (CIA, 2009). It is estimated that the population of Majuro is around 30,000 people.

Overall, for the Marshall Island according to CIA (2009), the population of the Marshall Islands is estimated to be 64,522 with a age distribution of:

- *0-14 years:* 38.6% (male 12,683/female 12,217)
- *15-64 years:* 58.5% (male 19,302/female 18,459)
- *65 years and over:* 2.9% (male 902/female 959) (2009 est.)

The birth rate is about 30.7/1,000 population with a death rate of 4.57 deaths/1000 population and a net migration rate of -5.41 migrants(s)/1000 population. Approximately 71% of the population lives in urban areas with a net 2.7% annual rate change. Infant mortality rate is around 25.45 deaths/1,000 live births with 28.58 deaths/1,000 live births for males and 22.17 deaths/1,000 live births for females. Life expectancy for males is a little over 69 years and for females is 71 years (CIA, 2009).

Overall, RMI has per capita GDP of $2,466 (DOI, 2006). Public sector employment has dominated employment since 1997. Ranging from 41.7 percent to 48.0 percent, total public sector employment averaged 44.7 percent of total in 1997-2006. Total private sector employment averaged 37.6 percent during the same period. Based on estimates made by the RMI's Economic Policy, Planning and Statistics Office (EPPSO) in 2004, the unemployment rate was an estimated 33.6 percent which could be substantially higher now (DOI, 2006).

2.1.2 GEOLOGY

Like most atolls, Majuro is composed of a ring of islands and reefs that separate a lagoon from the open ocean. Atolls are derived from the fringing reefs that surround volcanic islands which later become submerged. The geology of the island consists of calcareous sediments and limestone. In the Laura area, the lithology consists of three layers: 1) an upper layer of unconsolidated, calcareous, well-sorted beach sand with a thickness ranging between 20 and 40 feet.; 2) a lower layer of sediment that is a more cohesive, heterogeneous mixture of calcareous silts, sands and coarse-coraline materials with a thickness of between 35 and 40 feet; and 3) an underlying lower layer of highly permeable limestone (Hamlin and Anthony, 1987).

Freshwater is contained in the sediment layers (although recent overpumping has restricted the freshwater to the upper sediment layer). The limestone layer is very permeable and saturated with saltwater. The difference in characteristics of the sands and limestone and the difference in density between saltwater and freshwater allows a freshwater lens to form in the sand. This sand is not quite as permeable as the limestone but has a high infiltration capacity allowing rainwater to infiltrate. This also allows drainage from irrigated plots, seepage from privies, and other types of surface pollution to wash down into the aquifer with little or no attenuation making the freshwater lens very susceptible to pollution.

2.1.3 CLIMATE

The climate in Majuro is tropical, characterized by mild to warm temperatures, high humidity, and persistent winds. A pronounced dry season spans from January to mid-April, and a wet season spans from mid-April to December. Rainfall in Majuro is measured at three locations: in Laura, at the Majuro Weather Station Office (WSO) in Dalap, and at the airport. The Majuro Weather Station is operated by the US National Weather Service and has data dating back to 1954. Table 2-1 presents a summary of data for the period of record for this station.

Figure 2-1 is a bar graph showing annual precipitation at the Majuro Weather Station from 1960. These data indicate that periods of drought are not uncommon. Drought is defined as a prolonged period of dryness or shortage of water (Giambelluca and others, 1991). The end of a drought is associated with the end of the water deficit, which usually occurs after significant rainfall (Vandas and others, 2002). During 1954–2009, the dry seasons of 1970, 1977, 1983, 1992, 1998 and 2006 had significantly less rainfall than normal dry seasons, and were considered droughts. These droughts occur between 6 and 9 years apart. The characteristics of dry seasons that caused drought in Majuro generally show a 1- to 4-month period of monthly rainfall less than 2 in. per month, within a 3- to 7-month period (Presley, 2005).

Figure 2-1: Annual Precipitation at the Majuro Weather Station (WSO, 2009)

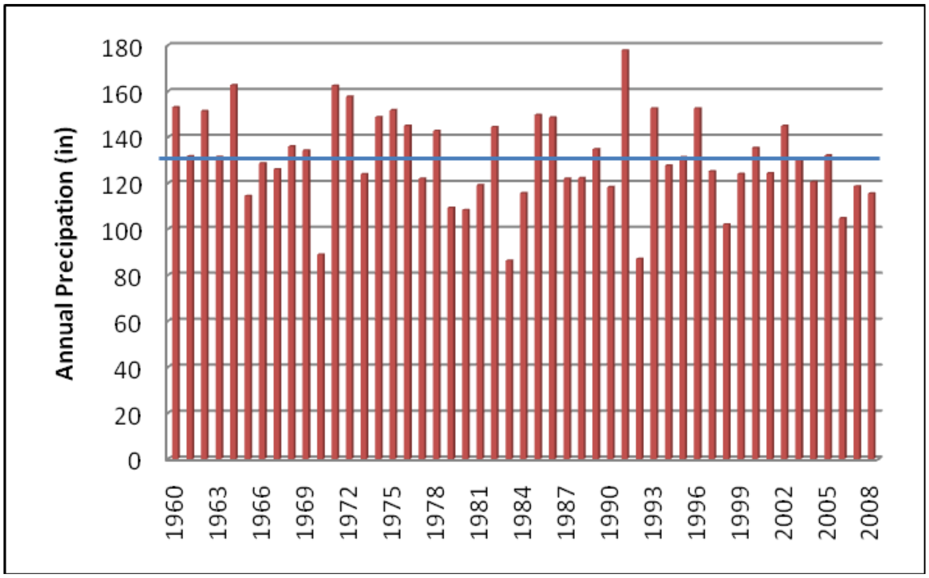


Table 2-1: Majuro Climate Summary

	Years of Record	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE (Deg. F)														
Normals														
-Daily Maximum		85	85.4	85.6	85.6	85.8	85.8	85.7	86.2	86.3	86.3	86	85.3	85.8
-Daily Minimum		76.5	76.7	76.6	76.5	76.6	76.3	76.1	76.3	76.3	76.2	76.3	76.3	76.4
-Monthly		80.7	81.1	81.1	81.1	81.2	81.1	80.9	81.3	81.4	81.3	81.2	80.8	81.1
% OF POSSIBLE SUNSHINE	35	61	64	66	60	59	56	56	61	59	56	53	53	59
RELATIVE HUMIDITY (%)														
Hour 04	39	80	79	81	82	84	84	83	82	82	82	82	82	82
Hour 10 (Local Time)	40	81	80	81	84	84	84	84	84	83	83	83	82	83
Hour 16	40	75	73	75	77	78	78	77	76	76	76	77	77	76
Hour 22	39	78	77	78	80	81	80	79	78	78	79	80	80	79
PRECIPITATION (in.)														
-Normal		8.43	6.15	8.28	10.28	11.18	11.59	13	11.52	12.42	13.84	12.8	11.85	131.34
-Maximum Monthly	41	21.97	18.34	29.54	31.1	22.23	17.63	21.17	19.98	21.11	24.26	23.56	24.8	31.1
-Year		1961	1957	1991	1971	1956	1975	1987	1986	1964	1955	1978	1968	Apr-71
-Minimum Monthly	41	0.78	0.2	0.15	0.36	1.49	5.4	5.34	5.33	5.9	6.17	4.53	2.28	0.15
-Year		1973	1992	1992	1992	1983	1984	1961	1959	1992	1990	1972	1957	Mar-92
-Maximum in 24 hrs	41	9.57	6.65	15.26	6.63	6.26	7.39	5.86	5.29	5.76	8.74	10.01	17.88	17.88
-Year		1961	1991	1991	1973	1992	1983	1987	1986	1982	1974	1957	1972	Dec-72

2.1.4 WATER RESOURCES

Majuro relies primarily on harvested rainfall and groundwater to supply most of its water demands. In addition, seawater is used to flush toilets and desalinated in a few reverse osmosis (RO) plants operated by bottled water companies and the two largest fish processing plants.

Airport Rainwater Catchment System The major source of water is a rainfall catchment system at the airport operated by the Majuro Water and Sewage Company (MWSC). This catchment system captures rainfall on the section of the runway and sand-covered areas adjacent to to the section of the runway toward the center of the picture below (Figure 2-2). This system was designed and installed by the US Army Corps of Engineers

Figure 2-2: Airport Catchment System

and uses the airport's runway as a large catchment area. The catchment has an area of around 88 acres and according to Presley (2005), theoretically, could yield about 2.4 million gallons of water for every inch of rainfall, assuming 100 percent collection efficiency. Water from the airport catchment is pumped to nearby reservoirs (Figure 2-3). There are seven reservoirs; six have the storage capacity of 5 million gallons per reservoir and one reservoir has a storage capacity of 8 million gallons. The total storage capacity is 38 million gallons. Water from six of the reservoirs is filtered through two large sand filtration systems (Figure 2-4) and chlorinated. This water is pumped to a seventh reservoir which has a floating cover. Water is delivered to Majuro City through two pipelines.

Figure 2-3: Freshwater Reservoirs (Google Earth, 2009)

Figure 2-4: Sand Filtration Tanks

ROOFTOP COLLECTION SYSTEMS Most households have roof and gutter rainfall collection systems. Tanks for these systems are usually between 1,000 and 2,000 gallons. A recent survey by the RMI Economic Policy, Planning and Statistics Office (EPPSO) indicates that 3,328 households have rainfall collection systems in Majuro. As presented in the Table 2.2 below, the average roof area for these systems is 423 square feet. Estimates by EPPSO indicate that these systems have the potential to produce between 15,000 and 24,000 gallons of water per year. The survey also indicated that 23% of the population surveyed did not have a rainwater collection system or access to piped water. At this time, there is no data on the number of businesses, churches, or governmental business that have rainfall collection systems. However, the team visited a number of schools and other large building and observed that many were collecting significant amount of water for storage in underground reservoirs and above-ground storage tanks.

Table 2-2: Household in Majuro with Rooftop Collection Systems

Roof Area (ft^2)	Number of Households (HH)
Less than 108	746
108-209	384
210-317	321
318-532	608
533-748	390
749-963	359
964-1286	211
1287-1609	152

Roof Area (ft^2)	Number of Households (HH)
1610-2147	68
2148 and Over	38
Not Reported	51
Total number of HHs in survey	3,328
Total square feet of all HHs	1,409,403
Average square feet per HH	423

GROUNDWATER The other major source of freshwater in Majuro is groundwater. Many houses have their own wells (the exact number is not known) and use this water to supplement their rooftop collection or, in the case of Laura, for irrigation. According to JIRCAS, there are over forty private wells in Laura. In terms of municipal water, three wells were drilled in the Dalap-Uliga-Darrit (DUD) area with the capacity to be pumped at 50,000 gallons per day (gpd). According to Presley (2005), these wells were found to be susceptible to saltwater intrusion during the drought. Private wells in Majuro City are rarely used because they have high concentrations of chlorides and are susceptible to contamination.

The principal source of groundwater today is the ***Laura lens***. The Laura freshwater lens overlies saltier water (see Figure 2-5). As illustrated in Figure 2-6, the shape of the lens is irregular. In 1991, it was estimated by Meinardi (1991) that the safe yield of the Laura lens aquifer was about 348,750 gallons/day (1320 m3/day) or 127 million gallons per year. In 1991, 7 abstraction wells were installed in Laura with a design capacity of 80,000 gdp per well (see Figure 2-7 for typical design). From 1992 to 1994, water was pumped from the seven wells using low pressure pumps which were originally rated at 70,000 gdp (circa 50 gallons/minute) each. During the 6-month drought in 1992 the Laura lens was the only source of water for all of Majuro's residents (Barber, 1994). In 1994, pumping from Well Number 4 was curtailed because of lease problems with the landowner. In 1995, only 5 wells were operational but with reduced efficiency. With the assistance of the Asian Development Bank (ADB), the situation was corrected by repositioning the pumps and installation of float switches after which each well delivered 50-60 gallons/minute for a total of about 400 000 gpd (Mink, 1996). During 1992-97, bacterial growth, sediment clogging of the horizontal infiltration galleries, and pump breakdowns resulted in an overall lowering of total pumpage (Presley, 2005).

