Chapter 23
Integrated Management of Urban Water Supply and Water Quality in Developing Pacific Island Countries

Ian White and Tony Falkland

1 Introduction

The general fragility and unique vulnerability of small island countries in the Pacific (see Fig. 23.1) to climatic, demographic, economic, and development pressures, as well as to natural hazards and extreme events, has been widely acknowledged for a long time (UNDESA 1994). So too has been the diversity of their geography, geology, and sources of available freshwater (Table 23.1). These are is particularly evident when it comes to managing the freshwater supply systems in urban centres on small islands whose typical land area is only 1–10 km^2. Some population centres in the Pacific and Indian oceans are close to – or have already exceeded long-term sustainable water extraction limits (White and Falkland 2011). Frequent severe droughts the El Niño–Southern Oscillation (ENSO), floods, cyclones, tsunamis, earthquakes, and volcanic eruptions coupled with limited resources and the capacity to respond to extreme events, compound freshwater supply problems.

Sparse island communities have demonstrated their remarkable resilience in the face of climatic extremes and natural hazards over the last 1,000–12,000 years. Despite limited financial, technological, and infrastructure resources, the well-developed local institutions, resilient social systems, sensitivity to environmental change, and the high value placed on equity in Pacific islands have provided capacities for adapting to threats and change and have allowed low density subsistence populations to survive (Barnett 2001).

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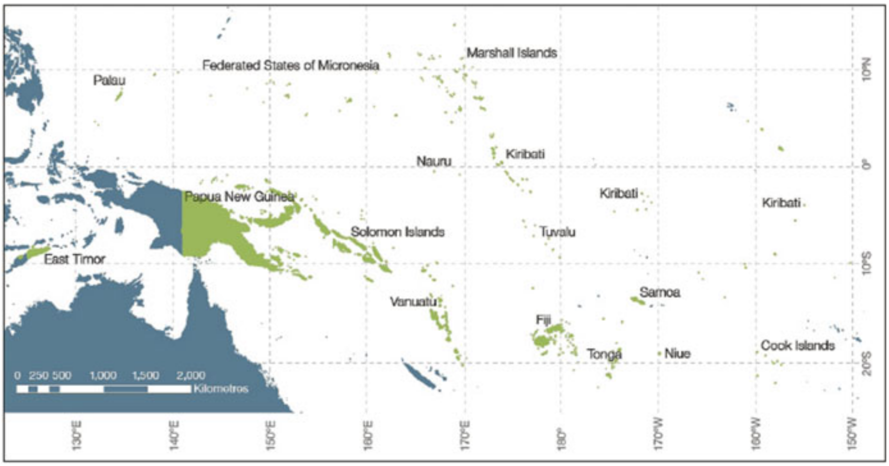

Fig. 23.1 Location of some of the Pacific Island countries in the central and south Pacific (PCCSP 2010)

Traditional coping mechanisms and customary rights and values, however, appear mismatched to the demands, responsibilities, and altered social dynamics of high-density urban centres, many of which are in an interactive phase between subsistence and urban living (Jones 1997; White et al. 1999a, 2008). To compound problems, many smaller Pacific island countries (PICs) have few trained water and sewage management personnel, and limited resources with which to tackle the challenges of urban living. The predicted effects of climate change, particularly sea-level rise (BOM and CSIRO 2011), add to the already complex challenges faced in urban centres in PICs.

Our initial entrée into this sector in the Pacific was as hydrologists and water engineers. Over the years it has become increasingly apparent that many factors beyond the technical contribute to the success or failure of water and sanitation projects in the region, and require attention. In this chapter, we outline the interactions between technical, climatic, social, and cultural factors in urban water supply and water quality in PICs. In working in many PICs over the last 35 years, our experience has been that to improve urban water supplies, policy makers, donors, and practioners need to recognise and address these complex interactions in an integrated way. Single-issue, infrastructure-focused solutions that have not engaged local communities have had a poor success rate in the region.

1.1 Water Security in PICs

A recent report (Falkland 2011) compared risks to water security from both climate change and non-climate factors in East Timor and 14 selected PICs – Cook Islands; Federated States of Micronesia (FSM); Fiji; Kiribati; Nauru; Niue; Palau; Papua

Table 23.1 Geographical and geological characteristics of Pacific Island countries and East Timor, and main sources of freshwater (Adapted from Falkland 2011)

Country	Land area (km^2)	Number of atolls or islands	Highest elevation (m)	Island geology	Main freshwater sources[a]
Cook Islands	237	15	652	Volcanic, limestone, atolls, mixed	SW, GW, RW
Federated States of Micronesia	701	607	791	Volcanic, atolls, mixed	SW, GW, RW
Fiji	18,273	322	1,324	Volcanic, limestone, atolls, mixed	SW, GW, RW, D (resorts)
Kiribati	811	33	87	Atolls & reef islands, limestone island	GW, RW
Nauru	21	1	71	Limestone	RW, GW (limited)
Niue	259	1	68	Limestone	GW, RW
Palau	444	~250	213	Volcanic, with some limestone	SW, GW, RW
Papua New Guinea	462,840	~600	4,509	Volcanic, limestone, atolls, reef islands, mixed	SW, GW, RW
Republic of the Marshall Islands	181	34	10	Atoll and reef islands	SW, GW, RW, D (emergencies)
Samoa	2.785	10	1,857	Volanic	SW, GW, RW
Solomon Islands	30.407	922	2,335	Volcanic, limestone, atolls, reef islands	SW, GW, RW
Tonga	650	176	1,033	Volcanic, limestone, reef islands, mixed	GW, RW, SW (limited)
Tuvalu	26	9	6	Atolls	RW, GW (limited), D (emergency)
Vanuatu	12,281	82	1,877	Volcanic with coastal sands and limestone	SW, GW. RW
East Timor	14,922	3	3,033	Mixed igneous, metamorphic, and sedimentary	SW, GW, RW

[a]*SW* surface water, *GW* groundwater, *RW* rainwater harvesting, *D* seawater desalination

New Guinea (PNG); Republic of Marshall Islands (RMI); Samoa; Solomon Islands; Tonga; Tuvalu; and Vanuatu (see Fig. 23.1). It concluded that, throughout the region out to the year 2030, the non-climate factors: increasing water demand; water pollution due to expanding populations; leakage from pipe systems and unaccounted-for water; poor water governance; and inadequate management; pose much greater risks to water security than does climate change. The most vulnerable areas identified were: densely populated urban and peri-urban settlements; remote communities; and communities in low-lying areas, particularly those in low coral atolls and carbonate islands with no fresh groundwater resources.

1.2 Urbanisation and Water Quality

Across the Pacific region, the percentage of urban dwellers in total populations ranges from about 20–100 %. About 50 % of islanders in the region are able to access improved water supplies although not all urban centres have treated, reticulated water supplies, as evidenced by the health statistics for water-borne illnesses (WHO 2005). Increasing urban population growth and inward migration (Ward 1999) mean that population densities are often high, with some exceeding 10,000 people/km^2. These densities, inadequate sanitation, the added burden of waste from domestic animals (especially pigs), and rudimentary waste disposal systems mean that the quality of shallow groundwater or neighbouring streams, on which communities depend, is often compromised. As a result, death rates and diseases due to preventable water-borne illnesses are tragically high in PICs, particularly among infants and the elderly (Fig. 23.2).

Following a major diarrhoeal outbreak in children in urban South Tarawa, the capital of Kiribati (Fig. 23.1), where treated freshwater remains in chronic short supply, the government of the republic requested assistance in upgrading water supply and sanitation systems. A field appraisal of the situation by the Australian International Assistance Bureau's (AIDAB) Pacific Regional Team (AIDAB 1993) concluded that the problem in South Tarawa was critical and should be addressed in as comprehensive manner as possible if sustainable and effective development was

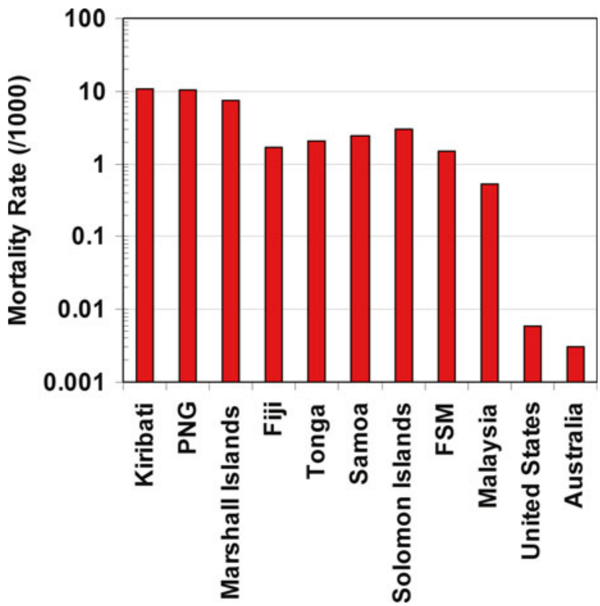

Fig. 23.2 Comparison of infant (<5 years) mortality rates per 1,000 due to diarrhoeal diseases for selected countries (data from WHO 2005)

to be achieved. It recommended a multidisciplinary, coordinated, long-term (at least 10 years) program with multiple components, including community health, education, water supply, sanitation, appropriate technology, and institutional strengthening and management, all conducted in parallel and with annual budgets of several million (1990) Australian dollars (AU$).

Sadly, this early recommendation for strategic integrated water resource management (IWRM, see e.g. Carpenter and Jones 2004), which embraced the cultural, social, governance, economic, geographic, and climatic contexts was shelved. Nonetheless, the Regional Team's appraisal exemplifies the fact that responses based on infrastructure alone are inadequate to meet the complex interacting factors encountered in urban water supply systems in the Pacific.

