An Economic Assessment of Drinking Water Safety Planning Koror-Airai, Palau

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Ocean and Islands Programme

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TABLE OF CONTENTS

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GLOSSARY

Disability Adjusted Life Year (DALY) – A measure of overall disease burden, comprising a combination of years of life lost (due to premature death) and years lived with the disability.

Flocculation – part of the water treatment process under which clays, polymers or other small charged particles or contaminants become attached and form a fragile structure, a *floc*.

Global Disease Burden – the total incidence, prevalence and severity of a health problem in an area measured by financial cost, mortality, morbidity, or other indicators, as measured by Disability-Adjusted Life Years (DALYs).

Nephelometric Turbidity Units – a unit used to measure water cloudiness or haziness caused by individual particles (suspended solids) generally invisible to the naked eye.

ACRONYMS

ADB	Asian Development Bank
BPW	Bureau of Public Works
DWSP	Drinking Water Safety Planning
EQPB	Environmental Quality Protection Board
EU	European Union
K-A	Koror-Airai
MDG	Millennium Development Goals
PALARIS	Palau Automated Land and Resource Information System
PICs	Pacific Island Countries
PNG	Papua New Guinea
SOPAC	Pacific Islands Applied Geosciences Commission
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

The current practice to ensure water safety in Pacific Island Countries (PICs) is to monitor the quality of the treated drinking water at the end of the supply chain through water quality testing and to assess compliance against national standards, WHO guidelines or US EPA standards. However, various shortfalls and limitations in relying on end-product testing have been identified, not least that this approach is unable to detect all pathogens and that – as it can only be conducted after water has been distributed and consumed – it does not prevent the consumption of contaminated water.

To overcome such limitations, the latest edition of the WHO Guidelines for Drinking-Water Quality (WHO, 2004) emphasises effective preventive management through drinking water safety planning (DWSP). DWSP is a "comprehensive risk assessment approach that encompasses all aspects of the water supply from catchment to consumer, to consistently ensure the safety of drinking water supplies".

A well prepared drinking water safety plan will be designed specifically for the supply situation at hand. It is intended to give confidence of consistently safe drinking-water throughout supply. The introduction of the DWSP approach is being piloted in Pacific Island Countries by SOPAC and WHO. Initial funding was received from AusAID over the 2005 to 2009 period. Palau is one the countries where the DWSP approach is being introduced and implemented. Thus, though 90% of households in Palau have access to piped, treated water, ADB (2009) claims that water management in Palau is not efficient. This makes the introduction of the DWSP approach to Palau a key step to improve water quality in the country. The approach is being implemented for the Koror-Airai (K-A) water supply with the intention that the benefits encourage the replication across Palau.

The K-A drinking water safety plan contains a technical analysis and threats of water safety issues as well as an improvement schedule, with a list of water management improvements to be made within a stated tentative timescale. Parts of the improvement schedule are now beginning to be implemented. The improvement schedule items are ranked according to the highest risk posed in relation to health and the urgency with which each item should be addressed (within available resources).

This document describes a preliminary economic assessment of the K-A drinking water safety plan. The information generated is to be used to inform stakeholders in Palau of the rewards from supporting the DWSP approach, demonstrating the potential benefits of investing in the Plan.

According to the assessment, the likely cost of establishing and implementing the K-A drinking water safety plan could potentially be around US$ 0.2 million in total over time. On the grounds of consultations with technicians and key stakeholders, the Plan would be expected to generate benefits in the form of reduced water-induced gastrointestinal diseases. In this respect, those at risk from gastrointestinal disasters are those with the weakest immune systems such as the young, the old and those with already compromised immune systems (already sick). Additionally, there would be a slightly reduced demand for bottled water for safety purposes from private consumers as they try to avoid consuming contaminated tap water. The total value of these benefits over time is estimated to be in the vicinity of US$ 1.34 million.