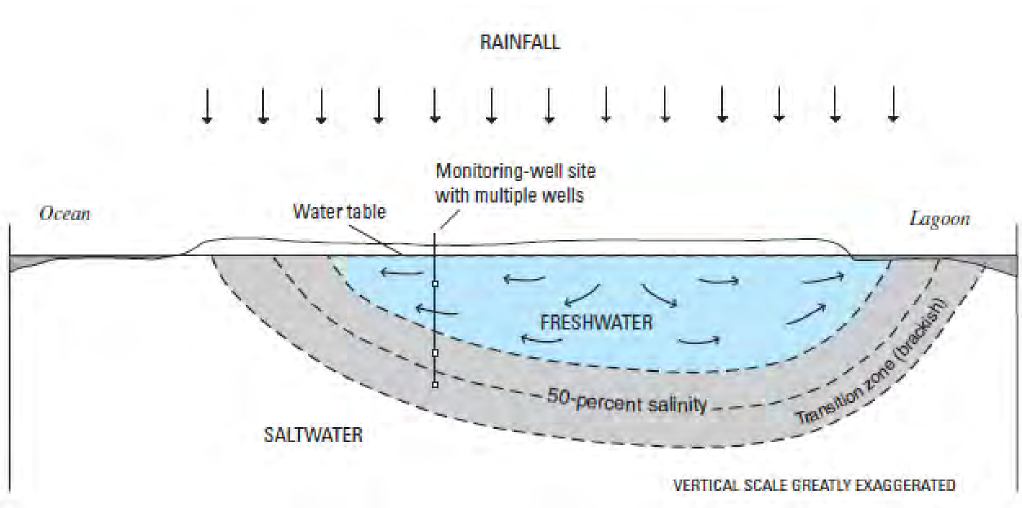


Figure 2-5: Cross-section of the Laura Lens (Presley, 2005)

In response to the 1998 drought, water-supply wells in the Laura area were refurbished with new pumps by the MWSC, allowing increased pumpage. These wells provided monthly mean pumpage rates from about 191,000 to a maximum of about 286,000 gal/day. During the drought, public concern arose about the condition of the freshwater lens in the Laura area because of increased pumpage in response to the water shortage, and the potential long-term effects of increased pumpage to meet the growing demand for potable water (Presley, 2005). Currently, there are four operational wells pumping 100,000 gallons/day two times a week.

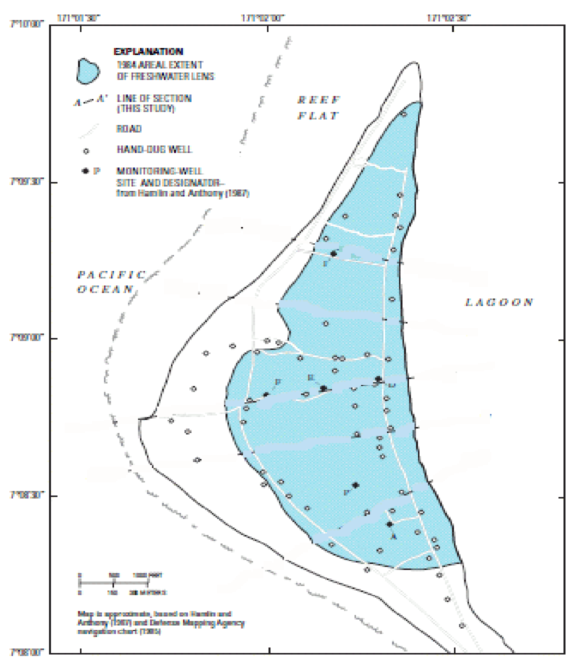


Figure 2-6: Aerial Extent of the Laura Lens and Typical Well (Presley, 2005)

REVERSE OSMOSIS UNITS During the 1998 drought, 8 RO units were supplied to Majuro and Ebeye to produce water on an emergency basis. Five of these units were supplied by the United States and each had a capacity of around 10,000 gallons per day. These were operated for awhile after the 1998 drought but now are in disrepair and no long functional. The other three units were supplied by Japan and had a much smaller capacity (about 2,000 gallons per day per unit). It is our understanding that these are in storage and are available for emergency water supply.

Currently, we understand that there are four operating ROs in Majuro. Two small units (between 2,000 and 10,000 gallons per day) are being used by water bottling companies. The other two RO units are larger (up to 150,000 gals/day) and are operated by the two major fish processing companies on the island. Another large unit is scheduled to come on line soon at the College of the Marshall Islands (CMI).

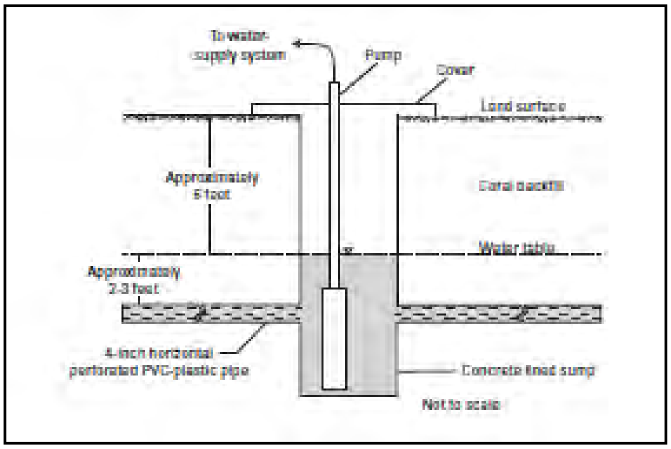


Figure 2-7: Typical Well – MWSC Well in Laura (Presley, 2005)

2.2 WATER MANAGEMENT

The MWSC is a private company under contract to the Government to provide piped water to the entire atoll; and sewerage services in the urban area of Majuro City. As noted earlier, the public water supply consists of treated rainwater collected from the airport runway supplemented by groundwater abstraction via wells and infiltration galleries in the Laura area. Figure 2.8 describes MWSC's water supply system. MWSC currently manages a centralized water distribution system consisting of three lines, one for freshwater, one for salt water, and one for wastewater. The pipeline between Laura and the reservoir network near the airport is used to supplement rainwater collection at the airport and supply water to customers along the pipeline. According to SOPAC (2000), water usage per capita is between 40 and 45 gallons/capita/day.

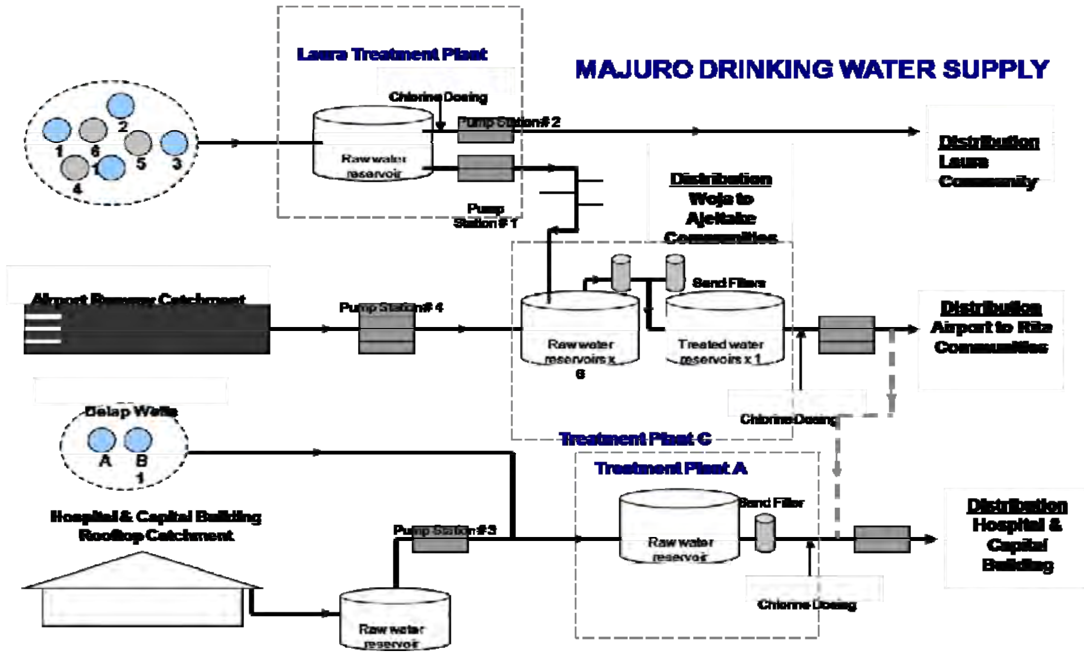


Figure 2-8: Majuro Water Supply (SOPAC, 2009)

CONNECTIONS MWSC has connected 3,232 residences, businesses and government buildings to the fresh-water distribution network. As described in Figure 2-9, most of these connections (1,964) are not active and have been disconnected for non-payment of water bills. According to MWSC, the cost of reconnecting inactive connections is $30 plus payment of delinquent accounts (or a portion thereof). According to the MWSC's webpage, http://www.doingbusiness.org/ExploreTopics/DealingLicenses/Details.aspx?economyid=123, the cost of a new connection is $235, including costs of permits, hook-up and water meter. For the salt water line, there are 2,113 connections. This water is used for flushing toilets. Currently, the centralized water supply system supplies roughly one-third of the total households with water while the remaining households obtain their water from roof top collection systems, delivery services, or private wells. It is estimated by EPPSO that 23% of household have no access to water.[1]

[1] Anecdotal evidence suggests that some households without a readily available source of water will obtain water from neighbors or family members in other residences

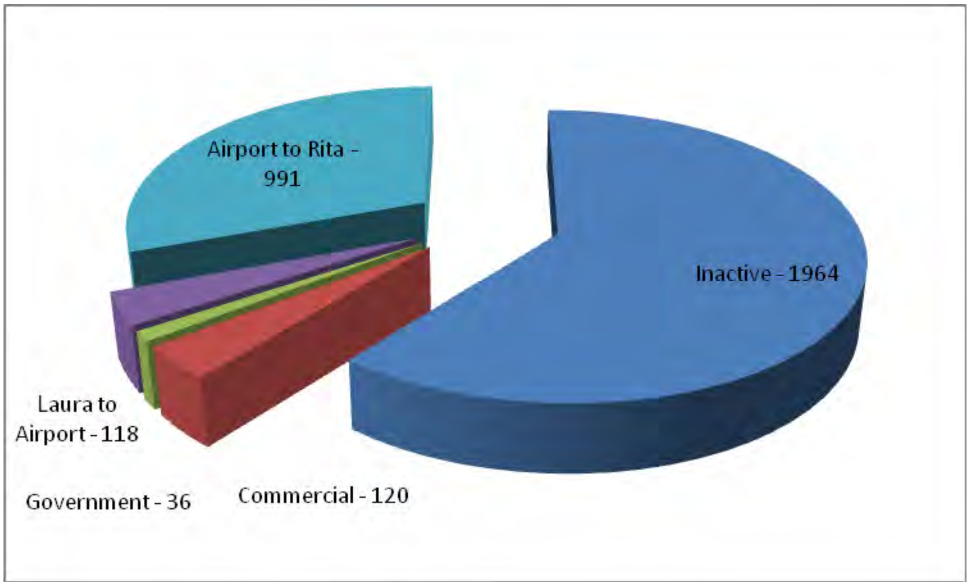


Figure 2-9: MWSC Freshwater Connection to the Main Water Trunk Line

WATER PRICING Water prices are structured according to the type of water, how it is delivered, and according to the type of customer for piped freshwater. Prices for water are as follows:

Freshwater

- Pipeline water delivered to residential customers–$0.006/gallon
- Pipeline water delivered to commercial and government use–$0.01/gallon
- Bulk water delivered by truck–$0.05/gallon
- Bulk water purchased at MWSC–$0.02/gallon

Saltwater

- Flat rate for residential and commercial customers–$12.00/month

3. PROBLEM DIAGNOSIS

This section provides an assessment of problems related to the sustainable provision of freshwater of the desired quantity and quantity. The section is divided into three parts focusing on an overview of non-climatic and climatic stressors and assessment of the vulnerability of freshwater resources to climate change and variability.

3.1 NON-CLIMATIC STRESSORS ON FRESHWATER RESOURCES

There are a number of stressors (factors) that can affect the availability and quality of freshwater resources in Majuro. Non-climatic stressors refer to those factors that would impact freshwater resources in the absence of climatic factors. Three groups of factors are described in this section: 1) population pressure; 2) pollution; and 3) management of public and private sources.