1.3 Scope of This Chapter

We concentrate in this chapter on freshwater management in urban settlements in PICs, recognising the important climatic, hydrogeological, cultural, and social contexts within which water supply is managed. Water supply systems in urban areas in the Pacific are extremely diverse, ranging from reverse osmosis desalination plants, through fully treated reticulated and treated water supply systems, to household rain tanks and shallow household groundwater wells bailed out with a bucket. Many households use multiple water sources of varying water quality, including seawater to supply their water needs. Despite this diversity, there are some common themes which apply across most urban areas.

Application of simple single-issue solutions, such as water infrastructure development or imposition of water tariffs, to complex urban water supply challenges in PICs have tended to be unsuccessful. Approaches are required which recognise the geographic, climatic, cultural, social, and economic contexts and the strengths and resilience of Pacific islanders and address the key issues broadly. We examine in this chapter issues connected with island development and water, water governance, assessment and monitoring of water resources, management and protection of water sources, management of demand and losses, capacity building, and the role of regional organisations and community empowerment in coping with climate variability and change.

2 Development, Water, and Aid

It has long been recognised that water plays an important role in creating wealth and in advancing national development (see e.g. AusAID 2003). Donor agencies have consequently funded many large water infrastructure projects in small island communities. It has been pointed out, however, that these have resulted in the loss of householder responsibility for water conservation and protection (Crennan 2002).

In other developing regions, widespread criticism of aid infrastructure projects has led to calls for 'pro-poor' development growth assistance with emphasis on improved management efficiency, institutional reforms, and community participation. Poverty in the Asia–Pacific is claimed to stem from institutional weakness and policy failures that prevent countries from taking advantage of the opportunities of globalisation and coping with its risks (Kaosa-ard 2003).

Lessons from other regions in the world that rely on freshwater both for subsistence and development are pertinent to PICs. In the Mekong, six factors have been identified that could cause relative poverty or disadvantage to increase (Kaosa-ard 2003).

1. Continuing deterioration of natural resources, on which the poor depend;
2. The conflict between national laws and customary rights;
3. Spending of public resources on large infrastructure projects rather than on social investment;
4. Inherent inability to transfer the opportunities of globalisation to the poor and its relation to property rights;
5. Institutional failures, conflicting jurisdictions and agendas between government agencies; and
6. Reluctance to empower community participation in natural resource management.

Some of these factors are apposite to PICs. It must be emphasised, however, that most Pacific islanders own or have access to land, so that true poverty as understood by Pacific people in the sense of landlessness is seldom encountered in the region (Barnett 2005; Pacific Forum Secretariat 2007). Also, the potential for small island communities to participate in the benefits of globalisation through improved irrigation are limited by restricted land areas, acute water shortages during dry times, and their isolation from markets. Some niche markets exist, such as the production of squash pumpkins in Tonga (van der Velde et al. 2007), but these are mainly confined to larger, higher, volcanic islands with fertile soils. Tourism could increase wealth generation in atolls, as in the Maldives, but it has high per capita water demands.

Aid and donor programs addressing institutional and governance weakness, policy failure, property and customary rights, community empowerment, and the deterioration of water and associated land resources – together with providing the broad community with appropriate knowledge and information – may provide the greatest benefits in PICs (White et al. 2007a). These, however, require long-term commitment and partnerships with regional, local community, and non-government organisations.

3 Water Governance

Impaired governance is claimed to be the main obstacle to better and more equitable water sharing, and improved water supply and services, in many water-stressed countries (Solanes and Jouravlev 2006; UNWWAP 2006). Importantly, improved governance is one of the four key priorities of the 2005 Pacific Plan (Pacific Islands Forum Secretariat 2007). One of the Plan's key governance strategies is 'improved transparency, accountability, equity and efficiency in the management and use of resources in the Pacific'. This strategy recognises that there are significant challenges in the governance of natural resources in the region which are especially evident in the water sector. This is emphasised in the Pacific Regional Action Plan (RAP) on Sustainable Water Management (SOPAC and ADB 2003) which identifies common themes across the Pacific region and calls for:

1. National water sector assessments;
2. Broadly-based national water vision;
3. National water action agenda and plans;
4. Empowerment of communities;
5. Design of capable institutions;
6. Integrated investment plans;
7. Regional support; and
8. Dialogue with investors and donors.

Problems identified by the RAP included the general absence of national government water policy; implementation plans; water resource legislation; and a lack of capacity and resources to develop and implement them. Public policy is an authoritative response by government to public issues or problems that provides leadership, direction, coordination, and resources (Bridgman and Davis 2004). The absence of national policy, legislation, implementation plans, and whole-of-government and community national steering committees in some PICs means that government priorities in the sector remain unspecified; resources are not directed towards particular needs; the roles and responsibilities of government agencies are not clearly defined; and, in many cases, there is no legal protection for water sources. In addition, there is a general absence of peak national water and sanitation bodies made up of members drawn from relevant ministries, agencies, and community organisations to advise government. A summary of the current state of progress in water governance in 14 PICs as well as East Timor is shown in Table 23.2.

Several of the countries in Table 23.2 have, with external assistance, had draft policies, plans, and legislation prepared, some for several decades, but they have not been submitted to parliament for consideration and endorsement. Table 23.2 reflects a general reluctance to announce national water policies and plans, enact national water legislation, define rights and responsibilities, adopt whole-of-government approaches, and involve communities in planning and managing water resources and related land resources. Part of this reluctance stems from the fact that, until recent urbanisation, water supply was largely an extended family or clan responsibility, while sanitation was an individual concern. Many PICs, however, have recent intermediate- to long-term sustainable development policies, plans, and vision statements in keeping with the Pacific Plan, most of which reflect the general community aspiration for improved and safer water supplies and appropriate sanitation services (see e.g. NDS 2011).

Table 23.2 Summary of water governance progress in 14 selected PICs and East Timor (modified from Falkland 2011). Dark grey – absence of instrument; light grey – draft instrument exists; no shading – instrument exists

Country	Water and sanitation policy	Water legislation	IWRM plans or similar	National water and sanitation committee or similar
Cook Is				
Federated States of Micronesia				
Fiji				
Kiribati				
Nauru				
Niue				
Palau				
Papua New Guinea				
Republic of the Marshall Islands				
Samoa				
Solomon Is				
Tonga				
Tuvalu				
Vanuatu				
East Timor				

3.1 Resource Ownership and Customary Rights

Part of the reluctance to endorse national water policy, plans, and legislation stems from wide-spread customary rights and the tradition that land ownership implies resource ownership, including adjacent surface water and underlying groundwater (White et al. 2007a). In many PICs, virtually all land is owned by traditional owners. This means the creation of water reserves on privately owned land to protect streams, catchments, reservoirs, or groundwater sources creates conflicts between governments and landowners, sometimes resulting in vandalism of water infrastructure (White et al. 1999a), disruption of services, or blockades, leading to the abandonment of suitable public water or hydropower sources (Low 2011).

Land ownership is fundamentally important in many PICs and is complex and very diverse even within single countries (Foukonga 2007). It is the primary source of wealth. Traditionally it confers subsistence rights, including fishing rights, on land owners and also provides a social security system for parents through the prospect of inheritance by their children who are therefore obliged to care for their parents (Jones 1997). The concept of ‘public use’ – of governments controlling private family lands for water supply to communities and villages remote from the water reserve – is often considered to be to the detriment of local obligations to the extended family and the local community. ‘Public use’ is a foreign concept in many island communities. From the landowner’s view, their long-term relationship with the land and its role in providing daily food for subsistence living for family members far outweighs any need of the government for public good (Crennan 1998).

In many PICs, constitutional law has supplanted customary law. The deep-seated belief, however, that land ownership also confers water ownership means that governments are reluctant to enact water policy or legislation which specifies that freshwater resources belong to the government, or to ban land uses with the potential to pollute water sources for fear of infringing landowner property-use rights. This issue is of extreme political sensitivity. As a consequence, in some PICs there is no legal protection of water from over-extraction or from contamination or misuse. In some cases, more than adequate water resources exists in remote regions of an island, but its transfer to urban areas in times of severe deficit, or its use for hydropower production, is virtually impossible because of land ownership issues (Low 2011).

The impact that traditional land and resource ownership has on national development has been recognised throughout the Pacific. The Prime Minister of Vanuatu, together with the Council of Chiefs, has recently commenced nation-wide negotiations on land reforms (C. Ioan, pers. comm., October 2013).

Many landowners also question the right of government to charge for water abstracted from private land. There is a general view that water is ‘a gift from God’. This view makes controlling demand through water tariffs a contentious issue and one which threatens the financial sustainability of urban water systems in several PICs (Low 2011; White 2011c).

While customary rights in relation to water ownership was appropriate in low-density, subsistence conditions it is ill-suited to high-density, urban populations where one household’s actions can immediately and directly impact both the quantity and quality of water available for its neighbours. Because customary rights are ingrained, it has been proposed that behavioural change is necessary for conserving and protecting water through longer-term education, awareness, and community engagement (Crennan 2002).

3.2 Development of Policy, Plans, and Legislation

An implicit assumption underpinning many attempts to assist PICs to develop national policy and plans is that the plethora of water policy frameworks, and policy and planning “tool kits”, available from developed world countries (see e.g. GWP 2003) are directly and rapidly transferable to developing countries. The assumption here is that such approaches are context-independent. But experience has shown that quick, developed-world formulaic solutions, which take no account of island priorities, traditions, strengths and practices that have evolved over millennia, are often politely but firmly ignored.

There are no easy prescriptions for the rapid translocation of relatively recent water governance reforms and water management frameworks from developed countries to developing PICs. There is often an underlying presumption that there are well-developed policy processes in place. In some PICs, policy processes are vague, not clearly defined, or even non-existent. In addition, they assume that there are adequate means to implement policy, plans, and legislation. In developed countries, there are frequently hundreds of people engaged in the implementation of policy, planning, and management of water resources whose ownership by the state is clearly legally defined. In this case, the major priorities are addressing the environmental impacts of water supply extraction and effluent treatment systems, controlling demand through long-established market mechanisms, and accommodating the predicted impacts of climate change.

