Issues for Community-based Sustainable Resource Management and Conservation: Considerations for the Strategic Action Programme for the International Waters of the Pacific Small Island Developing States

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Volume 2: A Synopsis of Information Relating to the Quality of Freshwater and Watershed Management Issues in the Pacific Islands Region

by Tony Falkland

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Participating Countries in the International Waters Programme

Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

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FOREWORD

The South Pacific Regional Environment Programme (SPREP) has been involved in many large regional initiatives since it was established in 1982. Among the more notable are the National Environmental Management Strategies, State of Environment Reports, regional preparations for the United Nations Conference on Environment and Development in Rio de Janeiro in 1992; the South Pacific Biodiversity Conservation Programme which also started in 1992 and concluded in 2001, preparations leading up to the World Summit on Sustainable Development scheduled for Johannesburg, South Africa in 2002 and this programme, the Strategic Action Programme for the International Waters of the Pacific Small Island Developing States (IWP).

The IWP is novel in many respects. It is the first large programme in which several Pacific regional organisations, united under the umbrella of the Council of Regional Organisations in the Pacific (CROP), are formally collaborating. While SPREP is the executing agency, responsibilities for the execution of the oceanic component of the Programme rest with the Secretariat of the Pacific Community (SPC), based in New Caledonia, and the South Pacific Forum Fisheries Agency (FFA), which is based in Solomon Islands. These two organisations are providing the science and the management advice respectively to assist the 14 countries participating in the Programme develop comprehensive conservation and management arrangements for the region's major renewable resource, tuna.

The Project Coordination Unit (PCU) of IWP is based at the SPREP Secretariat in Samoa. It is responsible for the implementation of the coastal component of the Programme. The objective of this component is to design and implement a project in each of the 14 participating countries that seeks to address priority environmental concerns in respect of coastal fisheries, marine protected areas, waste management or the preservation and conservation of freshwater resources. The focus of the projects, termed pilot projects in the Project Document, is to promote increased community involvement and responsibility for local resource management and conservation initiatives.

The Programme is an ambitious one. Involving 14 countries stretching over 30 million square kilometers of the western central Pacific, and working principally in isolated rural communities, there are bound to be many challenges encountered as the Programme is implemented over the next four years. Nevertheless, if in that short time frame we can learn more about processes that will motivate and support local communities to take a more proactive role in the sustainable utilisation and conservation of their renewable resources, we will have made a significant contribution to the future well-being of the Pacific region and the ecosystems it supports.

This report is one of six reports produced at the start of the Programme and, as such represents the first major output for the Programme. This series of reports seek to synthesize all the available information for each of the priority areas of interest to the IWP - coastal fisheries, marine protected areas, waste and freshwater as they relate to tropical island ecosystems, particularly in the western and central Pacific. The reviews of these four technical areas are supplemented with complementary reviews, in separate volumes, of economic issues to be considered in planning and implementing community-based sustainable resource management and conservation initiatives in island ecosystems, and of lessons learned from previous national and regional projects and activities related to the future areas of work for the IWP. Not only do these documents provide a useful reference for practitioners working on the priority environmental concerns of the region in relation to each of these four areas of interest but they also provide a comprehensive snapshot of our understanding of these critical issues in the region in early 2002.

As a result, these reports will provide a useful reference for understanding the baseline situation that existed in the region at the start of the IWP. They provide a valuable reference against which the situation in 2005 may be assessed. This will be a measure of whether progress was made in addressing these pressing issues during the Programme or if we continue to threaten the future of our fragile environment through poor management of the natural systems and resources with which we are blessed.

SPREP looks forward to working with participating countries on the successful execution of this Programme.

Tamari'i Tutangata
Director
SPREP

INTRODUCTION

Background

The member countries and territories[1] of the South Pacific Regional Environment Programme (SPREP), at their 8th Annual Meeting in October 1995, endorsed a project to prepare the Strategic Action Programme (SAP), under the International Waters focal area of the Global Environment Facility (GEF).

The GEF was created in 1994 to fulfill a unique niche – that of providing financing for programmes and projects to achieve global environment benefits in four focal areas: biodiversity, climate change, international waters, and ozone layer depletion - and in land degradation as it relates to these focal areas.

According to the GEF definition, international waters include oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries as well as rivers, lakes, groundwater systems, and wetlands with trans-boundary drainage basins or common borders involving two or more countries. The ecosystems and habitats associated with these waters are essential parts of the system. Because the global hydrological cycle links watersheds, the atmosphere, estuaries, and coastal and marine waters through transboundary movement of water, pollutants and living resources, international waters extend far inland and far out to sea.

The Pacific region's premier political body, the Pacific Islands Forum, at its Annual Session in September 1996, requested SPREP to coordinate development of the project. Formulation of the SAP, funded by GEF through project development funds (PDF Block-B), began in April 1997. The SAP was to combine the following activity areas:

- Integrated conservation and sustainable management of coastal resources, including freshwater resources;
- Integrated conservation and sustainable management of oceanic resources;
- Prevention of pollution through the integrated management of land- or marine-based wastes; and
- Monitoring and analysis of shore and near-shore environments to determine vulnerability to environmental degradation.

The basis for developing a Programme focus in these areas is found in the joint regional position prepared by Pacific island countries for the 1992 United Nations Conference on Environment and Development (UNCED), the simultaneous preparation of National Environmental Management Strategies (NEMS) by Pacific island countries between 1990 and 1996, as well as the Action Plan for Managing the Environment of the South Pacific Region (1997-2000).[2]

A Regional Task Force (RTF) was established to oversee preparation of the SAP. It was composed of one representative from the Governments of Fiji, Marshall Islands, Samoa, Tonga, and Vanuatu, with additional members from the Pacific Islands Forum; SPC, SPREP, the three GEF Implementing Agencies (the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and The World Bank (TWB)), two international non-governmental organisations (the World Conservation Union (IUCN) and The Nature Conservancy (TNC)), and one private sector representative (Fiji Dive Operators Association, recommended by the Tourism Council of the South Pacific (TCSP)). The Asian Development Bank (ADB) and the Economic and Social Commission for Asia and the Pacific (ESCAP) also participated.

Work undertaken during the SAP formulation process resulted in the identification of three priority transboundary concerns related to International Waters:

- degradation of their quality;
- degradation of their associated critical habitats; and
- unsustainable use of their living and non-living resources.

The SAP was reviewed and subsequently endorsed by the Heads of Government of the Pacific Islands Forum at its Session in Rarotonga in 1997. Refinement over a period of almost two years resulted in GEF Council approval of the SAP in August 1999. Execution by SPREP commenced in early 2000.

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[1] American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji, France, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, United States of America, Vanuatu and Wallis and Futuna.

[2] Revised in late 2000 as the Action Plan for Managing the Environment of the Pacific Islands Region (2001-2004) adopted by the 11th SPREP Meeting, Guam, USA, 9-12 October 2000.

The International Waters Programme (IWP), or Strategic Action Programme (SAP) in GEF parlance, is designed to assist Pacific island countries[3] improve regional capacity for management of transboundary water resources and create improved management structures to address environmental degradation and ensure the long-term sustainability of ocean fisheries in the Western and Central Pacific ecosystem. The IWP also intends to promote improved integration of environmental concerns into local, national and regional policy, and improved water quality and the conservation of key coastal and ocean ecological areas.

The GEF and UNDP view the "pilot" or "demonstration" nature of the 14 projects to be implemented under the national components of the IWP as providing the basis for future funding opportunities from GEF facilities for participating countries. The IWP, as a Strategic Action Programme, is considered an initial step leading to the development of Medium-Sized (up to US$1 million) or Full Projects (in excess of US$1 million) for technical assistance, capacity building or investment. Such projects may be regional or national in scale. As a result, the later stages of the IWP are likely to devote considerable effort to analyzing the results of the IWP to assist countries with the formulation of follow-up activities supported through the GEF and alternative sources of financing assistance.

Key Elements and Assumptions

The Project Document is formulated on the basis that the International Waters in the Pacific region are subject to threats that give rise to transboundary concerns. During the formulation of the IWP, threats were examined from the perspective of critical species and their habitats and living and non-living marine resources. Identified threats include:

- pollution of marine and freshwater (including groundwater) from land-based activities;
- the long term sustainable use of marine and freshwater resources;
- physical, ecological and hydrological modification of critical habitats; and
- unsustainable exploitation of living and non-living resources, particularly, although not exclusively, the unsustainable and/or inefficient exploitation of coastal and ocean fishery resources.

The IWP formulation process examined each threat in a legal, institutional, socio-economic and environmental context. The ultimate root cause underlying imminent threats was identified as deficiencies in management. Factors contributing to the management root cause were grouped into two linked subsets: a) governance, and b) understanding.

The governance subset was characterised by the need for mechanisms to integrate environmental concerns, development planning, and decision-making. The understanding subset was characterised by the need to achieve island-wide ecosystem awareness through improved education and participation. Island-wide awareness and participation will facilitate the development and implementation of measures to protect International Waters.

The IWP analysis revealed a set of information gaps required by decision-makers to responsibly address ultimate root causes and respond to imminent threats. Particularly important is the lack of strategic information presented in an appropriate manner to decision-makers, resource users, managers and communities to evaluate costs and benefits of, and to decide among, alternative activities. Improving information input and exchange at the regional, national, and community levels is an objective of the Programme.

The IWP provides for targeted actions to address the root causes of degradation of International Waters. The actions are to be carried out in two complementary, linked consultative contexts: Integrated Coastal and Watershed Management (ICWM) and Oceanic Fisheries Management (OFM). Through the ICWM and OFM approaches, the IWP suggests a path for the transition of Pacific islands from sectoral to integrated management of International Waters as a whole, the evolution of which is essential for their protection over the long term.

The IWP will place priority on liaising with donors who are active in the region to plan and coordinate regional and national development assistance for International Waters to address imminent threats and their root causes more effectively. The IWP is designed to provide a framework for overall national and regional planning and assistance for the management of International Waters and provide a catalyst for leveraging the participation of other donors in the project.

[3] The 14 countries participating in the IWP are: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

The Project Document acknowledges that all sustainable development issues related to International Waters cannot be addressed at once. Therefore, four high priority areas have been identified for immediate intervention:

- improved waste management;
- better water quality;
- sustainable fisheries; and
- effective marine protected areas.

Targeted action within these activity areas is proposed in five categories:

- management;
- capacity building;
- awareness/education;
- research/information for decision-making; and
- investment.

Institutional strengthening is included under management and capacity building.

The principal components of the IWP, as described in the PD, are summarised in Table 1.

Table A A summary of the principal components of the IWP including the broad Programme objectives and activity areas designed to address priority environmental concerns of participating countries.

Goal	To achieve global benefit by developing and implementing measures to conserve, sustainably manage and restore coastal and oceanic resources in the Pacific Region [Integrated sustainable development and management of International Waters]
Priority Concerns	Degradation of water quality • Degradation of associated critical habitats • Unsustainable use of resources
Imminent Threats	Pollution from land-based activities • Modification of critical habitats • Unsustainable exploitation of resources
Ultimate Root	Management deficiencies • Governance • Understanding
Solutions	• Integrated Coastal and Watershed Management, and • Oceanic Fisheries Management. (ICWM), (OFM)
ICWM Activity Areas	• Improved waste management • Better water quality • Sustainable fisheries • Effective marine protected areas
OFM Activity Areas	• Sustainable ocean fisheries • Improved national and regional management capability • Stock and by-catch monitoring and research • Enhanced national and regional management links
Targeted actions	• Management/institutional strengthening • Capacity-building/institutional strengthening • Awareness/education • Research/information for decision-making • Investment

UNDP is the GEF Implementing Agency and SPREP is the Executing Agency, on behalf of other CROP agencies associated with the Programme, the SPC and FFA.

This Review

This review is one of six reviews that were compiled during the early stages of IWP implementation for two reasons.

The first is to provide a source of current information for practioners – principally those practioners associated with the implementation of the pilot projects in each of the participating countries as it relates to the areas of primary interest to the IWP (waste, freshwater, marine protected areas and coastal fisheries). To provide as much practical benefit as possible, these reviews are supplemented with additional synopses of information concerning economic issues and lessons learnt in the design and implementation of community-based sustainable resource management and conservation initiatives.

The second reason for these reviews is to provide a snapshot of what is known about each of the four areas of primary interest to the IWP in 2001 and early 2002. This is done to provide a baseline overview of available information in the areas of primary interest at the commencement of the Programme. As a result, any review of these areas of interest towards the end of the Programme, in 2005, will have a useful reference for assessing change in relation to the management and conservation of these resources in the Pacific region.

The first of the six reviews was prepared by Mike Huber and Kerry McGregor who comprehensively reviewed activities and current thinking in relation to marine protected areas (MPAs) and their application to the management and conservation of coastal resources. While the focus of the review is the Pacific islands region, their presentation is supplemented with examples from other ocean regions. The review examines resource conservation and related habitat issues, management approaches, governance, and past and current priorities in respect of marine protected areas at the national level within the 14 countries participating in the Programme and regional initiatives relating to marine protected areas.

This, the second volume in the series, addresses issues relating to the conservation and management of freshwater resources in the Pacific islands region. It was prepared by Tony Falkland who provides a review of published and other information relating to freshwater quality, supply, management and conservation. The review places emphasis on community-based issues associated with the conservation and sustainable management of freshwater resources, reflecting the planned focus of subsequent pilot projects that may be instigated under the International Waters Programme.

The review by Leonie Crennan and Greg Berry, the third volume, provides an examination of issues relating to waste reduction, pollution prevention and improved sanitation in the Pacific islands region, and elsewhere, as it relates to the objectives of the International Waters Programme in terms of promoting management for improved waste reduction initiatives in communities. It summarises activities that have attempted to address low cost/no cost alternatives to reduce loadings of solid and liquid wastes, particularly in coastal and watershed communities where quality of drinking water resources is at risk. Information includes a review of priority waste concerns in Pacific island communities, management and governance issues, and options for increased community responsibility for managing waste problems.

In the fourth volume, Paul Dalzell and Don Schug review current information relating to sustainable coastal fisheries in the Pacific islands region and elsewhere as it relates to the objectives of the Programme in terms of promoting capacity building for improved resource management responsibility in communities. Information presented includes a review of coastal fisheries in the Pacific region, discussion of resource management and governance issues, customary marine tenure (CMT), the role of MPAs and past and current priorities in respect of the sustainable management of coastal fisheries at local, provincial, national and regional scales. Their review includes consideration of gender issues and women's activities in the coastal zone including the role of women in subsistence and artisanal fisheries in the 14 countries participating in the Programme. They also discuss cases that illustrate particular issues in community-based management of subsistence and artisanal fisheries; including government support for community actions.

Padma Lal and Meg Keen present a review of economic issues that should be considered in the design, implementation, monitoring and evaluation of community-based resource management and environment conservation projects in island ecosystems – the fifth volume. They describe economic issues that require detailed consultation with community members during the design, implementation and monitoring of projects such as those to be supported under the Programme. This includes the identification of institutional issues, socio-economic implications for communities (benefit/cost analysis and cost effective analysis), and suggested strategies for promoting broad community participation and support in conservation and sustainable resource use initiatives (incentives and transaction costs).

In the sixth and final volume in this series, Jenny Whyte and her colleagues at the Foundation of the Peoples of the South Pacific International and affiliated organizations provide a review of information relating to lessons learned and best practices for resource and habitat conservation and sustainable management initiatives in the Pacific islands region. The review focuses on community-based (participatory) issues associated with the conservation and sustainable management of resources and habitats in island ecosystems with emphasis on the four focal areas for the International Waters Programme (sustainable coastal fisheries, marine protected areas, community-based waste reduction and preservation of freshwater resources). Issues are considered in context of the entire project cycle - from project planning and design; selection of sites; method of community entry; community baseline assessments; participation of communities; the role and participation of governments and, if they are involved, external agencies, NGOs and development assistance agencies; education and awareness activities, completion and exit considerations such as alternative income generation, and monitoring and evaluation. The review considers social, cultural, economic, environmental, administrative, managerial, legal and political dimensions of such projects.

As a supplement, each author was asked to consider examples of what a pilot project might look like. As a result, at the conclusion of each review, three examples of community-based initiatives that may serve as a model or a template for a pilot project are presented.

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About the Author

Tony Falkland is a water resources engineer and hydrologist with over 20 years of experience in water resources and hydrological studies on small islands, especially coral atolls in the Indian and Pacific Oceans. He is a specialist in the field of groundwater assessment and appropriate development of the fragile groundwater (freshwater lens) systems that occur on small coral islands. He has written many technical reports and papers on the subject of island water resources and presented keynote papers at a number of regional and international conferences concerned with island hydrology. He was the major contributor and editor including of a major work on island hydrology for UNESCO (Hydrology and Water Resources of Small Islands: A Practical Guide).

In the Pacific Ocean, Tony has been actively involved in water resources studies of islands in the Australia, Cook Islands, Kiribati, Papua New Guinea, Tonga and Tuvalu. In the Indian Ocean he has undertaken similar studies in Christmas and Cocos (Keeling Islands (Australia) and in the Maldives. He has undertaken island water resources projects for a number of bilateral, regional and international agencies including AusAID, SOPAC, SPREP, ADB, UNESCO, UNICEF, UNEP, UNDP and World Bank.

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List of Abbreviations

AusAID	Australian Agency for International Development
CSI	Coastal and Small Islands Programme (of UNESCO)
CSC	Commonwealth Science Council
DFID	Department for International Development (UK)
EC	European Community
ENSO	El Niño Southern Oscillation
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organisation
FSM	Federated States of Micronesia
FSPI	Foundation of the Peoples of the South Pacific International
GEF	Global Environment Facility
GIS	geographical information system
GPS	global positioning system
ICM	Integrated catchment management
IETC	International Environmental Technology Centre
IHP	International Hydrological Programme (of UNESCO)
IRC	International Reference Centre for Community Water Supply and Sanitation
IWP	International Waters Programme (abbreviation for Strategic Action Programme for International Waters)
JICA	Japan International Cooperation Agency
kL	kilolitres (= 1,000 litres)
kL/day	kilolitres per day
km	kilometre
L	litres
L/day	litres per day
L/m/day	litres per metre per day
L/p/day	litres per person per day
L/sec	litres per second
mg/L	milligrams per litre
ng/L	nanograms per litre
MSL	mean sea level
NIWA	National Institute of Water and Atmospheric Research
NEMS	National Environment Management Strategy
NGO	Non-governmental organisation
NZODA	New Zealand Overseas Development Agency
PCM	Participatory catchment management
PIC	Pacific Island Country
PICCAP	Pacific Islands Climate Change Assistance Programme
PICs	Pacific Island Countries
PNG	Papua New Guinea
PVC	polyvinyl chloride
PUB	Public Utilities Board
PWA	Pacific Water Association
PWD	Public Works Department
RO	Reverse osmosis (a method of desalination)
SAP	Strategic Action Programme for International Waters
SIDS	Small Island Developing States
SIDT	Solomon Islands Development Trust
SIWA	Solomon Islands Water Authority
SIWIN	Small Islands Water Information Network
SPaRCE	Schools of the Pacific Rainfall Climate Experiment
SPC	Secretariat for the Pacific Community (formerly South Pacific Commission)
SOPAC	South Pacific Applied Geoscience Commission
SPREP	South Pacific Regional Environment Programme
ToR	Terms of Reference
TNC	The Nature Conservancy
UNDDSMS	United Nations Department for Development Support and Management Services
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Childrens Fund
USGS	United States Geological Survey
WERI	Water and Energy Research Institute (University of Guam)
WRU	Water Resources Unit (of SOPAC)
WWF	World Wide Fund for Nature

Glossary of Terms

For the sake of clarity and uniformity in this synopsis, a number of key terms are defined below:

Aquifer: a groundwater body. A more exact definition is a "permeable water bearing formation capable of yielding exploitable quantities of water" (UNESCO/WMO, 1992)

Catchment: the normal meaning of the word is a drainage area or basin. In this report, the word is used in the context of both surface water and groundwater. Also, the terms 'catchment' and 'watershed' are used interchangeably in the report, with the term 'catchment' being more commonly used.

Freshwater: water that is suitable for use by humans but may not be potable, owing to microbiological contamination. Freshwater is generally taken to mean water that has an acceptably low salt content. When salinity of the water is above an acceptable limit, it is often referred to as brackish water.

Freshwater lens: a specific type of aquifer found on small islands consisting of a freshwater zone overlying and in contact with seawater. Between the freshwater zone and the seawater, a transition zone occurs where salinity gradually increases with depth.

Integrated catchment management (or integrated watershed management): the process of formulating and implementing a course of action involving natural and human resources in a catchment, taking account of the social, political, economic and institutional factors operating within the catchment to achieve specific objectives (Hufschmidt and Tejwani, 1993). Alternative definitions are available, including one in FSPI Island Consulting (2001).

PICs: Pacific Island Countries. As not all of the participating islands consist of 'small' islands, this term has been adopted rather than SIDS (Small Island Developing States).

Potable water: freshwater that is safe to drink by humans. This means it does not contain any substances or organisms that are harmful to human health. The World Health Organisation (WHO, 1993) and other organisations publish guidelines for potable or drinking water based on acceptable physical, chemical, microbiological and radiological criteria.

Small Island: an island with area less than 2,000 km^2 (UNESCO, 1991). All of the participating countries have small islands but only a few (Fiji, PNG, Solomon Islands and, Vanuatu) have large islands. Individual islands of the PICs vary considerably in size from large to very small.

Watershed: a watershed has been defined in different ways. It can mean the boundary around a catchment, or the catchment itself. For instance, the Oxford Dictionary (1980) defines a watershed as the summit or boundary line separating waters flowing into different rivers, river basins or whole catchment areas of river systems. An alternative definition, in line with more common usage (including this report), is given by McKean and Baisyet (1994) as "the entire ground surface that drains water, sediment, pollutants and other dissolved materials to some common outlet point, usually along a stream channel". In this report, the term 'catchment' is used in preference to 'watershed'. As for the term 'catchment' (see above), watershed is used in this report to cover both surface water and groundwater systems.

Executive summary

Any assessment of freshwater resources and watershed (catchment) management issues in the Pacific Island countries (PICs) would necessarily conclude that the most important issue facing communities is that of basic human health. A safe, sustainable, adequate, reliable and affordable supply of potable water is a basic necessity for a healthy community. To achieve this, it is essential that freshwater resources are protected against contamination and over-extraction, that water supply systems are operated and maintained effectively and that freshwater use is conservative.

In many PICs, there is compelling evidence suggesting that the level of waterborne disease is high and that this is due to a range of factors including inadequate protection of water supplies from faecal and other contamination. **"The pollution of drinking water and the resulting health hazard may be one of the biggest watershed issues in island countries of the South Pacific." (Baisyet, 1994).** This major issue of water pollution in the Pacific region (and other regions) and the linkages with waterborne diseases is reiterated in more recent reports including ADB (1999).

Environmental concerns about downstream effects of catchment degradation due to forest clearing, urbanisation and resource extraction are also very important. High levels of turbidity and suspended sediment caused by excessive clearing, and faecal pollution from human settlements, particularly urban areas, are major issues facing freshwater supplies obtained from streams and rivers. Sedimentation and contamination in rivers and coastal waters also adversely impact on mangroves, coral reefs and coastal fisheries.

Groundwater resources in many PICs are polluted or at risk from pollution from human settlements, particularly resulting from the most common sanitation systems, pit latrines and septic tanks. In some PICs, over-pumping or inappropriate pumping systems in coastal zones of large islands and in parts of small islands has caused saline intrusion. The greatest impacts are felt on small coral islands where groundwater resources in the form of 'freshwater lenses' are limited in extent and thickness and very vulnerable due to thin, highly permeable soils.

Other primary sources of pollution for surface water and groundwater resources include animals (mainly cattle and pigs); industrial and mining waste discharges; hydrocarbon leaks, particularly near power stations, and agricultural chemicals.

The sustainability of water resources on islands is also a major issue particularly during droughts. In recent years, most PICs have experienced severe droughts, which have impacted on the availability of freshwater to supply even basic human needs. In some islands, this has led to the adoption of emergency measures such as importation of water or investment in desalination units.

There have been many responses to the problems of providing adequate and safe water supplies. Most past activities within the water sector in PICs have been based on institutional approaches rather than community-based, participatory approaches. These past activities are relevant to the International Waters Programme (IWP), however, as much of the work has been aimed at solving water resource management problems and issues for small and large (rural and urban) communities. One of the main differences between past and present approaches is that the level of community participation has increased. There is now a much greater awareness on the part of proponents of water projects and agencies involved in catchment management that a necessary condition of sustainability is active participation of communities.

This synopsis provides an overview of the main freshwater management issues facing PICs and their communities, and the measures taken to manage the threats to freshwater quality and sustainability. Based on priority concerns of PICs and the criteria set by the IWP, a number of potential community-based pilot projects are outlined. These pilot projects focus on community awareness and education in relation to key freshwater management issues, leading to action aimed at resolving current problems.

1 Introduction

This report (synopsis) was prepared for the South Pacific Regional Environment Programme (SPREP) as a part of the Strategic Action Programme (SAP) for the International Waters of the Pacific Small Island Developing States. The International Waters Programme (IWP), as this programme is also called, is a 5 year programme for 14 participating Pacific Island countries (PICs) as follows: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

The IWP has an oceanic and a coastal component, with the coastal component focusing on sustainable resource management and conservation issues in the coastal zone. Within the coastal component are four focal areas, one of which relates to freshwater resources management. The other focal areas are concerned with marine protected areas, sustainable coastal fisheries and community-based waste reduction. The coastal component will involve the implementation of 14 pilot projects, one in each of the 14 participating countries.

The objective of the synopsis is to provide a review of published and other information relating to freshwater quality, supply, management and conservation in the Pacific Islands region. As required by the Terms of Reference (ToR), shown in Annex I, the synopsis has placed emphasis on potable water and community-based issues associated with the conservation and sustainable management of freshwater resources. However, it is recognised in this synopsis that the water sector necessarily involves stakeholders at many levels including government agencies (in some cases at national and state level), island councils (or equivalent), village administrations and individuals. The water sector also receives financial, technical and other support from a number of international, regional and bilateral government agencies, and from a number of active non-governmental organisations (NGOs). Given the large number of stakeholders within the water sector, it was considered necessary to present an overview at the regional and national level as well as at the island and community level.

The report lists seven community-based potential pilot projects with a focus on key freshwater management issues that could be instigated under the IWP. As required in the ToR, more detailed outlines of three "model" projects are provided. Others could be developed into outlines from the list of potential projects.

The information in the report has been structured according to the following main sections:

- Information sources;
- Overview of freshwater resources and water supplies;
- Water resources management in participating countries;
- Major issues and concerns regarding freshwater resources;
- Measures to manage impacts and threats to freshwater resources;
- Potential community-based pilot projects;
- References and Annexes.

For the sake of clarity and uniformity in this synopsis report, a number of key terms are defined in the Glossary of Terms.

Where applicable, relationships between management of freshwater resources and the other three focal areas of the IWP (marine protected areas, sustainable coastal fisheries and community-based waste

2 Information sources

Information for this review was gathered from a variety of sources including:

- A series of regional meetings and workshops in the Pacific Islands region specifically concerned with freshwater resources, water supply and related issues on islands;
- Publications which expand on aspects of water resources management, including project reports;
- Reports on regional activities (e.g. SOPAC library) and bilateral aid projects and reports by educational and research organisations within the Pacific Region;
- Discussions with personnel from SPREP and SOPAC during visits to these two regional organisations;
- Communications and discussions with island personnel and a number of NGOs involved in the water sector in the Pacific Islands; and
- The author's own experience working on projects in a number of the Pacific Islands.

References cited in the report are contained in the reference list (section 8) while additional source material is contained in Annex VI.

For some PICs, the information available at the time of writing this report was not as extensive as it could have been, so there are some gaps. However, given the review covered a wide range of islands within the PICs, with varied climatic, geological and demographic factors and different political, cultural and economic conditions, it is considered that the review has summarised the main issues.

3 Overview of freshwater resources and water supplies

3.1 Summary data

Summary data for each of the 14 PICs participating in the IWP is shown in Tables 1 and 2. The data in Table 1 focuses on characteristics which impact on freshwater resources and freshwater supply issues in these countries. Table 2 provides data on growth rates and the degree of urbanisation in each of the PICs.

Table 1 shows that four of the 14 countries are in Melanesia, five are in Polynesia and five are in Micronesia. Large variations in demographic and selected physical characteristics (total area, number and geology of islands) are evident. Often the conditions within PICs vary considerably, with conditions on outer islands being significantly different from those on main islands.

Table 2 shows that many PICs have large percentages of their total populations living in the main centre ('capital') with the remaining population spread between villages on the main island and often numerous outer islands. In many cases, living conditions in the peri-urban areas on the fringes of the main centres are poor and normal urban utility services (including water supply) are sparse, inadequate or non-existent.

It is noted that, despite the recent date of source material (UNESCAP, 2000), some data in Table 2 appears to be outdated. For example, the current urban population for Samoa in 2001 is estimated to be about 40% of the total compared with 21% in Table 2. There was insufficient time to obtain more updated data for each country. However, the data does indicate a key fact that urban populations are a significant component of the total population in many of the countries.