3.1.1 POPULATION

As the population of Majuro grows, there will be increased demand for freshwater supplies. Population increases over the last thirty years have placed greater stress on the existing sources of freshwater. As the population grows, the number of households without water most likely will increase, particularly as a share of the population increase will be in-migration to Majuro from the outer islands and the number of disconnections outnumbers the number of new connections.

Access to freshwater is of particular concern during drought. Based on a storage capacity of 38 million gallons, a per capita water consumption rate of 40 gallons per day and a population of 30,000 people, MWSC could theoretically[2] provide water from storage during a drought for approximately 30 days. As the population increases, water availability will be more limited during droughts and other sources (rooftop collection and storage, groundwater from Laura, and reverse osmosis (RO) units will be required to supplement MWSC supplies.

3.1.2 POLLUTION

Pollution of freshwater resources is a major concern in the Marshall Islands. For the most part, drinking water comes from bottled water. However, lower income households who cannot afford bottled water may drink water directly from their storage tanks or tap water from the city supply. Bird and animal feces, sea spray, dust, urban pollution and other contaminants can pollute rainwater from residential and commercial rooftops. Storage tanks and the rooftop collection systems are usually not maintained and cleaned regularly to eliminate numerous kinds of bacteria. Even though freshwater collected from the airport runway collection systems is filtered and chlorinated, according to the EPA, chlorination is inconsistent and fecal coliform contamination often occurs in the freshwater supplied to Majuro. Fecal coliform indicates the presence of bacteria that cause waterborne disease. As indicated in Table 3-1, the incidence and cost of outpatient service for gastrointestinal illnesses in RMI have been increasing annually.[3]

[2] This assumes no leakage in the distribution lines and no evaporation from storage tanks

[3] The number of outpatient visits grossly underestimates the incidence of waterborne illness as many people will not visit their doctor, clinic or hospital. For example, SOPAC (2008) reports that the incidence of diarrhea among Marshallese in 2002 was 722 per 1,000 people, or more than 21,000 for Majuro, compared to 2,234 recorded visits.

Table 3-1: Waterborne Diseases and Associated Costs to RMI

Year	Gastrointestinal Outpatient Cases (Majuro and Ebeye)	Estimated Total Cost @ $119 per Majuro Outpatient Visit
2001	1,989	$236,691
2002	2,234	$265,846
2003	2,426	$288,694
2004	3,011	$358,309
2005	2,991	$355,929
2006	3,720	$442,680
Totals	16,371	$1,948,149

RMI Ministry of Health (SOPAC, 2009)

The freshwater lens at Laura is located in a rural area and pollution sources include:

- Privies (latrines) – nitrates, ammonium, and bacteria;
- Concentrated feed lots – nitrates and bacteria
- Fertilizers – phosphorous, nitrates
- Pesticide use
- Co-disposal of hazardous waste with solid waste

Irrigation return water can increase salinity. The Japan International Research Center for Agricultural Sciences (JIRCAS, 2008) notes that the irrigation from wells only occurs over the freshwater lens and is not extended to areas where the lens does not exist. However, the main cause of increased salinity relates to management practices and more specifically to overpumping.

In Laura, privies and feed lots pose the greatest pollution risk to the freshwater lens. At this time, there is no sewer system in Laura and toilet facilities mainly consist of privies constructed over hand dug or excavated pits. Wastes from these pits are not removed and seepage of contaminated water from these is a concern. In terms of livestock, sources of pollution include subsistence rearing of chickens and pigs and the large scale livestock business operated by the Taiwan Agricultural Mission. They raise a number of pigs and chickens (Sablan-Zebedy, 2005).

Recent studies by SOPAC and JIRCAS indicate that increase levels of pollution are occurring with the contamination plume originating at the Taiwanese experimental farm (Figure 3-1). In addition, insecticides and inorganic and organic fertilizers are used on the farms. The Taiwanese Technical Mission is working with local farmers on the safe application of fertilizer and insecticides. However,

Figure 3-1: Laura Pollution Map (SOPAC, 2009)

given the sandy nature of the soil, infiltration of pesticides and fertilizer to the groundwater is always of concern.

As for the other parts of County of Majuro, groundwater is used sparingly from wells. Here groundwater has been contaminated by leaky sewer pipes, our door toilets, storm water runoff, leaky underground petroleum storage tanks, and other sources. High bacteria counts are often found limited the use of these waters.

3.1.3 MANAGEMENT ISSUES

During the case study, the three most important management issues associated with the public supply of water concerned evaporation, leakage, and extractions from the Laura lens. For private catchment systems, the main concerns are maintenance and cleaning of rooftop, gutter, and storage tanks.

EVAPORATION The two major sources of evaporative losses are evapotranspiration losses from the surface of the storage reservoirs at the airport and from the runway collection system. It is estimated that approximately 3,000,000 gallons of water is lost to evaporation per month from the reservoirs at the airport. MWSC is aware of this problem and they are currently planning to address this problem with assistance from the Japanese government. It is currently proposed that covers be placed on these reservoirs to reduce this loss. The airport collection system is designed to effectively collect water from the runway and the sandy infiltration areas and transport the water to the storage reservoirs. If rainwater pools on the surface of the sand infiltration area, (Figure 3-2), this is an indication that fine particles have accumulated in the sand, slowing the rate of infiltration, or that the network of collection pipes is clogged with sediment. A regular maintenance program can address these sources of evaporative losses.

Figure 3-2: Pooling of Rainwater – Airport Collection System

LEAKY DISTRIBUTION PIPES All water distribution pipelines leak. Leakage represents non-revenue water (NRW), that is, water that is produced by the water company but cannot be billed to customers. NRW of 25-30% is typical of well-managed water companies. When NRW exceeds 50%, the financial situation of a water company is significantly decreased – it may be difficult to recover operating costs and maintain an effective maintenance program and replace depreciated capital. SOPAC estimates that leakage in Majuro's water supply system is around 50% or even greater due to several illegal offtakes. However, it is difficult to determine the leakage rate at this time because of the lack of metering or logging of bulk flow and pressure. For example, flow and pressure are recorded at Laura when water is pumped to the storage reservoirs at the airport but the meter to measure inflow at the airport is not currently functioning.

"SAFE YIELD" MANAGEMENT OF THE LAURA LENS – the Laura lens is sensitive to overpumping and its size can contract dramatically during droughts when it is pumped at a significantly higher rate at a time that recharge is minimal. The concern during droughts is that overpumping can alter the size of the aquifer and limit recovery to its former size (see additional discussion in Section 3.2). At present, the Laura lens is pumped at a rate far below the "safe yield" calculation of 348,750 gallons/day and has only been pumped at this rate or above during recent droughts. Improved management of the airport collection system and distribution pipes could reduce the need to extract water from Laura, except for local consumption and connections between Laura and the airport. During droughts, the availability of portable RO units to provide emergency water could reduce the risk of overpumping and irreversible damage to the Laura lens. As an emergency measure during the 1998 drought, five RO units were shipped to the Marshall Islands from the United States and three RO units were donated by the Japanese and provided much needed water. Today, none of the US RO units are operational. The main reasons given for this are lack of money for spare parts and technicians to operate them. However, the three Japanese units are in storage and still available for emergencies. These, however, these units each have the capability of providing only 2,000 gallons per day.

POORLY DESIGNED AND MAINTAINED ROOFTOP COLLECTION SYSTEM Approximately 51% of the households in Majuro depend on rainfall collection systems for the majority of their water. As illustrated in Figure 3-3, many rooftop systems are poorly designed with gutters that are incapable of handling the rainfall from the roof. In addition, few rooftop systems are maintained and clean with sediment buildup at the bottom of the tanks being a common occurrence (see Figure 3-4). There is currently a lack of public education of maintaining systems – Very little information is available for public outreach in Marshallese to instruct owners of rooftop collection systems on proper maintenance and cleaning of systems.

Figure 3-3: Poorly Designed Rooftop

Figure 3-4: Sediment in Tank

3.2 CLIMATE AND CLIMATE CHANGE IMPACTS ON FRESHWATER RESOURCES

Current climate and anticipated climate change impact on freshwater resources in a variety of ways. In combination with the stressors discussed in the previous section, climate presents a formidable challenge to the Marshall Islands in meeting the water needs of its people. As discussed below, the most immediate climate stressors are drought and severe storms. Over a longer time horizon, changes in precipitation patterns, temperature and sea level rise will affect the management of rainfall and groundwater.

3.2.1 CURRENT CLIMATE

DROUGHT Without question, drought is the number one concern in meeting demand for freshwater for Majuro on a sustainable basis. During periods of drought, the volumes of water produced from rainfall collection systems both the airport and roof tops is severely reduced, evaporation rates increase, further reducing volumes of water in the reservoirs and recharge to the aquifers, and exerting more pressure to extract water from the well field in Laura. Droughts in the Marshall Islands are associated with the El Nino Southern Oscillation and have occurred at regular intervals. The three most recent droughts are highlighted in Table 3-2. Each drought lasted five to seven months. The drought in 1982-1983 lasted six months, during which time recorded precipitation was 1.52 inches/month. The droughts in 1992-1993 and 1997-1998 had average-monthly precipitation levels of 2.38 inches and 3.57 inches respectively. However, the drought in 1998 is considered the worst of these because total rainfall during the four-month period, January-April was only 2.82 inches, compared to typical rainfall levels for that period of more than 30 inches.

Table 3-2 Rainfall in Majuro, 1978–2007

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	3.60	5.25	3.39	12.65	13.90	10.70	16.25	8.86	9.73	20.56	23.56	14.35	142.80
1979	6.78	2.77	7.14	11.75	7.91	13.23	6.67	13.03	6.54	15.04	11.33	7.10	109.29
1980	8.11	9.70	5.05	7.03	11.34	6.73	8.48	13.89	12.85	9.25	5.35	10.56	108.34
1981	0.90	4.34	17.40	10.20	9.04	5.43	16.53	12.24	6.71	7.28	14.61	14.47	119.15
1982	12.63	9.72	13.29	4.68	11.46	16.98	14.66	11.72	18.94	8.17	19.08	***3.17***	144.50
1983	***0.83***	***0.98***	***0.66***	***1.97***	***1.49***	14.45	12.58	6.05	11.25	13.47	9.84	12.74	86.31
1984	16.12	16.83	1.29	3.87	4.18	5.40	9.35	9.20	6.42	14.77	13.31	14.95	115.69
1985	8.70	16.56	4.59	15.38	9.67	14.67	13.18	16.77	8.03	18.06	12.81	11.30	149.72
1986	10.51	3.91	14.75	12.23	14.94	15.89	12.09	19.98	10.52	7.32	9.37	17.10	148.61
1987	6.24	10.38	4.34	2.14	9.22	14.76	21.17	8.36	11.09	11.29	15.45	7.48	121.92
1988	14.65	1.52	6.76	5.92	6.85	9.11	14.33	10.59	13.86	17.87	7.19	13.65	122.30
1989	7.75	8.30	4.76	8.54	11.18	7.20	17.44	10.34	14.55	16.41	19.84	8.52	134.83
1990	7.01	4.21	10.36	9.43	16.56	7.28	9.09	14.39	7.57	6.17	15.87	10.36	118.30
1991	9.87	11.68	29.54	20.46	13.24	16.60	16.41	11.04	19.73	10.44	15.35	***3.48***	177.84
1992	***7.73***	***0.20***	***0.15***	***0.36***	14.21	8.41	10.36	12.62	5.90	13.57	10.05	3.52	87.08
1993	5.82	8.51	13.49	14.10	11.31	8.17	13.92	13.32	9.80	20.48	14.41	19.24	152.57
1994	9.37	1.72	9.45	14.14	15.69	5.70	8.28	11.70	13.19	10.42	11.31	16.68	127.65
1995	8.17	4.37	4.59	21.97	7.91	12.22	10.60	11.89	15.78	10.59	11.18	12.10	131.37
1996	14.12	16.70	8.28	19.47	10.61	12.96	7.39	7.49	15.70	9.74	13.24	16.87	152.57
1997	5.44	6.95	6.57	14.54	21.33	8.19	4.93	11.69	19.09	10.91	***7.93***	***7.63***	125.20
1998	***1.57***	***0.34***	***0.27***	***0.64***	***6.59***	10.51	16.29	12.05	9.30	19.45	13.57	11.48	102.06
1999	7.23	3.82	10.15	5.32	8.20	13.07	8.94	10.99	11.35	17.85	17.27	9.85	124.04
2000	23.83	20.93	6.59	8.81	4.02	5.31	11.31	11.06	7.02	12.27	15.03	9.20	135.38
2001	5.73	5.10	0.46	4.07	7.07	15.10	10.04	11.72	20.89	20.19	14.92	9.02	124.31
2002	9.00	6.80	7.57	8.44	14.40	15.77	11.85	15.33	14.29	15.28	8.79	17.41	144.93
2003	8.62	9.95	1.47	13.38	10.55	11.50	10.16	6.33	16.62	17.02	9.14	15.26	130.00
2004	7.51	14.72	8.84	15.19	10.79	12.29	9.09	13.53	4.27	7.26	6.00	11.06	120.55
2005	5.59	9.92	9.31	9.51	6.84	8.02	12.79	14.94	10.32	14.56	18.50	11.84	132.14
2006	10.50	6.41	6.50	7.31	6.28	11.55	11.03	9.34	8.68	10.74	8.68	7.74	104.76
2007	2.00	4.90	4.31	11.26	11.42	6.67	8.64	7.27	10.25	20.74	20.31	-	107.77

Majuro Area (ThreadEx Station) Monthly Totals/Averages Precipitation (inches)

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Studies by the USGS indicate that droughts have had a profound effect on the shape and the extent of the freshwater lens in Laura (Presley, 2005). As illustrated in Figure 3-5, the size and shape of the freshwater lens at Laura decreases at times of drought. For instance, at the beginning of the 1998 drought, the freshwater lens was about 45 to 48 feet thick at its center, and about 25 and 38 feet at the monitoring well sites at the northern and southern ends of the lens, respectively. By comparison, the lens was less than 30 ft thick at the end of the drought. High chloride concentrations were detected near the center of the lens where the lens thickness was only about 18 feet. . Chloride concentrations increased during the drought and decreased during the wet season in samples collected from water-supply wells at the northern and southern ends of the lens.