In many small PICs, there are often only one or two trained water professionals whose tasks may range from replacing washers in domestic taps, replacing pumps, and unblocking clogged sewers to advising the minister and representing the country at international meetings. The major daily challenges in water governance they face are maintaining, even intermittently, supplies of adequate quantities of safe freshwater to growing populations – with very limited resources, no economies of scale, and coping with the complex cultural, social, and institutional changes necessary to move from subsistence to urban living.

Attempts to assist small island states to develop water policy, plans, and legislation must recognise local contexts, capacities, and inherent strengths of island communities (Barnett 2001) and be based on successful public policy principles. Some of the keys to effective, efficient, and widely-accepted public policy are (adapted from Sabatier and Mazmanian 1979):

1. The policy must be supported by the government;
2. Policy and associated implementation mechanisms are based on sound knowledge;
3. The policy, the law that gives effect to the policy, and its implementation contains clear policy directives;
4. Those responsible for implementing the policy have appropriate managerial political skills, information, and resources;
5. Policy and associated implementation mechanisms are actively supported by constituent groups; and
6. The relative priority of the policy's legal objectives is not undermined by other laws, policies, and implementation mechanisms.

Where there are multi-level or multi-agency governance arrangements, an additional key is:

7. Appropriate management structures exist that facilitate negotiations, agreements, and monitoring of implementation.

In assisting PICs to develop water policy and plans, a key strategy is to build on inherent island strengths using the well-developed local institutions, resilient social systems, and sensitivity to environmental change (Barnett 2001, 2005). Fortunately, extensive national consultations (Carpenter et al. 2002) prior to development of the Pacific RAP provided opportunities for island communities to raise their concerns and priorities over water and sanitation, so in most PICs there is already widespread community support for change and improvement. Challenges, however, arise at the organisational level of government, where agencies have a strong tendency to act as ‘silos’.

3.3 Peak Water Bodies

Urban water resource management in PICs encompasses health, environmental, economic, social, cultural, infrastructural, economic, and technical issues. Because of this, it is essential in small island states that all government agencies, community organisations, and businesses who have responsibilities and interests in freshwater participate in deliberations on policy and plans and in reviewing outcomes. The establishment of a whole-of-government, agency and community-representative peak bodies (such as a National Water and Sanitation Coordination Committee reporting to cabinet, or the designated lead government water agency) provides a PIC-relevant mechanism to help drive the policy development process, as well as to oversee policy implementation, progress, reporting, and dissemination (White et al. 2009a).

Debates have recently centred on the efficiency of engaging communities in water planning, especially in developed countries (see e.g. Daniell 2012). In island life, negotiation and consensus are fundamentally important in reaching decisions, so although the development of policy can be a lengthy process it is fundamentally necessary to gain widespread support. The process used in the Republic of Nauru (Fig. 23.1) is shown in Fig. 23.3, with the peak government–community water and sanitation body, CPSC, playing a pivotal role in driving an iterative policy development process (White and Falkland 2012).

3.4 Adaptive Process for Policy Development

In assisting Solomon Islands and the republics of Nauru and Kiribati to develop their national water policies and implementation plans, a 5-phase adaptive planning process (adapted from Ackoff 1999) was used with the respective peak bodies. This process is summarised in Table 23.3. The first two phases of the process identify priority issues to be addressed and to corresponding policy goals. The remaining three phases help construct the policy implementation plans.

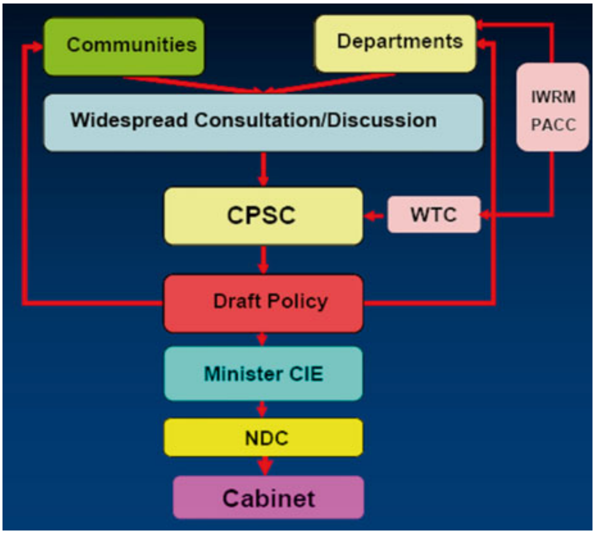

Fig. 23.3 Iterative process used in the Republic of Nauru for developing a draft national water, sanitation, and hygiene policy. CPSC is the Department of Commerce, Industry and Environment's (CIE) whole-of-government and agency–community Project Steering Committee. CPSC is advised by the whole-of-government and agency Water Technical Committee (WTC) convened by the Integrated Water Resource Management (IWRM) and Pacific Adaptation to Climate Change (PACC) project coordinators. Once the draft policy has been approved by CPSC and the responsible minister, it is submitted to the heads of departments and agencies National Development Committee (NDC) for consideration of cabinet

This process is easily understood, even in countries with loosely defined or non-existent policy processes, and assists in identifying pressing problems, priority goals, and the steps necessary to achieve them. Common issues appear in many PICs: a lack of knowledge of the amount, quality, or use of resources being managed; inadequate water supplies; unreliable or compromised water quality; financially unsustainable water supply systems; absence of effective demand management or unacceptable water losses; lack of community participation in the conservation and protection of water sources; poor or inadequate governance; and lack of resources and capacity to manage water resources and supply systems. Many of the pressing current and future problems in PICs appear to be addressed through eight policy objectives (White and Falkland 2011):

1. Improve understanding, assessment, and monitoring of water resources and their safe yields, quality, and sectoral use;
2. Protect and manage sources of freshwater;
3. Increase access to safe and reliable water supplies and appropriate sanitation;
4. Achieve financially, environmentally, and socially sustainable water resource and supply management;
5. Increase community participation in water management and conservation;

Table 23.3 The five phases of interactive planning used in developing national water policy and implementation plans (Adapted from Ackoff 1999)

Phase	Objective	Components	Principal outputs
I. Formulation of the issues	Determine issues, problems, and opportunities	Previous actions and policies; recognised issues; problems, opportunities, and their interactions; constraints to effective management	Issues to be addressed by policy, plans, legislation
II. Ends planning	Determine where you want to be and the gaps between that and now	Extract vision, principles, goals, and objectives to achieve the desired ends	Policy principles, policy goals and objectives
III. Means planning	Choosing mechanisms to achieve goals and objectives	Develop and select actions for achieving goals and objectives and indicators for completion of actions	Implementation plan actions
IV. Resource planning	Determine resources required for planned actions	Define resource needs and identify if resources are available or how they will be generated or acquired	Needs for implementation plan resources
V. Implementation and control	Determine responsibilities and schedules for implementation	Identify who is responsible for actions, when they are to be implemented, and how implementation is to be monitored	Implementation plan schedule and responsibilities for implementation. Inclusion in ministerial operations plans

6. Improve governance in the water and sanitation sector, use the principles of integrated water resource management, and regularly review policy outcomes and planning milestones;
7. Improve management of risk in natural hazards and extreme events; and
8. Provide resources, training opportunities, and mentoring for staff in the sector.

4 Resource Assessment and Monitoring

The first key principle in the list of Sabatier and Mazmanian (1979) for successful public policy (Sect. 3.2) is that policy and associated implementation mechanisms should be based on sound knowledge. In some PICs this remains a challenge. The full extent of their water resources, their quality and fitness for use are often only partly known; the sustainable yields are poorly characterised; the impacts of climate variability, water extraction, and land use on the resources are inadequately characterised; the demand for and use of freshwater by sectors is incomplete; and the impact of management regimes and policy decisions only partly recognised. A range of techniques, from simple approximations through to sophisticated geophysical techniques and modelling, are available for assessing the extent of water resources, their sustainable yield, and the quality of the water extracted (UNESCO 1991; Falkland 2002a, b).

These knowledge gaps are especially evident for vulnerable low, small island and atoll groundwater systems supplying growing urban areas, a situation where thorough resource assessment is required along with a commitment to ongoing monitoring, analysis, and reporting. In these systems, the salinity of the extracted groundwater is a result of the dynamic balance between rainfall recharge, pumping rates, and seawater intrusion. Regular monitoring ensures that sources remain viable (Falkland 2002a, b; White and Falkland 2010). PICs in the central and central western Pacific exhibit extreme variability in rainfall, which is closely correlated with sea surface temperature (Fig. 23.4). Faced with this variability, monitoring of rainfall, groundwater level, and salinity, as well as water extraction rates, is vital.

While monitoring is always contentious even in developed countries, the importance of monitoring is exemplified in one small urbanised island during the widespread 1998–2001 ENSO-related drought. A national state of disaster was declared by the government when urban supplies diminished, despite the fact that the main groundwater source contained more than adequate freshwater to meet reasonable demand. The lead water agency had stopped monitoring groundwater during the

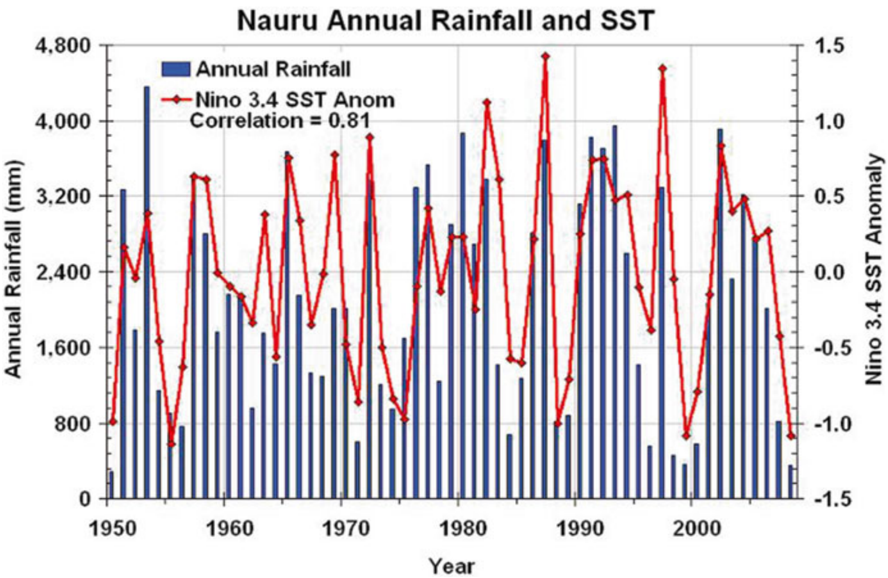

Fig. 23.4 In Nauru there is a strong correlation (0.81) between the large variability of annual rainfall and the variability of annual sea surface temperature anomaly in the Niño 3.4 region of the central-western Pacific (White 2011a)

drought, so the actual availability of water was unknown. The real problem was an inadequate and leaking urban water distribution system. Limited human and financial resources in many PICs mean that assessment, monitoring, reporting, and dissemination of information, even to government, are major challenges (van der Velde et al. 2007).