Table 1 Summary statistics of Pacific Island countries participating in the IWP

Country	Sub-Region	Approx. Population[1]	Total Land Area (km^2)[2]	Number of islands or atolls[3]	Types of islands according to geology
Cook Islands	Polynesia	16,800	197 (237)	15	Volcanic, volcanic & limestone, atoll
Federated States of Micronesia	Micronesia	114,000	710 (701)	607	Volcanic, atoll, mixed
Fiji	Melanesia	775,000	18,333	300 (approx.)	Volcanic, limestone, atoll, mixed
Kiribati	Micronesia	86,800	811	33	32 atolls or coral islands, 1 limestone island
Marshall Islands	Micronesia	65,000	181	29	Atolls and coral islands
Nauru	Micronesia	11,300	21	1	Limestone
Niue	Polynesia	2,000	259	1	Limestone
Palau	Micronesia	17,200	488	200 (approx.)	Volcanic, some with limestone
Papua New Guinea	Melanesia	4,690,000	462,243	[illegible]	Volcanic, limestone, coral islands and atolls
Samoa	Polynesia	161,000	2,935	9	Volcanic
Solomon Islands	Melanesia	400,000	28,370	347	Volcanic, limestone, atolls
Tonga	Polynesia	106,000	747	171	Volcanic, limestone, limestone & sand, mixed
Tuvalu	Polynesia	10,900	26	9	Atoll
Vanuatu	Melanesia	182,000	11880 (12,190)	80	Predominantly volcanic with coastal sands and limestone

Sources:

1. Human Development Report (UNDP, 1999) sourced from Pacific Island Populations (SPC, 1998) through SOPAC, Water Resources Unit summary sheet (C. Carpenter, pers. comm., 2001). Data shown to 3 significant figures.
2. UNEP (1999) and UNEP (2000). Areas shown in other publications (e.g. AusAID/PIC, 1997) are sometimes different. Where differences occur, the area from AusAID/PIC (1997) is shown in brackets.
3. ESCAP (1983) and various NEMS.

Table 2 Growth rates and urbanisation in Pacific Island countries

Country	Annual national population growth rate (%)	Annual urban population growth rate (%)	Annual rural population growth rate (%)	Percentage of total population in urban area (%)
Cook Islands	0.4	0.5	0.4	59
Federated States of Micronesia	1.9	1.3	2.1	27
Fiji	0.8	2.6	-0.6	46
Kiribati	1.4	2.2	1.0	37
Marshall Islands	4.2	8.2	-0.6	65
Nauru	2.9	2.9		100
Niue	-1.3	-0.3	-1.6	32
Palau	2.6	3.2	1.3	71
Papua New Guinea	2.3	4.1	2.0	15
Samoa	0.5	1.2	0.4	21
Solomon Islands	3.4	6.2	3.1	13
Tonga	0.3	0.7	0.1	36
Tuvalu	1.7	4.8	0.0	42
Vanuatu	2.8	7.3	2.1	18

Note: Data from SPC (1998). Pocket Statistical Summary, as presented in UNESCAP (2000).

3.2 Types of freshwater resources

There are two main types of naturally occurring freshwater resources found in PICs:

- Surface water, present as streams, rivers and lakes. Springs also occur on many islands. These are actually groundwater outflows that can occur above or below sea level;
- Groundwater occurring as perched and 'basal' aquifers. The later type of aquifer, which is in contact with underlying seawater can be sub-divided into coastal aquifers of large islands and 'freshwater lenses' which are found on small coral sand islands (e.g. the islands of an atoll) and medium to large sized limestone islands.

In addition, rainwater catchment systems are often used, either as primary water sources (e.g. Tuvalu, northern Cook Islands) or supplementary water sources (many islands). Collection surfaces are normally roofs of buildings or purpose-built rainwater collection surfaces above storage tanks. Special collection surfaces (e.g. paved airport runways) have also been used to collect runoff (e.g. Majuro, Marshall Islands).

Desalination is another less common method of freshwater production. Desalination systems have been used for regular water supply on Nauru (distillation using waste heat from power station) and on Ebeye, Marshall Islands (reverse osmosis). On South Tarawa, Kiribati, reverse osmosis plants have been installed at a number of sites including the main hotel, the hospital and one urban centre (Betio). Desalination systems have also been supplied to other islands as emergency sources of water during droughts (e.g. Marshall Islands and Tuvalu). They are also used on some tourist islands for water supply (e.g. Mana Island, Fiji and Akitua island, Aitutaki atoll, Cook Islands).

Importation of freshwater by ship, barge or pipeline is another measure sometimes used. Water is piped, for instance, to Manono Island, from Upolo in Samoa. In most instances, importation has been an emergency (and expensive) method to cope with scarcity of water on some small outer islands in droughts (e.g. Fiji, Tonga). Water is also 'imported' within islands by road tankers to some areas during droughts.

Another emergency source of drinking fluid is coconut water, which has been used by some remote island communities during severe droughts.

Another method for augmenting freshwater supplies is the use of seawater or brackish water for selected non-potable requirements (mainly toilet flushing, but also cooling water and fire fighting, if required). This is a means of conserving limited freshwater resources for primary water uses (e.g. drinking, cooking, bathing and washing). Examples of seawater reticulation systems are found on South Tarawa, Kiribati and on Majuro, Marshall Islands.

A summary of water resources and other water related data is presented in Table 3 for each of the 14 participating PICs. Further details are presented in the summary of water resources for each country in Annex II.

Table 3 Summary of water resources and water supplies

Country	Main Water Resources[1]	Access to safe water (% of population)[2]	Water supply coverage (% of population)[3]
Cook Islands	SW, GW, RW	95	100
Federated States of Micronesia	SW, GW, RW	44	-
Fiji	SW, GW, RW, D (tourist resort only)	77	47
Kiribati	GW, RW, D (limited)	76	-
Marshall Islands	RW (from airport catchment and buildings), GW, D (emergency)	82	-
Nauru	D (regular use), RW, GW (limited)	100	-
Niue	GW, RW	100	100
Palau	SW, GW, RW	86	79
Papua New Guinea	SW, GW, RW	24	42
Samoa	SW, GW, RW	100	99
Solomon Islands	SW, GW, RW	64	71
Tonga	GW, RW	95	100
Tuvalu	RW (primary), GW (limited), D (emergency)	85	100
Vanuatu	SW, GW, RW	87	88

Notes:

1. SW = Surface water, GW = groundwater, RW = rainwater; D = desalination.
2. Estimates from UNDP (1999).
3. Estimates for 2000 from WHO/UNICEF (2000) based on UNDESA (1999).

3.3 Major influences on island freshwater resources

The geological conditions within an island (refer Table 1) are one of the primary determining characteristics of the type and occurrence of freshwater resources. Volcanic islands, which are often 'high', generally have surface water resources in the form of streams and springs. This would apply for large islands (e.g. much of Fiji, Papua New Guinea, Samoa, Solomon Islands and Vanuatu). Coral islands, which are often 'low,' generally have only groundwater resources (e.g. Kiribati, Marshall Islands, parts of Federated States of Micronesia and Cook Islands).

In addition to geological conditions, other features having a major influence on the occurrence of freshwater resources are listed below. Further information is contained in UNESCO (1991).

- Area and width of island. Small islands have less potential for water resources. Very small islands generally have no surface water resources and must rely on limited groundwater and other sources (e.g. rainwater catchments). Narrow islands have less water resources potential than wide islands for a given land area;
- Topography and altitude;

- Climate and climatic variability (particularly the influence of El Niño and La Niña episodes);
- Vegetation (type and density);
- Soil conditions (type and thickness, high or low infiltration capacity, susceptibility to erosion). Soils not only have an influence on water resources but also on the potential for contamination of groundwater, particularly on small coral islands and in sandy coastal areas of larger islands. In these situations, the highly permeable, thin soils allow water and contaminants to move easily to the water table and into the groundwater;
- Natural disasters (cyclones, floods, tsunamis and storm generated waves and surges causing overtopping and destruction, earthquakes, volcanic eruptions, droughts). In particular, extended droughts have a major impact on the sustainability of freshwater resources, especially on small islands;
- Pattern and density of human settlement (rural, urban, peri-urban);
- Location and type of human activities (e.g. agriculture, forestry, mining, industry, tourism) particularly in sensitive water catchment areas (e.g. watersheds with streams and springs and groundwater systems which are used for town or village water supplies).

In addition to the above influences there is the potential for impacts from longer-term climate change and sea level rise, particularly for small low lying islands and low lying coastal areas of high islands.

3.4 Types of freshwater uses

The main uses of freshwater in PICs are:

- Water supply for human settlements, both urban and rural;
- Industrial (mainly in larger urban centres);
- Mining (mainly Melanesian islands);
- Agriculture and forestry (many islands);
- Environmental needs (freshwater biota).

Non-consumptive uses are hydropower generation (e.g. Fiji, Samoa), navigation and recreation.

By far, the largest water use in PICs is for urban and rural water supplies. The emphasis in this report is on these supplies, which is consistent with the requirement in the ToR to focus on potable water.

3.5 Extent and type of water supply systems

3.5.1 Overview

Data on the extent of water supplies in each of the participating countries are shown in Table 3. The data, obtained from different sources, is shown in terms of water supply coverage and access to safe water. The exact definitions of 'safe' and 'coverage' are not entirely clear. This data should be used a guide only, especially given the large variation between the UNDP (1999) and WHO/UNICEF (2000) estimates for some Pacific Island countries (e.g. Fiji, Kiribati). More detailed and updated data is undoubtedly available from national governments, but there was insufficient time to obtain this information.

The types of water supplies and associated management systems vary from centralised water supply systems to village level and household systems. The centralised systems are generally associated with urban areas while the other two types are normally associated with rural areas. Community participation in water supplies varies according to scale with the least involvement being with the urban systems, and the greatest being with household scale systems, typically rainwater tanks and household wells.

3.5.2 Urban water supply systems

The centralised systems are normally found in the larger urban areas (cities such as Port Moresby and Suva), large towns such as Nuku'alofa, Lautoka, Port Vila, Honiara and sometimes in smaller townships or large villages (e.g. Pangai-Hihifo on the island of Lifuka, Tonga). Urban systems can involve whole islands or major parts of islands including many villages (e.g. Rarotonga, South Tarawa and most of Majuro).

Urban water supply systems are normally reliant on large surface water resources such as streams or rivers, on substantial groundwater aquifers or freshwater lenses, or on a combination of both surface water and groundwater. They consist of pipe networks generally delivering water to taps within houses or to standpipes adjacent to houses. In most cases, these water supply networks are treated, although the effectiveness of the treatment varies considerably. For surface water systems treatment generally consists of a filtration system (either slow or rapid sand filter) and disinfection by chlorination. Groundwater systems, where treated, generally only have chlorination.

Management systems for urban water supply systems include water authorities (e.g. Samoa, Solomon Islands), government departments (e.g. Cook Islands, Fiji or Niue) or private companies (e.g. Majuro in the Marshall Islands and Port Vila in Vanuatu). A summary is provided in Table 4. There are moves in many PICs to corporatise or privatise urban water agencies (e.g. Fiji, PNG).

Most but not all urban water supply agencies charge consumers water rates for the use of the water. In many cases, charges to consumers are based on metered usage.

Table 4 Water supply agencies in urban areas

Country	Name of Agency	Type[1]	Area of responsibility and approx. number of people supplied
Cook Islands	Department of Water Works	G	Water supply for Rarotonga. Population served approx.7,800
Federated States of Micronesia			Water supply for Kolonia and nearby
• Pohnpei	Pohnpei Utilities Corporation	A	Population served approx.36,000
• Yap	Yap State Public Service Corporation	A	Population served approx.2,500
• Chuuk	Chuuk State Public Utilities Corporation	A	Population served: approx 10,000 on Moen
• Kosrae	Department of Public Works	G	Population served approx.3,000
Fiji	Water & Sewerage Section, Public Works Department	A	Water supply for Suva and large urban centres
Kiribati	Public Utilities Board	A	Water, sewerage and electricity for most of urban (south) Tarawa. Population served approx.25,000
Marshall Islands	Majuro Water and Sewerage Company	P	Water and sewerage for most of Majuro atoll.
Nauru	Nauru Phosphate Corporation	G	Water supply for island (approx. 11,300 people)
Niue	Public Works Department	G	Water supply for all population centres on Niue (approx. 2,000)
Palau	Palau Water Authority	A	Population served approx.15,000
Papua New Guinea	Eda Ranu	A	Port Moresby. Population served approx.200,000
	PNG Waterboard	A	11 district water supplies Population served approx.190,000
Samoa	Samoa Water Authority	A	Water supply for Apia and other parts of the country (approx 84% of total). Population served in Apia approx. 55,000.
Solomon Islands	Solomon Islands Water Authority	A	Water supply for Honiara and 3 other towns (population served approx. 55,000.
Tonga	Tonga Water Board	A	Water supply for 4 urban areas: Nuku'alofa, 'Eua, Pangai-Hihifo (Lifuka) and Neiafu (Vava'u). Total population served approx. 40,000.
Tuvalu	Public Works Department	G	Water supply operation (rainwater transfer), as required, for Fogafale on Funafuti atoll (approx. 5,000). There is no piped water system.
Vanuatu	UNELCO Ltd	P	Water supply for Port Vila Population served approx. 34,000
	Public Works Department	G	Other main towns

Notes:
1. Data from several sources including recent benchmarking survey conducted by PWA (ADB funded).
2. G = Government agency, A = Statutory Authority, P = Private Utility.

3.5.3 Rural water supply systems

Typical rural water supply systems consist of two types:

- Communal systems with pipe networks based on either surface or groundwater sources. These are generally operated at village level. Surface water systems (on 'high' islands) are normally based on gravity flow pipelines from streams or springs to tanks or standpipes in the village. A typical groundwater system consists of a pump, which is operated for a number of hours each day supplying water to an overhead tank feeding standpipes within the village. Groundwater supply systems have greater operational needs due to pumping requirements. Pumps are diesel, electric or solar;
- Individual household water supply systems, typically consisting of a well, a rainwater catchment or collection from a spring or stream source near the village. In some cases, water is extracted from shallow wells dug at low tide on the beach;
- In some PICs, villages may have both individual and communal systems. The most common example is the use of household rainwater catchments for potable water and other sources for non-potable water;
- Rural water supply systems are often managed by village or community 'water committees'. This may include collection of revenue to provide for operating costs (e.g. in Tonga, most rural water supplies use groundwater and village water committees raise revenue to pay for pump operation and maintenance costs). Village water committees are also the basis of rural water supply implementation and operation in the Melanesian countries (refer section 6.3.1 for further details);
- In other PICs, rural water supplies are operated by island councils (e.g. Kiribati) or municipal administrations (e.g. Federated States of Micronesia). This may or may not include the collection of revenue from households benefiting from the water supply;
- On Funafuti, the main island of Tuvalu, rainwater is collected in both household and communal tanks. During extended dry periods water is delivered by small tanker from communal tanks to household tanks where shortages are experienced. This service is provided by government and a fee is charged.

4 Water resources management in participating countries

A summary of freshwater resources management for each of the 14 participating countries of the IWP is presented in Annex II. Each summary covers the following key elements:

- Basic geographical, geological and climate data;
- Freshwater resources and significant issues regarding sustainability and quality;
- Water supply systems and management (urban and rural);
- Main agencies involved in the water (and sanitation) sector at national, island and village level;
- Special features including status of water resources legislation;
- Summary of issues and concerns.

Some countries have been treated in more detail than others, depending on the availability of information to the author. The summary of issues and concerns for each island was compiled from several sources including published reports and communications with island water personnel during the preparation of this report. For some PICs, issues and concerns may not be comprehensive, but it is believed that the major issues and concerns regarding freshwater have been considered in the process of reviewing all 14 participating countries.

The freshwater issues facing some countries are severe not only to the limited water resources but also to socio-economic factors such as population density and per capita income.

5 Major issues and concerns

5.1 Overview

This section attempts to summarise the major issues and priority concerns about the sustainable management of freshwater resources in PICs. As required in the ToR, the focus is on potable water issues, which essentially means water supplies for potable purposes.

The summary is based principally on material presented in the individual country summaries (Annex II) and on other information sources identified in section 2.

The issues and concerns have been summarised according to the following sub-sections. The order of these sub-sections does not reflect a priority ranking. Rather, it is a convenient means of introducing the major issues and priority concerns:

- Freshwater sustainability and availability issues;
- Increasing demand for freshwater, particularly in urban areas;
- Water quality degradation in surface water and groundwater catchments;
- Legislation, policy, planning and administrative issues;
- Insufficient community education, awareness and participation;
- Catchment management issues involving customary land ownership;
- Inappropriate technology and methods;
- Water leakage and other losses in distribution systems;
- Insufficient knowledge of island freshwater resources.

Further explanation and some case examples of these issues and concerns are presented below.

5.2 Freshwater sustainability and availability issues

The sustainability of freshwater resources and availability of water for beneficial uses, particularly potable water supply, is a fundamental issue in many of the Pacific Islands. Sustainability of freshwater resources is dependent on both the availability of the resources and on the demand for these resources. The issue of sustainability is particularly relevant as the scale of the island decreases and the population increases, both of which tend to increase the stress on available water resources to supply even basic human needs.

Major influences on the availability of water resources on islands are:

- Size and other physical characteristics of the island (refer overview in section 3.3) and hence nature and extent of water resources;
- Climatic variability with consequent effects on available rainfall. The prevailing rainfall patterns can have a major effect on locally available water resources. Surface water resources are often severely depleted and sometimes exhausted during extended droughts (as shown in a number of Pacific Island countries in the severe El Niño droughts of 1983 and 1997-1998: van der Brug, 1986; SOPAC, 1999a). Groundwater resources also become depleted in drought periods and may under natural (no pumping) conditions become brackish on small islands or near coastal zones of larger islands. During moderate to severe droughts, rainwater storages may become very low or empty (White et al, 1999a), even for the most basic of needs (e.g. drinking and cooking). In many small islands with low average rainfall and a high variability (e.g. Kiritimati Island in Kiribati), rainwater catchments do not offer a sustainable water supply and other sources are required (e.g. groundwater). Very small islands with highly permeable geological conditions (e.g. small limestone islands) are particularly vulnerable to droughts. These islands have no potential for surface water and very little if any, potential for fresh groundwater. During droughts when rainwater catchments are no longer able to supply water, other measures are required (e.g. importation by boat, as occurs in Tonga and Fiji);
- Type and extent of water resources development. In otherwise favourable conditions, inappropriate groundwater pumping systems can readily induce saltwater intrusion if care is not taken in their design and operation. Often systems are designed and implemented without the necessary investigations and monitoring systems required to ensure sustainable pumping rates (i.e. rates that can be maintained without causing saline intrusion even during droughts);
- Land management practices on high islands, which lead to obvious erosion problems with consequent downstream water quality deterioration. Clearing of native vegetation and conversion to open land for

grazing or crops increases the peak streamflow after heavy rainfall. This is due to decreased interception and retention of water by the vegetation and leaf litter and decreased infiltration into the soil. These same effects of clearing can also lead to decreased baseflow (low flow) in the streams, as much of the runoff occurs following rainfall. These hydrological influences of catchment changes are discussed in McKean and Baisyet (1994). Decreased baseflows mean lower yields of streams and rivers for beneficial purposes (e.g. for potable water supply);

- Biological and/or chemical pollution of surface and groundwater lead to contamination of freshwater resources with ensuing impacts on human health. Water quality issues are considered in more detail in section 5.4.

5.3 Increasing demand for water

Key factors, which are placing a major demand on available water resources in many of the Pacific Islands, are:

- Steadily and, in some cases, rapidly increasing populations in some PICs is leading to increasing overall demand for water in these countries. The rapid rate of urbanisation in some PICs is also concentrating population and hence demand for water in certain islands or parts of islands. Most PICs show a much higher rate of population increase in urban areas than in rural areas (refer Table 2). Urban water supplies have difficulty keeping pace with urban expansion in some cases. In others, water supplies are not capable of delivering water on a 24-hour basis owing principally to high leakage, and sometimes wastage. A current example is South Tarawa, Kiribati, where water is available to only part of the population and then only for a few hours each day (an ADB loan project is soon to be implemented to partially improve the water supply to South Tarawa);
- Increasing expectations for water supply by urban populations is increasing the water demand per capita. Past estimates of reasonable per capita water usage (say 40-50 litres/person/day (L/p/d)) are now not capable of meeting normal expectations of reasonable consumption levels. Recent design estimates based on analysis of usage in larger villages and small towns suggest demands of about 100-150 L/p/d (e.g. TWB, 1997; Goodwin, 2000a; AusAID, 2000a). Per capita water usage in the principal regional towns with continuous water supplies can be of the order of 250-330 L/p/d, according to a preliminary finding from a ADB benchmarking survey of water utilities in 2000-2001 (information supplied by SOPAC);
- Increasing demands for water in other sectors, for example, tourism, agriculture and industry;
- Leakage and other losses from distribution systems (refer section 5.9 for further details).

5.4 Water quality degradation

Water quality degradation is a major problem and threat to freshwater resources and potable water supply systems in many of the PICs. These have arisen due to either point source discharges of pollution or more diffuse pollution sources occurring within surface or groundwater catchments. A summary of major issues for both surface and groundwater resources are outlined below.

5.4.1 Surface water

Water quality degradation has arisen from:

- Discharges of untreated wastewater with associated pathogenic organisms into streams, rivers and coastal estuaries. These discharges occur from outfalls (point source pollution) and from more diffuse flows from on-site sanitation systems within urban areas of surface water catchments. The rapid urbanisation process, mentioned previously, is putting great pressure on both surface water (and groundwater) supply catchments used for urban and nearby rural water supplies. An example of this occurs in the catchments supplying water to Apia, Samoa, where urban expansion and agricultural activities are noticeable. A study of water quality in the Ba River and estuary, Fiji (Anderson et al, 1999) found it to be seriously contaminated, with the dominant source of faecal contamination being Ba Town;
- Direct faecal contamination of catchments and streams from animals (e.g. cattle, pigs). Runoff of waste matter from commercial piggeries and from less formalised urban and village pigpens is a major source of pollution in some PICs (UNEP, 2000);
- Solid waste disposal sites close to streams or elsewhere in catchments where runoff can readily transport pollutants to watercourses;
- Soil erosion resulting from exposure of soil, leading to increased sediment discharges, high turbidity and colour problems, due to:

- extensive or inappropriate clearing of native forest as part of logging operations or for agriculture;
- poorly designed or constructed unsealed roads and unplanned development activities;
- fire used to clear undesired weeds in farming and forestry areas. This is an agent of erosion as it exposes the soil and destroys the structure of the upper soil layer (Baisyet, 1994).

- The erosional effects of tropical forest clearing for agriculture and urbanisation, of road construction and other activities in surface water catchments are generally well known (e.g. Bruijnzeel, 1990; Bruijnzeel and Critchley, 1994 and many of the papers in Bonell et al, 1993). Examples of typical soil erosion problems in PICs are given in McKean and Baisyet (1994). The problems of erosion are also greater in tropical climates than in temperate climates owing to higher intensity rainfall and the destructive forces from cyclones and other major natural disasters. Added to this is the steep island topography, which cause large floods, landslides and sometimes major losses of vegetation and significant soil erosion;
- Runoff from agricultural land containing nutrients (from fertilisers) and sometimes toxic agro-chemicals (pesticides and herbicides);
- Persistent organic pollutants (POPs) which are a threat in some PICs due to their high toxicity, persistence in the environment, and ability to be transported long distances (Aalbersberg & Thaman, 2000). In PICs, there is only limited data on the levels of the 12 UNEP-designated POPs. According to Aalbersberg & Thaman (2000), the only reliable water sample results are from the Solomon Islands in 1992 where 6 samples were analysed. One sample had a very high DDT level and high values were also found for other POPs. While the sample size is small, the presence of POPs in water samples is a significant concern;
- Discharges or accidental spillages of toxic chemicals from mining sites into streams and rivers (e.g. from some of the gold mining sites in Papua New Guinea).

It is noted that the small size and steep slopes of many catchments on islands enable water and pollutants to move quickly to coastal areas, so that the timeframe of impacts is rapid. However, the reversal of impacts is difficult and time consuming.

5.4.2 Groundwater

Groundwater quality degradation and problems have arisen from:

- Discharges of untreated or partially treated sewage and wastewater (sanitation and greywater systems directly into the ground). This is a problem in both urban and rural areas, but the problems are greater in urban areas due to the higher population densities and number of sanitation systems, principally pit toilets (either latrine or pour flush) and septic tanks;
- Pit toilets allow direct contamination of the freshwater lens, as these are normally dug to the water table. Where septic tanks are used, the situation is better if the septic tanks are well constructed and maintained. However, this is sometimes not the case, with tanks often leaking due to poor construction. On many islands where septic tanks are installed, particularly outer islands, de-sludging vehicles are often not available and manual removal of the sludge is rarely practiced. Eventually overflows of raw sewage occur as a result of blockages, and this enters the soil and groundwater;
- On islands with thin highly permeable soils and shallow water tables (e.g. atoll islands and other small coral islands), contamination can occur readily (e.g. high level of contamination found in village wells on Lifuka, Tonga: Crennan, 2001). Similar high levels of contamination were noted in extensive surveys as part of the implementation of a reticulated sewerage project on Tarawa in the early 1980s (TSP, undated). Detay (1989) and Miller et al (1991) report extensive bacterial contamination of wells in islands in the Federated States of Micronesia. Dillon (1997) found the thickness of the unsaturated zone (i.e. zone between soil and water table) is the most significant influencing factor on groundwater contamination. Hence islands with sandy unsaturated zones with thickness of 1 to 2 m are probably the most vulnerable of all. Limestone islands also offer little protection to groundwater contamination unless they are overlain by thick soil sequences;
- Sanitation facilities are often sited without concern for the direction of groundwater flow, and possibly according to guidelines which are not applicable to island environments (UNESCO, 1991; Falkland, 1999a). The normally accepted minimum distance between a sanitation facility and well is about 15 m (50 feet). This is based on studies in hydrogeological environments quite different from those found on many small islands. Foster (1985) has mentioned that the early research on the attenuation of faecal bacteria in unconsolidated sediments was confined to those with relatively small grain sizes and flow velocities. In many small coral islands such conditions do not apply. Travel times through the groundwater

between sanitation facilities (where wastewater is injected into the groundwater), and groundwater wells can be short in such environments. This has been clearly demonstrated in an applied research and training project on the island of Lifuka in Tonga where tracers (dye and bromide) were used to measure the travel times between injection points and measuring points several metres away (Crennan et al., 1998; Crennan, 2001);

- The density of household sanitation systems is also a problem, especially in the small coral islands. Acceptable densities and separation distances outlined from studies relevant to tropical islands (Dillon, 1997) are well exceeded in many PICs, especially in urban areas;
- The problem of extensive groundwater pollution is prevalent not only in coral islands in the Pacific, but also impacts on many other islands (e.g. 200 populated coral islands in the Maldives). In the Maldives, water is most often drawn from wells located in each housing block. Sanitation is a mixture of septic tanks, 'gifilli' (defecation on the ground in special areas within the block and then covered) and going to the beach. Pollution is widespread and, as there are very few animals compared with the Pacific (no pigs, dogs), the major proportion of this pollution is of human origin. As septic tanks are not always well constructed and often dug to the water table, direct contamination of the groundwater occurs (Falkland, 2000);
- Direct faecal contamination of groundwater from animals (e.g. pigs, cattle) and sometimes humans (where sanitation systems are unavailable). On some islands including those with vulnerable groundwater resources, animals are allowed to wander freely through village areas with defecation occurring at random and sometimes close to wells. Human defecation in the 'bush' (often in urban areas) or on the beach is a necessary sanitation practice in some crowded urban areas on atolls, where sanitation systems are not available for all to use. Wells utilised for potable and other purposes are not always covered, and often have inadequate protection around the base. This enables pollutants to wash in after heavy rainfall;
- Inadequate solid waste disposal methods often add to the pollution problem on small islands. This is especially serious where solid waste, containing toxic chemicals and hydrocarbon residues, is dumped over, or close to, fresh groundwater areas. Locating landfill sites on the edges of the island, while it does act to keep pollution away from freshwater resources can, however, have a major impact on near-shore and marine resources;
- Chemical contamination of groundwater resources, caused by uncontrolled use of agricultural chemicals (insecticides and pesticides). Particular chemicals are being used in some PICs despite having been banned in other countries. The extent of the problem is not always known owing to little or no monitoring. Limited monitoring of groundwater (used for potable water supplies) for herbicides and pesticides have been conducted on groundwater samples from Tongatapu, Tonga and Aitutaki, Cook Islands (TWB-IDP, 1995, AusAID, 1997) and on a surface water sample from Mangaia, Cook Islands (AusAID, 2000a). None of these tests showed evidence of elevated levels of harmful chemicals. This is not to say that contamination may not be occurring. Previously, concerns have been raised in other reports about the use of agricultural chemicals in Pacific islands (e.g. Brodie et al., 1984; Lau and Mink, 1987; Detay et al., 1989; UNESCO, 1991);
- Other sources of chemical pollution are leakage of hydrocarbons (e.g. from poorly maintained fuel storages, power stations and pumping stations) or untreated industrial effluent discharges. This problem is also an issue for surface water resources. On the island of Betio, Tarawa atoll, Kiribati, the disposal of waste oil on the ground adjacent to the power station is a source of contamination for groundwater. Detailed water quality tests at special pollution holes near power stations on another atoll, namely, South Keeling atoll in the Cocos (Keeling) Islands have revealed heavy hydrocarbon, lead and arsenic contamination (Barratt & Falkland, 1999). Similar contaminants are likely to be present in polluted groundwater near power stations on other atoll islands;
- Seawater intrusion due to over-pumping from fragile groundwater resources has led to the depletion of groundwater resources on a number of small islands, as mentioned previously.