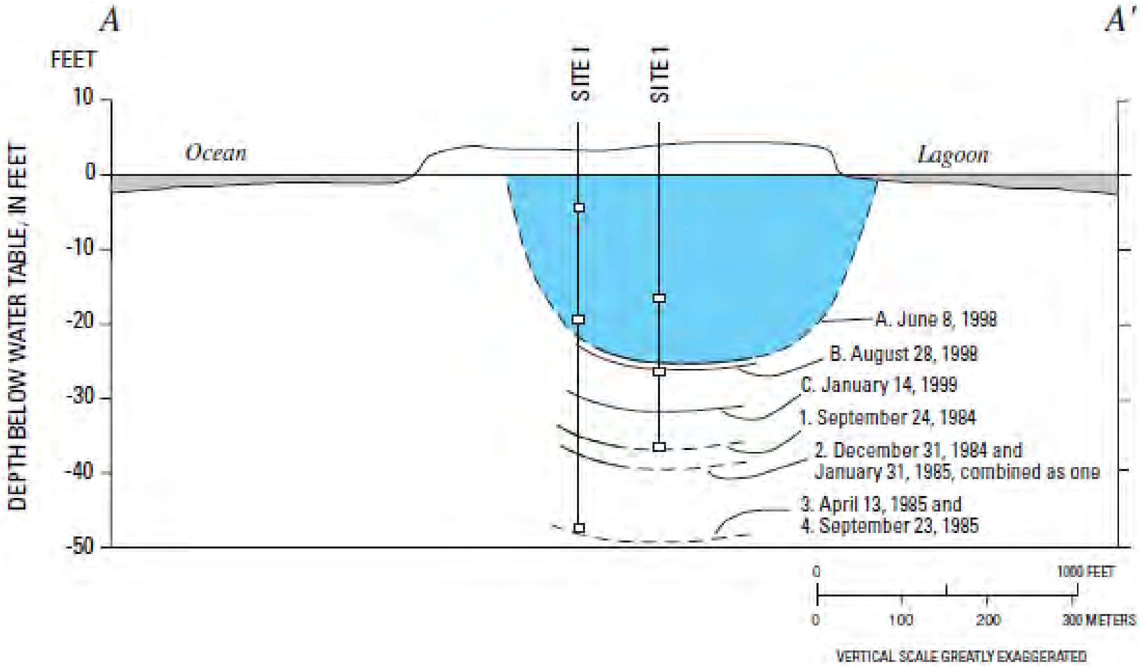

Figure 3-5: Changes in the Laura Lens due to Drought (Presley, 2005)

The USGS studies also indicate that there was rapid increase in freshwater-lens thickness during the 1998 wet season, and the increases shown during the earlier study (1984–85). This suggests that the response of the lens to variation in rainfall and pumpage can occur quickly in atoll settings relative to other hydrological settings. Increased or over pumpage decreases the thickness of the freshwater-lens thickness. For instance, the freshwater lens became thicker during the 1998 wet season by about 1 to 8 feet, depending on location. Even thought, the changes in thickness were not uniform because of the location of wells, these studies indicate that if the Laura aquifer is to remain a valuable freshwater resource careful management of the well field is required.

SEVERE STORMS Historically, typhoons have only intermittently occurred in the Marshall Islands. Majuro has on occasion been flooded due to these storms. Storm systems that have affected Majuro occurred in 1905, 1918, 1979, 1982, and 1992 with less severe storms occurring in 1899, 1988 and 2006 (Spennemann.et al, 1994).

On 15 December 2008, an unusual weather event occurred in the Pacific that caused flooding in Majuro and other islands in the region (Figure 3-6). The high tide coincided with high waves generated from a low-pressure weather system in the Wake Island area 500 miles north of Majuro. The impacts of the storm event included the displacement of 700 people in Majuro and Arno atolls, loss of 27 primary residences in Majuro and Arno, an estimated $1.5 million in damages to roads, cemeteries, and infrastructures, and significant amounts of debris and coastal erosion.

Figure 3-6: Clean-up After the December 2008 Disaster

Severe storms can contaminate freshwater supplies in a variety of ways. Flooding and sea spray can contaminate open wells, and seaspray can contaminate the airport collection system and rooftop collection systems. Rooftop collection systems also can be damaged by high winds. Sever storms can also accelerate coastal erosion processes and reduce the land area overlying freshwater lenses.

3.2.2 CLIMATE CHANGE

The process of predicting future climate is considered an extremely daunting task. As described by Burns (2003), it requires an assessment of the future state of a wide array of complex climatic components, including the atmosphere, the ocean, land surfaces, the stratosphere, and the sun, as well as the interactions among these components with the only practical method to make such projections being through the use of mathematical models, derived from weather forecasting, to represent the earth's energy and water cycles. The most sophisticated of these models, general circulation models (GCMs), use a three-dimensional grid overlaying the surface of the earth coupled to atmosphere-ocean general circulation models to simulate the earth's climatic system and facilitate prediction of changes in key climate parameters into the future. The developmentand parameterization of these models is coordinated through the United Nations' Intergovernmental Panel on Climate Change (IPCC). This section provides a brief overview of climate changes that are expected to occur for Majuro and the Marshall Islands and the potential impacts of these changes on freshwater resources.

PRECIPITATION As illustrated in Figure 3-7, precipitation data exhibits a slightly downward trend since 1960. Future changes in annual precipitation in the Marshall Islands are uncertain and the various models do not agree on the direction and magnitude of future changes. However, from the perspective of freshwater resources, the main concern is the frequency and intensity of droughts as such weather events impact on the production of rainwater-collected supplies and groundwater (SPREP 1999). Predictions indicate that climate change could result in an increased incidence of El Niño events, which in the past have been associated with massive decreases in rainfall in the western portion of the Pacific. During an El Niño event, the warm waters of the western equatorial Pacific flow east and the rainfall, in a sense, goes with them, leaving the islands in the west in drought.

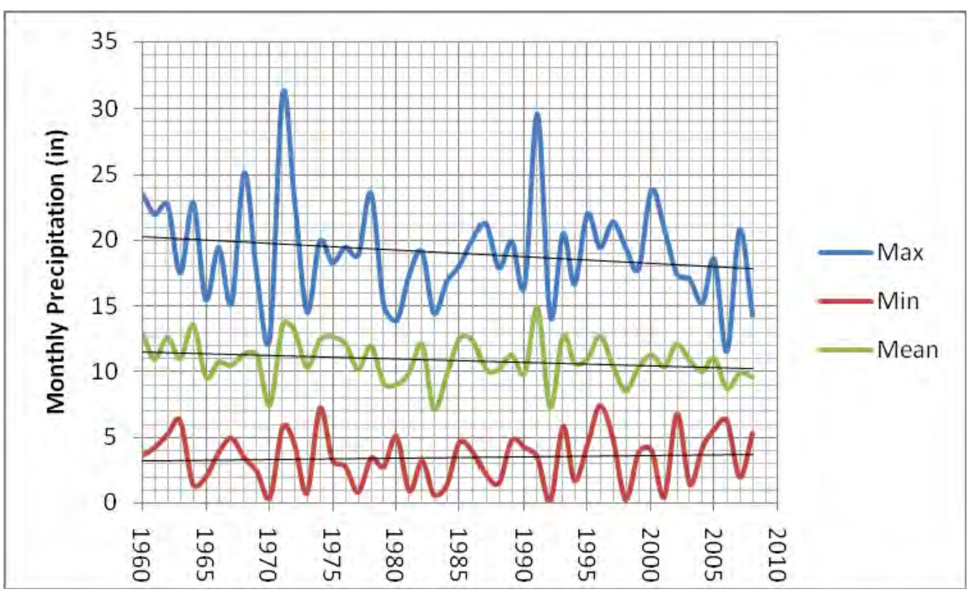

Figure 3-7: Annual Variation in Precipitation at the Majuro Weather Station (WSO, 2009)

A longer term precipitation phenomena that could significantly alter rainfall in the Marshall Islands is the movement of the inter-tropical conversion zone (ITCZ) "rain band." As illustrated in Figure 3-8, many of the atolls of the Marshall Isalnds are situated in the heavier rain bands. However, there is ongoing reasearch to determine if the rainband has moved 300 miles to the north over the last 350 years and whether this pattern is likely to continue.

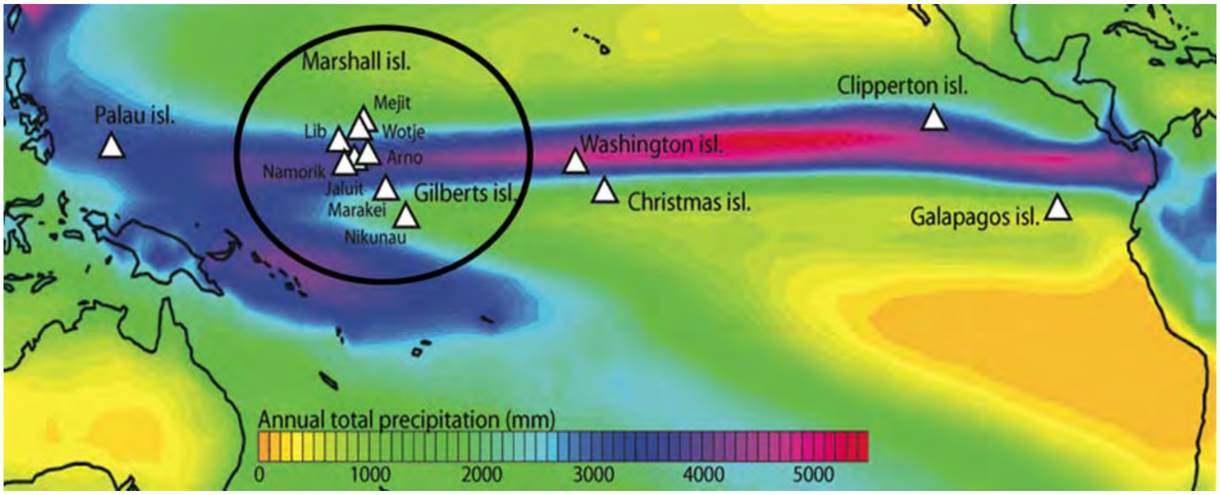

Figure 3-8: ITCZ Rain Band

TEMPERATURE Figure 3-9 shows that mean temperatures on the Marshall Islands have been increasing since the 1960s. The results from the various models (Figure 3-10) indicate that the upward trend in temperatures is like to increase to 2100. As illustrated in Figure 3-11, the Marshall Islands are situated in a zone where temperatures are expected to rise by about 2 to 3 degrees centigrade (4 degrees Fahrenheit). Higher temperatures may result in an increase in potential evaporation (atmospheric water demand) rates in Marshall Islands. This may accelerate the drying out of soil and vegetation, increase water loss in uncovered reservoirs, and decrease recharge to the Laura lens. Although these increases in temperature may be slight the long term impact on freshwater supplies may be substantial.