The establishment of peak government–community water and sanitation committees, with responsibilities for oversight of water resources and for reporting directly to government (Sect. 3.2), can promote regular monitoring, analysis, reporting, and wider dissemination of information; the committees need terms of reference that specify regular inter-agency discussions and reporting on the condition and use of water resources.

5 Protection of Water Sources and Water Quality

Island communities rely on a variety of public and private sources of surface water and groundwater, harvested rainwater, bottled water, brackish water, and even seawater. Strategies for ensuring that the quality of water supplied from surface and groundwater sources for communities is fit for consumption are based on the concept of maintaining multiple barriers to contamination between source and consumption. Protection of water sources from contamination and misuse is a prerequisite first step which requires effective land use planning and zoning, and regulation of land uses in areas around surface water sources and on land overlying groundwater sources. Human settlements, agriculture involving the raising of livestock, the use of chemicals and fertilisers, mining forestry, waste disposal, and especially defective or inappropriate sanitation systems all increase the risk of water contamination. Creation of water reserves surrounding water sources, however, are often problematic owing to land and resource ownership issues (Sect. 3.1) and unclear legal rights and responsibilities.

5.1 Water Reserves

The establishment of water reserves, by current governments and former colonial powers, in order to protect water sources has often failed to appreciate local community needs, culture, land tenure, and land use requirements. Such decisions have led to conflicts between local communities and government agencies, which have sometimes manifested in vandalism of infrastructure, disruption of supply, and demands for compensation by landowners (Low 2011). The impact of water resource development on the health and productivity of neighbouring traditional crops grown on or near water reserves is of social and economic concern to landowners, particularly where land use and access rights have been forbidden or severely limited (White et al. 1999a).

The tensions between ‘public use’ private family lands by governments for water supply and the landowers’ need for unrestricted access to their land for subsistence leads to long-standing conflicts. The resolution of land use conflicts requires appropriate legal, administrative, and financial provisions and the involvement of the local community in managing the reserve, or in some PICs even the local water supply system. Where land is limited, the provision of social amenities such as non-polluting sports fields on reserves appears possible (White et al. 1999a).

Because of the central, social importance of landownership, many governments believe that outright purchase of water reserves is not politically feasible. Instead, some PIC governments pay commercial rentals or annual compensation to land owners. Rental or compensation payments have three distinct disadvantages. First, they impose a heavy, continuing financial burden on water supply systems. Second, they tend to encourage misuse of the reserves since they are viewed as ‘government’ land with common property uses, including gravel mining and water disposal, and they generate disputes within the communities. Finally, there appears to be little overall long-lasting social benefits from cash payments.

5.2 Water Reserve Management Committees

In order to overcome misuse of reserves it has been suggested that, rather than pay water reserve landowners rental as compensation for loss of amenity, they be paid as water reserve managers with a contract to ensure that reserves are well cared for (White et al. 1999a). Involving local landowners in water reserve management committees can be a successful strategy in engaging island communities in the protection and care of water sources and in identifying land uses that minimise impact on water sources. Village-level water committees have proved successful in rural areas in Tonga and Samoa and offer a potential model for other PICs. These, however, need to be underpinned by legal protection for water sources from contamination and misuse, and the agency or agencies responsible for managing water reserves require a clear mandate and legal authority to enforce laws.

5.3 Appropriate Technology

Isolation, coupled with the generally corrosive conditions in PICs, dictates that the infrastructure used to extract, store, and supply water must be robust, and simple to operate, maintain, and repair (UNESCO 1991). In addition, the unique hydrogeology of groundwater in low, small islands requires the use of appropriate technology to maximise freshwater yield. The delicate hydrostatic balance between freshwater and the surrounding and underlying seawater in small islands is easily disturbed by inappropriate groundwater development. The most common method of accessing groundwater uses hand-excavated dug wells typically 2–3 m deep and approximately

1 m below the groundwater level. Groundwater is abstracted by buckets, hand pumps, or small electric pumps. Such systems work well at household levels, provided abstraction rates are low.

For public water supply pumping systems, single or multiple dug wells or drilled boreholes have been used on some small islands. These vertical abstraction systems can cause upconing of underlying brackish water or seawater, causing increases in salinity of the abstracted water to levels that are sometimes too high for potable use. Pumping from long, horizontal infiltration galleries (up to 300 m long) or skimming wells has proven to be a far better abstraction method, particularly in islands with thin freshwater lenses (Falkland and Brunel 1993).

Infiltration galleries skim fresh groundwater from the surface of a freshwater lens, and thus distribute the pumping drawdown over a wide area. In so doing, they avoid excessive local drawdown and upconing of saline water associated with pumping from vertical boreholes. Infiltration galleries are used for public water supply in Tarawa and Kiritimati atolls, Kiribati; Majuro and Kwajalein atolls in the Marshall Islands (Peterson 1997); Aitutaki island, Cook Islands; and Lifuka island, Tonga (Fig. 23.1). On Lifuka, replacement of boreholes with infiltration galleries significantly lowered the salinity of the water supply (Falkland 2000).

For raised limestone islands, where depths to the groundwater table are greater than 10 m and up to 50 m or more, such as in Tongatapu in Tonga, abstraction using vertical drilled boreholes is currently the most practical method of developing freshwater lenses. In the future, directional drilling from the surface may be an option for installing horizontal infiltration galleries on these islands.

5.4 Sewage and Waste Contamination

The tragically high infant death rates shown in Fig. 23.2 are partly due to contamination of water by faecal material (WHO 2005). Appropriate sanitation in small island urban centres is a major concern. Urban sanitation systems in PICs commonly use rather basic septic tanks and pit latrines. Domestic animal wastes, especially from pigs, add to biological contamination of water sources, particularly household groundwater wells, and pose major health risks in urban areas on many islands and even in designated water reserves (Fig. 23.5).

In parts of heavily populated atolls such as Majuro (Marshall Islands) and Tarawa (Kiribati), piped sewerage systems that use seawater for flushing (to conserve limited freshwater supplies) have been installed to address the problem of sewage contamination of groundwater. Squatter settlements in urban centres, however, do not have access to these systems. Compost toilets protect water sources as well as conserving scarce water resources, and these have been trialled in a number of PICs including Kiribati, Tonga, Tuvalu (Crennan and Berry 2002), and Nauru. While compost toilets have many advantages and have been accepted in some communities, cultural attitudes have so far limited their widespread use in others. Other technical solutions are available, including improved septic tanks and relatively simple

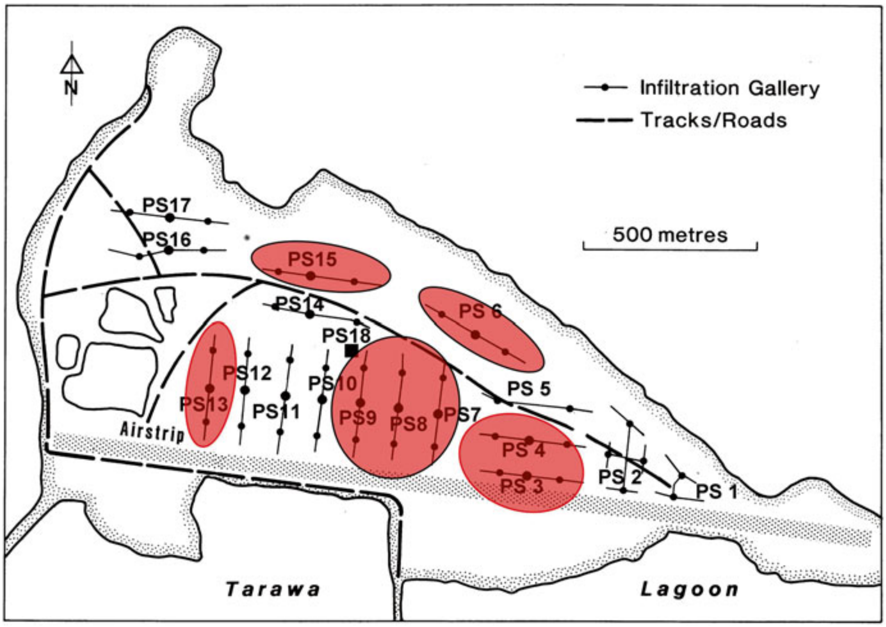

Fig. 23.5 Shaded ellipses show distribution of positive E. coli water samples taken from urban water supply pumping galleries (PS) on Bonriki water reserve, Tarawa Atoll, Kiribati. Positive samples were found to correspond with a graveyard, pig pens, market gardens using animal manure, and squatter huts (White et al. 2007b)

effluent disposal and treatment systems (Bower et al. 2005; WHO 2008). It is emphasised here that selection of appropriate sanitation systems in small island urban areas can be a matter of life and death.