The expected net benefits of the K-A drinking water safety plan in Palau are thus estimated at US$ 1.1 million – **a return of US$ 5.90 on each US$ 1.00 invested**.

The values are only preliminary; however data to conduct the assessment was scarce and there would be considerable benefit from improving access to data in the future. For example, access to up to date information on the incidence of gastrointestinal disease in Palau was extremely limited. Aside from its value in predicting returns from a DWSP and in monitoring the effectiveness of it, the more effective collection and assessment of health data would likely be valuable for national health planning in Palau more generally.

1.0 INTRODUCTION

1.1 Drinking Water Safety

According to WHO/UNICEF (2008), most of the Pacific region is not on track to achieve the Millennium Development Goal (MDG) of halving the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. Less than half of all Pacific Islanders have access to improved drinking water (WHO/SOPAC, 2008). The sanitation coverage in the region is also currently only around 50 per cent, with 16 per cent of islanders still practising open defecation (SOPAC/WHO 2008).

WHO/SOPAC (2008) also notes that in the Pacific region there are an estimated 2800 deaths per year due to diarrhoeal diseases. The problem is compounded by the limited availability of water resources such as groundwater. The combination of safe drinking water and basic hygienic sanitation facilities is a precondition for success in numerous MDGs, including: the fight against poverty and hunger; primary education; gender equality and women empowerment; child mortality; maternal health; HIV/AIDS and malaria; environmental sustainability; and, the development of global partnerships (WHO, 2010).

Governments of the Pacific region recognise the need to address these issues and have done so through various regional frameworks including the Regional Action Plan of Sustainable Water Resources Management (Pacific RAP) and the Pacific Framework for Action on Drinking Water Quality and Health (WHO, 2008, 2). The provision of centralised drinking-water piping to households is an important factor determining improved drinking water and sanitation coverage, as it avoids uninformed household connections to and misuse of potentially dangerous water sources.

1.2 Global Efforts to Address Water Safety

The WHO has published guidelines for drinking water for almost 3 decades. These WHO guidelines are ideal rather than essential, identifying safe levels of various potential contaminants that do not pose a threat under lower concentrations, and countries are recommended to come up with their own standards for compliance monitoring. However, many countries including Pacific Island Countries (PICs) do not and instead by default adopt the WHO guidelines in place of their own standards. Currently, the practice in PICs is to monitor the quality of the treated drinking water at the end of the supply chain through water quality testing and assessing compliance against standards. The various shortfalls and limitations in relying on end-product testing as an indication or guarantee of safe water quality are now being realised. For example, under such practices only a fraction of the water produced and delivered might be tested and negative results might not be timely as the unsafe water may already have been distributed and consumed.

To overcome such limitations, the latest edition of the World Health Organisation (WHO) Guidelines for Drinking Water Quality (WHO, 2004) emphasises effective preventive management through drinking water safety planning (DWSP). DWSP is a “comprehensive risk assessment approach that encompasses all aspects of the water supply from catchment to consumer, to consistently ensure the safety of drinking water supplies”. A well prepared DWSP will give confidence of consistently safe drinking water. Depending on the case at hand, DWSPs can vary in complexity, in many cases favouring a simple structure and focusing on key hazards identified for a specific system (WHO, 2004).

Mudaliar *et al*. (2008) identified some of the major benefits that can be expected from developing and implementing a DWSP such as:

- Health benefits – studies indicate that quality assurance processes such as Drinking Water Safety Plans can greatly reduce health burdens.
- Cost saving – studies have shown that by adopting the monitoring and verification process of the DWSP a cost saving of approximately 30% can be achieved.
- Investment planning – increased monitoring at field level results in clearer prioritisation of system improvement.
- Greater risk assurance – provides greater confidence in the continuous and sustainable delivery of drinking water.
- More integrated approach – recognises the linkage between source water, treatment processes, distribution, storage and handling as potential areas of risk and suggests greater communication between agencies for integrated management.