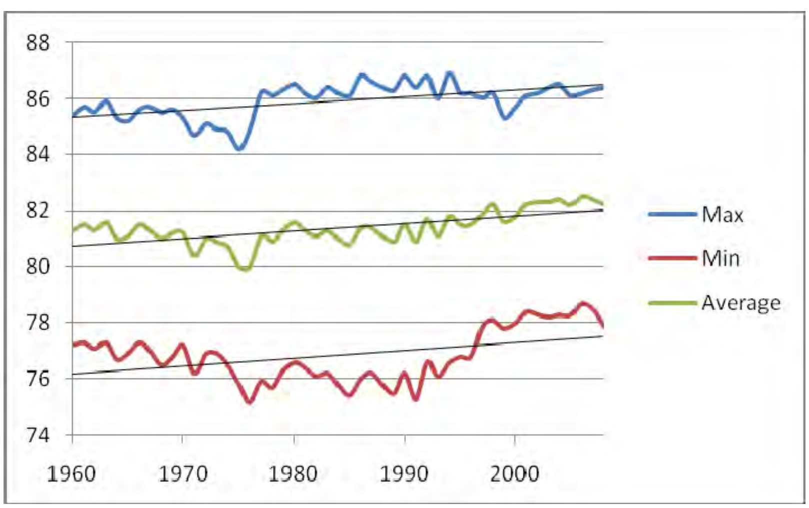

Figure 3-9: Annual Temperature Trends at the Majuro Weather Station (WSO, 2009)

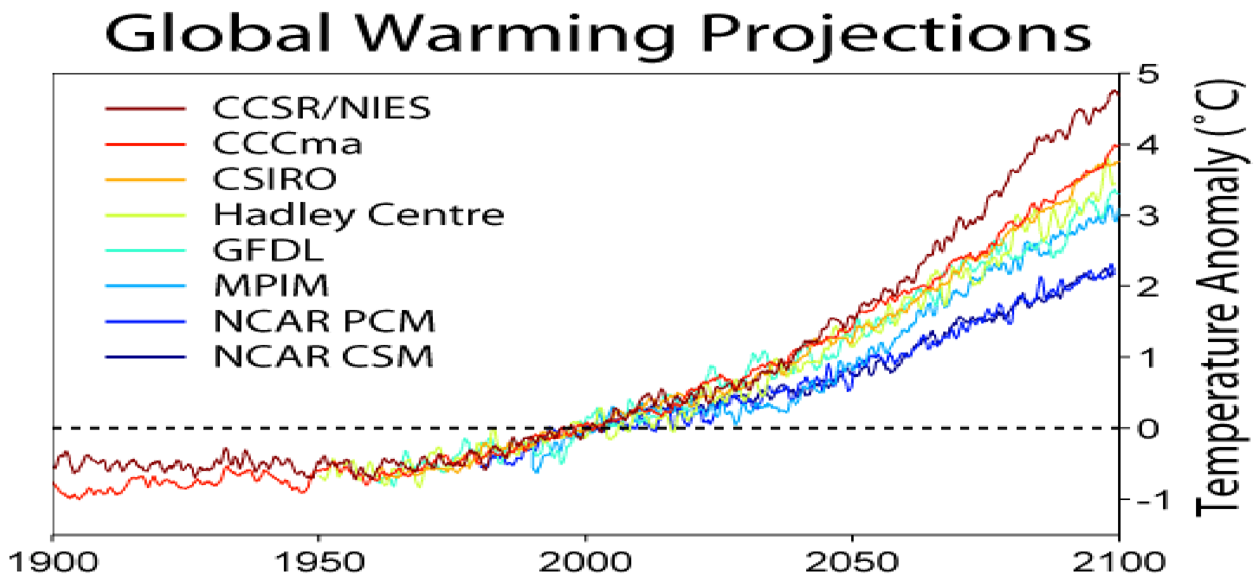

Figure 3-10: GCM Results for Temperature

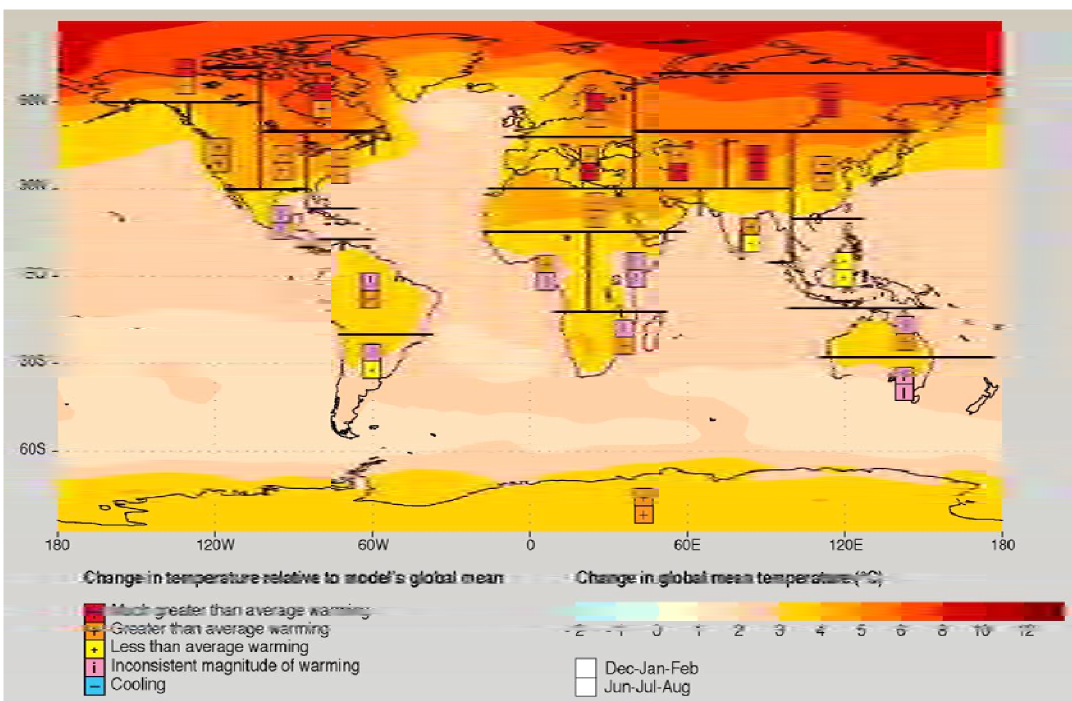

Figure 3-11: Climate Change to 2100: Temperature

SEVERE STORMS As sea temperature rises, there could be a greater exchange of energy and add momentum to the vertical exchange processes critical to the development of tropical typhoons and cyclones. Some researchers predict that the occurrence of tropical typhoons and cyclones could increase by as much as 50–60 percent (NASA 2001) and their intensity by 10–20 percent (Burns, 2003). It is uncertain if there will be an increase in tropical storm activities in the Marshall Islands. However, history tells us that these storms are both constructional agents and erosional agents. In areas that experience only occasional storms such as the recent event in Majuro and Arno, rubble may occur along the most exposed beaches, and shingle may veneer otherwise sandy islands where the reef flat is narrowest. Storms appear to have had a role in transporting larger material to construct the platform (Woodroffe, 2007). As mentioned earlier, storm surges have adversely affected fresh water supplies by contaminating both groundwater and catchment areas. To the extent that severe storms accelerate coastal erosion, they could reduce the land area overlying freshwater lenses and reduce recharge potential propotionally.

SEA LEVEL RISE Australian Aid installed a Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) gauge in Majuro in May 1993. This gauge records sea level, air and water temperature, atmospheric pressure, wind speed and direction. It is one of an array of instruments designed to monitor changes in sea level and climate in the Pacific. As illustrated in Figure 3-12, data from the SEAFRAME program indicates that sea level appears to be rising in the direct vicinity of the Marshall Islands at a rate of about 4 mm per year. Figure 3-13 shows the projections from various GCMs for sea level rise to 2100. The projected sea level rise accounts for thermal expansion of seawater and doesn't reflect recent model results that account for glacial retreat and melting of polar ice and project higher sea levels.

According to Burns (2003), some researchers have expressed concern that sea-level rise could result in intrusion of saltwater into the freshwater lenses of coral islands and atolls. Yet some research indicates that such a rise would have little effect on freshwater lenses. Given that the freshwater lens in Laura is well established, it is uncertain as to the degree sea level rise might affect it. Ongoing monitoring programs indicate that the lens is much more susceptible to decreasing recharge and higher extraction rates than sea level rise. However, there is the potential that rising sea levels will result in higher water tables in areas where the groundwater is not exploited. As the water table rises toward the land surface, it is more susceptible to evapotranspiration and depletion of the freshwater resource. It also makes the groundwater more susceptible to surface contamination. High tides may also raise the water table above the ground level causing floods. If the intrusion of saltwater into freshwater lenses due to sea level rise becomes more pronounced, it could also result in reductions in crop yield. Crops such as taro, breadfruit, and coconuts, which are grown on Laura, are sensitive to salinity in their root zones.

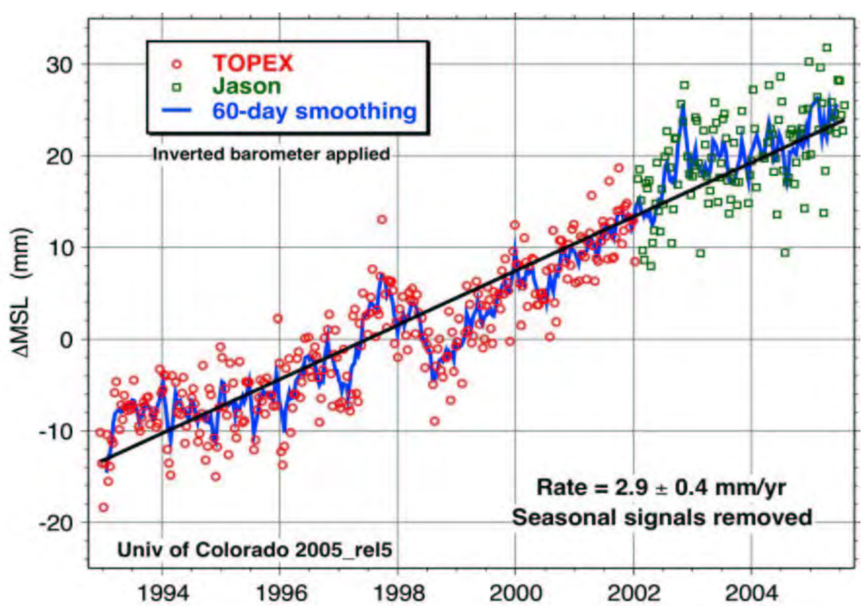

Figure 3-12: SEAFRAME Sealevel Measurements (SOPAC, 2009)