5.4.3 Downstream impacts

The 'downstream' impacts of these water pollution problems on both surface waters and groundwater are often severe for communities and the environment. Impacts on freshwater supplies can be summarised as follows:

- Impacts on human health due to microbiological contamination and elevated nitrate levels in water supplies. "The pollution of drinking water and the resulting health hazard may be one of the biggest watershed issues in island countries of the South Pacific." (Baisyet, 1994). This major issue of water pollution in the Pacific region (and other regions) and the linkages with waterborne diseases is reiterated in more recent reports including ADB (1999). The high incidence of diarrhoeal diseases and other infectious diseases (e.g. hepatitis, typhoid and sometimes cholera) on some small islands is often caused by poor quality groundwater used as a source of drinking water. A listing of water related diseases and connections with poor water quality are documented for islands of the FSM and Marshall Islands in Detay et al. (1989). The water supply on South Tarawa was implicated in the spread of cholera in 1977. Other outbreaks of cholera have occurred since, including cases on Chuuk (1982-1983) and Pohnpei (in 2000);

- Impacts on human health from chemical pollution, either directly from the water or through the food chain;
- Impacts on physical quality of water supplies making the water unusable for days to months. On the island of 'Eua in Tonga, high turbidity and suspended solids are experienced by consumers after periods of heavy rainfall, which make the water unusable for a day or more. The water quality problems there are at least partly due to clearing and cattle grazing within the formerly forested catchment above the water supply intakes. The effectiveness of water supply intakes and treatment systems is compromised by high suspended sediment loads, leading to higher costs of providing clean, safe water supplies. For instance, Apia's water supply, which is fed from a number of catchments above the town, requires filtration (roughing filter and slow sand filter) and disinfection (chlorination) to achieve adequate water quality for the consumers. It is reported by the Samoa Water Authority that the treatment plants filters require more frequent cleaning in recent years. This is most likely a result of ongoing clearing within the water supply catchments by landowners for the purpose of grazing cattle and planting crops;
- After very heavy rainfall, treatment plants have been overtopped by floods and covered in sediment from contributing catchment areas, causing disruption to water supplies for months (e.g. water supply for Apia was severely disrupted after a major flood in April 2001). This sort of event is most likely unavoidable but the frequency of major flooding which can cause such problems is increased by catchment clearing, leading to higher and more rapidly rising flows than under uncleared conditions;
- Sedimentation in water supply reservoirs is also cited as a problem in some islands (e.g. on Babelthuap Island, Palau: McKean and Baisyet, 1994).

Other downstream impacts, not connected with water supply are:

- Impacts on the environment due to sedimentation and high turbidity within rivers and streams, causing problems for aquatic life, inner reef lagoons and mangrove areas. Impacts on coastal fish resources (e.g. degradation of fisheries habitat and possible direct fish kills);
- Impacts on hard coral communities from sedimentation and promotion of algal growth due to excessive nutrient loading.

5.5 Legislation, policy, planning and administrative issues

There are many important issues related to water legislation and policy and to the planning and administration of water resources in the participating countries. These vary according to local circumstances, and with the perspective of the various stakeholders. Some prevalent themes have been identified below from a number of sources including UNESCO (1991), Baisyet (1994a, 1994b); Willard, 1994 and White et al, 1999b), as listed below.

From an overall water management perspective, the following issues are identified:

- Inadequate or no legislation to protect and conserve water resources;
- No clear-cut regulations applicable to the protection and management of watersheds. Sometimes there is legislation related to forest management or environmental conservation but no specific watershed management legislation;
- Insufficient institutional capacity to enforce legislation;
- Roles and responsibility of agencies involved in water matters are sometimes unclear. For instance, there may be a lack of clear distinction between agencies involved in the provision of water supply and the regulation and protection of water resources. There are many cited examples of fragmentation in, or even lack of, co-ordination between agencies involved in water resources management (e.g. UNESCO/SOPAC/UNDDSMS, 1994; McKean and Baisyet, 1994 and Samoan Government, 2000);
- Competition for funding between government agencies involved in water management;
- Environmental impact assessment is almost non-existent in some PICs and is in its infancy in others. This may encourage the development of projects that are not sound from a catchment management perspective;

- Water quality standards are often poor.

From a community perspective, additional issues are identified:

- Little, or lack of community participation in the planning and management of water resources (refer section 5.6 for further discussion);
- Customary land tenure systems are not readily compatible with areas designated by governments for water resources protection, particularly where these have been imposed rather than agreed (refer section 5.7 for further discussion);
- Water rights are often unclear. Legislation may claim that water resources are vested in the government yet customary land ownership encompasses land and other resources, including water (e.g. Samoa Government, 2000).

5.6 Insufficient community education, awareness and participation

In the past, there has often been insufficient emphasis placed on community education, awareness, consultation and participation in decisions affecting water resource development, management and protection in many PICs (Willard, 1994; Baisyet, 1994b). The important role that women have to play in provision of water, particularly in rural water supplies within PICs, has also been insufficiently recognised (Sofield, 1994; Berhane, 1994).

Local communities often have a very good appreciation of available sources of water resources on their islands. For instance, there is often valuable local knowledge about the most sustainable springs on a high island or the best parts of a small coral island for wells. This information is especially valuable in drought periods when such sources may become the most sustainable freshwater supply sources. This valuable source of local knowledge has not always been properly utilised in past assessments, sometimes leading to community frustration caused by lack of participation in the planning phase for water improvements.

Communities may become suspicious and even hostile to government agencies involved with water supply provision or water catchment management. Sometimes villages are adversely impacted by water resource development projects and associated administrative arrangements. The inhabitants may have had little if any involvement in the decision-making process, leaving them feeling resentful and alienated. Vandalism against water supply infrastructure and monitoring equipment is not uncommon. There are many other examples of problems associated with attempts to enforce regulations or to build water supply systems on customary land. Winter (1995b) cites examples from the FSM, where a community water supply project failed because a pipeline crossed land belonging to several landowners but did not provide them with water taps.

In addition, local communities may not be fully aware of the impacts of their actions on downstream water quality. The impacts of management practices in upstream areas on downstream areas and receiving waters, including lagoons, coral reefs and coastal fisheries may not be well understood. Examples are provided in several case studies in McKean and Baisyet (1994) about the general lack of awareness of catchment processes and downstream impacts. While some forms of surface water degradation are obvious (e.g. through increased turbidity and high sediment loads), chemical and microbiological contamination is not apparent.

While some impacts on surface water quality can at least be seen, impacts on groundwater quality are normally not visible. For instance, the connection between microbiological pollution of drinking water wells and nearby sanitation systems is not obvious. The health impacts of drinking such water may also be not well understood. A low level of awareness of these issues was noted in a study of groundwater contamination from sanitation systems in Tonga (Crennan et al., 1998, Crennan, 2001).

One of the needs identified in a detailed study of the Bonriki freshwater lens, Tarawa (White et al., 1999b) was education of people, in particular school children, about the hydrological cycle, groundwater, pollution and the influencing factors. A most important identified need is to show the linkages between sanitation and solid waste disposal practices on groundwater pollution and hence on water quality and human health. The need for simple, clear educational material directed at school children is universally applicable throughout the PICs. In addition, 'active learning' through practical demonstrations and student monitoring in specific areas (e.g. water quality) is an under- utilised method.

In the Federated States of Micronesia, Khosrowpanah and Heitz (1997) also identified a general lack of knowledge amongst the population about basic water resources concepts and about simple measures necessary to improve household and community water supplies.

A similar issue of lack of knowledge and understanding about water resources, water use, and the impacts of catchment management practices on water quality has been identified for Samoa (Samoa Water Policy, 2000).

Measures taken to improve community education, awareness and participation in water supply and catchment management are presented in section 6.

5.7 Catchment management issues involving customary land tenure

In some PICs, conflicts have arisen due to the actual or attempted imposition or regulation by governments of land uses for public purposes on customary land (also called 'traditional land' by some authors). In cases where mutual agreement over land use has not occurred, conflicts, uncertainty and protracted delays in achieving effective land and water management have resulted (White et al., 1999b).

These issues are most noticeable in PICs where a large proportion of land is under customary tenure (e.g. 97% for Vanuatu: Nari, 2000). Traditionally, land was valued as much for its symbolism as for its ability to provide subsistence requirements. Customary views were very different from the attitudes introduced in the colonial period where land was valued for what it could produce rather than for what it symbolised. At the same time, 'western' administrative and judicial systems were introduced together with the concept of individual land ownership (Nari, 2000). Over time, and with the move to a cash economy in many PICs major changes occurred in catchments due to the cultivation of cash crops with often little regard for downstream effects (e.g. Pohnpei, Federated States of Micronesia: Dahl and Raynor, 1996; Raynor and Kostka, 2001).

Tonga is an example where these specific issues do not arise as land is owned by the royal family, the nobility or the government. Nevertheless, catchment issues have arisen as 'illegal' cultivation of crops has occurred in water supply catchments on the island of 'Eua (e.g. Tonga country report in McKean and Baisyet, 1994).

Two case examples of inadequate attention to customary land ownership and use are provided below. One involves a surface water catchment (Pohnpei, FSM) and the other involves a groundwater catchment (Bonriki, Tarawa). In both cases, measures taken to attempt to resolve these issues are presented in section 6.2.

5.7.1 Surface water catchment case example

On the volcanic island of Pohnpei, native forest was reduced from 42% to 15% of the island's area in the 20 years from 1975 to 1995 (Dahl and Raynor, 1996; Raynor and Kostka, 2001). The main cause was the dramatic increase in the cultivation of kava (or *sakau*), which became the main cash crop and source of employment for Pohnpei's people. Planting this shallow-rooted crop on steep slopes in upland areas has led to soil erosion and sedimentation in downstream mangroves, lagoons and coral reefs and adverse effects on water supplies. Unsealed roads leading to areas of cultivation have been a major source of erosion and sedimentation (McKean and Baisyet, 1994; Dahl, 1995; Dahl and Raynor, 1996).

The need for catchment management in Pohnpei has been identified at least since 1979, as shown by the Forest Management Act of that year which allowed the government to declare Forest and Watershed Reserves (Baisyet, 1994). Initially, catchment management was focused on a regulatory approach. In 1987, the Pohnpei Watershed Forest Reserve and Mangrove Protection Act was made law. This legislation, the first of its kind in the Federated States of Micronesia, assigned all watershed and mangrove forest management responsibilities to government agencies and designated a 5,100 hectare Watershed Forest Reserve in the upper catchment (Dahl and Raynor, 1996; Raynor and Kostka, 2001). There was very little community awareness and the legislation failed to recognise customary land tenure and resource use. Enforcement of the legislation was not attainable due to poor public understanding and support, and "several near-violent incidents" (Dale and Raynor, 1996).

Measures taken since the late 1980s to resolve this issue and promote participatory watershed management are outlined in section 6.2.2.

5.7.2 Groundwater catchment case example

Bonriki Island in Tarawa, Kiribati has an international airport and a declared water reserve (i.e. a groundwater protection zone) above the main part of a large freshwater lens. Groundwater pumped from the lens is presently the primary water supply for South Tarawa. The land over which the water reserve is declared is privately owned, with multiple landowners claiming possession (White et al., 1999b; Crennan, 2001). The water reserve was declared in 1977 under the Laws of the Gilbert Islands just prior to the end of the colonial period (Kiribati became independent in 1978). By law, restrictions are placed over land use within the water reserve, to protect the quality of the groundwater. This has been a source of friction over many years between the landowners and the government, which has led to vandalism of the water supply and water resources monitoring boreholes, and ever- increasing demands for compensation. The establishment of water reserves (as at Bonriki and the adjacent island of Buota) have failed to appreciate local community needs, culture, land tenure and land use requirements (White et al, 1999b). In addition, the legislation for the water reserves shows a lack of identified roles and responsibilities due to the absence of overarching water resources legislation.

In the past 10-15 years, some landowners, tenants and 'squatters' have moved onto parts of the water reserve and established dwellings, both temporary and more permanent. This 'illegal' community with their associated gardens presented a threat to the groundwater quality. At the same time, the condition of coconut trees and other vegetation within the reserve has deteriorated. The Bonriki community claimed that the deterioration was due to excessive drawdown caused by the infiltration gallery pumps. However, water level monitoring conducted as part of a scientific study of recharge found that this was not the case (White et al., 1997, 1999b), as the influence on water level due to pumping was small compared with natural influences (tides, recharge variations). It became clear that the purpose of the claim was really an attempt to gain additional compensation from the government, a symptom of the discontent of the local community with the arrangements. Further details are presented in White et al. (1999b).

Recent measures taken to resolve this issue are outlined in section 6.2.4.

5.8 Inappropriate technology and methods

There have been many examples of water supply technologies and methods being introduced in past projects that have not been appropriate for either the natural environment or the socio-economic conditions.

A common example has been the use of inappropriate groundwater pumping systems, which have caused saline water intrusion and hence a brackish water supply. Problems have arisen where pumping rates have been set too high, or insufficient consideration has being given to the sustainable yield of the groundwater system. This issue is particularly important for freshwater lenses on small coral islands, where conventional wells or vertical boreholes (tubewells) are not the most suitable groundwater pumping solution.

Generally, systems requiring a high degree of operation and maintenance have led to problems. Simple systems using tried and tested technology are the most enduring. An example of a relatively complex technology is desalination, which has had limited applications in PICs. Desalination systems, while successfully operating in many countries of the world where there is ample expertise, a ready source of spare parts and revenue to operate them, have generally been unsuccessfully applied in the PICs. Harsh environmental conditions, often a lack of skilled labour, insufficient attention to maintenance requirements, difficulties in obtaining spare parts and the cost of operation have caused a number of failures when this technology has been introduced. Problems with desalination systems have occurred in a number of PICs. Islands where desalination is used for a significant component of normal water supply to local communities are few (e.g. Nauru and Ebeye, Marshall Islands). Tarawa, Kiribati is an example where a desalination plant is used on the island of Betio to provide a small proportion of the total water supply. Failures have recently occurred with two other reverse osmosis units at the hospital and main hotel on Tarawa. Where desalination systems are supported by external finance to operate and maintain them, they have generally been successful (e.g. a limited number of tourist resorts in islands of Fiji and the Cook Islands).

As sanitation systems are often closely linked to the microbiological quality of freshwater supplies, it is important to briefly consider sanitation systems (details in parallel synopsis on waste management: OPUS, 2001). Because of their high pollution potential, particularly in island environments where soils are permeable and water tables are shallow, pit toilets are often very inappropriate. Septic tank systems, while in theory a reasonable wastewater treatment option, are often unsuitable due to poor construction and lack of maintenance. In the past, these sanitation practices have been introduced by well-meaning external funding agencies without a full consideration or appreciation of the groundwater conditions on small islands.

Some examples of measures taken, or which could be taken, to introduce more appropriate technology and methods are presented in section 6.5.

5.9 Water leakage and other losses in distribution systems

Losses from piped distribution systems in urban centres and larger rural villages are recognised as a major issue in many PICs (e.g. SOPAC, 1999b). The Pacific Water Association (PWA) recognises it as one of the key issues facing water supply agencies in PICs. In some cases where data from meters is available, over 50% of the water diverted or pumped from sources is lost through leakage from pipelines (details are provided in some of the country summaries in Annex II). In other cases, the extent of leakage is not well known as meters are either not installed, or not regularly read.

Leakages in pipe networks are normally due to a combination of poor joints (e.g. PVC pipes that have been heated to form sockets, a common practice in some islands), or where joints are not properly prepared before solvent cement is used. Other problems occur with deteriorated joints (e.g. perished rubber rings) or broken, cracked or split pipes (due to earth movements or washaways after floods, or piercing due to poor backfill and insufficient cover above pipes). Corrosion of steel pipes is an additional problem. The use of pipes and other materials with different specifications is an additional source of leakages. Additional water ‘loss’ may occur in piped water supply systems due to illegal connections. Leakage and other losses represents lost revenue to water authorities operating water supply systems where charges are based on usage. In many cases, additional costs are incurred due to the costs of pumping and treatment of water that does not reach consumers.

Apart from leakage in piped water supply systems (operated by water authorities, government departments or private companies), additional leakage occurs in household plumbing systems. The reason is mostly due to poor joints caused by unsuitable materials or incorrect procedures. Additional losses are due to leaking taps and other plumbing fixtures including showers and toilet cisterns. Toilet cisterns were found to be the major source of domestic leakage in a recent leakage survey in Niue (SOPAC, 2000b).

The combined losses from pipe networks and domestic plumbing systems represents a significant loss of a valuable freshwater resource. As the water is often leaking into coastal zones or polluted urban areas, it is not a recoverable resource. Increased abstractions to supply leakages may lead to over-exploitation of available water sources. In many cases, water shortages during droughts (and often in more normal rainfall periods) could be averted or at least minimised, if regular and systematic leakage control and other demand management measures (education and awareness) were implemented. In addition, infrastructure costs to develop additional sources to supply future demands could be delayed.

In some distributions systems, especially urban systems where there are no charges for water consumption, wastage and over-use of water are a problem. In these conditions, there is no economic incentive to conserve water, generally leading to high per capita water usage. Water supply systems that operate on an intermittent basis, of which there are many examples in PICs, can also lead to water wastage because taps are often left open to maximise filling of buckets and other containers while the system is operating.

Measures taken to improve the capacity of agencies in PICs to manage the issue of water leakage and other loss improvements are presented in section 6.6.

5.10 Insufficient knowledge of island freshwater resources

5.10.1 Insufficient assessment and monitoring

In many islands, water resource assessments have not been conducted or have been based on limited data only. There is a shortage of good quality meteorological, hydrological, hydrogeological and water quality data on many PICs.

In terms of freshwater quality, there is generally insufficient or no baseline data from which to evaluate the impacts of various developments and land management practices (UNEP, 1999). Also there is insufficient data available about the physical, chemical and other biological processes that take place in island watersheds, including soil erosion and loss of biodiversity as a result of land conversion due to logging and other practices. Quantitative evidence of microbiological and chemical water quality deterioration in streams is largely unavailable despite much anecdotal and visual evidence of physical deterioration. Regular groundwater monitoring is not a common practice in some PICs. Water quality testing, especially for pathogenic organisms, is also not commonly conducted especially in outer islands.

These issues have been raised at many venues over the past 20 or so years but the issues still remain. National agencies concerned with data collection and storage have indicated their problems and needs. Major problems cited (e.g. CSC, 1984; UNDTCD, 1989; UNESCO/SOPAC/UNDDSMS, 1994; WMO, 1999) are shortages of trained staff and training opportunities, limited budgets and problems of co-ordination between agencies. Further difficulties are presented by large travel distances, access to remote sites, equipment failures due to exposure to harsh environmental conditions (humid tropical environment, sea spray) and natural disasters (e.g. cyclones, flood damage). This has been reiterated in a recent major review of information and training needs in PICs (SOPAC/WMO/UNESCO, 2001).

In some islands, there appears to be a decline in recent years in the quality of data collection from long-term rainfall gauges and climate stations. Recent gaps in data in otherwise continuous records are a symptom of the problem. The causes are multiple, but include inadequate and often declining funding from government, insufficiently trained staff and faulty equipment. In some islands, school-based raingauge readings (under the Schools of the Pacific Rainfall Climate Experiment or SPaRCE program) are used as substitutes for former meteorological stations with paid observers (e.g. some northern Cook Islands). In addition to the objective of supplementing existing stations, the raingauges serve as a very useful educational tool for young people. While this is a commendable move to fill an 'institutional gap' with a community-based initiative, the results may not be reliable or the records continuous. Good rainfall records are essential ingredients for long-term water resources assessment.

5.10.2 Insufficient applied research and training

In a major review of water resources of small islands including PICs (UNESCO, 1991), it was noted that insufficient research had been undertaken in island environments into some key issues. It was further noted that the results of hydrological research and investigations from large islands or continents are not directly applicable to small islands, owing to the different scales and response times. For instance, groundwater pollution, saline intrusion caused by over-pumping, and the impacts of activities in surface water catchments can occur very rapidly in small islands.

The need for further applied research in PICs was reiterated at the Pacific Water Sector Planning, Research and Training Workshop in Honiara, 1994 (UNESCO/SOPAC/UNDDSMS, 1994). This workshop recognised that the need extended not only to technical and scientific areas but also required an emphasis on social science and community based issues. It was also emphasised that training of personnel involved in water resources and freshwater supply systems was a major need in PICs.

National governments have also recognised this need. For instance, the "Water for All" draft national water policy for Samoa (Samoa Government, 2000) states that ongoing research and measurement of all aspects of water resources in Samoa is an essential step towards protection and enhancement of water resources.

Some important measures to improve this situation have occurred in recent years (refer section 6.8) but there are still some major gaps in knowledge. These gaps add to the uncertainty of sustainability of water supply developments in some islands, especially where resources are limited and demands for water high.

6 Measures to manage impacts and threats

This section presents an overview and some examples of measures taken to manage activities that have impacted on, or threatened, freshwater resources in PICs, as outlined in section 5. The section not only focuses on past and current initiatives, but also suggests ongoing needs in freshwater resources and water supply management.

The main focus of this section is the need to ensure sustainability of freshwater resources, which is of paramount importance to the livelihood of all people, including the inhabitants of the PICs. Sustainability can be interpreted in many ways, but here it is taken to mean the capacity of freshwater resources to sustain the health and welfare of communities (rural and urban) and to provide sufficient water to meet environmental needs (particularly needs of animals and birds). The issue of sustainability therefore relates to a broad range of topics. This includes the overall quantity of freshwater resources, water quality, water availability, appropriate technology to develop and manage water supplies, the water needs of communities, the impacts of communities on water resources through land use and pollution, appropriate means and methods of managing catchments and pollution sources, and vital needs in the area of information, education and awareness.

While there are many ways to attempt a summary of these topics, this section is presented according to the sub-sections listed below. As with section 5, the order of these sub-sections does not reflect a priority ranking.

- Measures to improve sustainability of freshwater resources;
- Integrated and participatory catchment management;
- Community education, awareness and participation;
- Institutional strengthening of water agencies;
- Appropriate technologies and methods;
- Water demand management;
- Measures to cope with water supply quality degradation;
- Measures to improve knowledge of freshwater resources;
- Climate variability, climate change and sea-level rise.

It is recognised that there are some overlapping elements of these sub-sections, which is unavoidable given the broad nature of the topic.

6.1 Measures to improve sustainability of freshwater resources

6.1.1 Effective planning of water resource development

Planning needs to take account of many factors including the nature and extent of water resources, climatic and other impacts on these resources, economic conditions, type and location of water demands, and community attitudes and practices through consultation.

The types of water resources that are developed vary between and within PICs. A crucial step in the planning is the assessment of water resources potential and water demands. Initially, 'conventional' surface water, groundwater and rainwater resources need to be adequately assessed and sustainable yields estimated. 'Non-conventional' options, including desalination and importation and use of other water (e.g. seawater) may need to be considered in special circumstances (e.g. where freshwater resources are very limited under normal conditions or during drought) but not before other more conventional, simpler and less expensive options have been thoroughly investigated.

Conjunctive (or complementary) water use schemes are evident in some islands, and this is a good approach to the management of water supplies. Typical conjunctive use schemes at village level on small low- lying islands are the use of rainwater for 'first class' needs such as drinking, cooking and the use of groundwater from wells for 'second class' needs such as bathing, washing and possibly flushing toilets (in urban areas). Conjunctive use of groundwater and rainwater is common in many small islands (e.g. FSM: Winter; 1995a, 1995b) and on some larger islands in Melanesia. Sometimes three classes of water are present in urban or peri-urban areas where piped water is available (e.g. parts of South Tarawa where some houses have access to local wells, rainwater and piped water). This arrangement has the advantage of allowing households to exercise some control over their own water supply and water quality.

Climate variability is not the only important consideration in the issue of 'local ownership' of water resources. The need for alternative water sources became evident during the recent conflict in Honiara due to a major water shortage caused by destruction of the surface water dam, which supplied 80% of water demand. Many residents installed rainwater tanks to overcome this problem.

Other forms of conjunctive use are evident in islands with limited freshwater resources in order to maximise the use of these resources for potable purposes. In Tarawa, where groundwater resources are limited and the demand for water is relatively high due to increasing population, reticulated sewerage systems in three main centres of population (Betio, Bairiki and Bikenibeu) use seawater for flushing. Similarly, to conserve available surface runoff collected from the airport catchment in Majuro, Marshall Islands, sewerage systems there also use seawater. Further discussion of sanitation options is provided in section 6.5.4.

6.1.2 Drought management strategies

Drought is one of the major natural 'disasters' facing islands in the Pacific and has a major impact on water resource sustainability.

It is important that drought management strategies be part of the long term planning for water supplies. While this is primarily an issue for the smaller islands with limited water resources, particularly those susceptible to long droughts (e.g. Kiribati), it is also important for islands with larger landmasses or where rainfall has a high variability. For instance, the drought associated with the 1997-1998 El Niño had a major impact on larger islands including PNG and Solomon Islands (Barr, 1999).

In urban areas, one drought management strategy often utilised is to introduce water restrictions. Such measures were taken in the 1997-1998 El Niño drought in several countries including PNG, Solomon Islands and Fiji (SOPAC, 1999a). Radio programs have been used as a means of raising public awareness to reduce water consumption in some countries (e.g. Marshall islands, Kiribati, Tonga and Samoa). On the main island of Rarotonga in the Cook Islands, where, during the drought, the combined surface water reduced to about 40% of normal flows at water intakes, the water supply agency performed leakage control measures to reduce the loss of water (SOPAC, 2000b).

Communities on small islands have long known methods appropriate for dealing with droughts. These have included collection of water from sustainable springs, digging shallow wells on beaches to extract groundwater and travelling by boats to nearby islands to collect water from more permanent sources. Other measures include the use of coconuts as a substitute for drinking water and using brackish or seawater for non-potable uses. It is probably true to say that very few communities will be totally devoid of freshwater or substitutes (e.g. coconuts). Exceptions are potentially, islands reliant solely on rainwater or where population pressure is extremely high and available natural resources are scare (e.g. Ebeye, Marshall Islands; Funafuti, Tuvalu). The main issue is how best to provide a reasonable water supply under all conditions, including drought.

In Tuvalu, rainwater collection is the primary source of water as rainfall is generally high and drought periods, although they occur, tend to be of short duration. When water shortages occur, communal tank water, used to supplement private rainwater catchment systems, is rationed. As one step towards improving the overall capacity of rainwater storage for the main centre of Fogafale on Funafuti atoll, public housing designs have incorporated separate underground cisterns for private household use and for communal use in times of drought. This is a positive move since it recognises the need to utilise as much roof area as possible when designing rainwater collection systems. It is also a practical demonstration of incorporating a community water supply into an otherwise private water supply system.

In the northern atolls of the Cook Islands, the main current water supply source is rainwater. Many years ago, groundwater was used when the communities were smaller. In recent studies (AusAID; 2000b, 2001a, 2001b), proposed drought management strategies for these atolls focused again on groundwater as a source that should be used to supplement rainwater when tanks run dry, especially for 'second class' water requirements. Following major destruction of houses and community facilities on Manihiki atoll, northern Cook Islands, by over-washing waves due to Cyclone Martin in 1997, rainwater tank improvements were implemented. These included the installation of large in-ground rainwater storage tanks as integral parts of new household cyclone shelters, as part of a move to more effective drought management.

In many islands, freshwater resources have not been adequately investigated and their yields estimated. This is by nature a technical task, requiring assessment of water resources. In some islands, community knowledge is a valuable component of such water resources assessment tasks and should be incorporated to supplement scientific approaches wherever applicable. In some islands, investigation of groundwater resources necessarily requires techniques beyond the normal capacity of local communities (e.g. drilling and testing for water salinity). This should be taken into account in island water resource assessment programmes (refer section 6.8).

Part of this process is to recognise the effectiveness of rainwater catchments in supplying basic needs throughout droughts. In the Ha'apai group of Tonga, where significant droughts can occur, many households recognise that rainwater should be conserved for only potable purposes when regular rainfall ceases. In other islands where the impacts of droughts are very severe (e.g. Kiritimati, Kiribati), normal rainwater catchment systems cannot supply sufficient freshwater for even basic demands.

To ensure sustainability of groundwater for public water supply during droughts, some island water supply agencies have adopted the philosophy that pumping rates should be set at a minimum constant rate, which has been designed to cope with worst historical drought periods. This approach is used for groundwater pumping from the islands of Bonriki and Buota in Tarawa.

One drought management strategy that can, and has been utilised in small islands reliant on groundwater, is to pump at low rates once salinity levels reach a threshold level but allow higher pumping rates when condition are favourable. This involves a detailed knowledge of the impacts of climate and pumping on freshwater lenses that can be done only after sufficient monitoring data has been collected and assessed. An example of an island where such a strategy is in place is Home Island, Cocos (Keeling) Islands in the Indian Ocean (Falkland, 1999b).

In some islands, desalination systems have been provided and installed as a response to severe droughts, and stored for emergency purposes when rainfall conditions have improved (e.g. Marshall Islands, Tuvalu). In the case of Kiribati, a desalination unit was installed during the long and severe drought in the late 1990's and was kept operational following the drought. The use of desalination systems to supplement potable water supplies in droughts is an appropriate response, provided that it is not a substitute for more effective and economical long- term water supply strategies.

6.2 Integrated and participatory catchment management

6.2.1 Outline

The problems associated with land use in catchments and impacts on downstream water resources were outlined in section 5.4. These problems and their causes are generally well known and described (e.g. Bruijnzeel and Critchley, 1994; Bonell et al., 1993; McKean and Baisyet, 1994). The scientific and technical measures required to manage surface water catchments from being eroded and polluted are also generally well known. These include appropriate forestry management and agriculture practices, soil erosion measures, proper road design and construction, building controls and wastewater management practices. The combination of measures taken to enable the rational utilisation and management of land and water resources with minimum impact on natural resources is often called catchment management (or watershed management). Island government departments dealing with forestry, agriculture, land and natural resources, assisted by training programmes by FAO (Baisyet, 1994a), are generally aware of the measures required to achieve effective catchment management.

While the scientific principles may be generally well known, the problem in the past in many countries, including PICs, has been insufficient attention to the 'human activity system' or social dimension of catchments. In PICs this means the recognition of traditional systems and values including land tenure systems and social structures.

The concept of 'integrated catchment management' (ICM) has been introduced over the past decade to recognise the importance of the social dimension and to integrate it with the physical dimension in the process of catchment management. ICM has been defined as the 'process of formulating and implementing a course of action involving natural and human resources in a catchment, taking account of the social, political, economic and institutional factors operating within the catchment to achieve specific objectives' (Hufschmidt and Tejwani, 1993).