It must be noted that DWSPs are created separately and specifically for different water supplies to identify and address the risks. Any "plan" or policy should naturally follow from this risk assessment and spread positive water management ethos to the rest of the area. Figure 1 illustrates the larger context in which the DWSP approach should be implemented. DWSP is primarily about protecting public health, but the risk analysis can also identify other risks such as financial and operational risks. However, health improvements as a result of DWSP are always the priority. A DWSP is used to identify the risks associated with all aspects of a specific water supply chain from catchment to consumer, in particular identifying whether any of the following four barriers to contamination are missing:

- Preventing contaminants entering the source water.
- Removing particles (turbidity) from the water (turbidity protects bacteria from the disinfection chemicals).
- Disinfection (using chlorine, boiling, bromine, heat, UV radiation, etc).
- Prevention of recontamination after treatment.

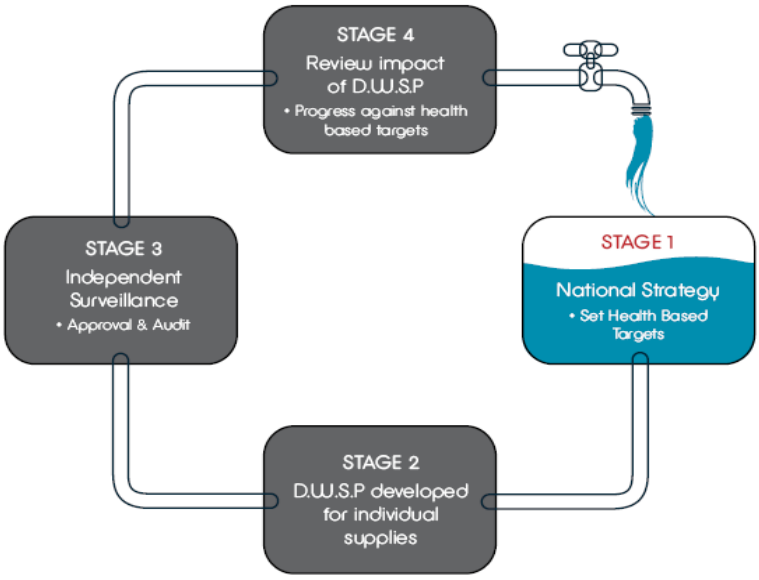

Figure 1. Background to Water Safety Planning (Source: Mudaliar et al, 2008).

1.3 Water Safety in Palau

The national water supply systems including water treatment plants have been substantially improved since Japanese investments in the late 1990s, particularly within the Airai State. Nevertheless, water problems do exist, ranging from watershed misuse on the larger island of Babeldaob to saltwater intrusion of freshwater lenses in its platform islands and atolls (IWRM, 2007).

To address this, the Government of Palau is implementing (in addition to a range of other water quality and quantity management activities) the DWSP approach in the K-A water supply. According to the Palau DWSP National Steering Committee, the K-A DWSP has several key objectives including:

- Initial water distribution and treatment system assessment;
- effective management to treat water; and
- prevent contamination and re-contamination through effective operational monitoring and management (with action plans for both normal and unforseen circumstances).

1.4 The DWSP Approach in Palau

The introduction of the DWSP approach to Palau is a key step in improving water quality in the country. The Republic is one of the four demonstration countries where the DWSP concept has been introduced and is being implemented (with assistance from SOPAC and WHO). The other Demonstration countries for DWSP are the Cook Islands, Vanuatu and Tonga.

Whilst the DWSP concept targets improved water quality management in Koror and Airai states, the ability of the DWSP to ultimately deliver benefits to Palau more broadly will rely on it being effectively implemented and expanded through ongoing investment in the improvement schedule.

The remainder of this document describes an economic assessment of the K-A DWSP in Palau, illustrating the potential returns from implementing the K-A DWSP. The information generated will be used to inform stakeholders in Palau of the rewards from supporting DWSP, thereby providing advocacy. Additionally, it will act as a case study of the economic value of adopting and implementing the DWSP approach for improved water safety in the region.