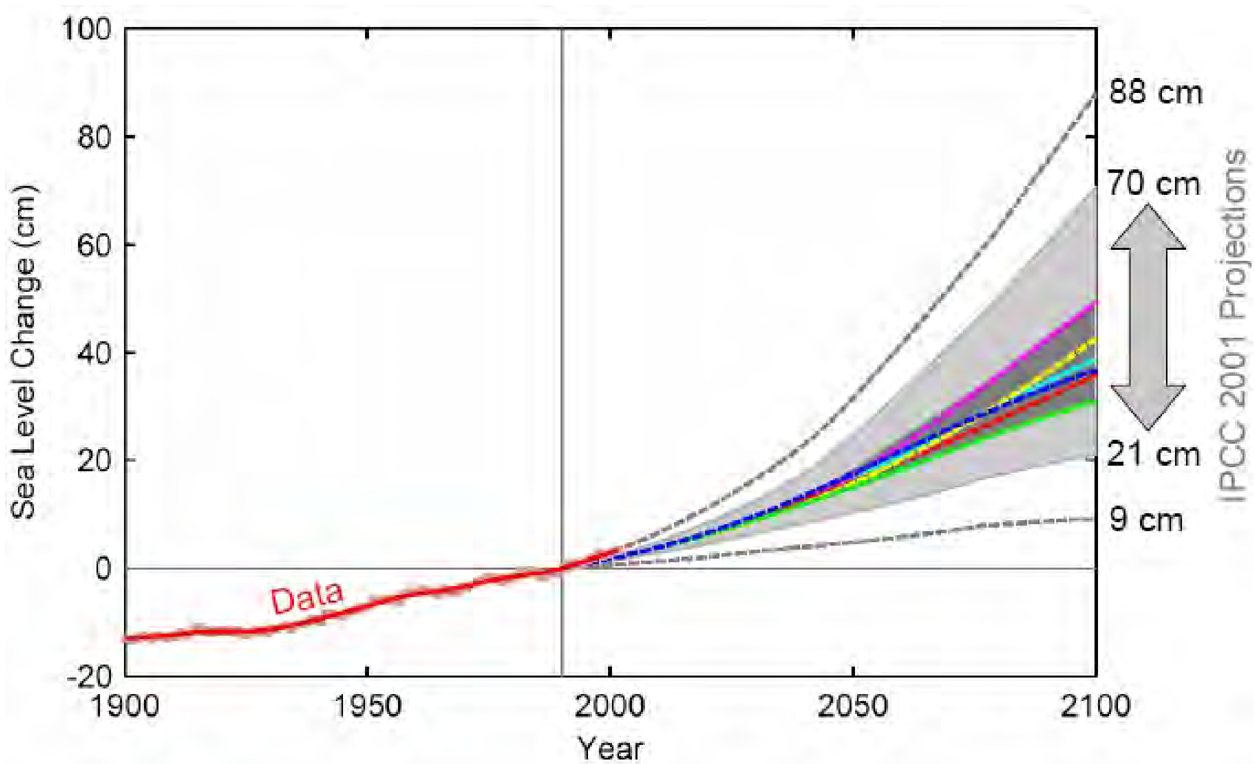

Figure 3-13 – Sea Level Rise to 2100 (IPCC)

3.3 VULNERABILITY TO CLIMATE VARIABILITY AND CHANGE: FRESHWATER RESOURCES

During the V&A Workshop in February, one of the small groups was tasked to to identify the valued assets that would be impacted by climate change, the nature of exposure and sensitivity, and current capacity of RMI to cope with climate impacts. The key results from this exercise are presented in Table 3-3.

Table 3-3 Freshwater Resources Vulnerability: Workshop Results

Valued assets	Impacts from CC	Exposure/sensitivity to climate variables	Adaptive capacity
Rainfall 3 different rainfall zones (dry in north, wet in south)	Droughts Increased rains	Highly linked to CC. Less or more rain Increased unpredictability	Lack of back up capacity Some experience dealing with drought, water shortages, storms, but could be improved Weather forecasting good, but could be improved FEMA and donors assist National Disaster Risk Management Plan exists Experts and champions Newer catchment tanks are more numerous, but more vulnerable to damage as compared to old concrete tanks Lack of land for expansion of run way catchment
Storage Catchment (individual and runway) Ground water lens	Pollution Floods Wind SLR Storms Increased evaporation rates?	Located on coasts Subject to damage from waves, wind, storms, etc. Salinization of groundwater due to saltwater intrusion	
Existing desalinization plants	Storms Energy costs	Located on coasts Damage from winds, storms, floods	

Valued assets	Impacts from CC	Exposure/sensitivity to climate variables	Adaptive capacity
Large scale importation of water	Storms Energy cost Social turmoil elsewhere	Subject to disruption of supply chain/problems with transportation Pollution of imported water	Need to improve all waste management activities Some financing exists for water activities but more needed Protection of Laura land and lens to maintain supply Maintenance expertise exists, but need more
Traditional Coconut trunks, groundwater, coconuts	Drought Tree loss	Fallen trees Intrusion of seawater and salinization of groundwater	

The results from the workshop on vulnerability of freshwater resources provided a starting point for the team in updating the vulnerability assessment. Table 3.4 presents the updated assessment of vulnerability, organized by climate impact rather than valued asset.

Table 3-4 Freshwater Resources Vulnerability: Revised Analysis

Climate Impact	Valued assets	Vulnerability to Climate Change	
		Exposure and sensitivity	Adaptive capacity
Drought	• Households, businesses, government and other public • Rainwater collection systems • Groundwater • Trees and other vegetation	• All consumers exposed to drought because precipitation primary source of water for island and rainwater collection systems • Groundwater sensitive to drought as precipitation required for recharge • Trees sensitive to drought – may not survive without water	• Current water supplies inadequate for prolonged droughts associated with El Nino events • Back-up sources (groundwater and reverse osmosis) provide support in emergencies • Weather forecasting good • FEMA and donors assist in prolonged droughts • National Disaster Risk Management Plan exists • Limited technical capacity to support rainwater harvesting best practices
Floods	• Private wells • Underground storage reservoirs • Residents	• Transport of pollutants and debris to uncovered wells and underground storage reservoirs • Increased incidence of waterborne illness	• Limited capacity to inspect wells and remediate flood damage to contaminated wells and underground storage reservoirs • National Disaster Risk Management Plan exists • FEMA and donors assist in flood emergencies
Increased temperature	• Rainwater collection systems • Storage reservoirs • Residents	• Reduced rainwater collection efficiency and storage due to evaporation • Increased water demand, higher incidence of illness	• Maintenance of runway collection system can be improved • Majority of storage reservoirs uncovered
Storms – high waves and winds	• Rainwater collection systems • Groundwater • Trees • Power	• Damage to rooftop collection systems from high winds • Disruption of power services needed to operate water infrastructure • Saltwater and sea spray contaminate uncovered storage and unprotected wells	• Bulding codes needs to stress improved materials • Land use planning and coastal erosion management strategy needed • Back-up power systems • Some maintenance and repair capacity, but could be improved

		• Accelerates coastal erosion and puts infrastructure at risk	• Limited financing for coastal erosion prevention and remediation
Sea level rise	• Rainwater collection systems • Groundwater • Trees and other vegetation	• Exacerbates coastal erosion processes due to storms • Intrusion of seawater and salinization of groundwater • Loss of productivity for certain trees and crops due to lower water tables and increased root zone salinity	• Land use planning and coastal erosion management strategy needed • Limited financing for coastal erosion prevention and remediation • Donor assistance to assess groundwater supplies needs to be augmented with better groundwater monitoring program

4. ADAPTATION OPTIONS

4.1 WORKSHOP RESULTS

To reduce vulnerability of freshwater resources to climate change, small group participants in the February 2009 workshop in Majuro identified potential adaptation measures in four categories: infrastructure, policy, good practices and capacity building. A selection of the adaptation measures identified by the small group on freshwater resources is provided in Table 4-1. Adaptation measures in *blue italics* are included in the list of measures we identified (although not necessarily as worded in the table) and assessed for possible inclusion in a freshwater strategy for Majuro (see Section 5).

Table 4-1 Freshwater Resources – Adaptation Measures

Adaptation Category	Adaptation Measures
Infrastructure	• *Expand reservoir storage capacity* • *Expand desalinization capacity (reverse osmosis units)* • Water treatment • *Improved rainwater harvesting* • Obtain fund to build and maintain infrastructure • *Improve all waste management services* • Water testing labs
Policy	• Fines for pollution • *Implement and enforce all existing policies* • *New building codes-must have water catchment* • *Improved planning on all levels* • Tax incentive for good practices, import of new materials/systems • Awareness of gender issues
Good practices	• *Water rationing/recycling* • *No car washing* • *Better showerheads* • *Dual flush toilets*
Capacity building	• Inclusion of gender issues • *Training in new methods and use of materials for all mentioned above* • *Outreach and training materials for all mentioned above* • *Involve youth*

4.2 REVISED LIST OF ADAPTATION MEASURES

The study team reviewed the adaptation options identified by the small group participants, refined their list and reorganized options into four thematic categories: 1) improved management of freshwater resources; 2) preparing for drought emergencies; 3) managing demand; and 4) outreach on water management and climate. The revised list of adaptation measures is presented in Table 4-2. Within each category, groups of adaptation measures have been shaded as blue or gray to indicate that these measures are designed to address similar issues within the category. For example, in the first category, the first blue-shared group includes adaptation measures to improve the public water supply, the gray group focuses on rainwater harvesting, and the third group (blue-shaded) is concerned with options to reduce pollution.

Table 4-2 Revised List of Adaptation Measures

Option	Type of Adaptation
Improved Management of Freshwater Resources	
Conduct a comprehensive audit of the public water supply system	Capacity Building
Implement performance-based management system	Capacity Building
Design and install major capital improvements to the water supply systems	Infrastructure
Increase household access to water	Policy/Infrastructure
Improve rainwater collection system cleaning and maintenance	Best Practice/Capacity Building
Strengthen building codes to require rooftop collection and storage systems	Policy
Develop and carry out pilot programs for community based collection systems	Infrastructure/Capacity Building
Assess coastal erosion surrounding the freshwater lens at Laura	Capacity Building
Implement and enforce pollution and waste management laws and regulations	Policy/Capacity Building
Complete well survey for Majuro	Capacity Building
Seal wells which are no longer in use to prevent contamination of the aquifer	Best Practice
Preparing for Drought Emergencies	
Strengthen drought emergency capacity	Capacity Building
Design and implement drought warning system	Best Practice
Procure emergency equipment	Infrastructure
Develop training programs	Capacity Building
Managing Demand	
Develop policies and incentives for water conservation	Policy/Best Practice
Train and equip inspectors to support water conservation and emergency measures	Capacity Building
Outreach on Water Management and Climate	
Design and implement a outreach campaign on rainwater harvesting	Capacity Building/Best Practices
Provide an education/awareness program on water conservation	Capacity Building/Best Practices
Develop curricula in schools on climate change and water	Capacity Building
Design and implement a “School Met” system	Capacity Building

5. ASSESSMENT OF ADAPTATION OPTIONS

This chapter provides a basic assessment of adaptation options for the four categories enumerated in the previous chapter. The assessment is very general, designed to provide a basic sense of how soon adaptations can be implemented, how difficult it would be implement adaptations, their costs and effectiveness. Each section provides brief discussion of the adaptation measures in Table 4-2 followed by a table summarizing the assessment results. In Chapter 6, we provide recommendations on short and medium-term strategies.

5.1 IMPROVED MANAGEMENT OF FRESHWATER RESOURCES

The options for improving management of freshwater resources are divided into three groups related to management of public water, rooftop rainwater harvesting and protection of groundwater.

5.1.1 MANAGEMENT OF PUBLIC WATER

CONDUCT A COMPREHENSIVE AUDIT OF THE PUBLIC WATER SUPPLY SYSTEM. This would include assessment of the operation of the runway collection system (maintenance and repair of infiltration areas and collection pipes), the water treatment plant, the well field in Laura and associated infrastructure, and the storage reservoir at the airport and distribution systems (Laura to airport, airport to Majuro City. The audit would provide recommendations on low cost improvements, maintenance and rehabilitation programs, and options for improving utilization through reduced evaporation and monitoring of leakage in the distribution system. Low cost improvements could be as simple as new meters, better chlorination system, training for operation, and the development of a real-time water monitoring system (both quantity and quality) for the network. High cost improvements could include covers for storage reservoirs, construction of new storage reservoirs, or rehabilitation of water distribution systems.

IMPLEMENT PERFORMANCE-BASED MANAGEMENT SYSTEM. Based on recommendations of the public water audit, MWSC should take steps to improve performance. This could be done by implementing a performance management system which would reward managers for good performance. Typical performance indicators include % NRW, recovery of operating and maintenance costs and/or capital costs, billing efficiency, water storage efficiency, energy costs per 1000 gallons of delivered water. In conjunction with a performance-based management system, MWSC should consider implementing a SCADA (Supervisory Control and Data Acquisition) system featuring continuous monitoring of well production rates, flow and pressure readings for the distribution system and the airport collection system, and volumetric monitoring equipment for the storage reservoirs. Line of site radio communications can be used to transfer data to a central data management system. Such as system would provide real time information that, if used properly, could help MWSC manage the water system on a performance basis.

DESIGN AND INSTALL MAJOR CAPITAL IMPROVEMENTS TO THE WATER SUPPLY SYSTEMS. This could include the development of new storage reservoirs, installation of new pipes to reduce leakage, installation of a SCADA system and associated metering and communications systems, and repairs and expansion of wastewater treatment. Priorities for wastewater treatment include:

i. Repair of the wastewater discharge pipe/outfall – wastewater is currently discharged too close to the shoreline. Also, longer term options for treating or partially treating wastewater from Majuro City should be explored.

ii. Develop wastewater collection system for unserved areas between the airport and Majuro City – there has been considerable residential growth on Long Island and collection and centralized treatment options should be explored.

iii. Design and develop a small scale pilot program for management of household and livestock waste in Laura. Such a program could be developed for Laura where groundwater contamination is a major concern and could consist of a variety of small-scale treatment options: bioreactor, composting toilets, or properly designed septic tanks.