Participatory catchment management (or 'participatory watershed management') emphasises people's participation and action as the central element of ICM. It adopts a partnership approach involving government agencies, NGOs and the local communities. Participatory catchment management (PCM) has often been recognised as a more effective means of achieving sustainable resource management, including protection of water resources, than the more commonly applied 'top down' approach (Hinchcliff et al., 1999).

Participatory approaches to catchment management have been applied in many parts of the world, and numerous case studies are cited in the literature, for example, Shah (1994), Sapkota (1995), Arya and Samra (1996) and Grewal (1996). A recent summary of case studies is provided in Hinchcliff et al. (1999). Participatory approaches to catchment management and wider issues of water resources management are presented in Gayer (2000).

While PCM has been a focus in many countries, it is not so well developed in PICs. However, where it has occurred, worthwhile results have been achieved. A case example of catchment (watershed) management in Pohnpei is outlined below. In other PICs, steps have and are being taken to recognise the need for participation of communities in catchment management and the wider issue of responsible water management and water use. These concepts are stated, for instance, in the Samoa "Water for All" national water policy (Samoa Government, 2000).

6.2.2 Surface water catchment case example

The example of the high island of Pohnpei and early failed attempts at catchment management in the 1980s were introduced in section 5.7.1. Starting in the late 1980s, a number of measures were taken to rectify water quality degradation problems through participatory watershed management. This management process evolved over several years in Pohnpei with support from various agencies including US Forest Service, ADB, SPREP and The Nature Conservancy (TNC). Some key events are described below.

- A multi-agency Watershed Steering Committee (WSC) was established in 1989, with government and NGO representatives. This was initially supported by the US Forest Service and later by SPREP, TNC and ADB;
- The WSC conducted an island-wide watershed education and consultation program, visiting all local communities. Communities showed interest and requested more input in the management of their forest resources and the inclusion of their traditional leaders into the process. The government saw the need to integrate communities in the planning and management of the catchments;
- An Integrated Watershed Management Strategy (WMS) was developed by TNC with assistance from SPREP and ADB, and approved in 1996 (Dahl and Raynor, 1996; Crocker et al., 1997; Raynor and Kostka, 2001). The WMS was based on participation of community members, traditional and civil leaders and the private sector. It recognised the authority of local villagers to manage their own forest and marine resources. One of the main objectives of the WMS was to develop a practical cost-effective monitoring program to measure the status and trends of Pohnpei's watershed resources and to be used as a guide to community-based resource management. A monitoring program was developed in 1997 (Crocker et al., 1997);
- Pilot programs using the WMS have been implemented in five municipalities. Local management teams have been formed, including community conservation officers who monitor and oversee the management of their community's forest areas;
- TNC has assisted its local partner, the Conservation Society of Pohnpei (CSP), and others in community-based conservation monitoring and enforcement throughout Pohnpei. They have also assisted farmers to plant kava (*sakau*) in the lowlands, under the shade of commercial fruit trees ("Grow Low" campaign);
- During this period, the Pohnpei Watershed Conservation Area Project under the South Pacific Biodiversity Conservation Programme (SPBCP) was also established. Its main objective was to protect and conserve the ecological functions and processes of the upland forest within the Pohnpei Island Watershed Forest Reserve area and the mangrove forests (SPREP, 2001a). Over time, this project has evolved from a defined watershed area to the island-wide conservation effort involving nearly 200 villages in the five municipalities. SPBCP's role and funding has become almost non-existent, relying mainly on the work of the TNC to support the project. (SPREP, 2001a). The project has been generally successful in raising awareness on the need for conservation of the upland watershed. Numerous posters in the local language have been printed and distributed, and project staff have worked very closely with local communities.

While not all aspects of this initiative have been successful (refer SPREP, 2001a), the overall process of developing the participatory approach to catchment management has been successful. It has allowed communities to become informed and gain ownership of the management of their own resources. The project has shown that government agencies, NGOs and communities can work positively together. Other communities are aware of the process and are requesting the same opportunities (TNC website: www.TNC.org).

6.2.2 Sustainable forest management practices

Sustainable forest management practices aim to enable logging operations to occur in catchments in a manner that is not detrimental to downstream areas, including the protection of water quality in streams and rivers. Where these practices are conducted to fully include the local communities in the process, they are examples of PCM.

Guidelines for sustainable forest management practices, including appropriate methods of logging and associated road construction in tropical rainforests, have been available for many years (e.g. Gilmour, 1977; ITTO, 1990; ITTO, 1998) and presented in the literature (e.g. Cassells et al., 1984; Bruijnzeel and Critchley, 1994). However, they have not generally been implemented in PICs until recently.

In the Solomon Islands, for example, measures have been taken to introduce 'eco-forestry' principles, which aim to harvest forests in a sustainable manner. These include the protection of water quality, recognition of customary land ownership and promotion of the need for benefits to flow to the communities involved (including engagement of local labour and equitable distribution of cash proceeds). The Solomon Islands Development Trust (SIDT), with assistance from other agencies, is co-ordinating this process through their Eco-Forestry Unit. The SIDT has adopted forest management guidelines from the US Forest Stewardship Council (F. Narasia, pers. comm., 2001). Some elements of these guidelines in relation to protection of watercourses and associated quality include the use of buffer zones between logging operations and watercourses. Buffer zones of widths of 25 m or 50 m have been nominated depending on the size of the watercourse. Other elements are road design, maintenance and timing of road use to minimize the entry of sediments into watercourses.

Community eco-forestry has been a major focus of FSPI with funding from the EC in a number of PICs through its South Pacific Community Eco-Forestry pilot project. The aim is to assist communities with sustainable management of their forests and trees (FSPI, 2001).

6.2.4 Groundwater catchment management

The problem of groundwater pollution is, to some extent, a more difficult one to solve than surface water pollution, as the resource and the factors affecting it are not readily visible and less well understood by communities.

In the past, most attempts to improve groundwater quality have been through institutional approaches, at various levels of government. For example, in the FSM (formerly part of the US Trust Territory of the Pacific Islands), it was recognised by the US Environment Protection Agency that groundwater protection is a very complex and difficult issue to address and would require sustained efforts 'at all levels of government' (Detay et al., 1989). This was essentially a 'top down' approach, focused on water resources policy, water system management, pollution control policy, sanitation practices, land use policy and public education. These and other elements were seen as part of a total groundwater protection program.

This issue has needed, and will continue to need an institutional approach to waste management, both liquid and solid, especially in urban areas. At the same time, there is an ongoing need for PCM principles. These are especially applicable in relation to community education, awareness and participation in matters of water supply, sanitation and solid waste practices. In addition, they apply to agricultural practices and the use of chemicals over freshwater lenses and other activities including the storage, use and disposal of hydrocarbons.

As outlined in section 5.2, one of the major issues for groundwater catchments is pollution from urban areas, particularly due to wastes from sanitation systems. This major groundwater issue, which impacts directly on human health probably more than any other in PICs, requires greater efforts by all sectors of society to achieve better solutions.

6.2.5 Guidelines for groundwater protection

Dillon (1997) presents a list of measures that consider important aspects of catchment management, governance and community involvement to improve the overall quality of groundwater. These items, slightly modified, are reiterated below:

- Provide public information on the linkage between sanitation and drinking water quality;
- Implement planning regulations to restrict population density of unsewered areas;
- Develop public health regulations on the design and maintenance of sanitation systems;
- Specify groundwater protection zones (minimum distances for contaminant sources);
- Establish (or continue) monitoring procedures for pathogens and nitrogen in drinking water supplies;
- Develop contingency plans for occasions when water does not meet the required quality;
- Disinfect water supply wells or use alternative water supplies (e.g. rainwater tanks);
- Establish centralised water supply and/or sanitation systems.

The measures in the above list are not universally applicable to PICs. National guidelines or site -specific guidelines, with similar measures have been prepared in some PICs in relation to groundwater protection, sometimes as part of draft or enacted national water resources (or water supply) legislation. These have been implemented to various degrees depending on local circumstances. In Tonga, for instance, legislation enables the Tonga Water Board to establish groundwater protection zones over freshwater lens areas used for water supply.

As with surface water catchments, there is a real need to consider customary land ownership and use when planning and implementing measures to protect groundwater resources.

6.2.6 Groundwater catchment case example

The example of a conflict between customary land use and legislated groundwater reserves on Bonriki, Tarawa, was introduced in section 5.7.2. In 2001, as a condition of the ADB funded loan project, which includes upgrading of the water and sewerage infrastructure, the people living on the freshwater lens were required to be moved. A compromise solution was found where most could be resettled along a 50m wide strip on the ocean side of Bonriki island, and effectively on the edge of the freshwater lens. This solution was proposed in AusAID (1992a). After a series of land boundary adjustments, the move has taken place. This solution was reached after consultation between the Bonriki landowners and government, recognising that the water reserve was a necessary long-term water supply for South Tarawa.

Further to this process, White et al. (1999b) presents a list of recommendations aimed at both the institutional and the community level, which could assist in longer- term resolution of potentially ongoing issues. One concept advanced to the government, was to establish village-based committees for the continued protection and management of activities on the freshwater lenses (P. Jones, pers. comm., 2001), representing a step towards participatory catchment management.

Methods used, and lessons learnt from the community consultation component of the Bonriki groundwater study, (which was primarily aimed at scientific issues, particularly recharge to the freshwater lens), are presented in Crennan (2001) and a UNESCO website which focuses on this topic (www.unesco.org/csi/act/pacific/tarawa.htm).

Based on issues raised during the Bonriki groundwater study, further applied research requirements have been highlighted. White (1998a, 1998b) presents research proposals for safe conjunctive land use practices over freshwater lenses and studies into the impacts of market gardens on fresh groundwater quality. A number of options are available in relation to conjunctive land use of areas from where groundwater is pumped, including sports fields and parks. Sanitation systems should either be avoided, or well-designed and constructed to 'export' pollutants from the catchments.

6.3 Community education, awareness and participation

Some examples of measures to improve community education, awareness and participation in relation to freshwater supply and water resources are presented below.

6.3.1 Village water supply project implementation and operation

This section considers examples of positive moves to involve communities, particularly rural communities, in improvements to, and operation of, their own water supplies.

In Solomon Islands, rural water supply systems for villages are implemented through the Rural Water Supply and Sanitation (RWSS) Department of the Ministry of Health and Medical Services. A major thrust of the RWSS Project is community participation (e.g. in planning and design) and involvement (e.g. in building and maintenance). When a village requires a water supply or improvements, they form a village committee, which applies to the provincial government. The RWSS Department then visits and discusses the project with the committee and the whole village community. Certain conditions are required for implementation, including the agreement from the owner of the land where the water source is to be developed. This agreement avoids potential later conflicts. Other requirements are a financial contribution from the village (between 10% and 50% depending on the province) and provision of free labour during construction. (In Fiji and Vanuatu, financial contributions of 30% apply in most cases). Women are included in the planning stages and trained in maintenance and monitoring of water quality. Operation and maintenance guides, compiled after numerous workshops involving the government, NGOs, communities and women's groups, are supplied to the village. These measures enable the community to participate directly and financially in the improvement of their own water supply.

The Solomon Islands Development Trust (SIDT) has assisted with the implementation of the RWSS. The SIDT is largely involved through its network of Village Demonstration Workers to promote clean and efficient water supplies and basic community hygiene and sanitation practices.

In Tonga, funding for village water supplies is co-ordinated through the Ministry of Health but involves local communities in the construction and operation of the systems. Most of these water supplies use groundwater, which is pumped to overhead tanks and reticulated via pipelines to taps at each house. Communities are involved in the construction by providing labour and sometimes cash contributions. Village Water Committees are established to operate and maintain the systems. They are responsible for pump operation and maintenance, all plumbing and the collection of fees to pay for operation costs (fuel, labour).

Similar village-based water committees are involved with construction and operation of rural water supplies in other countries. In PNG, Water Supply and Sanitation Committees fulfil a similar role to the examples above. Kolam (1994) mentions that community ownership of rural water supplies is the key theme to sustainability.

In section 5.7.2, the example of Bonriki, Tarawa showed that financial compensation or rent was paid by the government to the local Bonriki village landowners for use of their land for water extraction purposes. This is a special case, however, there are opposite examples where, with adequate discussion and consultation within the community, private or customary land has been made available for water supply purposes, even without compensation. This is the case for the main water supply system on the island of Aitutaki, Cook Islands, where the bulk of the water is pumped from a groundwater source. It was also the case for a public water supply system for a small village (Onou) on Namonweito atoll, Chuuk State, FSM (Winter, 1995a).

There have been many examples of communal projects to build ferrocement rainwater tanks throughout PICs. A variety of aid donors, NGOs and other groups have been involved in this work. In some cases, the projects aim at individual household tanks while others have built communal tanks near public buildings. For example, FSP Fiji has been co-ordinating a rainwater tank project at schools since the 1997-1998 drought caused major water shortages and some school closures. Many other examples are found throughout the participating countries.

In Tuvalu, rainwater collection systems are the primary source of potable water and there have been many projects, funded from various agencies to build rainwater tanks on the main island, Funafuti and in the outer islands. Taulima (1994) provides an insight into one such project to build additional rainwater storages. The project design placed emphasis on communal cisterns rather than household tanks. However, consultation with the communities indicated that household tanks were preferred because each household would have greater control over their own water supply. Also, operation and maintenance became a household rather than a community issue.

Bilateral aid donors now emphasise the need to consider community consultation, information and education. As part of the consultative process, many also require that gender issues be considered (e.g. AusAID, 2000c) in project design and implementation.

6.3.2 Linkages between water supply, sanitation and health

Community education and awareness programs are often integral parts of water supply and sanitation improvement projects. In Kiribati, for instance, there are a number of current projects that focus on community education in relation to water supply and waste management, including sanitation and impacts on the environment. These involve FSP Kiribati and other agencies. Two of these community education programs are integral parts of water supply improvements, namely, the Sanitation, Public Health and Environment Project in Tarawa (ADB loan project) and the Kiritimati Water and sanitation Project on Kiritimati atoll (AusAID funded project). In the past, other initiatives have produced useful bi-lingual booklets concerning water, sanitation and public health (Kiribati Water Unit, 1997b). Other forms of community education through community theatre (song and dance) have been successful in some PICs including Kiribati, Fiji, PNG, Tonga and Vanuatu.

While many forms of education may be useful at raising public awareness about the need for clean water and adequate sanitation, it is often difficult to demonstrate the linkage between sanitation systems and other forms of waste and pollution in groundwater, especially at wells.

A recent applied research project conducted in the island of Lifuka, Tonga concentrated on community education concerning the linkage between groundwater pollution from sanitation systems and contamination of nearby wells used for (non-potable) water supply. By using visual indicators such as dyes, the concept of pollution of wells from nearby septic tanks or pit latrines could be demonstrated (Crennan et al, 1998, Crennan, 2001). A number of experiments were conducted at a school. This was an excellent example of how scientific experiments could be used to raise awareness amongst the students and the wider community. At the start of this project, it was apparent that not many people understood that the groundwater was a means of transmission of pollutants.

6.3.3 Water conservation

Community education and awareness campaigns have been run in a number of PICs to promote water conservation. Some of the water authorities and other agencies have run radio programs in which water conservation issues are discussed during normal and drought periods (e.g. in Marshall Islands, Kiribati, Tonga and Samoa: SOPAC, 1999b). Periodically and often associated with water supply improvement projects, brochures and posters have been produced in local languages. Water conservation booklets have also been published with practical guides to water saving techniques (e.g. in Tonga: Helu & Tapealava, 1995).

In recent years, World Water Day has been a focus of activities (e.g. poster competitions from school students) in some PICs. In 2000, SOPAC and SPREP staff combined to develop a water awareness campaign involving students from schools in different PICs. Students were encouraged to conduct awareness campaigns in their schools in addition to fixing leaking taps while monitoring the effects of these measures (SOPAC, 2000a). These initiatives are a good means of involving communities in general awareness about the need to conserve water and protect catchments from activities, which have detrimental downstream impacts. For World Water Day 2001, SOPAC again developed publicity material including a website under the theme “Water and Health”.

6.3.4 Water resources monitoring and education

Initiatives to involve communities, particularly schools, in water resources monitoring programs have been implemented in a number of PICs. One of the most widely implemented projects is the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) which is a co-operative field project involving local meteorological services and schools. There are over 160 schools from approximately 22 different countries involved in this program. Data from SPaRCE stations is normally rainfall but in some cases includes additional climatic information (e.g. temperature and humidity). This program is co-ordinated through the University of Oklahoma in the USA and sponsored by a number of agencies.

Another project is the River Care project to be implemented in Fiji through Live & Learn Environmental Education. This programme, based on the Streamwatch programme in Australia, is a school and community water quality monitoring and education project designed to help raise community awareness of pollution in rivers (Live & Learn, 2000; C. Nielsen, pers. comm., 2001). It is not intended to be a solution in itself but is designed to raise awareness in students through river monitoring. Initially, it is intended to introduce it to schools and communities in the four most polluted river catchments in Fiji including the Rewa River catchment.

The example cited earlier of groundwater quality monitoring and dye tracing at a school in Tonga is another practical example of measures used to educate and raise awareness of water resources issues (Crennan et al., 1998, Crennan, 2001).

A number of these measures have been identified as elements of potential pilot projects under the IWP, as outlined in section 7 and presented in detail in Annex III.

In general, community-based monitoring has an educational rather than a regulatory objective. In this respect, it is worth reviewing a lesson learned from a water quality monitoring programme from the Sepik Community Land Care Project in PNG (WWF, 2000). Baseline data collection on heavy metals and fish populations in a river to investigate the impact of mining activities on river health was conducted by a student. The results were not accepted for regulatory purposes as they were deemed not to be of an "international standard" and the work was to be repeated by an "appropriately qualified scientist" (WWF, 2000).

6.4 Institutional strengthening of water agencies

The need to strengthen institutions in water resources planning, water supply development and operation and the wider field of environment management has been recognised in the design of major projects to assist PICs in recent years.

The emphasis in many projects has changed from essentially infrastructure improvement projects to ones which aim at developing the capacity within water supply and other agencies to plan and manage their own activities with the aim of achieving long- term sustainable water supply operations and water resources management.

Examples in recent years have been institutional strengthening projects funded by AusAID for a number of water authorities, namely, the Solomon Islands Water Authority, the Tonga Water Board and the Samoan Water Authority (ongoing). These projects were aimed at improving the capacity of the authorities at all levels including technical, financial, administrative, managerial and specific areas including legislation and customer relations. Other similar projects have been funded by the ADB in Kiribati, Marshall Islands and Federated States of Micronesia as part of wider infrastructure improvement projects.

6.5 Appropriate technologies and methods

6.5.1 Overview of recent work

Appropriate technologies for application in small island developing states to achieve sustainable development and management of water resources has been the focus of a major initiative in the past few years. UNEP and the International Environmental Technology Centre (IETC) sponsored a series of surveys, workshops and publications to evaluate and present a number of appropriate or alternative technologies for 'freshwater augmentation' in small island developing states. In the Pacific region, this work was undertaken largely by SOPAC with inputs from individuals in the Pacific, Indian Ocean and South China Sea regions. A workshop was held at SOPAC in February 1996 (SOPAC, 1996), which was followed by preparation and publication of a Source Book on Alternative Technologies for Freshwater Augmentation in Small Island Developing States (IETC, 1998). The purpose of the book is to provide information to water and environmental managers and planners about available methods for sustainable development of freshwater resources on small islands.

There have been other projects and reports aimed at providing useful methods, approaches and designs for sustainable water resources development and management. SOPAC has been a key agency in many of these initiatives, particularly in its role as a regional co-ordinator of workshops on relevant topics (e.g. hand pumps, solar pumps, demand management and appropriate sanitation for the management, conservation and protection of freshwater resources). A number of bilateral agencies including NZODA and AusAID have funded projects with a focus on providing sustainable solutions to water management.

Some examples of appropriate methods (rainwater catchment systems, infiltration galleries and composting toilets) are noted below. Others are raised in section 6.6 under the heading of water demand management. Further details of these and other appropriate technologies and methods are presented in IETC (1998).

6.5.2 Rainwater catchment systems

Household rainwater tanks are not only one of the most appropriate solutions to improving potable water supplies but they also increase the level of community involvement and self-reliance in rural water supply schemes.

As mentioned previously, conjunctive (or complementary) water use schemes are evident in some islands, and this is a good approach to the management of water supplies. Typical conjunctive use schemes at village level on small low lying islands are the use of rainwater for 'first class' requirements such as drinking, cooking and the use of groundwater from wells for 'second class' requirements such as bathing, washing and possibly flushing toilets (in urban areas). Conjunctive use of groundwater and rainwater is common in a number of small islands (e.g. Cook Islands, FSM, Kiribati and Tonga). The relative use of rainwater and groundwater is very much dependent on local factors including rainfall patterns, extent and size of rainwater collection systems and quantity and quality of groundwater.

Methods for the design of rainwater catchment systems are the focus of a number of papers in proceedings of a series of international conferences on this subject and other specific references (e.g. Gould, 1991). Specific design guidelines for particular countries have been developed including Tuvalu (Chapman, 1986) and Federated States of Micronesia (Heitz and Winter, 1996).

Rainwater catchment construction programmes in rural areas have been the focus of many aid projects in PICs. These programmes have been implemented with funding from a large number of international and bilateral donors and NGOs. Many involve the construction of ferrocement tanks which can be implemented in community based schemes. In some cases, this may involve local contractors (e.g. Tonga) while in others, whole villages have been involved in the process. Various guidelines have been written, often in the local language, to assist in the training of persons to carry out construction work, examples of which are presented in IETC (1998).

6.5.3 Infiltration galleries

Infiltration galleries are an appropriate method of pumping groundwater in small islands and coastal zones. If properly constructed and operated infiltration galleries, or "skimming wells", avoid the problems of saline intrusion that can and does occur due to pumping from wells or boreholes. Infiltration galleries generally consist of buried horizontal conduit systems which are permeable to water (e.g. PVC slotted pipes), laid in trenches dug at or close to mean sea level thus allowing water to be drawn towards a central pump. The trenches are dug by hand or with the aid of mechanical digger. Once the gallery pipes are laid, the area is backfilled and the only structure seen above ground level is a pump well and pumping system.

Infiltration galleries are successfully operating in a number of PICs including Tarawa, Kiribati (Falkland & Woodroffe, 1997), Kwajalein in the Marshall Islands (Hunt, 1996) and Lifuka, Tonga (TWB, 2000). On the island of Bonriki, Tarawa, a yield of about 1 million litres/day is obtained from 17 galleries, each 300 m long (White et al, 1999b). There are other examples in PICs in the Marshall Islands (Majuro and Kwajalein) and the Cook Islands (Aitutaki). Open trenches, as previously used on Kiritimati atoll in Kiribati, prior to recent construction of new galleries, are not recommended as these are subject to surface pollution.

On the island of Lifuka in Tonga, where groundwater pumped to the residents of the village of Pangai-Hihifo had traditionally been quite saline, improvements using infiltration galleries have significantly lowered the level of salinity of the water supply (TWB, 2000). The community has been acutely aware of previous attempts to improve the water supply by using wells and boreholes. They were also made aware of the infiltration gallery project, partly through public information sessions but also through involvement of local workers in constructing the galleries, fitting the solar and electric pumps, building a new tankstand and tank and finally experiencing the results of the improvements in reduced water salinity from the day the new system was commissioned.

It is noted that in some small coral islands, housing areas have been built and continue to exist over freshwater lenses from which water supplies are pumped. In order to ensure that contamination does not occur, properly constructed sewerage systems that 'export' sewage from freshwater lens areas are an option. However, such systems are expensive to construct and require adequate operational budgets and regular maintenance in order to be successful. Also, in order to guarantee the potability of the groundwater, adequate disinfection is essential. An example is Home Island in the Cocos (Keeling) Islands, Indian Ocean where the community of about 500 live above the main freshwater lens on the island and groundwater is pumped from infiltration galleries laid below streets and open space areas (Falkland; 1994, 1999b). The same principle can be applied in areas where sanitation systems are not effective at preventing groundwater pollution, provided that the pumping systems are sited well away from pollution sources (e.g. Lifuka, Tonga: TWB, 2000).

6.5.4 Improvements in sanitation systems

As outlined previously, there is an urgent need for improvements in sanitation systems to prevent ongoing and often widespread contamination of water resources, particularly groundwater resources, on small coral islands which have thin highly permeable soils offering no retention of bacteria before reaching the groundwater. In particular, pit latrines are the worst offenders, followed by septic tanks where these have no reasonable means of being effectively de-sludged. This problem is a major one for many small island communities as alternatives, while available, are not necessarily affordable or acceptable to all people. Unless urgent action is taken, the problem is likely to get worse as populations increase.

Without appropriate, affordable sanitation systems in many small communities on islands, there will not be any significant reduction in microbiological pollution of groundwater or surface water resources currently impacted by unsatisfactory sanitation systems. Consequently, it is difficult to imagine any reductions in human health problems brought on by inadequate sanitation and limited water resources on such islands. It is therefore important that the IWP and other initiatives address this issue in a major fashion. While the issue of sanitation is beyond the immediate scope of this synopsis (and rather the domain of the parallel report on community waste management: OPUS, 2001), the issue is so important that it needs special mention in this report as well.

Initiatives to improve sanitation systems have been made in the past (e.g. SOPAC, 1997a) and others are currently under way. At present, SOPAC, SPREP and PWA are planning a regional meeting on Sewage Management in the Pacific scheduled for October 2001 in the Marshall Islands. This is an initiative under the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). To date, two planning meetings have been held in February and March 2001 (SPREP/SOPAC, 2001 and SPREP/SOPAC/PWA, 2001).

One sanitation alternative that has had successful trials in some islands is the dry composting toilet. The main potential benefits of using composting toilets are savings in freshwater, (as no water is required for flushing), protection of the groundwater, simple technology, low costs (less than septic tanks) and production of an agricultural fertiliser/soil conditioner.

It is worth noting that trials have been conducted under AusAID projects in Tonga (on the island of Lifuka) and in Kiribati (on Kiritimati) and more recently as part of an ADB project in Tarawa. The trial in Tonga involved 15 units at 13 households and two schools. Overall, the trial, which was completed in 1999, was successful (Crennan, 1999) and the Government of Tonga has indicated that they wish to see a greater use of this form of sanitation. A large component of the trial project was community education, awareness raising and training. As part of the trial, educational videos were made. It is fair to say that the largest impediments to the introduction of this technology are social rather than technical (e.g. initial scepticism about the viability of this sanitation approach, fears of bad odours and important issues related to handling human waste, even after decomposition). However, these issues can be resolved with appropriate community education delivered before and throughout the course of a properly designed and conducted trial.

It is noted that a composting toilet pilot project is included as one of the potential community-based project activities under the waste management theme for the IWP (OPUS, 2001). This project is fully endorsed from a freshwater perspective because of its potential benefits in reducing groundwater pollution. Further, one of the pilot projects under the freshwater theme in this synopsis has potential to complement the proposed composting toilet pilot project (refer section 7 and Annex III).

6.6 Water demand management

Some water supply authorities in urban areas of PICs utilise a range of demand management measures including metering and charging for water on user pays basis, leakage control, water saving devices and education and awareness about water conservation.

6.6.1 Metering and charging

Metering and charging on the basis of water usage is an effective demand management tool and has been implemented in a number of PIC urban areas (e.g. PNG, Solomon Islands, Vanuatu, Marshall Islands, Tonga, Samoa and parts of the Federated States of Micronesia). In some PICs, metering and charging has been previously implemented but temporarily stopped due to operational problems (e.g. Kiribati) or has not yet been implemented (e.g. Cook Islands).

In rural areas where water charging is applied, it is normally done on a flat fee basis and collected by the village water committees (e.g. Tonga).

Water usage reductions have been noted following the introduction of these measures. An example is Apia, Samoa, where the consumption fell from an estimated 825 litres/person/day to 325 litres/person/day following the introduction of metering (Samoan Government, 2000).

6.6.2 Leakage control

Where pipe networks are used to distribute water, active leakage control can greatly assist in reducing losses. This requires adequate monitoring and analysis of the system with strategically placed water meters and stop valves to close off sections for testing and, if necessary repairs. In recent years, a number of urban water authorities have instituted leakage control programs (e.g. Fiji, Tonga and Samoa). Others recognise the need and have attended workshops on this subject to be made aware of methods and procedures. SOPAC has been instrumental at raising awareness, and organised a workshop on this topic in 1999 (SOPAC, 1999b) with assistance from other agencies and individuals and funding from NZODA. SOPAC has also conducted in-country investigations and associated pipe network modelling and training of local personnel, for example, Cook Islands, Fiji, Kiribati, Niue, Samoa, Solomon Islands, Tonga and Vanuatu (various SOPAC reports). Similar work is planned for the Marshall Islands (SOPAC, 2000a). The Pacific Water Association (PWA) is also involved in leakage detection promotion, as it is recognised as one of the main issues facing its members.

Using UNELCO, (the private water supply company which operates Port Vila's water supply in Vanuatu) as a benchmark, it is unlikely that leakage rates below about 20% can reasonably be achieved. Currently, leakage rates are about 23% in the Port Vila system compared to more than 50% when UNELCO started its contract in 1994. Systematic replacement of leaking pipes and repairing of leaking joints is essential for long term improvements.

Measures to improve leakage in plumbing systems in houses and other buildings (e.g. offices, schools) can have a beneficial impact on operational costs for pumped systems. In Niue, it was estimated that a 55% reduction of water usage was achieved by conducting a survey of every house in each village and repairing leaks in taps, showers and toilet cisterns. This measure nearly halved operational costs for groundwater pumping (SOPAC, 2000a).