The most appropriate strategy is to ensure that human settlements, including their sanitation and waste disposal systems and domestic animals, are placed well away from freshwater sources used for public water supply (see Sect. 5.1). A study using bromide tracer in Lifuka, Tonga, concluded there was no safe distance between pit latrines or septic tanks and water supply wells in urban areas because of the density of sanitation facilities and the high permeability of the unconsolidated aquifer (Crennan et al. 1998). Instead, the study recommended that alternative strategies such as source control of pollutants using composting toilets and water treatment are required. This is an area requiring major research.

Waste disposal in many developing urban centres in PICs is a continuing challenge for governments. The geographic isolation of PICs means that there are limited opportunities for recycling of wastes. Potentially polluting wastes, such as petroleum products, batteries, and sewage sludge, remain a problem and the separation of waste dumps from water sources is of utmost priority.

5.5 Water Treatment

The level of water treatment required for urban water supplies depends on the quality of the source water (WHO 2004). In PICs, water treatment systems vary from highly sophisticated, reverse osmosis plants; flocculation, sedimentation, filtration, and disinfection systems; through to the boiling of rainwater and household well water. Where water is reticulated to households, treatment is often required at source and close to delivery due to microbial build-up in water pipes and storages. Microbial build-up is a particular problem in systems that deliver water supply intermittently. In some urban centres, water is only supplied every third day.

In some PICS, the resources, supplies, and capacity necessary to manage water treatment facilities is limited. Because of this, a minimum water treatment strategy has been recommended for small island water supply. This strategy emphasises simple designs which minimise mechanical equipment; use of chemicals; and operation and maintenance (UNESCO 1991). One particular problem in PICs is that electric power supplies are sometimes intermittent, so that treatment systems that require power may not be fully functional. Recent advances in simple-to-operate, low-pressure, membrane filtration systems appear to have significant advantages for treating turbid and polluted stream water, groundwater, and stored rainwater, as has been demonstrated in Kiribati, Fiji, and East Timor (Skyjuice 2008, 2011).

The resources and technical skills required to manage wastewater treatment for human re-use is currently not a viable option for most PICs, with some discharging untreated sewage direct to surrounding oceans (Falkland 2011). Waste household grey water is, however, re-used for watering domestic animals, household vegetable plots, and fruit trees.

Many urban households in PICs source water from a range of sources including rainwater tanks, water wells, and the reticulation system, as well as seawater for both potable and non-potable use. Water quality from non-reticulated sources is a significant issue. In some urban areas, groundwater can be so polluted that it is unfit for any human use. In such areas, testing of local groundwater upon which so many households rely should be, but seldom is, routine. Rainwater tanks can also be contaminated and continuing householder education campaigns in the design, construction, maintenance, and care of rainwater harvesting systems are required (UNESCO 1991; SOPAC 2004). Local area water management committees could play a central role in such campaigns.

6 Management of Demand and Losses

Falkland (2011) identified increasing demand and continuing water losses from pipeline systems as major risks to water security in PICs to the year 2030, especially in urban areas (Sect. 1.1). This increasing demand is driven by natural increase in populations, inward migration to urban centres (Ward 1999), and increases in

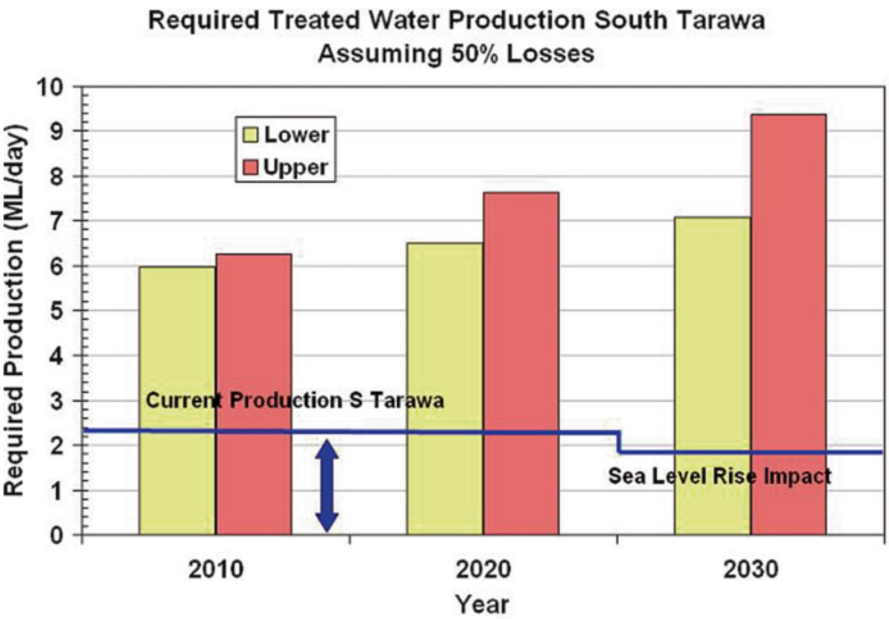

Fig. 23.6 Bars show estimates of the required daily production of treated freshwater required to supply the demand of the growing population of urban South Tarawa, Kiribati, assuming there is a conservatively estimated 50 % loss from the reticulation system. The estimates are compared with the sustainable yield of treated groundwater sources (*horizontal line*), and include a projected worse-case impact of sea level rise (White 2010)

standards of living. In some urban areas in the region, annual population growth rates are as high as 6 %, which places major strain on water supply and sanitation systems as well as urban services. To illustrate this risk, Fig. 23.6 shows the estimated water production required to meet both demand and the estimated current pipeline losses for the urban capital of Kiribati, South Tarawa, compared with the estimated sustainable yield of treated water to the year 2030 (including the projected impact of sea level rise). Households meet the current deficit in production by using water from untreated sources such as rainwater tanks and from unsafe, polluted household wells. Managing water demand and controlling losses are clearly major current and future challenges in PICs.

6.1 Estimating Demand

Designs for urban water supply systems require adequate information on the expected demand for water as well as the losses from the system (unaccounted for, or non-revenue water). Population growth rates and per capita water use are needed for demand projections. Only a few urban centres in PICs have adequate pipeline

Table 23.4 Summary of the estimated per capita freshwater demand for the urban capital, South Tarawa, Kiribati. Toilet flushing is excluded as it is assumed to be sourced from the seawater system (Adapted from White 2010)

Year	Total per capita demand (L/person/day)
1973	18
1975	10–37
1978	14–27
1982	34–35
1986	47
1992	50
1996	40[a]
2000	50[a, b]
2002	40[a]
2003	40[a]
2010	68[c]

[a]Assumes only 80 % of all households supplied with piped water
[b]Includes institutional, commercial, and industrial demand and 30 % assumed losses
[c]Assumes 6 L/person/day ICI demand and an extra 2 L/person/day due to increase in temperatures due to climate change

metering and metered household connections. Estimating demand and losses therefore present challenges. Because of inadequate data, some water supply system designs have been based on estimated minimum per capita island freshwater requirements based on a 'consensus' of needs in developing countries (Table 23.4) or merely on a share of the estimated available water yield. Household surveys suggest that these minimum requirements underestimate total water use, and make no allowance for future increase in per capita water consumption with increasing living standards or with increased temperatures due to climate change. In Table 23.4 the estimate for South Tarawa, Kiribati, in 2010 was based on household surveys from a similar urban environment in a distant atoll, together with a broad estimate of the institutional, commercial, and industrial water use (and a small allowance for increased water consumption due to projected higher temperatures from climate change). Data on institutional, commercial, and industrial water use is often difficult to find. In the absence of metered water supply systems, surveys of water use appear to be the best alternative for estimating demand.

6.2 Non-Revenue Water

Supply system design requires estimates of both demand and system losses. Leakage from water supply pipelines and other losses contribute to 'non-revenue water', the difference between the volume of water extracted from a source and the volume of billed, authorised consumption. In PICs these other losses include illegal

Table 23.5 Estimated non-revenue water in selected urban centres in island countries

Urban centre	Country	Water source	Non-revenue water
South Tarawa[a]	Tarawa Atoll, Kiribati	Shallow groundwater	50–70 %[i]
London[b]	Kiritimati Atoll, Kiribati	Shallow groundwater	20–50 %[i]
Nauru[c]	Nauru	Desalination	75–90 %[i]
Nuku'alofa[d]	Tonga	Groundwater	75 %[i]
Honiara[e]	Solomon Islands	Surface and groundwater	50 %
Majuro[f]	Marshall Islands	Rainwater	50 %
Dili[g]	East Timor	Surface and groundwater	85 %
Auki[e]	Solomon Islands	Surface water	49 %
Noro[e]	Solomon Islands	Surface water	54 %
Tulagi[e]	Solomon Islands	Surface water	77 %
Malé[h]	Maldives	Desalination	<10 %

[a]White (2011c), [b]ADB (2007), [c]White (2011b), [d]White et al. (2009b), [e]SINIIP (2013), [f]SOPAC (2007), [g]Falkland (2011), [h]M. Didi, pers. com., March 2013
[i]Estimated value, incomplete or adequate water metering

connections, theft, non-metered connections, and uncontrolled overflows at community or household tanks in urban centres and larger rural villages. Non-revenue water is a major problem for urban water authorities in PICs (see e.g. SOPAC 1999; SIWA 2013). In many urban centres, losses are difficult to assess because of the absence or malfunction of water meters. Losses equal to or exceeding 50 %, and even as high at 90 %, have been measured or estimated in a number of PIC urban water supply systems (see Table 23.5).

There are two contrasting values for non-revenue water from desalination systems in Table 23.5. Nauru's desalination plant, which supplements rainwater harvesting for the island's 10,000 people, consumes one-third of the total national electricity production per year. The magnitude of the non-revenue water there represents a major national economic loss. In Malé, the capital of the Maldives, the Malé Water Authority, a public–private partnership, has a tiered tariff system in place for strictly metered desalinated water supply to the island's 100,000 residents. Malé has very low non-revenue water.