It is important to note that DWSP is a process and a road-map to identify how safe water can and will be achieved. There is a cycle of steps involved in the process and for the K-A water supply, some of which have been achieved (A) and others that have still to be determined (TBD):

1) Assemble the DWSP team – A
2) Describe the water supply – A
3) Identify hazards and prioritise actions needed – A
4) Technical review to identify corrective actions and develop improvement schedule – A and some corrective actions taken
5) Develop monitoring schedule – TBD
6) Sustainability plan discussed – TBD
7) Improve processes that support DWSP – ongoing
8) Verify the DWSP – TBD
9) Review the DWSP – TBD

2 BACKGROUND

2.1 Country Background: Republic of Palau

The Republic of Palau is made up of about 350 islands in the far North-Western Pacific Ocean. It stretches between 2 and 8 degrees north of the equator and is approximately 3000 km South of Tokyo and 1600 km East of Manila. The Republic has a total land area of 487 km^2. The largest island Babeldaob, has an area of 334 km^2 (IWRM, 2007). Ten of Republic's 16 states including Airai are located on this island, which also hosts the capital Ngerelmud. South of Babeldaob is the island chain of Koror, which is the central commercial site and former capital of the Republic. Stretching south of Koror for 45 km are hundreds of tiny mushroom-shaped islands, the "Rock Islands", which are internationally renowned for tourism, particularly for diving, snorkelling and boating (IWRM, 2007).

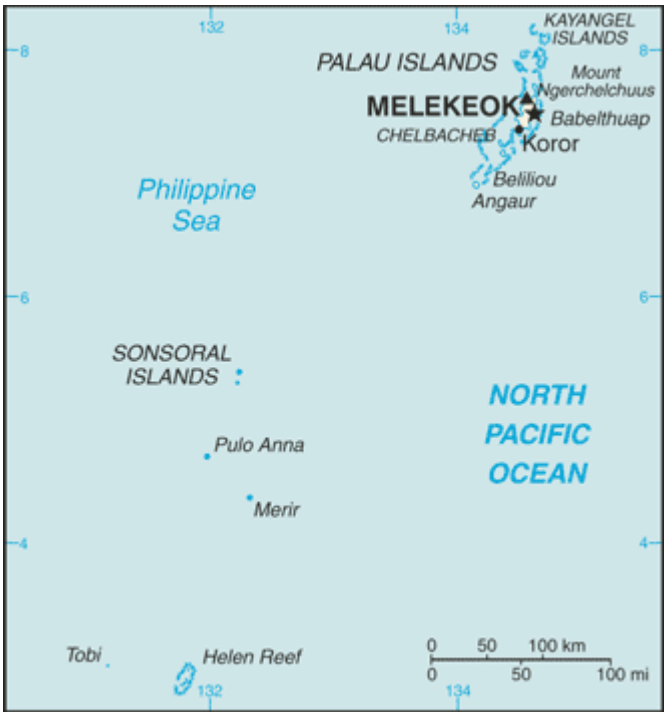

Figure 2. Map of Palau (Source: CIA 2010).

The Republic has a population of 20,796 (CIA, 2009) of which 24 per cent are under 14 years old, 70 per cent between 14-65 years old, and 6 per cent are older than 65 years old. The urban population is estimated at 78 per cent. The country as a whole has a population density of 44.6 persons per km^2. An estimated two thirds of the population live in Koror and Airai states, which have a population density of 245 persons per km^2, all of whom rely on the K-A Water Treatment Plant (WTP).

Introduction of DWSP in Palau

Following the inclusion of Palau in the SOPAC/WHO implemented Pacific DWSP programme funded by AusAID in 2006, a mission and a DWSP workshop were undertaken, during which the Palau DWSP National Steering Committee was formed. In April 2007, New Zealand drinking

water assessors and engineers worked with the Steering Committee to begin development of a DWSP for the K-A Water supply.