INCREASE HOUSEHOLD ACCESS TO WATER. As noted earlier, 23% of the household in Majuro do not have direct access to water. Two options, individually or in combination might be considered to address this problem:

i. EPPSO has grant funding of 395,377 Euros for development of rainwater collection systems in Majuro and Ebeye. Not all residences will be suitable for rainwater collection systems because of roof construction and/or condition. It may be useful to conduct a feasibility study on the development of community systems either in cooperation with churches or schools to increase their storage capacity for community water, or by constructing new systems. Survey data developed by EPPSO could be used to determine residential areas that would benefit from community systems.

ii. MWSC might consider the use of pre-paid meters as part of a reconnection program. As noted earlier, MWCS will reconnect inactive accounts for $30 and settlement of delinquent accounts. It might be considerably more cost-effective than construction of residential rooftop collection for MWSC to forgive delinquent accounts and reconnect if households pre-pay for water (e.g., in increments of 1,000 gallons – a $6 dollar pre-payment. This would limit the non-payment problem and increase access.

5.1.2 ROOFTOP RAINWATER HARVESTING

IMPROVE RAINWATER COLLECTION SYSTEM CLEANING AND MAINTENANCE. Organize neighborhood audits and training for households on the benefits and best practices for cleaning and maintaining rooftops, collection drains and storage tanks. In conjunction with audits, it would be useful to assess local capacity to supply replacement parts and improve collection systems (repair or expansion of drains).

STRENGTHEN BUILDING CODES TO REQUIRE ROOFTOP COLLECTION AND STORAGE SYSTEMS. All new construction and major renovations should be required to optimize rainwater harvesting capacity. Rainwater collection efforts are stymied by poor roof designs, undersized gutters and limited storage capacity. While residential units cannot be required to invest in excess storage capacity, RMI should take advantage of the large roof areas at schools and other public buildings and design storage systems that could meet the building's water needs and potentially provide water to residents without access to public water or rainwater.

DEVELOP AND CARRY OUT PILOT PROGRAMS FOR COMMUNITY BASED COLLECTION SYSTEMS. Feasibility studies should be developed in the first year and RMI or donor financing explored. There may be opportunities to work with churches and community organizations to develop rainwater supplies for residents in the community who do not have access to public water. The cost of a pilot program should be minimal and could be rolled out to other communities in a second phase.

5.1.3 PROTECTION OF GROUNDWATER

ASSESS COASTAL EROSION SURROUNDING THE FRESHWATER LENS AT LAURA. There are three keys to the long-term sustainability of the Laura freshwater lens: maintaining land area for rainwater capture and recharge, management of extractions and protection against pollution. While land loss is a less important near term issue than overpumping or pollution, it would be useful to assess erosion in Laura to determine the rate of land loss, impacts of reduced land area on recharge and options for mitigating coastal erosion above the freshwater lens.

IMPLEMENT AND ENFORCE POLLUTION AND WASTE MANAGEMENT LAWS AND REGULATIONS. There are numerous household and agricultural sources of pollution in Laura which are not currently managed, monitored, or enforced effectively. Given the high value of freshwater in Laura and its role in enhancing water and food security for Majuro, a concerted effort is needed to ensure pollution and waste management best practices are implemented by households, farmers, and livestock operations. Some consideration should also be given to the design and construction of a small wastewater treatment plant in Laura.

COMPLETE WELL SURVEY FOR MAJURO. Extensive work has been carried out to survey private wells in Laura but little is known of the wells in the other areas of Majuro. The concept of this survey would be to identify private wells, determine if they are in use, levels of pollution and which wells could be permanently sealed.

SEAL WELLS WHICH ARE NO LONGER IN USE TO PREVENT CONTAMINATION OF THE AQUIFER. As a second phase to the well survey, wells that are no longer in use or those that pose a threat by allowing surface water contamination to leach into the aquifer would be sealed. The sealing of the wells would be carried out in accordance with "best management practices" and would entail removing the pump from the well, pulling the well casing and pumping a suitable grout down the well to finalize the seal.

Table 5-1 Assessment of Adaptation Measures: Improved Management of Freshwater Resources

Option	Time Period	Ease of Implementation	Cost	Effectiveness
Conduct a comprehensive audit of the public water supply system	< 1 year	LD	L	H
Implement performance-based management system	1 to 2 years	VD	M	M
Design and install major capital improvements to the water supply systems	1 to 2 years	VD	H	H
Increase household access to water	< 1 year	D	M	H
Improve rainwater collection system cleaning and maintenance	< 1 year	LD	M	H
Strengthen building codes to require rooftop collection and storage systems	1 to 2 years	D	L	M
Develop and carry out pilot programs for community based collection systems	1 to 2 years	D	M	M
Assess coastal erosion surrounding the freshwater lens at Laura	< 1 year	LD	L	M
Implement and enforce pollution and waste management laws and regulations	1 to 2 years	D	L	M
Complete well survey for Majuro	< 1 year	LD	L	M
Seal wells which are no longer in use to prevent contamination of the aquifer	1 to 2 years	D	M	M

- Ease of Implementation – LD = less difficult, D=difficult, VD=very difficult
- Cost – L=low cost (<$100,000), M=medium cost ($100,000 to $1,000,000), H= high cost (>$1,000,000)
- Effectiveness – L = low (probably not effective in assisting adaptation), M = medium (a good probability that this option with reduce the effects of climate change), H = high (high probability of being effective to reduce the effects of climate change)

5.2 PREPARING FOR DROUGHT EMERGENCIES

Droughts are frequent phenomena in RMI. On Majuro, with its capacity to capture and store 38 million gallons of water, only the prolonged droughts associated with El Nino events significantly stress public supplies. On many outer islands, even a month or two without precipitation can tax storage capacity. Plans are in place to assist islanders in coping with drought emergencies. MWSC has adopted policies to restrict water supplied to the distribution system depending on the amount of water in the storage reservoirs: water is delivered three times a week, unless the volume of water falls to 21 million gallons, at which point, water is delivered twice a week. If the volume of stored water falls to 10-11 million gallons, water is delivered once a week.[4] As plans for managing water during droughts already are in place, recommendations focus on suggestions for fine-tuning these plans in concert with improved water management and managing water demand.

STRENGTHEN DROUGHT EMERGENCY CAPACITY. Recently, RMI implemented the 2008 National Action Program (NAP) to Combat Land Degradation and Mitigate the Effects of Droughts. The NAP has a duration of 5 year ((2008-2012) with its implementation to be monitored and coordinated by the Office for Environmental Planning and Policy Coordination (OEPPC) with the support of a national coordinating body. Within the OEPPC, there is a high level of frustration with disaster planning and preparedness in the RMI (OPPEC, 2008). This suggests it would be useful to review the NAP, identify weaknesses in planning and integration and coordination with MWSC and determine resource and staff capacities needed to execute the NAP (see also the two adaptation options described below).

DESIGN AND IMPLEMENT DROUGHT WARNING SYSTEM. Early warning technologies are available for almost all types of hazards, and are in operation in most parts of the world. In some locations, useful forecasts or now casts are possible even for hazards such as climate impacts. Currently, NOAA has in place a six month to one year outlook for El Nino as well as drought warning system that consists of three phases – Normal, Drought Alert, and Drought Warning with the later being the most severe. The major challenges in implementing such as sytem are: 1) communicating the different warning levels to the public and 2) ensuring that drought emergency plans for the outer islands are coordinated with the two worning levels. The objective of this program would be to work with organizations such as MICS to design and implement a communication program with outer islands as well as agencies within the RMI government and link the communications system with practical planning and response measures.

PROCURE EMERGENCY EQUIPMENT. In 2008, OPPEC (2008) suggested the need for RO units with 27,000 gallon per capacity for Majuro and 10,000 gallons per day capacity on Ebeye. In addition, they felt that additional water trucks were needed, solar powered RO units for outer islands, and additional RO units for islands that have sufficient power. There is little doubt that the procurement of emergency equipment such as RO units to supply drinking water during a severe drought is important and should be taken as a proactive step. However, such an investment should be carefully sized and coordinated with improvements in MWSC's management of storage capacity and private sector bottled water producers. Other RO options might be considered besides procurement of portable units. For example, there might be economies in scale to siting RO at MWSC and augmenting rainwater collection even before storage volumes fall to critical levels. In addition, given current consumption levels of 40 gallons per capita per day or about 1.2 million gallons per day, additional RO capacity may be needed (and would also reduce pressure to overpump Lauro during droughts). Purchase of additional water trucks should be considered as part of an overall water delivery strategy and compared with options of setting up emergency standpipes for delivery to residents.

DEVELOP TRAINING PROGRAMS. During the drought emergency of 1998, at least 8 RO units were brought to the Marshall Islands to help meet the drinking water needs of the country. Five of these units were high capacity (10,000 gallons per day) with the others with lower capacity (around 2,000 gallons per day). Currently, none of the large capacity RO units are operational with the smaller units in storage. One of the reasons

[4] Efforts to restrict the frequency of delivery may not save much water as residents have incentives to invest in storage capacity to ensure they have adequate supplies on days that water is not delivered.

that the larger units are not functional is that they have not been maintained and that there is a general lack of trained personnel to maintain them. This program would assist the RMI is developing programs perhaps through the CMI to train technicians not only on maintenance procedures for equipment but also on proper storage and operation.

Table 5-2 Assessment of Adaptation Measures: Preparing for Drought Emergencies

Option	Time Period	Ease of Implementation	Cost	Effectiveness
Strengthen drought emergency capacity	< 1 year	LD	L	M
Design and implement drought warning system	< 1 year	D	M	H
Procure emergency equipment	1 to 2 years	VD	H	M
Develop training programs	1 to 2 years	LD	M	M

- Ease of Implementation – LD = less difficult, D=difficult, VD=very difficult
- Cost – L=low cost (<$100,000), M=medium cost ($100,000 to $1,000,000), H= high cost (>$1,000,000)
- Effectiveness – L = low (probably not effective in assisting adaptation), M = medium (a good probability that this option with reduce the effects of climate change), H = high (high probability of being effective to reduce the effects of climate change)

5.3 MANAGING DEMAND

Each of the concepts developed above provide actions that could be taken by the RMI to improve management of freshwater resources and lessen the severity of drought on the population. Adjustment of water consumption behavior during drought can help stretch supplies and avoid even more draconian reductions when droughts extend to several months. Because many residents are not connected to the public system and seawater is used to flush toilets (and many residents do not have flush toilets), some of the international best practices for water conservation may be less effective in Majuro than they are elsewhere. Nevertheless, there are options for encouraging water conservation (also see Section 5.4 for outreach on water conservation).

DEVELOP POLICIES AND INCENTIVES FOR WATER CONSERVATION. These might include provisions that require all new buildings to have water conservation devices, incentives to retrofit water fixtures, standards for water efficient appliances. Government offices and private businesses such as restaurants and hotels could take the lead in reducing water consumption and demonstrating the water savings associated with effective maintenance programs.

TRAIN AND EQUIP INSPECTORS TO SUPPORT WATER CONSERVATION AND EMERGENCY MEASURES. A cadre of inspectors could help manage water supplies more effectively. Activities could include more frequent reading of meters during droughts to ensure that all customers are reducing water consumption, assisting customers to identify water conservation practices (behavior and technological), investigating leaks in distribution systems, and wasteful water use. There are numerous methods to inspect pipes for leakage. These can be automated or be manual, handheld acoustic devices that can detect leaky pipes from above ground. With perhaps 50% of piped water lost in distribution systems, a program would be developed to obtain the right equipment for the RMI and train technician in the MWSC in the use of leak detection equipment.