The magnitudes of non-revenue losses in PICs in Table 23.5 are extremely costly and wasteful. They add to water shortages and cause intermittent supply, even in non-drought periods. Reduction of losses and systematic leakage control to reduce shortages, improve services, increase financial sustainability, and delay the need for future investment in new water infrastructure is a regional priority (SOPAC and ADB 2003). Despite this, detection and reduction of losses has been a lower priority for donor and loan agencies than new infrastructure projects.

Regional capacity building programs in leak detection have been run, but many countries have not adopted leakage control as a mainstream activity. This is largely due to inadequate financial resources and insufficient trained personnel. While an adequate water metering network is an essential first step in identifying losses, there is a strong continuing need for training in leak detection and reduction and support for such programs.

6.3 Rainwater Harvesting

As shown in Table 23.6, most of the main urban centres in the regions have annual rainfalls exceeding 1,500 mm. The exceptions are Dili in East Timor and Port Moresby in Papua New Guinea, both in the monsoon belt. Household and public rainwater harvesting has the potential to supplement, and in some cases supplant, limited reticulated supplies and reduce system demand, particularly in peri-urban areas (SOPAC 2004). Rainwater harvesting is vital in urban centres with no surface or groundwater sources, such as Nauru and Funafuti in Tuvalu. Large rainwater storages fed from bigger public buildings such as churches, schools, meeting halls, and government buildings can be used for public water supply, especially during dry periods when household tanks fail, as in Tuvalu.

Rainwater harvesting is attractive in PICs because its water quality may be safer than other sources and the supply is directly under household control. Rainwater harvesting is not, however, the universal answer to urban water supply in PICs. Estimated unit production costs for large rainwater harvesting schemes in Tarawa, Kiribati (with assumed lifetimes of 50 years and a 5 % failure rate) were five times greater than those for shallow reticulated groundwater pumping and over three times those of desalination (with an assumed lifetime of 10 years) (White 2011c). Unit production costs for smaller household systems in PICs are even higher.

Cost is not the only factor in the viability of rainwater harvesting. The variability of rainfall (Fig. 23.4) and the length of regular dry seasons (Table 23.6), coupled

Table 23.6 Mean annual rainfall, coefficient of variability, and distribution of dry and wet season rainfalls in selected urban centres of island countries (Falkland 2011)

Country	Capital/urban centre	Mean annual rainfall (mm)	Coefficient of variation (CV)	Mean percentage in 6 month dry/wet seasons
Cook Islands	Rarotonga	2,000	0.2	35/65
Federated States of Micronesia	Pohnpei	4,700	0.15	45/55
Fiji	Suva	3,000	0.19	37/63
Kiribati	South Tarawa	2,000	0.47	39/61
Nauru	Yeren	2,100	0.54	40/60
Niue	Alofi	2,100	0.24	34/66
Palau	Melekeok	3,700	0.13	41/59
Papua New Guinea	Port Moresby	1,100	0.24	20/80
Republic of the Marshall Islands	Majuro	3,300	0.15	43/57
Samoa	Apia	2,900	0.20	30/70
Solomon Islands	Honiara	2,000	0.20	32/68
Tonga	Nuku'alofa	1,700	0.24	38/62
Tuvalu	Funafuti	3,500	0.20	42/58
Vanuatu	Port Vila	2,100	0.27	33/67
East Timor	Dili	900	0.32	20/80

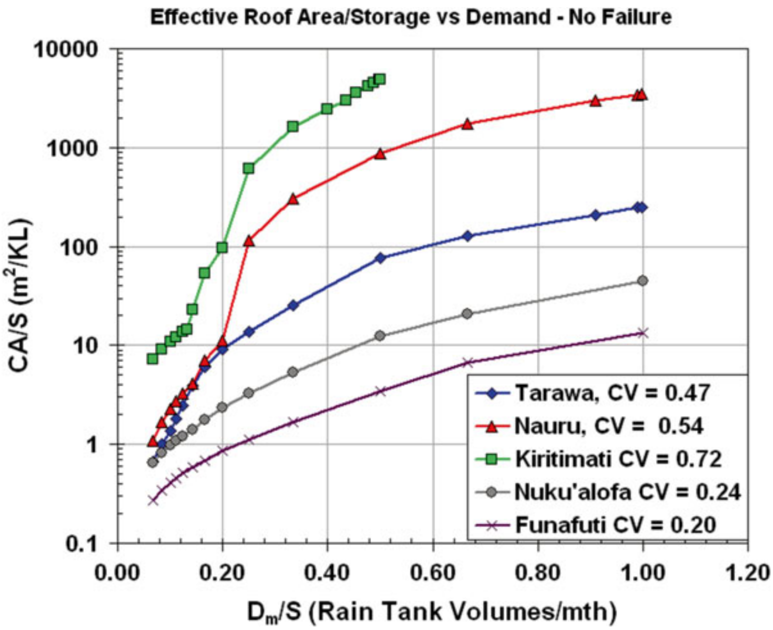

Fig. 23.7 Effective roof area, CA, per rain tank capacity, S, required to meet a monthly demand, Dm, per rain tank capacity for selected PIC urban centres with variable annual rainfalls. The parameter C is the efficiency of capture of rainfall ($0<C<1$)

with available roof catchment area, affordable rain tank capacity, and household demand, need to be considered. The impact of all these factors on the effective roof area per kilolitre of rainwater storage capacity required to supply total household demand relative to storage volume is shown in Fig. 23.7 using historic rainfall records.

Figure 23.7 demonstrates that urban centres in the central Pacific Intertropical Convergence Zone (PICZ) with large annual coefficients of variability (CV) of annual rainfall –South Tarawa, Nauru, and London in Kiritimati atoll – are, because of the variability, generally not able to supply all household demands for freshwater without failure. The size of roof catchment areas and rain tank capacities required to meet reasonable demands without failure, when households can contain up to 31 people, is financially and in some cases physically not possible. For countries with lower annual CV, outside the PICZ, such as Funafuti in Tuvalu, rainfall harvesting is viable even if expensive.

Because of the benefits of supplementing water supplies in urban centres with safe rainwater, some countries have established mandatory building codes to ensure installation of adequate rainwater collection and storage facilities on new buildings. Others, with donor support, have established revolving loan schemes to assist households with purchase of rain tanks and guttering. In order to guarantee safe stored rainwater quality, maintenance and management of rainwater harvesting and storage tanks schemes are essential (SOPAC 2004).

6.4 Demand Management

In some PICs with rapidly increasing populations, demand management is essential but nonetheless difficult. There is an aversion to pay for water, partly because it is viewed as the government's responsibility to provide water, partly because it is considered a common property resource (Sect. 3.1), and partly because of unreliable supplies (White 2011c). Some PICs have no means of controlling overall demand other than by supplying water intermittently for a few hours every 2 or 3 days. This strategy has four disadvantages: households leave taps open to collect the spasmodic water flows in small containers, causing high losses; customers are very reluctant to pay for an intermittent water supply; intermittent supplies are prone to bacterial build-up in supply lines (SOPAC 1999); and households closer to the supply source are able to intercept more water than those further down the pipeline.

At least one government has tried continuous, trickle-feed systems designed to mechanically control demand and give a more equitable supply. These supply a limited volume of water to a 500 L household tank, distributed to most households, over a 24–48 h period (Fig. 23.8). With an average of about 10 people per household this was designed to meet an assumed per capita demand for treated water of 25–50 L/day (see Table 23.3), the 'average' minimum daily requirement. This system was designed to permit continuous pipeline flows. Householders, however, tampered with the trickle-feed valves to increase discharge. As a result, households closer to the source of supply intercepted more water while others at the pipeline terminus received none at all, and the system reverted to intermittent flow. Without legal restrictions on tampering with the water supply, without enforcement of regulations, without water meters, and without general community disapprobation of tampering, such purely mechanical attempts to control demand seem destined to fail.

Fig. 23.8 Trickle feed system for a 500 L household water supply tank designed to limit demand by supplying a fixed daily volume of water to meet the assumed daily household demand. The system failed due to removal of the trickle feed by householders

PICs which have unmetered reticulation or supply systems use either a bulk monthly water charge or no charge at all. In many cases the bulk charge is only a small fraction of the actual cost of water production, distribution, operation, and maintenance, so systems are financially unsustainable and provide no control on excessive or inequitable use or wastage. Even in systems with metered connections, unaccounted for water (water losses) can be as high as 90 % (Table 23.4).

In severe droughts it may be necessary to shut down leaky domestic reticulation systems and supply water either from fixed distribution centres, such as village tanks or by tanker delivery (White 2011c). This reduces the large losses from the domestic pipe lines as well as allowing revenue collection from distribution centres, as is often done for bulk water tanker deliveries. This, of course can disadvantage urban squatters so that a base survival allocation may be necessary.

Efforts to control demand in urban areas by non-tariff means have led to situations where distribution of water is inequitable, where wastage is not controlled, where anti-social and even illegal actions are ignored, and where the water supply is financially unsustainable. Some PICs do meter consumption and have tiered tariffs in urban areas to discourage profligate use and wastage. These strategies tend to occur in larger PICs, where there are stronger governance structures or which have established local institutions such as the *matai* (chief) and *fono* (village council) systems in Samoa. Even in the larger countries with tariff systems, non-revenue water can have a major impact on being able to meet demand (Table 23.5).

One of the problems faced in PICs which have water tariffs is the number of large households with limited capacity to pay. Metering consumption and tiered tariffs appear the only sensible long-term strategies for controlling excessive demand and waste, provided it is well managed and contains measures to accommodate the disadvantaged. The success of pre-paid meters for household electricity supply in some PICs suggests that a similar system for water may be viable. However, water tariffs are only part of the process. A determined, long-term campaign to promote behavioural change, increase awareness, and accompanied by school education programs are required. The safety and adequacy of freshwater as a shared resource, and the importance of water conservation, need to be emphasised. Backing up such a campaign there need to be regulations and community disapprobation for tampering with water supply systems, meters, and pipelines, and stringent enforcement.