6.6.3 Water saving devices

Water saving devices, such as spring loaded taps for standpipes and improved household plumbing fixtures (low and dual flush toilet cisterns, low flow taps and shower heads) can assist in water conservation. In recent water supply designs in Kiribati for villages on Kiritimati (AusAID funded water and sanitation project) and urban areas of South Tarawa (ADB SAPHE Project), constant flow systems have been included for each household so as to restrict the total daily flow to a selected volume (e.g. 300 litres per house per day). This is done by means of a small orifice in the pipeline and a small household tank sufficient in volume to store the incoming water. It is expected that this approach will enable demand to be managed through the restriction on water usage per household.

Composting toilets are a waterless alternative to many other forms of sanitation, this providing water saving in addition to other advantages.

Designs of water supply systems should ensure adequate but not excessive pressure, as leakage rates increase as pressure does.

6.6.4 Education and awareness about water conservation

Education and awareness about water conservation is a most important part of overall demand management and is presented in more detail in section 6.3.3.

6.6.5 Future improvements

There is an ongoing need to ensure effective designs, active leakage control and demand management programs to ensure that the water from existing water sources is used wisely. As part of this process, monitoring is an essential tool. The old saying 'If you do not measure it, you can't manage it' is most appropriate in this context.

There is an ongoing need for innovative methods of education and awareness about the necessity for water conservation and leakage reduction. A project proposal has been developed around this theme (refer section 7 and Annex III).

6.7 Measures to cope with water supply quality degradation

Where water resources have become degraded through adverse impacts within surface or groundwater catchments, particularly impacts from land conversion and urbanisation, special measure are required to ensure that water supplies can provide potable water.

Measures to cope with freshwater quality degradation, specifically related to potable water supply, include:

- removal or treatment of sources of pollution; and
- methods to avoid or minimise impacts of pollution.

Removing the source of pollution is the most effective strategy. Some effective strategies for 'point source' pollution include wastewater treatment for liquid wastes and sanitary landfills for solid wastes. These measures have been adopted in many of the larger towns in PICs, where centralised piped sewerage systems are used and where municipal solid waste collection occurs. However, there are many urban areas, which have only very rudimentary methods in place, thus allowing point source pollution to continue.

For more diffuse sources of pollution, such as high sediment loads and microbiological and chemical contamination from areas cleared for agriculture, cattle grazing or pig farming, control is more difficult. In the absence of better catchment management measures, the response has been to deal with the problem by attempting to avoid or minimise the impact on freshwater resources.

Existing water supply systems are sometimes modified to cope with the changed circumstances. In others, new sources are investigated and utilised. Often, however, the water supplies are not modified and hence the water supply systems provide poor water quality water (in terms of physical, chemical and microbiological indicators).

For some surface water supplies, filtration systems have been built and maintained to remove suspended solids and hence clarify the water. Examples are the roughing and slow sand filters used for the Apia water supply in Samoa. These require maintenance (e.g. replacements of sand) at more frequent intervals as catchment water quality becomes worse.

In urban areas, chlorination is often used to disinfect both surface water or groundwater supplies where the raw water quality cannot be guaranteed to be bacteria free. Chlorination plants are present in most urban water supply systems in PICs, with some using powder (calcium hypochlorite) and others using gas chlorination systems. There are advantages and disadvantages of both types of system.

If sources become too polluted, then alternative sources have been used. An interesting case example is the water supply for Pangai-Hihifo on the island of Lifuka in Tonga. Groundwater was once extracted from household wells in the village but after water quality tests revealed high and persistent faecal coliforms, the Ministry of Health closed the wells and alternative sources were found outside the village. However, the method of pumping (large pumps in dug wells) led to the water becoming saline. Later boreholes were drilled outside but closer to the village and equipped with smaller pumps. After several years even these sources became salty. Following more extensive investigations, it was confirmed that the village was located above the main freshwater lens. This lens would need to be utilised in order to reduce the salinity of the water supply. However, the lens suffered from pollution from nearby sanitation systems. Open space areas (e.g. sports fields) within the village, which are removed from the immediate impact of sanitation systems next to houses, were used to construct infiltration galleries. Pumping from these with solar and electric pumps has significantly improved the salinity of the water supply while maintaining adequate microbiological quality.

Where groundwater quality has become severely degraded due to bacteriological contamination, rainwater tanks have been advocated as a means of supplying potable water. This is a sound measure whereby water is used conjunctively and is typical of approaches on some atolls where other options are not available. It is also a recognition of an unfortunate, yet avoidable loss of the groundwater as a source of potable water.

6.8 Measures to improve knowledge of freshwater resources

Fundamental to all forms of freshwater resource management, is the need for knowledge about the availability and quality of these resources and the impacts of human activities and natural influences (climate variability and change, extreme events including natural disasters). For instance, while much is known about the impacts of deforestation, very little data has been collected in PICs to quantitatively assess these impacts on downstream communities. Also, while there is much circumstantial evidence to indicate that sanitation systems cause major microbiological contamination of groundwater, there are only a limited number of studies in PICs which have analysed this issue in depth (e.g. Tonga).

6.8.1 Assessment and monitoring improvements

A necessary first step in understanding an island's water resources, is to assess their behaviour under present climate variability. In particular, it is necessary to assess the sustainability of surface and groundwater resources during drought periods. Estimates of sustainable yield cannot be accurately provided unless this is done.

Surface and groundwater monitoring programmes are being implemented in most PICs but to varying levels of effectiveness. This is often due to shortage of staff and the difficulties of getting to sites where monitoring equipment is in place. Recently, NIWA installed several streamflow gauging stations in the Cook Islands and Samoa. In the latter case, damage has occurred due to floods and in one case, vandalism.

A recent review of training needs in PICs (SOPAC/WMO/UNESCO, 2001) has identified strategies to address training requirements including the use of existing regional organisations (e.g. SOPAC) to facilitate training. This would be done with short courses and "train the trainer" approaches ensuring gender balance amongst trainees. Where possible, trainers would have specific knowledge of island water resources and hydrology. This initiative is still in the planning stage.

To overcome the shortage of staff to undertake routine water resource monitoring in Vanuatu, a proposal has been written which would utilise school students in streamflow and water quality assessments (Vanuatu Hydrology Section, 2001). Students would receive training in appropriate water resources monitoring and would be expected to undertake regular visits to selected sites to undertake this work.

Other community based monitoring initiatives are the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) which is operating in many PICs, and the River Care program about to commence in Fiji (refer to section 6.3.4).

Bacteriological testing, which has often been problematic in PICs especially on remote outer islands, has been simplified in recent years. Rather than using the more common membrane filtration test, a colour change indicator method has been developed (several types) which can indicate the presence or absence of bacteria (total and faecal coliforms). This test is good for rural and even urban water supplies as it is simple to use, does not require a laboratory or expensive equipment and provides sufficient information to show if water supplies are fit or unfit for potable use (according to WHO guidelines for drinking water: WHO, 1993). A cheaper presence/absence method is the use of hydrogen sulphide paper strip tests to detect hydrogen sulphide producers that inhabit the intestinal tracts of warm-blooded animals, rather than direct evidence of total or faecal coliforms. Correlations with more conventional tests have shown good results (D. Sharp, pers. comm., 2001).

6.8.2 Applied research in island freshwater issues

Given the paucity of scientific data in key areas of water resources management, a number of applied research projects were proposed at the Pacific Water Sector Planning, Research and Training Workshop in Honiara, 1994 (UNESCO/SOPAC/UNDDSMS, 1994). In each case, it was recognised that community consultation, participation, education and awareness are as important as the scientific and technical issues. Other key elements to be addressed were the training of water professional and technical staff, and the discussion of test results with the local communities during and following monitoring projects. Three projects were proposed as most in need of implementation. These are briefly described as:

- Groundwater recharge project with the aim of quantifying the key hydrological processes affecting the amount of water which recharges groundwater (freshwater lenses) on small coral islands;
- Groundwater pollution study with the aim of analysing the linkage between sanitation systems and groundwater pollution in nearby wells;
- 'Catchment and communities' project, aiming to study the impacts of upstream activities (e.g., deforestation, mining) on downstream communities.

The first two projects were implemented in the late 1990s in Tarawa, Kiribati and Lifuka, Tonga, respectively. UNESCO played a major role with initial funding, and further support was provided by SOPAC and a number of institutions in Australia. Literature surveys were completed in the early stages of both projects (White, 1996; Dillon, 1997). Reports have been completed for both projects (White et al., 1999b; Crennan et al., 1998; Crennan, 2001). The third mentioned project has not yet been implemented.

At a 1997 UNESCO Water Resources Workshop (Sankey et al., 1997) and again at a Pacific Focal Group for Water Resources meeting in 2000 (White et al., 2000), progress was noted on the projects in Kiribati and Tonga. Further work on these projects and commencement of work on other projects was recommended. In order of priority, the projects for which additional funding was recommended were as follows:

- Catchment and communities project;
- Groundwater recharge and modelling (further work in initial and other sites);
- Groundwater pollution due to sanitation systems (further work in initial and other sites);
- Integrated island water resources study;
- Groundwater and surface water pollution due to chemicals;
- Rainwater catchment study;
- Appropriate groundwater extraction systems.

Research into the impacts of droughts on different water resources (e.g. groundwater and rainwater) on small coral islands has led to the development of a broadly applicable 'drought index' (White et al., 1999a). This drought index approach, developed for Tarawa, but applicable to other drought- prone island nations, uses a relatively simple analysis of monthly rainfall data to identify the severity of various drought periods. Using this information, critical drought indices can be used to trigger various water conservation or relief strategies, as appropriate.

In addition to the research mentioned above, which has involved largely 'South Pacific' countries, applied research has been conducted in the former US Trust Territory islands (i.e. Federated States of Micronesia, Marshall Islands and Palau) by US agencies including the US Geological Survey, the Water Resources Research Centre of the University of Hawaii and the Water and Energy Research Institute of the University of Guam. This has led to a wide range of water resources studies on many of the islands in these countries. Examples include Mink (1986), Miller et al. (1991) Spengler et al. (1992), Hunt (1996), Peterson (1997) and Buddemeier and Oberdorfer (1997). Others are provided in the reference list (section 8) and in Annex VI (additional references).

While there has been significant commitment to island hydrological research in recent years, there is still a need for further commitment in this area. Such commitment to applied research, training and technical transfer can provide great benefit to small islands in offering solutions to some of the fundamental hydrological issues (e.g. sustainability of water resources, impacts of droughts, pollution, etc.).

6.9 Climate variability, climate change and sea-level rise

To finish this section, it is considered appropriate to make a brief mention of these topics. Small island nations are concerned about current climate variability and the possibility of climate change and sea-level rise and the impacts this would have on their islands, communities and resources. The impact of current climate variability in PICs, especially in relation to droughts, has been a major focus in recent years (e.g. SOPAC, 1999a). This topic has attracted considerable attention in the scientific community (e.g. Terry, 1998), the popular media, and by funding agencies (e.g. World Bank, 2000).

In recent years, PICs have been assisted by a number of studies and regional meetings organised by the Pacific Islands Climate Change Assistance Programme (PICCAP). This SPREP programme which is funded through GEF and the UNDP, has aimed to raise awareness of climate change and strengthen national capacity to understand the science, impacts and responses to climate change and sea level rise scenarios. The PICCAP programme has been assisted by a number of organisations in the region, particularly the International Global Change Institute (IGCI) in New Zealand.

Climate change scenarios for PICs vary according to location and the models used. Most models predict an increase in frequency of El Niño episodes and increased intensity of cyclones (World Bank, 2000). There is less certainty about changes to rainfall, which could impact on the availability of island freshwater resources. Current scenarios indicate a small rise in sea level over the next few decades (approx. 0.2-0.4 m).

The impact of current sea-level rise scenarios on freshwater resources is likely to be relatively minor, compared with other influences (e.g. present climate variability, human impacts). The main potential impact would be inundation on the edges of low-lying islands and coastal zones of high islands. Tarawa, Kiribati has been the focus of impact studies under possible sea level rise and climate change scenarios. Results of groundwater modelling studies to assess the impacts on a freshwater lens under combined effects of pumping, climate change and sea level rise are presented in Alam & Falkland (1997) and World Bank (2000). These studies show that impacts of sea level rise on freshwater lenses are not detrimental provided that land is not permanently lost by inundation at the margins.

It is noted that the current focus on the impact of climate change and sea-level rise on small island nations is useful in raising awareness of the issue. However, it should not be used to deflect attention away from more immediate and probably greater problems such as inadequate water supply and sanitation, and the poor standard of human health in some PICs. This is not to suggest that interest in climate change and sea level rise should be curtailed, but rather that there is an urgent need to focus attention on the current major water and sanitation issues.

7 Potential community-based pilot projects

This section outlines the types of community-based pilot projects that could be implemented to address freshwater sustainability issues in the Pacific Islands region under the IWP. These projects have been identified as part of the review of major issues and concerns in PICs and in accordance with the selection criteria listed below.

7.1 Selection criteria and key elements

Selection criteria for appropriate community-based pilot projects, outlined in UNDP-GEF (1999) and SPREP (2001b), are summarised below:

- Adequate community participation and support;
- Maximum potential for replication;
- Consistency with the IWP;
- Previously stated country interest (as included in IWP related country project submissions);
- Representation among the three island types (high islands, low islands and atolls), among the three lineal systems in the region (matrilineal, patrilineal, and mixed), and the three ethnic separations (Melanesia, Polynesia, and Micronesia).
- An analysis confirming the most appropriate site for specific demonstration activities.

In UNDP-GEF (1999, Activity 2.2), four pilot projects were to focus on the following four topics:

- Assessment of watershed capacity and quality;
- Assessment of available potable water at acceptable pumping rates;
- Strategies for preventing and/or supplementing shortfalls;
- Measures for demand management and/or conservation of freshwater resources.

Based on the above criteria and the need to maximise the benefits of the projects, the following key elements were seen as important for the pilot projects:

- Community education and awareness raising of the issue;
- Improvement of understanding of catchment (watershed) processes and impacts on freshwater quantity and quality through appropriate data collection and monitoring;
- Examination of factors which are impacting on sustainability and water quality of the freshwater resources;
- Demonstration of methods or technologies that can be used to resolve or improve current conditions;

- Discussion with communities and other stakeholders and preparation of future management options and preferred approaches;
- Local and wider dissemination of results through appropriate media.

7.2 Summary of potential pilot projects

Based on the above criteria and key elements, seven potential pilot projects with a focus on freshwater management have been identified in Table 5. These are ranked in priority order, based on key selection criteria and the author's own judgement. Three projects stand out as being very high priority (numbers 1, 2 and 3), and more detailed project outlines for these three are presented in Annex III as per the TOR for this synopsis (Annex I).

Other project outlines could be developed later if required. It is noted that one of the projects (No 7) is essentially a waste management project, but because of its major benefits in terms of groundwater protection and water conservation, it is also listed here under potential freshwater management pilot projects. Also, cross checking of potential pilot projects with projects in other focal areas may identify needs to modify the proposed pilot projects.

Table 5 Potential types of pilot projects for freshwater management

No.	Name & Brief Description	Key Elements	Application	Notes	Rates according to selection criteria
1	Stream Health (Monitoring for ‘stream health’ to improve community understanding of threats and to assist with catchment management and water supply quality improvements)	• Consultation & site selection with community • Design & Implementation: local community in conjunction with relevant agencies (eg water supply agency and other agencies , NGOs active in this area) • Monitoring by local schools students and possibly other community members (stream parameters – physical, chemical, biological) & rainfall) • Visits to and discussion with upstream landowners & /or users about land use practices. • Study of available aerial photographs, satellite imagery maps and other land management data to assess changes in catchment over time • Analysis and synthesis of information and data • Education & awareness of community • Recommendations for action within the catchment based on conclusions • Implementation of improvements where possible	High volcanic island	• Links with WM, MPA and SCF • Modified from UNESCO Catchments and Communities (proposed project) • Use elements from Live & Learn programme (Fiji) but could adapt the kit to a simpler one with all on-site measurements • Some improvements may be beyond resources/control of the local community • Could be done as a ‘paired catchment’ exercise to compare results from relatively unused catchment(s) with one or more that have undergone changes.	A: Very high B: High C: High D: High Overall: High to very high
2	‘Groundwater Health’ (Groundwater monitoring to improve community understanding of linkage between groundwater pollution, water quality at groundwater at wells and disposal sites, and human health)	• Consultation & discussion of water supply and sanitation issues with community • Site selection for groundwater tests and monitoring with community, focusing on wells near sanitation • Monitoring of nearby wells for salinity and bacteria and rainfall by/with community • Education and awareness of community • Recommendations for improvements (e.g. alternative sanitation, better siting guidelines)	Coral atoll island, raised limestone island, or low lying sandy coastal zone of high island	• Links with WM • Build on previous work carried out under UNESCO/SOPAC Groundwater Pollution project in Lifuka, Tonga • Could lead to compost toilet (dry sanitation)	A: Very high B: High C: High D: High Overall: High to very high

Table 5 (Continued) Potential types of pilot projects for freshwater management

No.	Name & Brief Description	Key Elements	Application	Notes	Rates according to selection criteria
3	'Leakage Watch' Water flow monitoring and leakage control at schools and possibly other institutions (hospitals, hotels, etc) leading to action to conserve water through leakage reduction)	• Consultation & site selection • Meter installation (if necessary) and fitting of a simple data logger • Monitoring and data analysis • Investigation and repair of simple leaks (eg washers, seals) and possibly more complex leaks (pipe repairs with external trained assistance) • Education and awareness about importance of leakage control as a demand management & water conservation tool	Applicable to villages or towns with piped distribution systems	• Build on programmes through SOPAC • Use resource people with demonstrated experience in this area within PICs	A: Very high B: High C: High D: Moderate Overall: High
4	Rainwater catchment improvements Purpose: to ensure adequate water quality and sustainability of water supply, and to improve community awareness about needs of regular maintenance	• Consultation & site selection with community • Selection of roof area, tank volumes based on hydrological data and available budget • Examine and decide first flush devices and other means of controlling water quality • Implementation by the community • Monitoring of rainfall and tank water level as a community/school project • Development of drought management strategies using rainwater in conjunction with other sources • Maintenance programme to be established as a community effort	Any island	• Use information from existing rainwater catchment programmes & design guidelines • Could apply to both household and community tanks adjacent to buildings or as standalone tanks with their own purpose-built • Build on UNEP funded program on empowering women in rainwater harvesting in the Pacific atoll islands (UNEP, 2001)	A: Very high B: High C: High D: Moderate Overall: High
5	Sustainability and quality of water supplies from spring and surface water and sources (Assessment, development & monitoring to improve sustainability, reliability and water quality of community water supply from surface water sources during droughts	• Consultation with community • Use of traditional knowledge from community • Site selection with community • Design & Implementation with community (to include appropriate infrastructure works (eg spring cappings, surface water intakes with appropriate filters, gravity pipelines with air valves) • Monitoring and management by the community • Evaluation of system through monitoring Recommendations for further improvements	High volcanic island	• Aimed mainly but not exclusively at spring (groundwater) sources, which may be more sustainable than surface water streams but require capping and piping to community • Utilise existing local information re sustainability. • Emphasis on education and awareness through community involvement including monitoring	A: Moderate B: High C: High D: Moderate Overall: High

Table 5 (Continued) Potential types of pilot projects for freshwater management

No.	Name & Brief Description	Key Elements	Application	Notes	Rates according to selection criteria
6	Sustainability and quality of water supplies from groundwater sources (Assessment, development & monitoring to improve sustainability, reliability and water quality of community water supply from groundwater sources during droughts)	• Consultation & discussion of existing water supply issues with selected village (covering wells within village which may have become salty or polluted, adequacy and reliability of pumped supplies outside the village area) • Inspection and discussion with the community and responsible water agency about current issues/ problems (design, siting, construction, water salinity, reliability) and possible solutions • Assessment of possible options to improve water supply quality and reliability through use of appropriate pumping systems (eg infiltration galleries rather than wells or boreholes) based on experiences in other similar island environments • Procurement & installation of monitoring equipment (raingauge, portable salinity meter, water meter) and monitoring by community (could also be school project) • Education and awareness of community • Design & Implementation of improvements (e.g. conversion of wells to infiltration galleries, possible fitting with solar pumps, tanks and/or standpipes in village) • Monitoring and management of the water supply by the community • Evaluation of system through monitoring • Recommendations for further improvements (if applicable)	Coral atoll island or low lying sandy coastal zone eg rural village on outer island	• Aimed at medium size villages which are reliant at least partially on pumped groundwater from near the village for water supply • Use knowledge gained in some small coral islands and coastal areas of larger islands (eg Kiribati, Tonga and Cook Islands) to solve problems in other islands/countries (appropriate technology transfer) • Emphasis on education and awareness through community involvement in the process including monitoring and management	A: Moderate B: High C: High D: Moderate Overall: High

Table 5 (Continued) Potential types of pilot projects for freshwater management

No.	Name & Brief Description	Key Elements	Application	Notes	Rates according to selection criteria
7	Compost toilet (dry sanitation) project Purpose: to protect highly vulnerable freshwater resources from wastewater contamination	• Consultation, explanation of project with all benefits disadvantages outlined • Selection of participants within the community. Target groups could be individual houses, schools, etc. • Selection of design with local features to suit (design should be simple and based on successful trials elsewhere eg alternating double batch) • Construction (where possible with community assistance) • Monitoring/ feedback by community and specialist in this field • Training in appropriate methods of use and disposal over a period of at least two years • Modifications as required • Evaluation with the community as to success (or not) of the project, and suggestions about improvements if necessary	Mainly atoll islands and limestone islands (but could be all hydrogeological environments/ eco-systems)	• Strong link to IWP (WM) • Utilise designs and community consultation model from successful projects (eg Lifuka, Tonga as part of an AusAID project) • Major emphasis on community consultation, awareness, information, education • Advantages are seen as protection of fresh groundwater, demand management, production of a useful fertiliser	A: High B: Moderate C: Very High D: Moderate Overall: High

Notes:

1. WM = Waste management, MPA = Marine protected areas, SCF = Sustainable coastal fisheries
2. Selection criteria as follows:
   - A: **Replication potential**
   - B: **Adequate community participation and support**
   - C: **Consistency with the IWP**
   - D: **Previously stated country interest**
3. Rating against selection criteria are: very high, high, moderate

8 References

The list of references below are cited in the report. A list of additional references for further information on freshwater management issues in Pacific Islands and related environments are provided in Annex VI.

Aalbersberg W. and Thaman B. (2000). Persistent Organic Pollutants (POPs) in Pacific Island Countries, University of South Pacific, Suva, Fiji.

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Annex 1 Terms of Reference

(source: Attachment A of the Consultancy Agreement between the South Pacific Regional Environment Programme and Ecowise Environmental)

A Synopsis of Information Relating to the Quality of Freshwater and Watershed Management Issues in the Pacific Islands region

Project Description

The objective of this consultancy is to provide a review of published and other information relating to freshwater quality, supply, management and conservation in the Pacific Islands region. The review will place particular emphasis on community-based issues associated with the conservation and sustainable management of freshwater resources, reflecting the planned focus of subsequent pilot projects that may be instigated under the Strategic Action Programme for the International Waters of the Pacific Small Island Developing States[1] .

Output

The output of this review will be a report submitted to SPREP in electronic format. The report, in the format described at Attachment B, and not exceeding 46 pages plus appendices and bibliography, will include:

- a cover page that clearly displays the title of the report, the authors, their affiliations, and date;
- a table of contents including appendices;
- list of tables and figures;
- a disclaimer;
- acknowledgements;
- an executive summary; and
- an expanded bibliography of additional readings that includes references cited in the report;
- as one of the appendices, an outline for three "model" community-based pilot projects that conceivable could be implemented under the International Waters Programme inclusive of a schedule for the acquisition of relevant economic, and the tools required to generate that information, that could incorporated into the design, and subsequent implementation, of the project. Each outline will not exceed one page in length and will be additional to the 30-page suggested limit placed on the main body of the report;
- a list of potential resource people, complete with contact details, who may be able to contribute to the design, implementation and evaluation of pilot projects as they proceed; and
- a listing of web sites of relevance.

Terms of Reference

The consultancy will result in a report that will be used by the Project Coordination Unit (PCU) and stakeholders in the 14 participating countries to assist with the selection, design, implementation, monitoring and evaluation of pilot projects to be implemented under the International Waters Programme.

The pilot projects will address issues associated with sustainable coastal fisheries in communities, marine protected areas, community-based waste (no-cost/low cost) reduction and the protection of freshwater resources (as described at part D of the Project Document).

The report will include:

- A review of current information relating to freshwater resources management in the Pacific Islands region. Emphasis will be on potable water quality;
- The review should summarize activities, within the region or elsewhere, which have attempted to improve capacity to manage activities that threaten freshwater resources within communities. As with all elements of the review, adequate discussion of issues associated with different ecosystems (low island/high island and coastal/upper watershed) shall be presented.

[1] The 14 participating countries are: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

- Information may include:
  - threats to freshwater resources;
  - a review of priority concerns in Pacific Island communities in relation to securing adequate quality freshwater;
  - the relationships between the effective management of freshwater resources and other issues to be addressed under the SAP concerning community waste, marine protected areas and sustainable coastal fisheries; and
  - management and governance issues associated with securing sustainable quality freshwater sources in communities that are generally experiencing rapid population growth.
- An outline of the types of community-based project activities that could be implemented to address freshwater sustainability issues in the Pacific islands region under the SAP, as described above;
- A list of references, additional readings, potential resource people, and web sites relating to the SAP's programme in freshwater.

The review should focus on (but not be exclusive to) activities in the 14 participating South Pacific countries with adequate representation and discussion of case studies from Melanesia, Polynesia and Micronesia.

Travel to Suva, Fiji to collaborate with the South Pacific Applied Geosciences Commission (SOPAC) and Apia, Samoa, to discuss the review with PCU staff at the offices of the South Pacific Regional Environment Programme (SPREP) may be required. Any such travel will be arranged under the conditions provided for in the main body of the contract.

Concurrent Activities

At the same time as the review of freshwater issues is underway, other consultants will be working on reviews of technical areas of interest to the SAP. These are:

- A review of past, current and planned country activity as it relates to potential work of the international waters project;
- A synopsis of information relating to marine protected areas;
- A review of economic issues associated with community-based sustainable resource management and conservation initiatives in the Pacific Islands region;
- A synopsis of information relating to sustainable coastal fisheries;
- A synopsis of information relating to waste management, pollution prevention and improved sanitation with a focus on communities in the pacific islands region; and
- A review of lessons learned and best practices in integrated coastal watershed conservation and management initiatives in the Pacific Islands region.

The Terms of Reference for these assignments is presented at Attachment C. The contact details for the people undertaking the reviews are included with that attachment.

Part of the Terms of Reference for the review of economic issues involves the exchange of information between the consultants undertaking this review and the consultants undertaking the other reviews referred to above.

Within 10 days of the commencement date, the principal researcher (Mr Tony Falkland), will provide the principal investigator of each of the above six consultancies with:

- a comprehensive outline of the draft report for freshwater issues; and
- the bibliography prepared to date.

This exchange will take place by email and will be copied to the Project Manager, International Waters at the PCU at SPREP.

Without detriment to the preparation of the report for economic issues, subsequent exchanges between consultants that are mutually beneficial are encouraged.

Draft Report

The consultant will be required to submit a draft report to SPREP for peer review. The PCU will arrange for the draft to be reviewed and returned to the consultant within 10 working days of its receipt.

Final Revisions

The draft, complete with the comments of the reviewer(s), will be returned to the consultant for finalisation. The time frame for finalisation of the review will be mutually agreed between the Project Manager at the PCU and the consultant but will not exceed 15 working days.

Final Report

The Final Report will be submitted to the Director of SPREP, and copied to the Project Manager, within 15 days of the receipt of SPREP's comments on the initial draft. The Final Report may be submitted in electronic format.

Annex II Water resources management in the 14 participating countries

Overview

This annex provides a brief summary of freshwater resources management for each of the 14 participating countries in the IWP. This summary starts with a list of relevant publications, which have both national case studies and more general information in relation to freshwater resources management. Following this is a country by country summary, in alphabetical order, as follows:

- Cook Islands
- Federated States of Micronesia
- Fiji
- Kiribati
- Marshall Islands
- Nauru
- Niue
- Palau
- Papua New Guinea
- Samoa
- Solomon Islands
- Tonga
- Tuvalu
- Vanuatu

Each summary covers the following elements:

- Basic geographical, geological and climate data;
- Freshwater resources and significant issues regarding sustainability and quality;
- Water supply systems and management (urban and rural);
- Main agencies involved in the water (and sanitation) sector at national, island and village level;
- Special features including status of water resources legislation;
- Summary of issues and concerns.

Some PICs are treated in more detail than others as more information was available for these islands to the author. Also the issues facing some countries are more severe than others, due not only to the availability of water resources but also to socio-economic factors such as population density and per capita income. Relative severity between countries is not identified.

The summary of issues and concerns for each island was compiled from published reports and some verbal accounts from island water personnel obtained during the preparation of this report. For some PICs, issues and concerns may not be comprehensive, but it is considered that these have been addressed in the overall coverage of the 14 participating countries.

References cited in the following 14 country summaries are provided in the reference list of the main body of the report (section 8).

Reference material

A large amount of information on freshwater resources and related management issues within PICs is contained in workshop reports, conference proceedings and other publications produced over the past 20 years.