The resulting DWSP was technically reviewed and the improvement schedule costed in May 2009 (see Annex 5). A further mission in December 2009 identified the progress with the DWSP implementation and priority items that are funded from the SOPAC/WHO budget.

A range of threats exist to drinking water safety in Palau, including soil erosion and sedimentation, especially following heavy rainfalls; nutrient, fertilizer and pesticide pollution; and inadequate solid waste disposal. For example, the clearing of forests in Palau for development purposes and agricultural farming has caused higher sediment loads into rivers and out to the coral reefs (IWRM, 2007). Increasing sedimentation in the rivers increases the need to use more chemicals at the WTP, reducing turbidity levels to achieve drinking water standards and also increasing the use of disinfectants to ensure safe drinking water. This response results in an increase in expenditure on chemical supplies. Simple filtration systems do not remove enough turbidity and this causes reticulated water from such systems to be non-potable regardless of disinfectant levels. In such instances, human health is at risk if public water systems are the main drinking water sources, therefore deforestation management should ultimately comprise a crucial part of Palau's DWSP to reduce sedimentation (IWRM, 2007). Furthermore, given climate change phenomenon, and the damaging impact that a rising sea level will have on Pacific Islands' ground water reserves, securing a safe and efficient water system early on will be a crucial part of climate adaptation.

With near completion of the Japanese-funded Compact Road around Babeldaob, further development is expected in the watersheds of the Republic, causing potential degradation which is a concern for water quality and to the health of the Republic's population, as increased development will compound current water management issues such as sediment pollution and leaching septic tanks (IWRM, 2007).

Ongoing threats such as those mentioned above threaten drinking water through the risk of bacterial contamination of the water, or by adversely affecting the treatment processes designed to control them (e.g. excess turbidity, and settlement, which raises the risk of a turbidity breakthrough that consequently protects pathogens from the disinfection process).

Furthermore, in the Republic there is no limit to water extraction by any company or individual, from either surface or ground water, and there is no fee for use of the public sewerage system. Without demand management and consumption control, safe drinking water availability may be compromised. Such issues must ultimately be factored into the Plan.

The K-A DWSP: Threats and Risks

A DWSP is always supply-specific. The DWSP developed in Palau is specifically for the K-A water supply. The DWSP has been compiled by the Republic's DWSP National Steering Committee on behalf of the Ministry of Resources and Development, which is responsible for the implementation and oversight of the DWSP (Parsons Brinckerhoff, 2009). The DWSP contains a technical analysis and threats of water safety issues as well as an improvement schedule, with a list of water management improvements to be made within a stated tentative timescale (see Annex 3). The current draft DWSP involves risk assessments in the areas of;

- catchment and intake;
- treatment and storage;
- distribution; and
- general areas.

All areas are crucial for health improvements. The improvement schedule is now beginning to be implemented. The improvement schedule items are ranked according to the highest risk posed in relation to health and the urgency with which each item should be addressed. Included in the improvement schedule are various educational expenditures, which are the most straight forward and least time-consuming efforts included on the improvement schedule itself, therefore these are first to be put in action, as compared to intricate equipment purchases (for example, see Annexes 2 and 3). Some of the Republic's DWSP action-points have already received practical attention: new bulk water meters are being installed this year according to Giles-Hansen (2010) and the proposal for increasing the current US$0.85 per/1000 gallons water usage fee is under political consideration, according to the ADB (2009). This latter point is crucial for long-term cost recovery purposes (see Section 6).

Current status of DWSP in Palau

Currently, the DWSP is operational and there are some improvements to be carried out. Next steps include:

- Purchase of a new jar test unit.
- Arrangements for operator training and certification and development of SOPs.
- Review of next steps with in-country counterparts.