6.5 Urban Growth

Controlling per capita demand is only one part of the required strategy. The high urban population growth rates in several PICs are as threatening as climate change. Migration towards urban centres is a world-wide phenomenon, with the attraction of improved social services, increased amenity, and better employment prospects. In addition, the obligation of householders in PICs to their extended family mean that some households in urban areas can contain 30 or more people as distant rural relatives move in. Providing adequate and safe water and sanitation services to such large households and to attendant squatter populations is a universal problem (Kaosa-ard 2003). Strategies such as distributed, multiple growth centres have been proposed but have proved difficult to establish, and population growth remains a major, and largely officially overlooked, threat to the sustainability of urban and peri-urban areas in PICs.

7 Capacity Building

While human and financial resource capacities in the water and sanitation sector in PICs vary widely across the region, the Pacific RAP (SOPAC and ADB 2003) acknowledges the sector's general regional shortcomings in these areas. One of the key factors set out by Sabatier and Mazmanian (1979) for the success of public policy (Sect. 3.2) was that *those responsible for implementing the policy have appropriate managerial political skills, and information, as well as resources.* Capacity and resources are fundamental to improvements in the sector.

As has been discussed throughout this chapter, water agencies are often very under-resourced, partly as a result of financially unsustainable water supply systems, and often because of insufficient professional and technical staff to conduct routine operations. Water improvement projects are generally beyond the financial and human resource capacity of many local agencies. As a result, external development aid is required for planning, design, and implementation. Externally organised and funded projects can place impossibly large additional burdens on local staff, especially when multiple projects are running concurrently. These projects can distract them from important but routine tasks (Falkland 2011). In addition, more lucrative opportunities elsewhere make it difficult to retain trained staff.

It is evident that there is an urgent and long-term need for capacity building and training within water and sanitation agencies and departments. Both in-country and external training and development programs for technical and professional staff, combined with appropriate external courses, are required to build the capacity of these agencies and their staff.

Regional organisations, such as the Applied Geoscience Division (SOPAC) of the Secretariat of the Pacific Community (SPC), the Secretariat of the Pacific Regional Environment Programme (SPREP), the University of the South Pacific (USP), and the Pacific Water and Wastes Association (PWWA) – which pool expertise, share local experience, and provide training opportunities – have a continuing long-term role in supporting PICs through capacity building in urban water and sanitation management and operation. These regional organisations are invaluable in aid, loan, and donor bi-lateral programs in the water and sanitation sector in PICs. They can provide both a long-term memory of successful regional and local strategies and independent advice for in-country staff.

8 Community Empowerment

Another of the key planks of public policy success (Sect. 3.2; Sabatier and Mazmanian 1979) is that *policy and associated implementation mechanisms are actively supported by constituent groups*. In PICs, the active support of the general and local community is at the heart of successful water reforms. Well-developed local institutions, resilient social systems, sensitivity to environmental change, and high degree of equity in Pacific islands (Barnett 2001) provide a basis for change and improvement in the water and sanitation sectors – provided the community is empowered to participate at all levels. Strategies for facilitating community participation have recently been reviewed by Daniell (2012), and there is potential for investigating their use in island communities.

Including community representatives on national peak water and sanitation bodies, emphasised in Sect. 3.3, is a strategy which builds on unique island strengths. In one PIC, this proposal was strongly resisted by senior bureaucrats, who believed that water was 'government business' (White et al. 2009a). When finally community representatives were included in the committee, real progress on development of national policy and implementation plans occurred. These committees, however, require support and training in their role and responsibilities, some of which may require definition in law and at least in policy.

In Sect. 5, the complex interaction of land ownership, customary rights, and public good were raised in relation to protecting water sources. Although underpinning regulations are essential for providing legal protection of water resources, they are largely ineffective unless land owners and local communities are actively involved in the protection and management of reserves (White et al. 1999a). Local water reserve management committees (Sect. 5.2) involving representatives of land owners, local communities, and relevant government agencies appear a useful way of increasing protection and decreasing vandalism. In Tonga and Samoa, the existing *matai* and *fono* village council and village water committee systems responsible for local water supply management are useful Pacific models which build on island community strengths. Such committees require information, resourcing, and training and need to be adapted to the diverse cultural situations throughout PICs. While debate in developed countries continues on the efficacy of community engagement in water planning (see e.g. Daniell 2012), our argument for its value in PICs is based on the fundamental importance of negotiation and consensus in island life, and on examples of successful village or island-owned and managed systems in Samoa, Tonga, and the Maldives.

To control increasing demand (the main risk to water security in the Pacific), as well as to promote water conservation and reduction of wastage, community attitude change and community participation are essential. These values are not part of the old 'extended-family-centric' tradition of subsistence in the Pacific. Behavioural change is necessary for transitioning to urban living (Crennan 2002), and it is a long-term process that requires wide-ranging education programs, focused particularly on school children. Even in urban environments, it is possible that local area water committees, similar to those operating in Tonga and Samoa, could assist in reducing demand and wastage and promoting conservation, again so long as adequate training and resourcing is provided.

9 Coping with Climate Variability and Change

Over the past 1,000–12,000 years, low-density island communities have demonstrated remarkable resilience in coping with major natural hazards and calamities. As they move to high-density urban centres, however, their traditional coping mechanisms are not well-suited and their vulnerability to imposed threats increases. The prime threat from climate change to low-lying islands and atolls is sea level rise. Major threats posed by climate change to PICs have been detailed by the Intergovernmental Panel on Climate Change (Mimura et al. 2007). Some authors, however, conclude that the global focus on climate change has distracted PICs from addressing the actual, local sustainability problems facing island communities (Connell 2003), particularly managing vital freshwater resources (White and Falkland 2010). The conclusion in Sect. 1.1 – that non-climate factors, particularly increasing demand and losses, pose greater risks to water security in PICs out to the year 2030 than predicted climate change impacts (Falkland 2011) – adds weight to Connell's conclusion. The historic variability of rainfalls in the Pacific, and especially in the Intertropical Convergence Zone in the central and central-western areas (see Fig. 23.4), already poses major headaches for island water supply managers, particularly when losses are so high (Table 23.4).

9.1 Climate Variability

Variations of annual or seasonal rainfalls in urban centres in the Pacific are particularly large in the central and central-western Pacific. Nauru and the South Tarawa and Kiritimati atolls of Kiribati (see Fig. 23.4) have the highest variation, followed by the capitals of Vanuatu, Niue, PNG, and Tonga (Table 23.6). Variability of rainfall in these urban centres presents particular difficulties for rainwater harvesting (see Sect. 6.2). Roof areas and rain tank capacities are generally small, and household size and demand are usually large. Even in the capital of Tuvalu, Funafuti atoll, which has a much lower variability of annual rainfall and is heavily dependent on rainwater harvesting, some household rain tanks are exhausted after only a week with no rain.

Key drivers of high rainfall variability in the Pacific Intertropical Convergence Zone are the strong correlations between rainfall, local sea surface temperatures (Fig. 23.4), and major ENSO events. It is that strong coupling between rainfall and sea surface temperature which results in frequent, long, and severe droughts. In Nauru, the median interval between meteorological droughts relevant for rainwater harvesting is only 5 years, and the median drought duration is 19 months (White

2011a). Similar conditions prevail in Kiribati's capital, South Tarawa (White et al. 1999b), and in the urban area of Kiritimati atoll, Kiribati.

In order to replace the current (albeit inadequate) reticulated groundwater supply rate in South Tarawa of 2,000 m^3/day from communal rainwater harvesting, with zero risk of failure, we would require a rainfall collection surface of 1 km^2 and a storage capacity of 600,000 m^3 (White 2011b). In crowded urban South Tarawa, there is no free space available for such large rainfall collection and storage areas. More importantly, the estimated unit production cost of communal rainwater harvesting, using cost recovery over a 20 year lifetime, is over AU\$22/m^3, far in excess of most other options including desalination, whose estimated unit production cost over a 10 year lifetime is around AU\$5/m^3 (White 2011b). In these centres, rainfall harvesting remains a valuable supplementary source of freshwater with limited reliability in droughts.

The very strong relation between sea surface temperature, Southern Oscillation Index (SOI), and rainfall in several PICs (see Fig. 23.4) provides a basis for predicting the probability of below average rainfall several months in advance. The SCOPIC program developed by the Australian Bureau of Meteorology for PICs (BOM 2012) is designed to provide seasonal climate forecasts in the Pacific 3 months in advance. These predictions, and the Climate Outlook Programme coupled to drought contingency plans, provide a basis for coping with the frequent central Pacific droughts.

Significant ENSO-related droughts and floods have impacts across the whole region, with major impacts on stream flows (e.g. Terry and Raj 2002), power generation, groundwater availability, water supplies, agriculture, and health. In PNG, the 1998–2000 El Niño drought affected over 70 % of the PNG population, with severe impacts on water, food, agriculture, education, health, and other sectors (World Bank 2009). These climatic extremes are most severely felt in small PICs, who have only one or two water specialists and very limited financial and physical resources to deal with emergencies, especially during cyclones. Cyclones often cause severe wind damage, floods, landslips, erosion, downstream sedimentation, and saline intrusion, and produce major damage to infrastructure (including water supply infrastructure), buildings, and agriculture, as well as loss of life (Terry 2007).

Fresh groundwater lenses on small, low-lying islands can be inundated with seawater during island overtopping by cyclone-generated waves. Many months are required to naturally 'flush' saltwater from groundwater lenses and restore water supply to potable conditions (Terry and Falkland 2010). One major fear concerning climate change is that it will increase the frequency and intensity of climatic extremes in the region, including droughts, floods, cyclones, and island overtopping.