Firstly, a series of important regional meetings and workshops have been held in the Pacific Islands region specifically concerned with freshwater resources, water supply and related issues on islands. These were organised in response to the hydrological and water resource management needs and concerns of Pacific Island countries, and to some extent Indian Ocean Island countries within South East Asia with large numbers of small islands. Major events since 1983 are listed below (proceedings of each meeting are listed in section 8):

- Meeting on Water Resources Development in the South Pacific, 1983 (ESCAP, 1983);
- Regional Workshop on Water Resources of Small Islands, 1984. (CSC, 1984);
- Interregional Seminar on Water Resources Management Techniques for Small Islands. 1989 (UNDTCD, 1989);
- Workshop on Water Sector Planning, Research and Training, 1994 (UNESCO/SOPAC/UNDDSMS, 1994);

- Workshop on Technologies for Maximising and Augmenting Freshwater Resources in Small Islands 1996 (SOPAC, 1996 and IETC, 1998);
- Small islands Developing States Working Group Meeting on Water, 1997 (SOPAC, 1997b);
- Small Islands Water Information Network (SIWIN) Workshop, 1997 (SOPAC, 1997c);
- Water Resources Workshop, 1997 (Sankey et al., 1997);
- Workshop on Water Demand Management Workshop, 1999 (SOPAC, 1999b);
- Workshop ENSO Impact on Water Resources in the Pacific Region, 1999 (SOPAC, 1999a);
- Meeting of Pacific Focal Group for Water Resources, Priority Issues in Water Resources, Christchurch, New Zealand, November 2000 (White et al., 2000);
- Meeting of Experts on Hydrological Needs of Small Islands, 1999 (WMO, 1999);
- STAR (Science, Technology and Resources) technical presentations at SOPAC Annual Sessions.

Secondly, international and regional publications which expand on aspects of island hydrology and water resources management, include the following (full citations in references, section 8):

- Pacific Island Water Resources (Dale, 1981);
- Groundwater in the Pacific Region (UNDTCD, 1983);
- A bibliography of hydrogeology of small islands: a list of some recent publications with particular reference to coral reef islands of the Pacific (Dale, 1984);
- Coral island hydrology: a training guide for field practice (Dale et al., 1986);
- Hydrology and water resources of small islands, a practical guide (UNESCO, 1991);
- Small Tropical Islands, water resources of paradises lost (UNESCO, 1992);
- Geology and Hydrogeology of Carbonate Islands (Vacher & Quinn, 1997);
- Source book of alternative technologies for freshwater augmentation in small island developing states (IETC, 1998).

While some of the above references are somewhat dated, they contain useful background information about the water resources of PICs.

Thirdly, there are numerous reports on regional water activities, which also refer to specific Pacific SIDS. These include reports by regional organisations (e.g. SOPAC), international organisations (e.g. UNESCO, WHO), donor and loan agencies (ADB, EC and various bilateral donors), and by educational and research organisations within the Pacific Region. These are too numerous to be covered in this report but many are contained in the main reference list (section 8) and the additional extensive list of references in Annex VI.

Fourthly, information has been gained from a number of NGOs (e.g. FSPI, TNC, WWF) and individuals about community-based water related projects in PICs.

Cook Islands

The 15 islands are all small, with the largest being Rarotonga (67 km^2). The geology varies from volcanic islands to coral atolls. Some of the volcanic islands have extensive limestone formations around the rim (e.g. Mangaia) and one is a 'near atoll' with a large volcanic island on one side (Aitutaki).

Average annual rainfall in the Cook Islands varies from about 1,900 mm in the south to 2,700 mm in the northeast (Thompson. 1986). The islands are prone to droughts and cyclones.

The larger volcanic islands (Rarotonga and Mangaia) have streams, which are used for water supply. Other islands use groundwater, rainwater or a combination of both. The most extensive use of groundwater is on Aitutaki where water is pumped from one or more infiltration galleries near the coastline of the volcanic island. Rainwater catchments, which are used as the main source of water in the Northern Cook Islands, consist of a combination of communal systems and private systems.

The populated atolls in the north (Manihiki, Rakahanga, Puka Puka and Penrhyn) have limited groundwater in the form of freshwater lenses. These atolls have been impacted by cyclones including overtopping by waves, the most recent occurrence being in 1997 when infrastructure on Manihiki was badly damaged and lives were lost. One result of this event was the building of cyclone-strengthened houses and private cyclone shelters. The latter have been built above concrete water cisterns with a capacity of 20 kilolitres (kL).

Droughts in the Southern Cook Islands are associated with El Niño episodes while in the Northern Cook Islands, they are associated with La Niña episodes (similar to Kiribati). Droughts have a serious impact on water resources with streams running low or even dry, rainwater catchments diminishing and freshwater lenses being depleted.

Background information on the hydrogeology and water resources of the Cook Islands is available in Waterhouse et al. (1986), Hein et al. (1997) and recent AusAID reports for Mangaia and three of the northern atolls, Penrhyn, Manihiki and Rakahanga (AusAID; 2000a, 2000b, 2001a and 2001b).

The water supply on Rarotonga is operated by the Department of Water Works of the Ministry of Works, Energy and Physical Planning. On the outer islands, water supply is now the responsibility of Island Councils with technical support from the Office of the Minister for Outer Island Administration. There are no fees charged for water supplies although this issue is currently being debated.

Maintenance of water supplies is a major problem due to limited financial resources, particularly for outer islands. On the volcanic islands with streams, filters at intakes are sometimes blocked with sediment after heavy rain. Floods carrying debris from the catchments have caused damage to water supply intakes and sometimes pipelines. Groundwater pumps are in many cases old and in need of replacement. Communal rainwater tanks, installed with funding from previous NZODA and AusAID projects, are in need of urgent repair.

Some water supply infrastructure improvements have recently been undertaken. On Rarotonga, part of the water supply infrastructure has been upgraded in recent years. Much needed hydrological monitoring stations were installed under a NZODA project in 2000.

On Aitutaki, a major infiltration gallery has been extended, pipelines have been replaced and a large water storage tank installed under recent AusAID projects.

Investigations, recently funded by AusAID, have shown that more extensive use of groundwater could be made on the northern atolls, especially as emergency water supplies during droughts. SOPAC has carried out groundwater investigations in the coastal plain of Rarotonga showing good potential for use of groundwater, provided that the resource is appropriately developed (SOPAC, 1998b).

Catchment management is a large issue in the volcanic islands where agricultural activities are conducted in catchments above water supply intakes. For instance, faecal contamination is sometimes found in the raw water intakes on Rarotonga. As the water supply is not disinfected, residents are advised to boil the water. Farming practices in and near streambeds can cause erosion, additional turbidity and sediment problems at intakes. Agricultural chemicals are often used on taro patches and other food crops to control weeds. About a third of Rarotonga's water supply comes from the Takitumu Conservation Area, which helps to protect the water resources in those catchments (Tiraa and Wilmott, 2001).

Limited water supply testing for a range of agricultural chemicals on Aitutaki and Mangaia has not found evidence of them in the raw water supply (AusAID; 1997, 2000a).

Major issues and concerns could be summarised as:

- Water quality problems (e.g. sewage pollution and solid waste disposal were noted as high priority issues in 1997 (GEF-IWP, 2001));
- Limited water resources and sometimes severe shortages during droughts on some islands. Freshwater shortage was noted as a priority issue in 1997 (GEF-IWP, 2001);
- Need for more awareness of catchment management (e.g. Baisyet, 1994);
- Ageing water supply infrastructure, shortage of funds for repairs and replacements and shortage of trained staff and training opportunities, especially on outer islands;
- High losses in some water supply systems and need for more adequate leakage control and water conservation;
- Outdated water resources legislation and inadequate policy and regulations (WMO, 1999);
- Shortage of hydrological and water quality data (e.g. WMO, 1999).

Federated States of Micronesia

The FSM is divided into four states: Pohnpei, Chuuk, Yap and Kosrae and consists of approximately 600 islands. The islands, all categorised as small, are a mixture of volcanic and coral types.

Average annual rainfall variability is quite high. On Pohnpei (area 338 km^2 and maximum elevation 760 m), the rainfall at sea level is approximately 3,500 mm compared with over 10,000 mm at altitude (Spengler et al., 1992). In other islands, the average annual rainfall varies between about 3,000 (Yap), 3,600 (Chuuk) and 5,000 mm (Kosrae) (van der Brug, 1986).

Droughts, connected with El Niño episodes, have seriously affected the availability of water resources in many of the islands, particularly the smaller coral islands. Hadley (1999) identifies the impacts of the 1998 drought on islands in the Federated States of Micronesia.

Detailed information on the water resources of the islands of the FSM are contained in a number of technical reports including Mink (1986), Spengler et al. (1992), Hadley (1994; 1999), Goodwin (1994), Winter (1995a, 1995b) and Anthony (1997).

Detay et al. (1989) provides a summary of groundwater contamination problems in the Federated States of Micronesia, Marshall Islands and Palau, and links to water related diseases. Detailed water quality analyses for bacteriological contamination have been conducted on some islands. One report looks in detail at the water quality of shallow wells and rainwater tanks on the island of Moen, Chuuk State (Miller et al., 1991).

Water Master Plans have been developed for each state (Hadley, 1994) under a UN Water Resources Assessment and Development Project in the early to mid 1990s. There is no national water resources legislation.

Urban water supplies are operated in each state by water authorities (see Table 4 in main body of report). On Pohnpei, the water supply system utilises surface water supplemented by groundwater when necessary. The water is treated. The Pohnpei Utilities Corporation (PUC), the largest utility corporation in the Federated States of Micronesia, operates the water, sewerage and electricity systems in the urban areas. The water system serves approximately 40% of the total population of Pohnpei. The Chuuk Public Utility Corporation is responsible for the water supply and other utilities in all of Chuuk State. As most people live on Moen, most of the emphasis is placed on that island. The water supply systems use both groundwater and surface water. The Yap State Public Service Corporation is responsible for water and sewerage on all the islands. On the main island of Yap, the water system is derived from surface and groundwater and the water is treated. The Kosrae Department of Public Works operates the water systems for the two main villages Lelu Tofol and Okat, where the majority of the population lives. Surface water sources are used and the water supply is treated.

Water supply improvements have been implemented in recent years (1997-2001) in the urban and nearby village areas in all four states. Improvements include a new treatment plant on Pohnpei and extended distribution lines, drilling of additional groundwater wells and treatment plant for Chuuk, and drilled wells and distribution extensions in Yap. These improvements have been funded under a loan project from the ADB (Goodwin, 2001). The US Department of the Interior has also provided financial assistance under the Operations and Maintenance Improvement Programme (OMIP) to refurbish existing water and sanitation systems in the four states. This assistance is provided on a 'dollar for dollar' basis with the state governments.

Rural water supplies are the responsibility of municipal offices in each state of the FSM. There are many villages throughout the FSM, which use surface water, groundwater and/or rainwater depending on locality and available water resources. In the volcanic islands, most use surface water sources, generally a small dam on a stream or a spring connected by pipeline to the village. In the small coral islands groundwater is used, which is often supplemented with rainwater. Funding for projects comes from a variety of sources including grants from US Department of Commerce's Economic Development Administration, NGOs and church groups.

Winter (1995a, 1995b) presents a good overview of the development and management issues of rural water supply systems and sources, and appropriate measures for resolving some of these issues. He describes the types of water supply systems, including household and community rainwater collection systems, dug wells, hand pumps, solar pumps and ram pumps. Practical guidance is given on lessons learnt and methods to improve water quality using case examples. Examples describe some community water supplies that have failed due to lack of maintenance, lack of training and too little consideration of local land ownership, customs and practices.

The Water and Energy Research Institute (WERI) has been involved in practical research to improve water supplies in villages. One initiative is the development of a book and program to analyse rainfall catchments (Heitz and Winter, 1996; WERI website).

Major issues and concerns could be summarised as:

- Pollution of water resources associated with sewage systems and solid waste disposal was the highest priority issue in 1997 (GEF-IWP, 2001) for all four states. This issue is also raised in Hadley (1994) and Goodwin (1994);
- Catchment management issues associated with conversion of forest to agriculture (refer Pohnpei case study in sections 5.7.1 and 6.2.2 of main report and Raynor and Kostka, 2001);
- Freshwater sustainability especially through droughts. Freshwater shortage was noted as one of the high priority issues in 1997 (GEF-IWP, 2001) for all four states. This issue was noted as a very high priority in other reports (e.g. Goodwin, 1994);
- High losses in some water distribution systems from leakage and wastage (Goodwin, 1994);
- Limited monitoring of water resources and water quality (Goodwin, 2001).

Fiji

Fiji consists of both large and small islands. The largest islands are Viti Levu and Vanua Levu with areas of 10,390 and 5,540 km^2, respectively. The combined area of these two islands is over 85% of the total land mass of Fiji. All the larger islands are volcanic and there are numerous small volcanic, limestone and coral sand islands.

Average annual rainfall varies from about 1,500 mm on some of the smaller islands to about 7,000 mm at altitude on the main islands (Simpson et al., 1994). There are major differences in rainfall from the eastern wetter side to the western drier side on both main islands. Cyclones and droughts have had severe impacts on land and water resources (Terry and Raj, 1998).

The larger volcanic islands have numerous catchments with rivers, streams and spring sources. The limestone islands and coral atolls rely on groundwater and, in some cases, supplementary rainwater catchments for their water supplies. With an increase in population, urbanisation, and industrial growth on the main islands, there are increased demands for adequate water supplies. It is anticipated that groundwater will be used more to supplement surface water supplies especially in the drier parts of the islands.

There are numerous reports about the water resources and water supply systems in Fiji. Simpson et al. (1994) provides a good overview while Ferry et al (1997) provide further insight into hydrogeology and groundwater supplies in some of the islands. A comprehensive report on the hydrogeology is presented in Gale and Booth (1991).

The Water and Sewerage Section of the Public Works Department (PWD) is responsible for the water supply to the capital, Suva and several larger towns. Most of these supplies are based on surface water sources, in particular river intakes, although some use groundwater (e.g. Sigatoka). These water supplies include treatment facilities, reservoirs and reticulation systems to consumers. Currently, there are moves towards corporatisation of the Water and Sewerage Section.

Rural water supplies are based on one or more of the three common methods: surface water, groundwater and rainwater schemes. They are generally untreated. The PWD assists with design, construction and training. In many cases, villages provide one third of the costs of materials and assistance with labour. Rural water supplies are generally operated and maintained by local village communities.

Estimates of the coverage of water supplies in Fiji are shown in Table 3 in the main body of the report. As shown in that table, there are large differences between estimates from two reports (77% and 47%). Simpson et al (1994) quote a figure of 68%.

Apart from water supply, water resources are used in Fiji for agriculture and for hydropower generation (on Viti Levu). A bottled water company (Fiji Water) uses groundwater for its operation.

Normally, availability of water is not a problem but severe droughts, such as that experienced during the 1997-1998 El Niño (SOPAC, 1999a), cause a serious decline in rainfall with major impacts on available water resources and water supplies. In severe droughts, some village water supplies are inadequate to meet needs and emergency water is carted or shipped to these communities. Millions of dollars have been spent in the past on provision of emergency water (Raj, 1998).

Flooding is also a major problem in parts of Fiji. The magnitude of floods is, to some extent, influenced by the clearing of forested areas within catchments. In addition to increasing the magnitude of floods, clearing also impacts on erosion and subsequent high turbidity and sediment loads in streams and rivers in floods (Simpson et al, 1994). This impacts adversely on water supplies in downstream areas, leading to siltation problems in the lower reaches of rivers and sediment discharge onto coastal reefs.

Some rivers and streams are threatened with pollutants from agricultural runoff containing chemicals and fertilisers, pollution from liquid and solid wastes from industrial processes and forest harvesting (WMO, 1999). Previous investigations of rural water supply systems have indicated widespread contamination of drinking water from human and animal activities (Simpson et al., 1994).

Fiji has a stream monitoring network on the main island operated by the Hydrology Section of PWD. Groundwater monitoring is undertaken by the Mineral Resources Department, which also assists in the planning, assessment and development of ground water resources. Water quality sampling and monitoring is not undertaken regularly (WMO, 1999).

Regarding legislation, a Water Supply Act covers water supply systems but not whole catchments. Water resources legislation covering catchment management issues is in development by the Mineral Resources Department and other relevant government departments.

SOPAC has been involved in recent water related projects including training of PWD technical staff in the use of hydraulic network software and outer island water supply assessments.

FSP Fiji has been actively involved in co-ordinating and implementing a project to build ferrocement tanks (approx. 20,000 litres capacity) for schools in Fiji. This commenced after the serious drought in 1998. In the past 2-3 years, about 60 such tanks have been built at 30 schools. FSP Fiji also is involved with the Waibulabula project (Living Waters) project aimed at rehabilitating reefs through the management of watersheds and of wastewater being generated by human activity in the coastal zone. This project is concentrated at the Fijian Resort. Other projects involved in the research and development phase of this project include a commercial piggery at Vuda, half way between Nadi and Lautoka.

Major issues and concerns could be summarised as:

- Water quality problems (e.g. sewage pollution and solid waste disposal were noted as high priority issues in 1997 (GEF-IWP, 2001));
- Limited water resources and sometimes severe shortages during droughts on some islands. Freshwater shortage was noted as a high priority issue in 1997 (GEF-IWP, 2001). This is also noted by Simpson et al. (1994) and WMO (1990);
- Outdated water resources legislation (Simpson et al., 1994; WMO, 1999);
- Shortage of hydrological and water quality data, especially in outer islands;
- High losses in some water supply systems and need for more adequate leakage control and water conservation;
- Contamination of some rural water supplies. (WMO, 1999).

Kiribati

Kiribati consists of 33 islands, 32 of which are either coral atolls or single coral islands. One island. Banaba (Ocean Island), is a raised limestone island in the western part of the country.

Rainfall varies considerably between the islands and from year to year. On average, annual rainfall in the western part of Kiribati (Gilbert group) varies from about 1,000 mm in the south to 3,000 mm in the north. In the eastern part (Line Islands) annual average rainfall varies from about 800 mm on Kiritimati to 4,000 mm on Teraina in the north. Very high rainfall is associated with El Niño episodes and long droughts can be associated with La Niña episodes. During the past 3 years, Tarawa has experienced its worst long- term drought in more then 50 years.

The water resources of Kiribati consist largely of groundwater in the form of freshwater lenses, which are found within the coral sand islands on many of the 32 distinct coral atolls and reef islands. Groundwater is supplemented by rainwater on many of these islands. It is uncertain if fresh groundwater occurs on Banaba, which relied for water during the phosphate mining period on rainwater and importation by ship (as for Nauru).

Details about the water resources and water supply systems for the whole country are summarised in Metutera (1994) and IETC (1998, section 5.1). Specific water resources studies of Tarawa and Kiritimati, the two main urban centres of population, are presented in various AusAID reports and White et al (1999b).

The water supply for the main urban area of South Tarawa (approx. population of 30,000, or over one third of the national total) is based on pumping of groundwater from infiltration galleries on Bonriki and Buota islands. These freshwater lenses have been the subject of extensive hydrogeological investigations and monitoring (AusAID, 1982, 1992a and 1999a; White et al., 1999b). Sustainable yields are being re-assessed at present under the ADB funded Sanitation, Public Health and Environment (SAPHE) Project. This ground water is supplied via a piped system to consumers. The Public Utilities Board (PUB) is the agency responsible for the water supply (and sewerage systems and electricity supply) on South Tarawa. The water supply infrastructure is soon to be upgraded under the SAPHE Project (ADB loan project). Community consultation and education concerning water supply, sanitation and public health was implemented by an Australian company and FSP Kiribati.

Freshwater supply on South Tarawa is supplemented via private rainwater tanks at some houses and buildings, local groundwater wells and desalination (reverse osmosis or RO) units. Three RO units have been installed in the past 2 years to supply water to the main hotel and the hospital and to supplement water to the heavily populated island of Betio. It is recently reported (T. Metutera, pers. comm., 2001) that only the Betio RO unit is now operational.

The operation of the water supply on Kiritimati is the responsibility of the Ministry of Line and Phoenix Development. Following years of poor quality groundwater supplies, public water supply systems are being upgraded with new infiltration galleries, pumps, pipelines, chlorination systems and distribution pipelines to household tanks. Improvements to the water supply and sanitation systems are being implemented under an AusAID funded aid project. The project has a water supply component (including investigations and groundwater protection) as well as other components concerned with sanitation, and solid waste disposal improvements, training, capacity building and community information, education and consultation. FSP Kiribati is assisting with community education in relation to water conservation and environmental health. Initially, the water resources protection component identified that no settlement should occur on major freshwater lenses on the island and one village was identified for complete removal. Following concerns from the local community, a more sensible approach was adopted, which took measures to minimise sources of pollution (including improved sanitation), solid waste disposal and management of animals.

Water supplies for villages in North Tarawa and other islands of Kiribati are largely based on groundwater, either from wells close to housing or from communal water pumping systems. The communal pumping systems, which use either hand pumps or solar pumps, were largely implemented in the early to mid 1990s by the Water Unit of the Public Works Division, Ministry of Works and Energy using local labour and with funding from UNDP. Other donors of present and former schemes include SPC, Save the Children Foundation and the Norwegian Government (IETC, 1998). The WHO was involved with a windmill pump project on one of the islands.

As part of the implementation of the outer island water supplies, training was provided so that the communities could operate and maintain the water supplies. Training included the preparation of maintenance manuals written in both I-Kiribati and English (Kiribati Water Unit, 1997a). Generally, the village level operation and maintenance has worked well but in some cases hand pumps are broken and not repaired. Solar pumps have been found to be reliable in the first 5 years of operation. Where breakdowns occur, technical assistance is provided by the Water Unit.

There are administrative and legislative issues regarding the use of private land for public water supply purposes. This has been a major issue for the Bonriki and Buota freshwater lenses where water reserves (groundwater protection zones) are established over privately owned land, leading to conflicts and vandalism of public assets. One of the main issues in recent years has been illegal settlement within the water reserves, with high potential for groundwater pollution from sanitation systems and other activities. This issue is discussed in detail in White et al (1999b). As a condition of the ADB funded SAPHE project, these people have recently been moved either to the edge of the island (50m wide strip on ocean side) and away from the main part of the freshwater lens, (as recommended in earlier reports eg AusAID, 1992a), or to other parts of the atoll. The movement of the people was done after a series of meetings between government, the land owners and the settlers.

In recent years, SOPAC has been involved with a demand management and leakage control project on South Tarawa (SOPAC, 1998a) and a preliminary groundwater assessment of Banaba (SOPAC, 2000b).

Tarawa has been the focus of impact studies under possible sea level rise and climate change scenarios. Results of groundwater modelling studies to assess the impacts on a freshwater lens under the combined effects of pumping, climate change and sea level rise are presented in Alam & Falkland (1997) and World Bank (2000).

FSP Kiribati has been actively involved in the community education component of two major projects. (a) Two Kiritimati based FSP Kiribati staff are working with villages to promote water conservation, environmental health and community participation in the Kiritimati Island Water Supply and Sanitation Project (AusAID funded). (b) Community awareness raising on environmental health education, water conservation and storage and alternative sanitation options for the ADB funded Sanitation Public Health & Environment (SAPHE) Project.

Major issues and concerns could be summarised as:

- Pollution associated with sewage systems and solid waste disposal was noted as the highest priority issue in 1997 (GEF-IWP, 2001);
- Freshwater sustainability through droughts. Freshwater shortage was noted as a high priority issue in 1997 (GEF-IWP, 2001);
- Future water resource development for Tarawa, given the high population increase;
- Management of groundwater catchments particularly for the main ground water supply sources (White et al., 1999b);
- No national water resources legislation (White et al, 1999b);
- Insufficient use of rainwater for supplementary water (Shalev, 1992; Metutera, 1994b);
- Insufficient demand management including leakage control and water conservation in relation to urban water supplies (Metutera, 1994b, SOPAC, 1998a).

Marshall Islands

The Republic of Marshall Islands consists of 29 atolls in two chains known as the Ratak group and Ralik group. The total number of islands and 'islets' is about 1,225. Of the total population estimated in 1999 of 65,000, about 70% of these reside in the urban areas on the main atoll of Majuro (Goodwin et al, 2000a). The island of Ebeye on Kwajalein atoll, serving as a residential centre for workers on the adjacent Kwajalein Island (US military facility), is one of the most crowded islands in the Pacific.

Rainfall varies considerably between the islands and from year to year. The average annual rainfall in the western islands is about 2,500 mm to 3,500 mm in the south. Droughts are associated with El Niño episodes. During the 1998 drought, the water situation on Majuro was serious and desalination (reverse osmosis) units were flown in to provide emergency sources of freshwater (provided under an emergency assistance scheme by the US Government). An appraisal of water supply options was undertaken by SOPAC during this drought (SOPAC, 1998d).

The water resources of the Marshall Islands consist largely of groundwater in the form of freshwater lenses. Groundwater is supplemented by rainwater catchments on many of the islands. Desalination (distillation) is the primary source of water to the population on the residential island, Ebeye, on Kwajalein atoll (SOPAC, 1998d).

In the past, the United States Geological Survey and the University of Hawaii have conducted very useful groundwater assessments in the Marshall Islands, particularly on Kwajalein (e.g. Hunt & Peterson, 1980; Hunt, 1996 and Gingerich, 1996) and on Majuro (e.g. Hamlin and Anthony, 1987). A summary of reports on hydrogeology and groundwater in these two islands is contained in Peterson (1997). Buddemeier and Oberdorfer (1997) provide an overview of groundwater in Enewetak atoll. Detay et al (1989) provide a summary of groundwater contamination problems in the Federated States of Micronesia, Marshall Islands and Palau.

On Majuro, the main source of water is provided by rainwater collection from the concrete paved runway. This system, unique in the Pacific Islands, consists of a set of inlet pits and collection pipes from both sides of the runway to a central sump from where surface runoff from rainfall is pumped to large lined water storages. The water is then treated and pumped to the main population centre. Rainwater is also collected from private roof catchments.

Groundwater is also pumped from the Laura freshwater lens at the western end of Majuro atoll. This water is used to supply the local residents and to supplement the main supply for the urban eastern end of the atoll. The groundwater in the Laura lens has shown signs of being over-pumped from the 'lens wells' and is also at risk of microbiological and chemical pollution from some residences and agricultural activities on the lens. SOPAC has been involved in a recent evaluation of groundwater protection issues at the Laura lens.

The water supply on Majuro atoll is operated and maintained by the Majuro Water and Sewerage Company, (a private company and part of the Majuro Electric Company).

Other water management measures have been adopted on Majuro. Seawater, distributed via a second pipe network, is used for toilet flushing in the urban area of Majuro. The desalination units brought to Majuro during the previous severe drought are retained on standby for emergency use in future droughts.

In recent years, an ADB funded loan project provided improvements to the water supply and sewerage infrastructure. Prior to the project, leakage in the transmission and distribution mains was a major issue (Bungitak, 1994).

One of the issues with the airport runway catchment is that a combination of high tides and waves can cause overwash with seawater and sand, requiring time consuming clearing and cleaning.

Desalination and rainwater catchments have been used for regular water supply on Ebeye. Groundwater supplied from infiltration galleries near the airfield is used as the main source of water supply on Kwajalein Island.

On the outer islands, groundwater from shallow dug wells and rainwater, harvested by both household and community rainwater catchment systems are used conjunctively. However, the dug wells often do not provide safe drinking water due to poor construction and susceptibility to pollution, and the rainwater tanks are often of limited storage capacity (Goodwin et al, 2000a).

Recent preliminary groundwater investigations have been undertaken and water resource development plans have been prepared for 10 atolls. These reports comprise a summary report (Goodwin et al, 2000a) and a detailed report for each atoll (e.g. Goodwin et al, 2000b). Each atoll report provides an inventory of existing sources of water, a water demand assessment (based on 25 US galls/day i.e. approx. 100 L/day), groundwater resources assessment (albeit rather cursory) and a proposed water development programme. Groundwater was found to be available for development using infiltration galleries (similar to Kiribati).

It was recognised that these atolls have "long suffered from the limited availability of freshwater and chronic water shortages which assume catastrophic proportions during El Niño droughts, such as the ones which occurred in 1983, 1987, 1992 and 1998." (Goodwin et al., 2000a). The report goes on to say that the inadequacy of the water supply infrastructure in the outer islands is one of the constraints to economic development outside of the main centres on Majuro and Kwajalein.

Major issues and concerns could be summarised as:

- Pollution associated with sewage systems and solid waste disposal was noted as the highest priority issue in 1997 (GEF-IWP, 2001). Also, groundwater pollution due to agricultural and wastewater practices on the Laura freshwater lens, Majuro atoll is a concern;
- Freshwater sustainability especially through droughts. Freshwater shortage was noted as a high priority issue in 1997 (GEF-IWP, 2001);
- Need for upgrading of outer island water supplies and for greater use of rainwater catchments for water supply.

Nauru

Nauru Island is a raised coral atoll in the central Pacific Ocean with a land area of 22 km^2 (Jacobson et al, 1997). The island has a population of around 11,300 persons (see Table 1 in main body of report) who dwell mainly around the coastline. The interior of the island has been mined for its surficial phosphates over the last century.

The average annual rainfall is 2,085 mm, with a high degree of variability, and the island is prone to droughts associated with La Niña episodes (similar to Kiribati).

The island's daily potable water requirement is estimated to be 1,500 kL/day (WHO, 2001). The majority of this is supplied by a desalination unit operated by the Nauru Phosphate Corporation (NPC), using waste heat from the power station. The desalination unit produces approx. 950 kL of freshwater per day, which is distributed by tanker to households, at no cost to consumers.

The groundwater resources of the island are described in Jacobson et al. (1997). There is a freshwater lens underlying the island, which is currently not being pumped except on the coastal margin.

Other sources of water are brackish well- water and household rainwater collection. There are also a few small household desalination (reverse osmosis) units. A large-scale rainwater collection system constructed by NPC in earlier decades has been allowed to decay since the desalination unit commenced operation in 1992.

Additional potable water is required on a continuous basis to meet the island potable water requirements. The potential additional supply options identified in WHO (2001) were desalination plant (reverse osmosis, solar powered or distillation processes), rainwater and extraction from the freshwater lens. Restoring and expanding the collection and storage of rainwater is the preferred option. Conservation of water is a critical issue, which needs to be implemented with any of the options (WHO, 2001).

Major issues and concerns could be summarised as:

- Water resources availability and sustainability given that the primary water supply is now desalination;
- Need for comprehensive groundwater assessment (WHO, 2001);
- Water quality problems (e.g. sewage pollution and solid waste disposal 1997 (GEF-IWP, 2001));
- Possible over-pumping of wells on the coastal margin causing them to yield brackish water.