Table 5-3 Assessment of Adaptation Measures: Managing Demand

Option	Time Period	Ease of Imple-mentation	Cost	Effective-ness
Develop policies and incentives for water conservation	< 1 year	D	L	M
Train and equip inspectors to support water conservation and emergency measures	< 1 year	LD	M	M

- Ease of Implementation – LD = less difficult, D=difficult, VD=very difficult
- Cost – L=low cost (<$100,000), M=medium cost ($100,000 to $1,000,000), H= high cost (>$1,000,000)
- Effectiveness – L = low (probably not effective in assisting adaptation), M = medium (a good probability that this option with reduce the effects of climate change), H = high (high probability of being effective to reduce the effects of climate change)

5.4 OUTREACH ON WATER MANAGEMENT AND CLIMATE

This section focuses on outreach and education on water management and climate and views these as "stand alone" adaptation measures for the purposes of the case study. However, there is a need to establish an over-arching, sector-wide approach to climate outreach and education to ensure that outreach/education programs in water management, food security, disaster management, coastal land use, etc., convey consistent and integrated messages to the public and private sector about climate, climate change, climate impacts, and RMI's vulnerability to climate change.

5.4.1 OUTREACH ON WATER CONSERVATION AND RAINWATER HARVESTING

Design and implement an outreach campaign on rainwater harvesting. There is considerable outreach and educational material available on designing and maintaining rainwater harvesting systems, including brochures developed by SOPAC. These materials should be tailored to RMI and translated into Marshallese. In addition, the dissemination of materials should be coordinated with neighborhood "field schools" on cleaning and maintaining roof top collection systems. Outreach and field school could be offered by CMI, MICS, MWSC, or some combination of organizations.

Provide education/awareness program on water conservation. In most places in the World, water shortages affect people in different ways. The poor are mainly affected but also the middle and upper classes can also be affected. People do not always understand the importance of saving water especially during periods when water is not a problem. However, understanding the need for conservation during a "drought alert" period is very important. This program would be designed to provide education to all classes of people on the importance of water conservation especially during periods of drought and to explain the benefits of changing water behavior and switching water-using technology. USAID has funded a number of international water conservation campaigns using a wide range of delivery mechanisms (e.g., television, radio, newspaper, inserts in water bills, posters and banners). In some countries, an outreach program is timed to seasonal dry periods or extended droughts.

5.4.2 SCHOOL PROGRAMS ON CLIMATE AND WATER

Develop curricula in schools on climate change and water. Education on climate change begins in schools. Experience dictates that the more students understand about climate, the more likely the message will also reach their parents. This program would train teachers and administrators on the importance of climate change and how to establish curricula at different educational levels from primary school to CMI. A number of organizations in the Pacific as well as USAID can provide reference and training material for a range of education levels.

DESIGN AND IMPLEMENT A "SCHOOL MET" SYSTEM. One way to increase awareness of climate among students is to implement a climate monitoring program in which students use small solar powered meteorological kits to record temperature, precipitation, and other climate parameters. They can track intervals between rainfall and longer term trends in precipitation. IRG can provide information on the design of a "School Met" program we implemented in Cyprus and work with the Majuro Weather Station or other partners on developing "school met" for Majuro and outer islands. Tasks would include selection and installation of met stations, training of teachers, preparation/adaptation of educational materials on climate and water, and organization of network of school met systems to facilitate inter-island comparisons.

Table 5-4 Assessment of Adaptation Measures: Outreach on Water Management and Climate

Option	Time Period	Ease of Implementation	Cost	Effectiveness
Design and implement an outreach program on rainwater harvesting	< 1 year	D	M	M
Provide education/awareness program on water conservation	< 1 year	LD	L	H
Develop curricula in schools on climate change and water	< 1 year	D	L	M
Design and implement a "School Met" system	< 1 year	LD	L	M

- Ease of Implementation – LD = less difficult, D=difficult, VD=very difficult
- Cost – L=low cost (<$100,000), M=medium cost ($100,000 to $1,000,000), H= high cost (>$1,000,000)
- Effectiveness – L = low (probably not effective in assisting adaptation), M = medium (a good probability that this option with reduce the effects of climate change), H = high (high probability of being effective to reduce the effects of climate change)

6. RECOMMENDATIONS

This chapter provides recommendations for bundling adaptation options into a freshwater resources strategy and for extending the strategy to RMI's outer islands. Section 6.1 presents factors we considered in selecting adaptations for a freshwater strategy. While we believe all of the adaptation measures described and assessed in the previous chapter have merit, we recognize that, taken together, they would significantly task staff capacity and financial resources to implement simultaneously. Thus, Section 6.2 enumerates our recommendations for short and medium term priorities. Finally, Section 6.3 describes proposed next steps for elaborating a freshwater strategy for the outer islands.

6.1 STRATEGY BASICS

In developing recommendations for a freshwater resources strategy, we have adhered to the following principles:

1) Climate change is an additional stressor on freshwater resources and should be assessed and addressed in concert with non-climatic stressors
2) Climate is changing gradually and many of its impacts will only be observed over a period of time that is much longer than the time frame for most projects, policies, programs, strategies, or plans. Communities and countries are encouraged to:
   i) recognize and monitor climate and its anticipated impacts; and
   ii) avoid irreversible decisions and maladaptations
3) "No regrets" options should be stressed in selecting adaptation measures and integrating them into projects, policies and strategies. That is, if adaptation measures are implemented and climate does not change at the projected rate and magnitude, the options will have been desirable from the perspective of benefits and costs based on current climate. Thus, RMI should have **no regrets** about taking actions that would improve water management, increase access to water and sanitation, or reduce waterborne illness.
4) In bundling adaptation measures into strategies, attention must be focused on determining if options are "substitutes" for one another or are "complements" that add incremental value when combined with other measures. In choosing among substitutes, they should be assessed in terms of benefits and costs to the extent possible. To the extent, possible, we have identified adaptation measures that are complements.
5) By definition, a strategy represents the outcome of a process of prioritization because of capacity and resource constraints. If these constraints are not respected, strategies take on the look of "wish lists" and are of less use in organizing actions.

6.2 RECOMMENDATIONS FOR A FRESHWATER RESOURCES STRATEGY

The overarching goal of the freshwater resources strategy should be to provide access to safe water to its residents and businesses on a sustainable basis. There are four main challenges in meeting these goals:

1) Addressing the lack of access to freshwater for a significant minority of the population;
2) Supplying water during droughts;

3) Improving collection, storage, and distribution efficiency; and

4) Providing water of high quality.

As forecasters believe the next El Nino climate phenomena may be developing in the Pacific this summer (http://www.noaa.gov), our recommendations for short term priorities will not be able to address the challenge of supplying water for a drought this summer if forecasts are correct. Nevertheless, short term priorities related to drought are designed to foster a strategy that will afford protection from droughts on a sustainable basis. Below, we have summarized recommendations for short term/immediate priorities and medium-term priorities that can be implemented over the next few years and/or represent follow-up actions to short –term priorities.

6.2.1 SHORT TERM PRIORITIES

Short term priorities are actions that can be implemented within the next year, are not expected to significantly task human resources and only require modest levels of funding.

PUBLIC WATER SUPPLY We would recommend two short term activities for improving the delivering of public water. As described in Section 5.1, MWSC should conduct a comprehensive audit of the public water system, covering all aspects of water production: collection, storage, treatment, and distribution. This study would help determine options for increasing water availability, their effectiveness and costs. Second, RMI needs to assess options for increasing access to water and sanitation for those members of the community that lack access. Such an assessment should be a precursor to policies and infrastructure investments designed to increase access through the public water distribution system and/or residential and community rainwater systems.

RAINWATER HARVESTING We would recommend that neighborhood audits and training be organized for existing rainwater collection systems in coordination with the development of outreach material on the benefits and proper steps in maintaining residential rainwater collection systems. This activity could be carried out by MICS and/or CMI in coordination with the RMI government.

GROUNDWATER There are two immediate priorities related to groundwater protection that can be carried out immediately. First, a groundwater protection strategy is needed for Laura that will ensure that pollution and waste streams are managed, treated, and disposed in a way that does not reduce water quality for the freshwater lens. As discussed earlier, laws and regulations for pollution and waste should be reviewed, implemented, and enforced and all new potential sources of pollution should be required to meet a high management standard. In addition, we recommend that RMI extend the well survey to other areas of Majuro besides Laura.

DROUGHT If forecasters are correct in predicting an El Nino event this summer, the highest priority should be given to a study to monitor the drought, observe and assess RMI response effectiveness, costs of the drought, adequacy of emergency equipment, and to prepare recommendations for correcting deficiencies in emergency response capacity. If the forecast for a drought is a false alarm, RMI is recommended to review the NAP in coordination with MWSC as discussed in Section 5.2 in order to improve preparedness and response capabilities for the next El Nino event.

WATER CONSERVATION Three actions are recommended related to water conservation. First, RMI should review and develop and/or strengthen policies to encourage water conservation. Second, a water conservation campaign can be developed quickly and materials disseminated cost-effectively in a short period of time. If there is a drought this summer, materials could be prepared and a campaign launched quickly, and if not, more time could be invested in design and delivery of the campaign. Third, we recommend that an audit be conducted of water use in government buildings, schools, and other public buildings to better assess current practices, technologies, and maintenance practices.

6.2.2 MEDIUM TERM PRIORITIES

Medium term priorities include activities that are linked to short term activities such as audits and assessments. They require more significant staffing levels and entail financing levels that will require support from RMI and/or other funding sources such as donors and international development banks.

PUBLIC WATER SUPPLY The major recommendations for medium-term actions to improve water supply include the following: 1) implementation of performance-based management practices designed to provide incetives for MWSC management to set and reach performance targets; 2) elaboration and implementation of a financing strategy to address capital investments in water college, storage, distribution, and waste management – this strategy would include cost estimates for investments, assessment of effectiveness, and sources of financing; 3) implementation of policies and investments to increase water access for unserved residents.

RAINWATER HARVESTING We would recommend that neighborhood audits and training be continued in the medium term. One challenge beyond the first year would be to identify a financing mechanism to sustain these activities. In addition, we recommend that some of the options for expanding rainwater collection, using schools, churches, and other community buildings be explored and implemented on a pilot basis.

GROUNDWATER Medium term priorities for groundwater protection would focus on follow-up activities including implementation of measures to protect the Laura lens from contamination from households and agriculture, and sealing of private wells that are no longer in use. It is also recommended to examine the coastal erosion issue in Laura from the perspective of preventing loss of land which is essential for recharging the aquifer. In the development of the financing strategy for public water, described above, we would recommend that a wastewater treatment system for Laura be given high priority.

DROUGHT Medium-term priorities for drought should focus on developing and implementing a drought early warning system and address capacity and equipment gaps in responding to drought emergencies. Planning and financing discussions should be informed by plans to improve freshwater management and coordinated with MWSC and private bottling companies. Training activities for staff should be coordinated with the training of inspectors under water conservation below.

WATER CONSERVATION All of the short-term priorities for water conservation should be continued beyond the first year. For policies and incentive programs, there will be a need for implementation and outreach and possibly a modest amount of funding for demonstrations (e.g., in retrofitting schools or other public buildings. In addition, we recommend the hiring and training of inspectors to support water conservation and drought emergencies, as described in Section 5.3.

CLIMATE AND WATER EDUCATION IN SCHOOLS If there is interest, capacity and funding, the activities described in Section 5.4 related to climate and water education in schools could be implemented immediately. However, these activities are viewed as medium term priorities because they will contribute less to the goals of the freshwater resources strategy. As noted, IRG has conducted extensive research on Met Kits for schools, and implemented such a program in Cyprus. We believe the School Met would also yield useful precipitation results from the outer islands that, although not as reliable as MWS monitoring, would help to document differences in rainfall patterns throughout RMI.

6.3 ROLL-OUT TO THE OUTER ISLANDS

While the main focus of this case study has been on Majuro, a number of the outer islands face even more critical water shortages and more prolonged and frequent droughts than Majuro. The outer islands rely mainly on groundwater and rainfall for their water supplies, although RO units have been provided to some of the islands for emergency purposes. While all elements of this case study may not be of appropriate scope or scale to be considered in the outer islands, we have provided a list of activities that could be implemented in outer islands below:

- Adapt and.or replicate outreach and education materials on rainwater harvesting and water conservation for outer islands.
- Conduct a pilot study on freshwater resources for an outer island. MICS staff indicated that a neighboring island such as Mili could be appropriate for such a study as there might be an opportunity to develop a runway catchment system there, albeit on a smaller scale.
- Develop School Met for outer island schools and adapt climate and water curricula to outer island schools
- In parallel with drought management assessment, conduct assessments for selected outer islands.
- Conduct assessment of pollution and waste loadings for key freshwater lenses on outer islands.

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