9.2 Climate Change

In searching for current evidence of change in the climate records of PICs there are three major limitations: the limited nature of the data (for example almost no information on evapotranspiration, solar radiation, or short duration rainfall intensity);

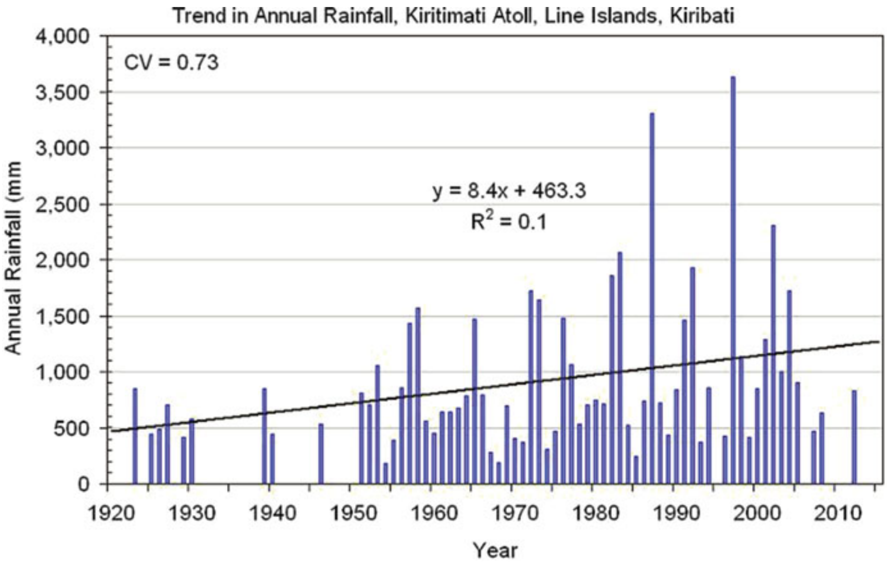

Fig. 23.9 Line shows the increasing trend of 8 mm/year in annual rainfall in the urban centre, London, Kiritimati atoll, the growth centre in the eastern Line Island Group of Kiribati. The bars show the large annual variability which is closely linked to sea surface temperatures and ENSO events

the inherent variability of the records; and the generally short climate records. The last two make identification of trends difficult. As an example, Fig. 23.9 illustrates the weak increasing trend (+8 mm/year) in measured annual rainfall for Kiritimati atoll, the growth centre in the eastern Line Island Group of Kiribati in the central Pacific, embedded in an exceptionally variable annual record (coefficient of variation = 0.73) which is strongly correlated with ENSO events. This trend is split evenly (about 4 mm/year) between the wetter (January to June) and drier (July to December) parts of the year. A similar weak increasing annual trend is found in the urban capital of Tonga (White et al. 2009b). Increasing rainfall in small island countries is generally expected as sea surface temperature increases.

The Pacific Climate Change Science Programme (PCCSP 2011) used the outputs from 18 global climate models (GCMs) for two CO_2 emission scenarios to provide projections (relative to the baseline 20 year period centred on 1990) for a number of climatic and ocean parameters for selected PICs out to 2030. For the most likely emission scenario, most countries (in preliminary estimates) were predicted to have only small changes in mean annual rainfall, with only Kiribati, Nauru, and PNG predicted to have larger increases; potential evaporation for the region was also expected to increase by 1–3 % by the year 2030 (Falkland 2011). However, since GCMs do not handle cloudiness well, the predicted impact on actual evapotranspiration is difficult to assess.

There was no consensus between models on the predicted change in frequency of cyclones, and GCMs do not, in general, predict ENSO events. Given that these are key drivers, the projected risks to urban water security in PICs posed by climate change are difficult to assess. The risks, however, posed by population-driven increased demand and continuing large unaccounted-for water losses from urban systems are much easier to assess (Falkland 2011). The conclusion is that addressing basic issues of demand and losses will assist adaptation to climate change.

9.3 Adaptation to Change

The threats posed by climate change to urban areas in PICs are daunting, particularly in low atolls and carbonate islands threatened with partial inundation from sea level rise (Mimura et al. 2007). Despite the magnitude of these risks, some are optimistic that PICs can adapt to climate change, provided, firstly, that the rate of climate change is slowed and eventually stopped, and, secondly, that PICs can achieve a high level of domestic sustainability to promote social and ecological resilience (Barnett 2005). In this sense, adaptation to climate change can be viewed as but one aspect of addressing the broader challenges of sustainability, which are exacerbated in small island states because of their fragility and vulnerability to natural and anthropogenic pressures (UNDESA 1994).

In the face of uncertainties surrounding the magnitude and timing of climate change (Barnett 2001), as well as its impacts and the lack of detail about ecosystem functioning in PICs, it has been concluded (Barnett 2005) that the only rational adaptation strategy is "to develop the general capacity of a society to cope with change by building up its institutional structures and human resources while maintaining and enhancing the integrity of ecosystems". He concluded that the inherent local strengths in PICs are the basis for considerable capacity to adapt to climate change.

Dovers (2009) has argued that challenges faced in adapting to climate change are not new. Humans have had to cope with climate variability for a long time, and he cites examples in developed countries covering water management, local and regional economic vulnerability, biodiversity, health and well-being in remote communities, energy reform, and emergency and disaster management.

A significant problem exists in higher density urban areas in PICs, especially those subject to inward migration with large squatter populations. In these, many of the traditional coping mechanisms, local institutions, and social systems are weak, ineffective, or almost absent. The challenge of maintaining and enhancing the integrity of ecosystems around urban centres in the Pacific is significant, particularly when governments in the region have been reluctant to address the pressing problem of urban population growth over the past 40 years (Hughes 2011).

10 Conclusions

Urban centres across the Pacific region have an extreme diversity of fresh water resources, supply systems, and institutions and markedly different environmental, climatic, geographic, social, cultural, and economic contexts. Even within countries, there is remarkable diversity. In this chapter we have concentrated on identified common issues the region has in terms of urban water systems. These are central concerns about the adequacy and safety of water supplies and the impact of climate on them.

Some of the challenges faced in PICs are common to other developing areas throughout the world. Others are more regional and specific. Urban water resource issues in the Pacific are some of the most challenging and complex in the world. Their isolation, vulnerability to natural and human impacts, hydrogeology, limited resources and capacity, and high urban growth rates,, are intertwined with customary rights and underlying subsistence traditions. Because of the complexity, we have argued that simplistic approaches, focusing on single issues such as infrastructure, water tariffs, and governance tool kits have been largely unsuccessful. Instead we have sought to adopt a broader approach in this chapter, one consistent with the identified regional risks to urban water security.

It has been argued elsewhere that movement towards ecologically sustainable human development is the only rational adaptation strategy to climate change. We believe that this strategy has broader application beyond climate change. Here we have applied it to development in the water and sanitation sector in PICs, where there are difficult interactions between subsistence and urban life styles.

A general lack of government leadership, priorities, laws, plans, and structures has been identified as a regional issue. In three PICs, however, there is now an adaptive policy and plan development process carried out through a whole-of-government and community peak sector committee. This process is broadly acceptable and easily understood, and is one which engages the community strengths. It is particularly useful in countries with limited policy processes.

The first key factor for successful public policy is that policy and implementation mechanisms be broadly supported by government. This remains a challenge in areas where water and sanitation are largely seen as responsibilities of the extended family, the household, or the individual. Inadequate sanitation remains the largest threat to water quality and human health in urban centres in PICs. In many respects it is a 'wicked' problem and affordable solutions remain elusive.

The second key factor is that policy and related mechanisms be based on sound knowledge. Sound knowledge is essential because in PICs there is a delicate balance between water inputs and outputs, and that balance impacts on water availability and quality, and quality in turn has major health implications. Water resource assessment, use of appropriate technology, monitoring, analyses of data, and reporting provide vital information for improved management of freshwater sources. Peak sector government–community committees can play important roles in coordinating information and in sharing and disseminating it to government, relevant agencies, and to the broader community.

Limited land areas in many PICs mean that urban settlements encroach on and contaminate water sources. Protection of water sources, as well as water treatment, are key steps in a 'multiple barrier' approach to water safety. Traditional ownership of land in water reserves, source areas, and catchments, coupled with customary rights, remains a politically very sensitive issue. Engaging landowners and local communities in the care and management of water source areas appears to hold promise of increasing protection and reducing conflict, but it requires widespread consultation.

The two greatest threats to the water security and safety of urban water supplies in PICs are burgeoning demand and large losses from water reticulation and storage systems. Reducing non-revenue water losses has the potential to double the amount of water available in most urban centres across the region. These should be addressed first before any additional investment in new water sources occurs.

Rainfall harvesting has the potential to provide safer water to supplement household water supplies, especially in peri-urban areas. However, limited roof areas, small tank capacities, and large households mean that, with few exceptions, rainfall harvesting cannot meet all demands for freshwater across the region. There will be times when tanks run dry, especially in the central Pacific Intertropical Convergence Zone. Continual maintenance and good management of rainwater harvesting systems is essential for providing safe water.

Controlling demand presents one of the greatest challenges to PIC governments, partly because of customary beliefs and traditional rights, and partly because of unsustainable urban growth rates. There are no easy solutions here. Tiered water tariffs have proven successful in some counties but in others determined, long-term campaigns to promote behavioural change and increase awareness are required. Education in schools to underline the importance of safe and adequate freshwater has long-term value. In addition, increasing community disapprobation of interfering and tampering with water supply systems, meters, and pipelines, and backed up by enforceable regulations, would reduce inequities in community water supply.

A major regional priority is continued capacity building and training within water and sanitation agencies and departments. Regional organisations have played, and need to continue to play, an important role in assisting with capacity building across the region.

Well-developed local institutions, resilient social systems, sensitivity to environmental change, and the high degree of equity in Pacific islands provide basic strengths to build water reforms upon and to adapt to climate variability and change, particularly when island communities are empowered and informed. Successful models of village water supply systems are based on engaged and supported communities. Throughout this chapter we have emphasised the fundamental roles that the community can play, at all levels, in peak sector bodies, in water reserve management committees, and local area water committees; together these efforts can bring about behavioural change in the use, conservation, and management of water. Finally, with an eye to the future, school education campaigns are a key ingredient to the sustainable development and improved health and well-being of island communities.

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