Niue

Niue is a raised coral atoll with an area of 259 km^2 and a population of about 2000.

Mean annual rainfall is approximately 2,040 mm. Niue lies within the southern boundary of the southeast trade winds and is also within the belt of cyclones, which occasionally affect the island. The island suffers from droughts, which generally coincide with El Niño episodes.

There is no surface water owing to the highly permeable soils and underlying limestone. A freshwater lens occurs under the island. The groundwater resources of the island are described in Wheeler and Aharon (1997).

Rainwater collected from roof catchments was initially the main water source. With the gradual advent of the public groundwater supply scheme, rainwater became more of a supplementary source. Now, nearly 100% of the population use the public water scheme. Each village has its own public water supply pipe network, and is supplied by electrical submersible borehole pumps. The Water Supply Division of the Public Works Department operates and maintains the water supply system. The potential for groundwater pollution near boreholes was noted as an issue (Chapman, 1994).

Over the period 1997-2000, AusAID implemented the Niue Water Supply and Water Management Project to improve water supply and waste management on the island. The main objectives of this project were to upgrade the level of service and to assist with community awareness about the needs for water conservation and proper waste disposal (liquid and solid).

The overall demand relative to the groundwater resource is low. However, large losses in the distribution pipe network and house plumbing has meant wasted pumping costs. A leakage control program has been active in recent years and led to a 55% reduction in the amount of water pumped (SOPAC, 2000a) with a similar reduction in pumping costs. The reductions were mainly achieved by conducting a survey of all houses and fixing leaking taps, shower outlets and toilet cisterns. The last item was found to be the major source of leaks (SOPAC, 2000a). SOPAC is continuing leakage reduction activities on the island.

Major issues and concerns could be summarised as:

- Potential contamination of groundwater (WMO, 1999), principally from septic tanks and solid waste disposal sites (Niue Country Input, 1997);
- Ongoing control of leakage from distribution systems;

No ranking of priority concerns was provided in the Niue report in 1997 (GEF-IWP, 2001).

Palau

Palau is an archipelago of six island groups totalling over 200 islands. The total land area is about 490 km^2. The islands consist of both volcanic and limestone islands.

On most major islands annual rainfall exceeds 3500 mm.

Perennial streams occur on the volcanic terrain of Babelthuap Island, but not in the limestone caps of other islands where runoff is transient. In the limestone islands (e.g. Peleliu and Angaur), groundwater is the main source of water (Mink, 1986). On many islands, supplementary water from rainwater catchments is used.

The Palau Water Authority is responsible for water and sewerage in all of the states of Palau. The main systems serve the states of Koror and Airai and are operated and maintained by the federal government. The water supply is sourced from surface water and has a new treatment plant installed in 1998 with a grant from Japan.

Water supplies on outer islands generally depend on dug wells and rainwater catchments.

The Palau Conservation Society assisted by TNC have been actively involved in environmental conservation programme, particularly in relation to marine areas. This work is also focused on conservation efforts and environmental standards in relation to road construction to avoid adverse downstream effects (TNC website, 2001).

It is noted that no ranking of priorities according to the GEF model format was provided in the 1997 country submissions from, as Palau was not a GEF eligible country at the time.

Papua New Guinea

Papua New Guinea consists of many large and small islands. The main island shares a land border with Indonesia.

Average annual rainfall varies from about 1,000 mm at sea level to about 10,000 mm in mountain peaks (Mark, 1994).

Severe droughts, such as that experienced during the 1997-1998 El Niño, can cause a serious decline in rainfall with impacts on available water resources, water supplies and agricultural production. In the 1997-1998 drought, approximately 100,000 people experienced critical problems with drinking water supplies, including shortages or access only to brackish or contaminated water (Barr, 1999). The majority of the rural population was accessing water from other than their normal sources and many had to walk for up to 2 hours to obtain drinking water.

Heavy rainfall, can impact severely on unprotected soil, especially on steep slopes. Excessive soil erosion causes streams and rivers to become dirty and unsuitable for most water uses. It can also impact on coastal fisheries and hence on the food resources of coastal communities.

Water resources include large rivers, streams and groundwater. Surface water, groundwater and rainwater are used depending on location. In general, water sources (surface water and groundwater) are plentiful but insufficient facilities have been developed to collect or store the water. Rainwater collection is encouraged but this does not last due to corrosion of storage tanks in coastal areas and vandalism in some areas (WMO, 1999). Water quality problems include sedimentation, bacterial contamination and toxic chemical and heavy metal pollution in some rivers and streams due to mining and industrial activities.

Eda Ranu, a corporatised state-owned enterprise, operates the water supply for the capital, Port Moresby (population 200,000). The PNG Waterboard, a statutory authority, operates piped water supply systems in 11 districts (out of the 19 districts). The Government of Papua New Guinea has commenced privatisation of these two water agencies.

High unaccounted for water, leakages and illegal connections (estimated at 25% of connections) are problems with the distribution systems (Joel, 1999). Water wastage is reported to be high and effective demand management is yet to be implemented.

About 75% of the population live in rural areas without access to clean, safe water (refer Table 3 in main body of report and Joel, 1999).

Implementation of rural water supply and sanitation projects is the responsibility of the Department of Health. Village communities are responsible for the operation and maintenance of their water supplies and collection of revenue to support operation and maintenance costs (Kolam, 1994). Technical support and training is provided by the Department of Health (DoH). The DoH also assists in forming water and sanitation committees, and evaluating progress.

Community participation and ownership is seen as a key factor in ensuring the sustainability of the rural water supply and sanitation projects (Kolam, 1994). Funding for these rural water supplies has come from a variety of sources including ADB, EU, UNICEF, bilateral funds from Australia, church organisations, NGOs and community groups (e.g.

FSP-PNG, WWF and Rotary International). WWF (2000) outlines water supply improvements in a number of villages involving dams or weirs feeding to header tanks and then to reticulation systems.

There is legislation for resource management and use, especially the Water Resources Act, but there are no specific policies to enforce such legislation (WMO, 1999). The water sector is very fragmented with multiple agencies involved in the administration of water supplies (Joel, 1999).

Major issues and concerns could be summarised as:

- Freshwater sustainability through droughts for some areas of the country. Freshwater shortage was noted as a high priority issue in 1997 (GEF-IWP, 2001);
- High unaccounted for water, leakages and illegal connections (Joel, 1999);
- Increasing concern about water quality due to increased development activities upstream of watercourses (e.g. Joel, 1999; WMO, 1999);
- Risk of surface water and groundwater pollution from mining and industrial activities (Joel, 1999; WMO, 1999);
- Growing concern about microbiological quality degradation and many untreated water supply systems (WMO, 1999);
- Communication problems between water agencies.

It is noted that no ranking of priorities according to the GEF model format was provided in the 1997 country submissions from PNG (GEF-IWP, 2001).

Samoa

Samoa consists of two larger islands, Savai'i and Upolu, and several smaller ones. The islands are volcanic. Savai'i has a central core of volcanic peaks surrounded by a ring of lava-based plateau, then lower hills and coastal plains. Upolu has a chain of volcanic peaks running the length of the island with hills and coastal plains on either side.

Average annual rainfall in the south and south-east windward areas varies from 5,000 to 7,000 mm. On the leeward side, the islands receive from 2,500 to 3,000 mm of rain. There is a marked dry season from May to August. The country is prone to cyclones and to droughts, the latter being associated with El Niño episodes.

Water resources consist of surface water and groundwater resources. Rainwater catchments are used in some areas. Most water supply schemes are fed from inland streams and springs and reticulated by gravity. Groundwater is pumped to a number of villages from boreholes, mainly in coastal areas.

There is some generation of electricity by hydropower. Owing to leakage, however, the dam is capable of storing only about 30% of its design capacity, which limits hydropower generation.

The Samoa Water Authority (SWA), established as a government owned corporation in 1994, manages the water supply for the majority of people (approx 84%) in Samoa. The others come under the control of local chiefs.

In 1998, the SWA estimated that consumption before metering was approximately 825 L/p/d. Preliminary indicators have shown a decrease in water consumption to around 325 L/p/d after the introduction of water metering. Metering of house connections is an ongoing programme at present. Leakage control is one of the current training exercises within SWA under a wider, AusAID funded institutional strengthening project.

For Apia, water quality is affected by high turbidity after storms, a problem which is made worse by land clearing in catchments. Water quality is also impacted by faecal contamination due to urbanisation. Full water treatment including filtration and chlorination is now used in a number of catchments for Apia's water supply. Rural water supply systems are not generally treated. The EU has been funding a number of rural water supply projects.

The Lands, Survey and Environment Act of 1989 states that the Government owns all water resources, streams and rivers, which is contrary to customary land ownership (Samoa Government, 2000). Catchment (watershed) management principles are contained within the Watershed Protection and Management Regulations of 1992, which is jointly administered by the Ministry of Lands, Survey and Environment and the Ministry of Fisheries, Forestry and Meteorology.

Hydrological data is sparse (WMO, 1999). In 2000, NIWA installed several streamflow gauging stations in Samoa with the Hydrology Division at the Meteorological Office. Unfortunately, damage has occurred to some due to floods, and in one case, vandalism.

Major issues and concerns could be summarised as:

- Decline in freshwater quality due to pollution from land-based activities including sewage, solid waste, nutrients, sedimentation and chemicals (GEF-IWP, 2001, Samoa Government, 2000);
- Freshwater sustainability through droughts for some areas of the country. Freshwater shortage was noted as a priority issue in 1997 (GEF-IWP, 2001);

- Limited knowledge about water resources (WMO, 1999; Samoa Government, 2000);
- Insufficient means (equipment, vehicles and personnel) to carry out much needed hydrological measurements (WMO, 1999);
- Need for greater public education and awareness about water conservation and greater community participation in water resources management (Samoa Government, 2000).

Solomon Islands

The Solomon Islands is comprised predominantly of volcanic islands but also has some raised limestone islands (e.g. Rennell and Bellona) and four atolls in the north, the largest being Ontong Java.

Average annual rainfall in the Solomon Islands is generally higher than much of the Pacific region, varying from about 2,200 mm at sea level to about 5,000 mm (ESCAP, 1983). In mountainous areas it may be as high as 10,000 mm areas (Tolia, 1994).

The larger volcanic islands have numerous catchments with rivers, streams and spring sources. In general the availability of water is not a problem. However, severe droughts, such as that experienced during the 1997-1998 El Niño, can cause a serious decline in rainfall with impacts on available water resources and water supplies (Barr, 1999). Heavy rainfall, often associated with cyclones, can impact severely on unprotected soil, especially on steep slopes. Excessive soil erosion causes streams and rivers to become dirty and unable to be used for washing and drinking. It can also impact on coastal fisheries and hence on the food resources of coastal communities.

The limestone islands and coral atolls rely on groundwater and, in some cases, supplementary rainwater catchments for their water supplies. In droughts, groundwater from existing wells on some islands can become depleted, brackish or polluted (due to overuse and introduction of contaminants).

The Solomon Islands Water Authority (SIWA) is responsible for the water supply to the capital, Honiara and three other urban centres. Sources of water are both surface water and groundwater. During the recent conflict, about 80% of Honiara could not be supplied owing to destruction of infrastructure at the town's main water source (Kongulai dam on White River). Repairs and new pump installations have been being implemented under funding from the European Community. Many residents installed alternative means of water supply, mainly rainwater tanks, to overcome this problem.

AusAID has recently finished an institutional strengthening project for SIWA.

Statistics published before the conflict (WHO/UNICEF, 2000) suggested that the overall coverage of water supplies within the Solomon Islands is 71%, with a 94% coverage in urban areas and a 65% coverage in rural areas.

A national Rural Water Supply and Sanitation (RWSS) Programme has existed for a number of years with the aim of providing sustainable water supplies and adequate sanitation facilities to rural villages throughout the country. Most rural water supplies are gravity-feed systems from springs and streams while a small proportion use hand pumps from groundwater from hand pumps and rainwater catchments. A typical project is a gravity-feed water system from an intake on a stream, pipeline to the village, storage tanks and a pipe network to standpipes in the village (Fugui, 1994). The agency responsible for rural water supplies is the Rural Water Supply and Sanitation (RWSS) Department of the Ministry of Health and Medical Services.

In the past 5 years, AusAID has been the major contributor to the RWSS programme through the implementation of the RWSS Project. The Solomon Islands Development Trust (SIDT), a local NGO, has assisted with the implementation of the RWSS. The SIDT is largely involved through its network of Village Demonstration Workers to promote clean and efficient water supplies and basic community hygiene and sanitation practices.

A major thrust of the RWSS Project is community participation (e.g. in planning and design) and involvement (e.g. in building and maintenance). Women are included in the planning stages are also trained in maintenance and monitoring water quality. When a community decides they need a water supply, they form a water committee which applies to the government or an RWSS office with their request. Certain conditions are required for implementation, including the agreement from the owner of the land where the water source is to be developed. This agreement, if given, avoids potential later conflicts. Other requirements are a financial contribution from the village (between 10% and 50% depending on province) and provision of free labour during construction.

Engineering assistance and training in construction is provided by the RWSS Department. Operation and maintenance guides, compiled after numerous workshops which involving the government, NGOs, communities and women's groups, are supplied to the communities.

Other aid donors (e.g. Canada Fund) have also been involved in rural water supply and sanitation improvements.

Regarding major issues and priority concerns, the country submission from the Solomon Islands for the IWP (Solomon Islands, 1997), prepared in 1997 and summarised in a review of country submissions at the First Regional Task

Force meeting in March 2001 (GEF-IWP, 2001), did not rank freshwater issues as priority concerns (compared with other higher priority items). The country submission however did describe pollution of freshwater (including ground water) and marine water from land-based activities as being one of the major problems.

Specific freshwater resources and supply issues have been summarised in previous publications. Tolia (1994) and WMO (1999) raise the following issues:

- Surface water is frequently turbid and often as a result of clearing activities in upper catchment areas (as mentioned in Solomon Islands (1997), upstream landowners have allowed logging on their land to gain an income. If coastal ecosystems are to be protected, there is a need for upstream landowners to properly manage the land);
- Most water supplies are subject to fluctuations in water quantity and quality. Most urban centres have limited reticulation systems and have been unable to keep up with demand;
- Increasing demand on water resources from developments including hydro-power generation, nickel, gold mining, rice production, increasing population and continued logging activities in water catchments;
- Responsibility at government level for water supply is spread over a number of ministries;
- Groundwater resources on smaller islands are in urgent need of assessment;
- Insufficient resources and staffing to carry out routine hydrological assessments.

Tonga

Average annual rainfall in Tonga varies from approximately 1,800 mm in the south (Tongatapu), 1,700 mm in the central Ha'apai group, 2,200 mm in the Vava'u group and over 2,300 mm in the far northern Niuas group. The country is prone to cyclones and to droughts, the latter being associated with El Niño episodes.

The islands are either volcanic or uplifted coral limestone, sometimes with sand deposits near sea level. The volcanic islands form a north-south line on the western side of Tonga with the coral comprised predominantly of volcanic rock and alluvium derived from this type of rock. Some islands have mixed volcanic and limestone geology, including 'Eua.

The water resources of Tonga have been well described in AusAID (1992b), Furness & Helu (1993) and Furness (1997). More recent detailed studies of some islands were carried out under a recently completed AusAID funded project to assist the Tonga Water Board.

The water supplies for the township of Nuku'alofa and most of the villages use groundwater. In some cases, supplementary rainwater is harvested from roof catchments. On the island of 'Eua, small streams flowing from caves are used for the primary water supply. Groundwater is normally pumped from drilled wells and some old dug wells, some of which are up to 50 m deep. On the island of Lifuka, where the groundwater resource (freshwater lens) is limited, water supply improvements have been implemented by constructing infiltration galleries to replace earlier boreholes. This has led to a significant reduction in salinity.

The Tonga Water Board (TWB) operates the water supply systems for the four main urban centres. Consumer connections are metered and consumers are charged on a water usage basis. The rural water supplies are operated by Village Water Committees with support and training provided by the Ministry of Health. Rural water supplies are not metered but charges are levied on a fixed fee basis. The TWB is sometimes asked to provide technical assistance to the rural villages and there is presently ongoing discussion about TWB providing a greater role in village water supplies in the future.

JICA is currently funding a major upgrade of pipe systems and other water supply infrastructure in Nuku'alofa. Prior to this, the TWB benefited from a 5 year AusAID funded institutional strengthening project. The EC have funded water supply infrastructure improvements (new wells and pumps, storage reservoirs, and treatment in Vava'u). AusAID, NZODA and other aid donors have a continuing involvement in house rainwater collection systems in villages. NZODA is funding a project to upgrade the water supply on 'Eua.

The Tonga Community Development Trust (an NGO affiliated with FSPI) has been actively involved in rainwater catchment projects throughout Tonga.

There is water supply legislation for the TWB but no national water resources legislation. The TWB does have the power to establish groundwater protection zones over freshwater lens areas used for water supply.

Catchment management on the island of 'Eua, where surface water flows form the main water supply, is an issue. Grazing of cattle and planting of crops is linked to high turbidity and sometimes faecal contamination in the streams. Recently, measures have been taken to relocate farmers away from the water supply catchment areas.

A UNESCO and SOPAC funded applied research project on groundwater pollution was conducted in the late 1990s. This project demonstrated the close linkages between sanitation systems and groundwater pollution of wells, through a series of experiments at a school using tracers including a dye. The process and results of the trial are presented in Crennan et al. (1998) and Crennan (2001).

Major issues and concerns could be summarised as:

- Pollution associated with sewage systems and solid waste disposal (highest priority issue in 1997 (GEF-IWP, 2001));
- The need for a greater level of water resources assessment and protection (S. Helu, pers. comm. 2001);
- Present water supply problems (intermittent supply) in Neiafu, Vava'u and in Nuku'alofa (low pressure in some areas) largely as a result of high leakage;
- Water supply problems in remote islands during droughts, sometimes requiring importation of water by boat.

Tuvalu

Tuvalu is comprised of nine coral atolls or islands.

The average annual rainfall throughout Tuvalu is higher than in most other parts of the Pacific. On the main atoll, Funafuti, where the average annual rainfall is approximately 3,500 mm. The minimum annual rainfall in the record 1927-1998 was 2,220 mm. Long term 'droughts' do not occur in the sense that they do in some other PICs (e.g. Kiribati to the north).

Tuvalu is largely dependent on rainwater catchment systems, both household and communal, for water supply. Water storages consist of either above-ground tanks made of a variety of materials (primarily ferrocement, fibreglass and plastic (polyethylene)) and in-ground cisterns made from concrete and concrete blocks. Under normal circumstances, all water needs can be met by each household from its own rainwater catchment. During dry periods when household supplies run low (e.g. when no rain has occurred for a month or so) water deliveries are made by tanker to household tanks from communal cisterns which are fed by rainwater from community buildings (e.g. churches, halls, offices).

Previous studies of water resources and water supply systems include van Putten (1988), Salzmann-Wade & Hallett (1992), Reynolds (1993), SOPAC (1998c), Saitala (1999) and AusAID (1999b). On Funafuti, local knowledge indicates that water can change from fresh to brackish in the pulaka (taro) pits within and adjacent to the village of Fogafale. These changes appear to be seasonal changes associated with high and low rainfall periods. Another reported feature of the groundwater is its relatively high fluctuations. These observations are consistent with a large amount of mixing between freshwater recharge to the groundwater (from rainfall) and underlying seawater. This has most probably lead to the development of a reasonably wide brackish layer or 'transition zone' (AusAID, 1999a).

Conclusions are that fresh groundwater is extremely limited on Funafuti but is found on some of the larger outer islands. Despite more favourable rainfall conditions in Tuvalu than in Kiribati, the thickness of the freshwater lenses in islands of Tuvalu appear to be much less than in similar size islands of Kiribati. This is largely a function of the geological conditions of Tuvaluan islands where the upper sediments tend to be coarser and more permeable than in islands of Kiribati. The Tuvaluan islands have been at least partially built by cobble to boulder size sediments due to storm waves associated with cyclonic activity. By comparison, the islands of Kiribati, which tend not to be affected by cyclones and associated storm waves, appear to have finer, less permeable sediments due to more tranquil building processes. The more permeable sediments in Tuvaluan islands enable easier mixing of fresh and seawater, leading to thinner freshwater lenses than in Kiribati islands.

Following a longer than normal dry period in 1999, the Government of Tuvalu declared a state of emergency for the island of Funafuti in August, water was rationed and a desalination (reverse osmosis) unit procured and shipped to the island. This was installed but later removed when the rainfall returned to normal.

In 1990, in a similar emergency, two RO units were flown in to provide freshwater. After several months these were non-operational owing to problems with membranes and other parts. The technology was not suited to a long term solution for the island owing to high operation and maintenance requirements, need for skilled operators and the expense of producing water (AusAID, 1990; Saitala, 1999).

Ferrocement rainwater tank and concrete cistern construction programmes have been implemented in Tuvalu over many years. Guideline manuals for ferrocement tanks have been prepared on appropriate methods of construction. These projects have generally been community based projects with volunteer labour to help with construction.

Ferrocement tanks have lost popularity owing to the need for sand (a scare resource) and some cases of cracking and leaking. Polyethylene tanks are more popular but more expensive than ferrocement tanks. However, they have advantages of ease of installation and saving in sand resources. Although not tested over long durations, they are likely to last over many years.

SOPAC has recently assisted Tuvalu with an inventory of rainwater catchments on GIS and a technical review of draft legislation covering standards for roof catchments.

Major issues and priority concerns can be summarised as:

- Issue of sustainability of rainwater catchments through droughts (freshwater shortage was noted as the highest priority issue in 1997 (GEF-IWP, 2001) and later in Saitala (1999)). Requirement for greater storage facilities, especially for Funafuti as demand rises (e.g. Taulima, 1994b; AusAID, 1999b, Saitala, 1999);
- Optimal rainwater catchment design procedures;
- Alternative options for water use apart from rainwater on Funafuti (e.g. use of brackish groundwater for toilet flushing for some buildings in Funafuti, such as hotel and new offices) (AusAID, 1999b);
- It is noted that groundwater quality problems are not seen as an issue in 1997 (GEF-IWP, 2001) but was considered an issue in Taulima (1994b). The apparent change in priority is possibly more to do with individual preferences than overall policy differences;
- More adequate drought forecasting methods (UNESCO/SOPAC/UNDDSMS, 1994, p13; Saitala, 1999, AusAID, 1999b);
- Further knowledge of sustainability of fresh groundwater resources on outer islands (UNESCO/SOPAC/UNDDSMS, 1994, p13).

Vanuatu

Average annual rainfall in Vanuatu varies from about 2,500 mm to 4,500 mm (ESCAP, 1983). The country is prone to cyclones. Droughts are not seen as a major problem for the larger water supplies on main islands but can be a problem for communities in smaller islands (SOPAC, 1999c).

The islands of Vanuatu comprise predominantly volcanic rock and alluvium derived from this type of rock. In the coastal zones of some islands, sand deposits and raised coral limestone are found. Groundwater is found in many parts of the islands, particularly from sand and limestone aquifers in the coastal plain.

Due to generally small size, and steep topography, many stream courses are short and the flows are not perennial. Larger perennial rivers are found on some of the larger islands (e.g. Espirito Santo). Some lakes occur in craters (UNDTCD, 1983).

Approximately 20% of the population lives in the capital, Port Vila, with the remaining 80% spread between three other urban areas and many small villages.

A private water company, UNELCO, operates the water supply in Port Vila under a long- term contract with the government. The population served is approximately 34,000. The water source is a groundwater aquifer close to Port Vila. Leakage in the system has been reduced from about 50% in 1994 to about 23% in 2001 (J. Chaniel, pers. comm., 2001). There is no legislation for a groundwater protection zone but urban sub-divisions are not permitted in the groundwater catchment area. However, some people have settled in the upper parts of the catchment area. (Hawkins, 1995).

The Public Works Department is responsible for the water supplies in urban centres outside Port Vila. These supplies are sourced from groundwater close to the populated areas.

Smaller villages scattered over the islands, in both coastal and higher areas, obtain their water supplies from either groundwater, surface water (streams or springs) or rainwater catchments. Water supplies using surface water may suffer from turbidity after heavy rain. The movement of coastal people to inland areas is jeopardising the quality of water that serves coastal villages (Temakon, 1994).

Rural water supplies are implemented by the Rural Water Supply Section of the Department of Lands, Geology, Mines & Water Resources. A contribution of one third of the costs for construction is sought from villagers and labour is also often supplied (SOPAC, 1999c). The schemes are then operated and maintained by the villagers under the direction of village water committees. Improvements could be made in community participation in the planning, design and implementation of rural water supplies (SOPAC, 1999c).

FSP Vanuatu has assisted with practical water projects, including rainwater tanks and roof catchments (including repairs after the 1999 cyclone), and improvements to water supply systems for villages and schools.

Water resources management is the responsibility of the Department of Geology, Mines and Water Resources. The Hydrology Section of the Department is responsible for water resources data collection. There is a serious shortage of water resource and water quality data throughout the country. This issue has been raised by Temakon (1984), WMO (1999) and the Vanuatu Hydrology Section (2001). Without such data, it is not possible to properly assess the surface water resources nor to identify the impacts of land use changes within catchments (e.g. urbanisation, forestry practices, mineral extraction and agriculture) on flows and water quality. Human and financial resources within the Hydrology Section are very limited. To overcome this limitation, a draft proposal has been developed by the Hydrology Section under the title "Catchments and Communities" to involve local communities in the monitoring programmes. Under the proposal, six water monitoring sites, equipped with water level recorders and raingauges, would be located near high schools, and students would be trained in the use of hydrological and biological monitoring equipment (Vanuatu Hydrology Section, 2001).

Major issues and priority concerns can be summarised as:

- Water quality problems especially pollution from sanitation systems (e.g. sewage-related liquid pollution, was noted as a high priority issue in 1997 (GEF-IWP, 2001), followed by solid waste and nutrients). Settlement in inland areas is posing a pollution threat to downstream coastal villages;
- High risk of saline intrusion in coastal groundwater, particularly where coral limestone is present;
- Severe shortage of water resources data and lack of water quality monitoring for both surface water and groundwater (WMO, 1999; SOPAC, 199c);
- There is a need for more emphasis on water demand management in rural water supplies (SOPAC, 1999c);
- Fragmented administration of water resources and water supply.

Annex III Outlines of potential community-based pilot projects

Summary of projects

1. 'Stream Health' (Community Awareness and Catchment Management through Stream Health Monitoring and Education).
2. 'Groundwater Health' (Community Awareness and Groundwater Catchment Management through Groundwater Monitoring and Education).
3. 'Leakage Watch' (Community Awareness about Water Conservation through Monitoring, Education and Action).

Potential Pilot Project No 1

'Stream Health'
(Community Awareness and Catchment Management through Stream Health Monitoring, Education & Action)
Outline of Project

Stream and catchment monitoring for 'stream health' to improve community awareness and understanding, and to assist with catchment management and water supply quality improvements.

Background and Problem Statement

Surface water resources, catchments (watersheds) and downstream environments (mangroves, lagoons, reefs, coastal fisheries) have been degraded in many high islands due to the impacts of deforestation, urbanisation with pollution from liquid and solid waste, industry, construction activities and resource extraction activities. Deterioration in the physical, chemical and microbiological quality of streams and rivers has occurred. Baseflow of streams can be severely lowered, in addition to the adverse water quality impacts. Water supplies can be adversely affected by lower yields, higher and more frequent suspended solids and turbidity problems, higher levels of microbiological contamination and possibly chemical pollution. These problems can directly impact on human health unless expensive treatment measures are implemented or new sources found.

Measures have been implemented in some Pacific Island countries to counteract these impacts. Where applied, these have been in the form of legislative approaches attempting to control development. Few approaches have endeavoured to enlist the cooperation of the communities within these catchments who own and use their customary (traditional) lands, although this trend is increasing in some islands. Participatory catchment management approaches involving government, NGOs and local communities offer great potential to resolve the underlying causes of catchment and water degradation.

One of the current limitations in the process of catchment management has been the low awareness of the impacts on water quality due to upstream activities. While some impacts are sometimes obvious, others are far less evident such as gradual upward trends in turbidity and chemical or microbiological contamination (e.g. from urban areas encroaching on catchment areas). There is a real need for greater education and awareness within communities of these issues. This can be achieved through targeted monitoring of 'stream health' in selected areas. Through this, the level of understanding of impacts on water quality from upstream practices will improve. With better understanding, individuals and communities are more likely to be committed to action to assist in a community-based participatory approach to manage their catchments.

Project Goal

To improve the quality of freshwater resources in surface water catchments of high islands, through education, monitoring, awareness and action.

Project Location(s)

In surface water catchments (watersheds) of high islands, preferably with sub-areas that are not impacted by deforestation and development. For comparison, other sub-areas should be included that have undergone changes causing obvious water quality degradation. The catchment could be in a rural area undergoing deforestation or an urban/rural catchment where clearing for land development is underway. The catchment should be small enough so that the main causes of water quality degradation are reasonably obvious and not caused by a multiplicity of factors.

Specific Objectives

- Improve awareness and understanding within communities about the impact of activities within catchments on 'stream health' (flow and water quality) of downstream areas, through appropriate data collection and monitoring;
- Develop a database of information about water quality and other key characteristics (rainfall, soils, vegetation, land use practices) based on monitoring information, in conjunction with relevant government or other agencies;
- Assist in developing strategies and implementing activities to improve surface water quality through improved catchment management practices.

Expected Outputs and Results

- Database of information about the catchment, including water quality, for community and government use;

- Report and presentation of the findings of the project to key stakeholders, including all communities within the catchment and government agencies involved with land and water management;
- Initiation of appropriate actions to improve catchment management, and through this to improve water quality;
- Public awareness campaign and wide dissemination of the results of the project using appropriate media.

Project Tasks

The following staged tasks are suggested:

- Selection of site(s) based on identified problems or threats;
- Consultation about the project with villages/communities, traditional landowners and other stakeholders (e.g. government agencies) in a selected area;
- Selection of partners to be involved in the project (e.g. school(s), NGOs, government agencies);
- Gather information about catchment land uses from previous reports, aerial photographs (if available) and by conducting a catchment survey. Include visits to and discussion with landowners and others about land use practices. Where existing maps or aerial photographs are not adequate, a GPS may be required to locate key features within the catchment;
- Selection of sites for water monitoring, noting that 'clean' and 'affected' sites should be chosen. Two of each would be a good combination. Obtain permission and cooperation of landowners to use the sites;
- Install stream height (gauge) posts to measure stream height at selected sites at each visit. Install a raingauge (and possibly join The Schools of the Pacific Rainfall Climate Experiment (SPaRCE) raingauge program);
- Regular rainfall and stream monitoring over one to two years including a combination of simple physical, chemical and biological indicators (e.g. using existing kits: refer 'Suggestions for project implementation' below). This should include visits during high and low flows. If possible, utilise services of water resources agency to measure flows with current meter and establish a rating curve for the site (flow vs height). If possible, utilise services of water authority or health department to take samples for microbiological tests. Another option is to purchase a microbiological test kit or colour change presence/absence test kit which can be used by less skilled people. Further investigation of suitable options will be required before final selection;
- Analyse and synthesise water quality and other data and develop database with technical assistance from appropriate agency. If possible, enter catchment use data into a geographical information systems (GIS), using technical assistance from government agency or other specialist agency. This will assist in presentation of results as well as enabling the data to be geographically referenced;
- Discussion of results in schools at regular intervals, particularly focusing on differences between the selected sites and reasons for differences. School projects could include analysis of various aspects of the monitoring programme. Graphs could be updated and displayed showing rainfall, stream height and water quality. Combine this with education and awareness programme at schools about basic catchment hydrology and impacts of land use (with water authority or others);
- Presentation and discussion of results at selected intervals to wider community and other stakeholders in the catchment (e.g. government agencies);
- Assess and recommend strategies for catchment management to improve stream health (and hence reduce impacts on downstream areas and water supplies);
- Encourage establishment of community based catchment management committee and encourage wider participation within the community using appropriate media;
- Implement improvements during life of project, if possible;
- Prepare report and other publicity material for wider dissemination about the project outcomes.

Suggestions for project implementation

- Involve a school (or schools) as primary implementer of the project and, if possible, include the project in the school curriculum;
- Nominate a locally based group (e.g. NGO) to assist with project coordination;
- Build on or complement existing programmes where possible (e.g. Live & Learn Environmental Education in Fiji, other NGOs, SPaRCE);
- Use existing kits for simple physical, chemical and biological indicators (e.g. Streamwatch (Sydney Water Board), New Zealand Stream Health Monitoring and Assessment Kit: or SHMAK Kit brochure: (refer NZ Landcare Trust, undated));

- Utilise technical assistance from government agencies and consultants with some aspects of the programme (e.g. stream flow measurements, microbiological tests).

Complementary proposals and activities

- This project has linkages with other focal areas of the IWP, particularly waste management, but also with coastal fisheries and marine protected areas, which may be impacted or at risk from catchment activities;
- Live & Learn Environmental Education in Fiji is proposing to implement a River Care programme using schools (Live & Learn, 2000);
- 'Catchments and Communities' Project originally proposed as a UNESCO applied research project at the Pacific Water Sector Planning, Research and Training Workshop in 1994 (UNESCO/SOPAC/UNDDSMS, 1994). It was developed further by the New Zealand National Institute of Water and Atmospheric Research (NIWA) (Sankey et al., 1997; White et al., 2000).

Potential resource persons and agencies

- Christian Nielsen, Live & Learn Environmental Education, Suva, Fiji;
- Personnel from NGOs including FSPI and its affiliates, TNC and WWF (depending on country or countries selected);
- Personnel from Water Resources Unit, SOPAC, Suva, Fiji;
- Seema Deo, Environmental Education Officer, SPREP;
- Bob Curry, NIWA, New Zealand;
- Professor Ian White, Water Research Foundation of Australia, Canberra, Australia;
- Local personnel in country or countries chosen for the project.

(for full contact details and potential roles refer to Annex IV)

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Potential Pilot Project No 2

'Groundwater Health'
(Community Awareness and Groundwater Catchment Management through Groundwater Monitoring, Education & Action)

Outline of Project

Groundwater monitoring and education to improve community awareness and understanding, and to assist with groundwater catchment management and water supply quality improvements.

Background and Problem Statement

Groundwater resources (in the form of 'freshwater lenses') on small coral islands are particularly vulnerable to over-extraction and pollution from sanitation systems, solid waste disposal sites, agricultural chemicals, oil and other hydrocarbons, and concentrations of domestic animals such as pigs. Impacts are high salinity and microbiological and chemical contamination of water supplies. These problems directly affect human health and can also cause additional environmental problems. Contaminated groundwater is a major source of disease in a number of small Pacific Island countries.

Probably the main pollution threats to groundwater in small coral islands, especially in urban centres, are inappropriate sanitation systems, particularly pit latrines but also septic tank systems, which are often poorly constructed and not maintained. Due to thin, highly permeable soil and shallow water tables contamination can occur readily. Limestone islands also offer little protection from groundwater contamination unless they are overlain by thick soil sequences.

Design, siting and construction of sanitation facilities are often done in a way that leads to direct contamination of the groundwater. Travel times between such facilities and nearby wells used for water supply are short, and pathogenic micro-organisms can easily enter wells through the groundwater (Dillon, 1997). The linkages between sanitation and solid waste disposal practices on groundwater pollution, the quality of water supply and human health, is often not well understood. This has been demonstrated in a recent applied research study of groundwater pollution and impacts on groundwater wells in Tonga (Crennan, 2001). Similar findings about groundwater were obtained from another study of groundwater processes in Kiribati (White et al., 1999).

There is a real need for greater education and awareness within communities of these issues. This can be achieved through targeted monitoring of 'groundwater health' in selected areas to aid in understanding of the linkages between sanitation practices and groundwater quality and human health. This education and awareness through groundwater quality monitoring can also be extended to other sources of contamination such as waste disposal sites, piggeries (or concentrations of pigpens) and agricultural chemicals. With greater awareness, individuals and communities are more likely to be committed to seek to improve the condition of their groundwater resources through better practices (e.g. liquid and solid waste management, limit use of chemicals on gardens). The implementation of improved practices would require a combined response from communities and government agencies, but could conceivably be organised through village- based catchment management committees.

Project Goal

To improve the quality of fresh groundwater resources on small coral islands through education, monitoring, awareness and action.

Project Location(s)

A coral atoll or raised atoll environment with a mixture of land uses so as to ascertain groundwater quality in heavily impacted areas and compare it with groundwater in lesser impacted areas. Alternatively, a low- lying, sandy coastal zone of a high island could be selected.

Specific Objectives

- Improve awareness and understanding within communities about the impact of sanitation systems and other pollution sources on 'groundwater health' through appropriate data collection and monitoring, and targeted education;
- Develop a database of information about groundwater quality and other key characteristics (rainfall, soils, vegetation, land use practices) based on monitoring information in conjunction with relevant government or other agencies;
- Assist in developing strategies and implementing activities to improve groundwater quality, particularly in relation to sanitation systems and other waste management practices.

Expected Outputs and Results

- Database of information about the catchment, including water quality, for community and government use;
- Report and presentation of the findings of the project to key stakeholders, including all communities within the catchment and government agencies involved with land and water management;
- Initiation of appropriate actions to improve catchment management and through this to improve water quality;
- Public awareness campaign and wide dissemination of the results of the project using appropriate media.

Project Tasks

The following staged tasks are suggested:

- Selection of site(s) based on identified problems or threats;
- Consultation about the project with villages/communities, traditional landowners and other stakeholders (e.g. government agencies) in the selected catchment;
- Selection of partners to be involved in the project (e.g. schools, NGOs, government agencies);
- Gather information about catchment uses from previous reports, aerial photographs (if available) and by conducting a survey. Include visits to and discussions with landowners and other landusers about land use practices;
- Selection of sites for groundwater monitoring, including a series of wells near to and further from various land use activities (e.g. urban development, areas used for agriculture, sites near power stations and sites away from major impacts, i.e. both 'clean' and 'affected' sites should be chosen). Obtain permission and cooperation of landowners/other agencies to use the sites;
- If available, install raingauge at suitable site (e.g. school). Possibly join the SPaRCE raingauge programme;
- Map sampling sites and nearby potential sources of pollution;
- Regular rainfall and water quality monitoring over one to two years using selected chemistry and microbiological tests (e.g. electrical conductivity, specific ions such as nitrate, faecal coliforms). A suitable kit will need to be assembled for this purpose. If possible, utilise the services of the water authority or health department to take samples for baseline microbiological tests. For regular testing, a microbiological test kit, colour change presence/absence tests, or H_2S paper strip tests (Sharp, 2001) can be used by less skilled people. Further investigation of the most effective options will be required before final selection. The methods outlined in research proposals by White (1998) on Safe Conjunctive Land Use in Groundwater Reserves is a useful guide;
- Conduct groundwater movement tracing study between an injection site (simulated sanitation facility) and nearby withdrawal sites (simulated groundwater wells). This experiment can be done by students with appropriate guidance. It will provide information on rates and direction of groundwater flow under simulated conditions of a toilet being flushed. Select a suitable study site (e.g. at one or more schools) using existing wells or digging shallow pits to the water table. For tracers, a food dye for visual demonstration purposes and a bromide tracer would be effective. This was demonstrated in a previous UNESCO/SOPAC study in Tonga (Crennan et al., 1998; Crennan, 2001). Measure water level and tracer concentrations at appropriate intervals. The educational benefits of this type of experiment were found to be very valuable when carried out at a school in Tonga. The design of this experiment will require further investigation to maximise benefits;
- Analyse and synthesise water quality and other data, and develop database with technical assistance from appropriate agencies. Analyse and synthesise water quality and other data and develop database with technical assistance from appropriate agency. If possible, enter catchment use data into a geographical information systems (GIS), using technical assistance from government agency or other specialist agency. This will assist in presentation of results as well as enabling the data to be geographically referenced;
- Discussion of results in schools at regular intervals combined with education and awareness programme at schools and in public meetings about the linkages between health, water supply and current sanitation practices (with health officials). Education also to focus on basic hydrology and groundwater flow in small coral islands, and on sanitation and other potentially polluting land use practices (with water and health authorities and others). School projects could include analysis of various aspects of the monitoring and testing programme;
- Presentation and discussion of results at selected intervals to wider community and other stakeholders in the catchment (e.g. government agencies);
- Assess and recommend strategies for improved methods of sanitation and other land use practices;
- Encourage establishment of community-based catchment management committee, and encourage wider

participation within the community using appropriate media;

- Implement improvements during life of project, if possible. One option is to link this project with a composting toilet trial project (OPUS, 2001);
- Prepare report and other publicity material for wider dissemination about the project outcomes.

Suggestions for project implementation

- Involve a school (or schools) as a primary implementer of the project and, if possible, include the project in the school curriculum;
- Nominate a locally based group (e.g. NGO) to assist with project coordination;
- Use previous projects and proposals as a guide for designing the details of the monitoring and testing;
- Use relatively simple chemical and microbiological tests for the majority of the monitoring programme but also recognise that some tests (e.g. for baseline survey) will require support from a laboratory;
- Utilise technical assistance from government agencies and consultants with some aspects of the programme (eg stream flow measurements, microbiological tests). Contact WHO, Fiji for further information on suitable presence/absence tests for faecal coliforms or similar tests (e.g. H_2S test).

Complementary proposals and activities

- This project could be linked with the Community Dry Sanitation System (composting toilet) pilot project proposal;
- This project has linkages to a recent applied research project proposal on safe conjunctive land use in groundwater reserves (White, 1998);
- This project can build on the experience of a UNESCO/SOPAC sponsored study of groundwater pollution in Tonga (Crennan et al., 1998; Crennan, 2001).

Potential resource persons & agencies

- Christian Nielsen, Live & Learn Environmental Education, Suva, Fiji;
- Personnel from NGOs including FSPI and its affiliates, TNC and WWF (depending on country or countries selected);
- Personnel from Water Resources Unit, SOPAC, Suva, Fiji;
- Seema Deo, Environmental Education Officer, SPREP;
- Professor Ian White, Water Research Foundation of Australia, Canberra, Australia (project design and implementation);
- Dr Peter Dillon, Centre for Groundwater Studies, CSIRO, Adelaide, Australia;
- Dr Leonie Crennan, Ecological Sanitation, Stockton, Australia;
- Dr Don Sharp, WHO, Suva, Fiji;
- Local personnel in country or countries chosen for the project.

(for full contact details and potential roles refer to Annex IV)

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Potential Pilot Project No 3

'Leakage Watch'
(Community Awareness about Water Conservation through Monitoring, Education and Action)

Outline of Project

Measurement of water consumption and practical steps to reduce leakage and wastage to improve community awareness and understanding about water conservation.

Background and Problem Statement

Leakage of water from pipe distribution systems, and from plumbing fixtures and pipe joints in houses and other buildings is a major problem in water supply systems within Pacific Island countries and elsewhere. These problems not only occur in the larger towns but also in rural villages, which have pipe distribution systems. Losses of over 50% (of water supplied from source(s)) have been measured in some systems. The high level of waste usage, sometimes caused by taps left running, is also a concern in some islands.

Apart from leakage in piped water supply systems (operated by water authorities, government departments or private companies), additional leakage occurs in household and other plumbing systems. The reason is often due to poor joints, unsuitable materials and incorrect use of solvent cement. Other losses occur from leaking taps and plumbing fixtures including showers and toilet cisterns.

Water authorities in PICs are aware of the problems, and steps have been taken in some countries to implement leakage control programmes (SOPAC, 1999). Consumer education and awareness programmes have also been implemented. Further work in this area is required, particularly at community level to recognise the issues concerning water losses and impacts on water supply systems and water resources. Practical procedures can be initiated to measure the amount of water usage in houses and institutions (e.g. schools, offices and hospitals).

A number of the water authorities and other agencies have run radio programmes in which water conservation issues are discussed. Periodically, and often associated with projects concerned with water supply improvements, brochures and posters have been produced in local languages. Water conservation booklets have also been published with practical guides to water saving techniques. In recent years, World Water Day has been a focus of activities (e.g. poster competitions from school students) in some PICs. In 2000, SOPAC and SPREP staff combined to develop a water awareness campaign involving students from schools in different PICs. Students were encouraged to conduct awareness campaigns in their schools in addition to fixing leaking taps, while monitoring the effects of these measures (SOPAC, 2000).

In Niue, for instance, a leakage control programme has been active in recent years. This has led to a 55% reduction in the amount of water pumped, with a corresponding reduction in pumping costs. The reductions were mainly achieved by conducting a survey of all houses and fixing leaking taps, shower outlets and toilet cisterns.

Project Goal

To reduce water leakage and improve water conservation through education, monitoring, awareness and action.

Project Location(s)

Schools and other institutions in urban or rural areas that have water distribution systems.

Specific Objectives

- Improve awareness and understanding within communities about leakage in water supply systems. Emphasise the need for water conservation to lessen impacts on water resources and reduce costs of water supply operations;
- Identify the major causes of leakage and wastage;
- Demonstrate simple, inexpensive methods of repairing leaks and improving water conservation;
- Develop a simple manual on methods of water conservation and leak repair within houses and institutions.

Expected Outputs and Results

- Database of information about water usage before and after implementation of programme at selected sites;
- Report and presentation of the findings of the project to key stakeholders, including water authority or village water committee, as appropriate, and to wider community groups;
- Publication and distribution of a simple manual for water conservation and leak repair;

- Public awareness campaign and wide dissemination about the results of the project using appropriate media;
- Wide dissemination about the results of the project using appropriate media.

Project Tasks

The following staged tasks are suggested:

- Selection of site(s) based on identified problems;
- Consultation about the project with villages/communities and other stakeholders (e.g. water authority) in the selected area;
- Selection of partners to be involved in the project (e.g. school(s), NGOs, government agencies);
- Gather information about water usage within the community, from meters if available, or estimations as appropriate;
- Select site(s) for more intensive tests (e.g. schools, hospital). Fit water meter(s) on supply line(s) (if not already fitted) with assistance from water authority or village water committee;
- Fit simple data logger to selected meter to analyse flows in more detail. This would probably be best done at a school. Provide instruction in use of data logger and software required to download and analyse data;
- Take daily readings of water meter(s) and do weekly downloads of data from the logger;
- Analyse results to check water usage over period of 12 months;
- At start of project, conduct initial audit of all water outlets. Prepare database of all outlets (taps, showers, toilet cisterns, etc) noting condition of each. For all visible outlets record losses (e.g. no drips, x drips per minute, etc). For cisterns, estimate flows;
- Repair leaks in staged fashion (e.g. all taps in one week, all cisterns the following week). Note progressive reduction in water usage, particularly' night flows' when no or limited other water use is occurring;
- Analyse and synthesise data with technical assistance from appropriate agency or specialist;
- Discussion of results in schools at regular intervals combined with education and awareness programme at schools and in public meetings about the results and implications for water conservation (and possibly reduction in water bill). Education to focus on water conservation and impacts on water resources (less stress on them in droughts, lessen requirement to augment supplies, etc);
- Presentation and discussion of results at selected intervals to wider community and other stakeholders (e.g. water authority);
- Review other educational material on water conservation and develop own reference manual for use in local community;
- Conduct demonstrations on means of fixing leaks and general water conservation methods for community groups and individuals;
- Prepare report and other publicity material for wider dissemination about the project outcomes.

Suggestions for project implementation

- Involve a school as a primary implementer of the project and, if possible, include the project in the school curriculum;
- Nominate a locally based group (e.g. NGO) to assist with project coordination;
- Utilise services of technical expert in this area (e.g. from local water authority or other resource person);
- Use relatively simple data logger with simple software. Results can often better be shown and graphed in a spreadsheet package.

Complementary proposals and activities

- Leakage control programmes and other water conservation measures being implemented in several PICs by water authorities;
- SOPAC Water Resources Unit involved in demand management measures in several PICs;
- Active demand management schemes, including school education programmes operated by many utilities in larger countries. A good example is the Wide Bay Water authority for in Queensland, Australia, which has been active in this area for several years (Wide Bay Water, 2000). The Chief Executive, Mr Tim Waldron, has also been involved in leakage control and demand management projects in several PICs, including Solomon Islands and Tonga. He was also a chief resource person at a SOPAC workshop on Water Demand Management held in Fiji in 1999 (SOPAC, 1999).

Potential resource persons & agencies

- Personnel from Water Resources Unit, SOPAC, Suva, Fiji;
- Mr Tim Waldron, Wide Bay Water Authority, Hervey Bay, Queensland, Australia;
- Personnel from NGOs including FSPI and its affiliates, TNC and WWF (depending on country or countries selected);
- Seema Deo, Environmental Education Officer, SPREP;
- Local personnel in country or countries chosen for the project.

(for full contact details and potential roles refer to Annex IV)

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Annex IV Potential resource people and contact details

Potential resources people and contact details are listed below. The potential roles and project involvement for each person or organisation are also identified.

In addition to the above list, a number of Pacific Island people, currently working in the water sector in PICs, would also be valuable resource people within the countries selected for freshwater pilot projects. These could be nominated once the countries are selected.

Person, Organisation & Contact Details	Potenetial Role and Project
SOPAC Water Resources Unit Co-ordinate through: Clive Carpenter Manager Water & Sanitation Water Resources Unit SOPAC Private Mail Bag, Suva Fiji Tel: +679 381 377 Fax: +679 370 040 E-mail clive@sopac.org.fj	Advisory role Co-ordination with water sector personnel in island countries selected for water projects Assistance with design, implementation and evaluation Evaluation All projects
Foundation for the Peoples of the South Pacific International (FSPI) and its affiliated organisations in a number of PICs Co-ordinate through: Sylvia Troost Regional Program Coordinator FSPI PO Box 14447 Suva Fiji Tel: +679 300 392 Fax: +679 304 315 E-mail: sylviatroost@yahoo.com	Advisory role Co-ordination with local organisations and community groups in island countries selected for water projects Assistance with design, implementation and evaluation All projects
Bill Raynor Director FSM Country Program Director The Nature Conservancy Pohnpei Federated States of Micronesia) E-mail: braynor@mail.fm	Advisory role Co-ordination with local organisations and community groups in island countries selected for water projects Assistance with design, implementation and evaluation Project 1 in particular
Christian Nielsen Regional Director Live & Learn Environmental Education 25 McGregor Rd Suva Fiji Tel: +679 315 868 Fax: +679 305 868 E-mail: livelearn@is.com.fj	Environmental Education adviser Project 1

Person, Organisation & Contact Details	Potenetial Role and Project
Bob Curry National Institute of Water and Atmospheric Research (NIWA) PO Box 14-901 Kilbirnie, Wellington New Zealand Tel: +644 3860 584 Fax: +64-4 3860 491 E-mail: r.curry@niwa.cri.nz	Technical adviser re design, implementation & evaluation Surface water resources specialist Project 1
Professor Ian White Water Research Foundation of Australia Australian National University Canberra, ACT 0200 Australia Tel: +612 6125 0660 Fax: +612 6125 0757 E-mail: ian.white@cres.anu.edu.au	Technical adviser re design, implementation & evaluation Surface water and groundwater specialist Projects 1 & 2
Dr Stephen Winter Appropriate Technology Enterprises, Inc Chuuk Federated States of Micronesia Tel: 872 761 356338 (satellite phone) E-mail: swinter@mail.fm	Technical adviser re design, implementation & evaluation Projects 2 & 3
Mr Tim Waldron Chief Executive Wide Bay Water P O Box 45 Hervey Bay, Qld 4655 Australia Tel: +617 4197 4101 Fax: +617 4122 5118 E-mail: waldrons@msn.com.au	Technical adviser re design, implementation & evaluation. Specialist in leakage control programmes and associated community education programmes Project 3
Dr Paul Jones Urban Management and Planning Adviser The Virtual Consulting Group PO Box 321 Albury, NSW 2640 Australia Tel: +612 6041 1150 Fax: +612 6023 2768 E-mail: paul@virtualgroup.com.au	Technical adviser re design, implementation & evaluation. Specialist in urban planning in PICs Projects 1 and 2
Dr Peter Dillon Centre for Groundwater Studies CSIRO Adelaide Australia Tel: +618 8201 5632 E-mail: Peter.Dillon@adl.clw.csiro.au	Technical adviser re design, implementation & evaluation. Groundwater specialist Project 2

Person, Organisation & Contact Details	Potenetial Role and Project
Dr Leonie Crennan Ecological Sanitation 85 Dunbar St Stockton, NSW 2295 Australia ph: +612-4928 4074 Fax: +612-4928 4082 E-mail: l.s.crennan@bigpond.com	Technical and community education adviser re design, implementation & evaluation. Specialist in dry sanitation systems Project 2
Mr Hans Thulstrup Science Advisor, International Hydrological Programme contact UNESCO Office for the Pacific Island States Apia Samoa ph: +685 24276 Fax: +685 22253 E-mail: hans.unesco@org.ws	Liaison with UNESCO about its freshwater programmes in PICs including International Hydrological Programme (IHP) and Coastal and Small Islands Programme (CSI) and science education.
Mr Henry Taiki WMO Office Apia Samoa ph: +685 21929 Fax: +685 20231 E-mail: wmo.srop@sprep.org.ws	Liaison with WMO about its programmes in climate and water resources in PICs.
Mr Don Sharp Environmental Engineer World Health Organisation PO Box 113 Suva Fiji Tel: +679 304 600 Fax:+679 300 462 E-mail: sharpd@who.org.fj	Technical advisor re microbiological testing Projects 1 & 2

Annex V List of selected relevant websites

Organisation and Web Address	Potenetial Role and Project
Regional organisations with focus on water in PICs	
The Small Islands Water Information Network (SIWIN) http://www.siwin.org/ http://www.sopac.org.fj/Projects/Siwin	SIWIN is an initiative of the Commonwealth Science Council, the British Geological Survey and the UK Department for International Development. The aim is to provide water sector professionals on small islands with a forum for access to and exchange of information
South Pacific Applied Geoscience Commission (SOPAC) http://www.sopac.org.fj Water Resources Unit (of SOPAC) http://www.sopac.org.fj/Secretariat/Units/Wru/index.html For World Water Day, 2001 involvement refer: http://www.sopac.org.fj/Secretariat/Units/Wru/WorldWaterDay2001/wwd2001.html	The Water Resources Unit of SOPAC has a large involvement in Pacific Islands water and sanitation programmes.
Pacific Water Association (PWA) http://www.pwa.org.fj	Provides outline of PWA's purpose, membership, services offered, work programmes, news items and tenders.
Water Resources Research Centre (WRRC), University of Hawaii http://www2.hawaii.edu/~wrrc/WRRC.html	Lists programmes and publications including water research projects.
Pacific Islands Climate Change Assistance Programme (PICCAP) http://www.unitar.org/cctrain/PICCAP.htm	Provides details of PICCAP including training packages and workshop, library.
Water and Energy Research Institute (WERI), University of Guam www.uog.edu/weri/	Lists programmes and publications including water research projects.
Water and Energy Research Institute (WERI), University of Guam www.uog.edu/weri/	Lists programmes and publications including water research projects.
Selected NGOs with some involvement in water resources, water supplies and catchment management in PICs	
The Schools of the Pacific Rainfall Climate Experiment (SPaRCE) http://www.evac.ou.edu/sparce	Provides details of this climate programme in PICs with examples and links to other sites.
Foundation for the Peoples of the South Pacific International (FSPI), Suva and Vanuatu http://www.fsp.vu/fspi/	Provides information about FSPI programs and affiliated organisations in many PICs.
The Nature Conservancy (TNC) http://www.TNC.org	Provides links to TNC's work in some of the PICs including Federated States of Micronesia, Palau, Papua New Guinea and Solomon Islands.
Greenpeace http://www.greenpeace.org	General information about Greenpeace activities but nothing specific about work in PICs.
World Wide Fund for Nature (WWF) http://www.wwf.org	General information about WWF activities but nothing specific about work in PICs.

Organisation and Web Address	Potenetial Role and Project
Organisations with focus on water supply and sanitation at community or local level in developing countries	
IRC International Water and Sanitation Centre http://www.irc.nl/ircdoc	Provides information, advice, research and training on low-cost water supply and sanitation in developing countries.
Water and Environmental Health (WELL) http://www.lboro.ac.uk/well/	Provides information about studies, reports and other publications.
Lifewater Canada http://www.lifewater.ca/ndexman.htm	Provides practical information on community water supply improvements.
International Rainwater Catchment Systems Association http://www.ircsa.org	For the promotion and advancement of rainwater catchment systems and technology. Provides international forum for all concerned with rainwater catchments.
Rainwater Harvesting Research Group http://www.rainwaterharvesting.com	Provides details of relevant publications, organisations, conferences about rainwater harvesting and links to other sites.
International and other organisations with focus on water resource, water supplies and catchment management	
UNESCO's 'Water Portal' http://www.unesco.org/water	Provides links to the current UNESCO programmes on freshwater (e.g. IHP and CSI) and to websites of water-related organizations, government bodies and NGOs, including a range of categories such as water links, water events, learning modules and other on-line resources (for specific information concerning PICs contact Hans Thulstrup at UNESCO office, Apia, Samoa).
World Meteorological Organisation (WMO) http://www.wmo.ch/	International agency with focus on climate and water resources assessment (for specific information concerning PICs contact Henry Taiki at WMO office, Apia, Samoa)
World Health Organisation (WHO) http://www.who.int	International agency with focus on human health including water supply and sanitation improvements (for specific information concerning PICs contact Don Sharp at WHO office, Suva, Fiji).
World Water Vision http://www.worldwatervision.org	Envisages a world where all people have access to enough safe water to meet their needs including agricultural needs within management plans that maintain the integrity of freshwater ecosystems..
Water Supply and Sanitation Collaborative Council (WSSCC) http://www.wsscc.org	WSSCC is an international organization aiming to enhance collaboration in the water supply and sanitation sector, specifically in order to attain universal coverage of water and sanitation services for poor people around the world.

Organisation and Web Address	Potenetial Role and Project
Global Applied Research Network (Garnet) http://www.lboro.ac.uk/departments/cv/wedc/garnet/grntover.html	Provides a mechanism for information exchange in the water supply & sanitation sector using low-cost, informal networks of researchers and practitioners.
International Water Association http://www.iwahq.org.uk	Provides information on all aspects of water supply and treatment, wastewater collection, treatment and disposal and overall management of water quality and quantity including environmental and public health issues.
World Resources Institute (WRI) http://www.wri.org/watersheds	WRI provides information about , watershed degradation and management issues and list publications and other sources.
Watershed Information Technical Systems (WITS) http://www.ceres.ca.gov/watershed/	Provides information and tools to support local watershed planning, restoration, monitoring and education (based in California, USA).
FAO Community Forestry Unit (CFU) http://www.fao/forestry/FON/FONP/cfu/cfu-e.stm	Provides information about the CFU and efforts to strengthen participatory processes in forestry.
Small island websites, not specifically related to water	
International Scientific Council for Island Development (INSULA) http://www.insula.org/	Aims to contribute to the economic, social and cultural progress of islands throughout the world, as well as to the protection of island environments and the development of their resources.
The Small Island Developing States Network (SIDSNET) http://www.sidsnet.org/	Provides mechanism for sharing information on common issues between small island developing states covering a wide variety of themes (biodiversity, climate change, coastal and marine, energy, tourism, trade and others. Also provides links to other sources of information on freshwater resources issues.

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Note: these references, additional to those in Section 8, are from a number of sources. Those held at the SOPAC Library, Suva, Fiji have a 'Location' at the end of the reference.

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