2.2 Water Management in Palau

In the Republic, the Environmental Quality Protection Board (EQPB) is the regulating agency behind the DWSP in Palau, monitoring the quality of water supplied by the K-A WTP. On the other hand, the Bureau of Public Works (BPW) manages the water supply and the distribution network on a day-to-day basis (Kingston, 2004). According to Castalia (2010) and in line with WHO assessment, the provision of water infrastructure in the Pacific is poor when compared to other island states around the world, although Palau specifically has improved water infrastructure sources above the Pacific average (see Figure 1). The BPW only provides 64 per cent of the Republic population with drinking water from its public surface water supply systems (ADB 2009, p.2).

Other than the BPW, there are currently 15 public water supply systems that rely on surface water intakes, 4 public water supply systems which rely on groundwater and in the northernmost inhabited atoll, the old distribution lines are being reconnected to a new well for water supply. The islands of Peleliu, Angaur and Kayangel rely on freshwater lens sources for their public water supply systems. The largest WTP is in Ngeruobel in Airai State, which services the States of Koror and Airai and was re-built in 1998 with Japanese Aid funds to increase its capacity by 17 million litres per day. It should be noted that after these investments, drinking water quality has improved greatly with current effluent turbidity levels ranging from 1 to 3 Nephelometric Turbidity Units (Kingston, 2004). The K-A WTP has five filters and provides chemical feed and flocculation and the distribution system comprises pumps and pipes made of different materials (Hajkowicz *et al.*, 2005). Hajkowicz (2005) claims that watershed pollution in the Republic is not a significant issue because of the effectiveness of sediment removal through filtration.

However, according to the ADB (2009), water management operations in Palau are less than efficient, including high water leakages, low revenues and unmetered usage in many areas, with 3,009 metered and 734 unmetered water connections in Koror and Airai states. ADB (2009) also observes that water tariffs are inadequate to cover operating costs and that subsidies for the operation and maintenance of Palau's public water supply systems are a major burden on the national budget (ADB, 2009, document 2).

A number of recommendations have been made to improve the efficiency of the water sector, including raising the water usage charge (ADB, 2009). Additionally, Castalia (2004) claims that new management models will be required to combine efficient water utility operation and cost recovery with increased provision of services to the poor.

2.3 Efforts to Address Water Quality

Since 2006 the following elements have already been put into place in order to improve water safety in Palau:

- National Policy promoting water safety plans.
- Checklists for system description/analysis and for risk assessment.
- Maps, schematics, layouts etc. have been created for water supply systems within Palau including outer island state water supplies.
- Improved water quality monitoring programmes by BPW and EQPB.
- Strategies developed for public consultation and community participation to tap into local knowledge.
- K-A supply DWSP and associated improvement schedule.
- Network established for sharing of information including water resource status reports, water quality monitoring data and health surveillance statistics.

2.4 Water Supply

Natural water abundance

The humid and tropical climate of Palau, with rainfall of 3800 mm per year, generates an abundant supply of naturally occurring surface water from the streams and rivers predominant on the main island of Babeldaob, where the largest water body is the inland lake of Ngardok. A secondary source of water for public consumption in Palau is groundwater from volcanic or limestone rocks (depending on a given island's composition), although these have not been extensively tapped by the BPW mainly due to maintenance and contamination problems (Kingston, 2004).

Government water supplies

The K-A WTP produces and delivers 300 billion gallons of water per year. The island of Babeldaob has 5 major watersheds and 11 minor watersheds. The Ngerikiil River in Airai supplies 3 million gallons per day to the K-A WTP, which is supplemented daily by the Ngerimel Dam by 1 million gallons. The total 4 million gallons per day is then distributed by the BPW to households, 7 pre-school facilities, 9 schools and 1 Hospital (Republic Census, 2005). This supply is used by the two thirds of Palauans living in Koror and Airai states – the remainder of the Republic's population relies on groundwater sources and rainfall.

2.5 Demand for Water

Per capita water consumption in the Republic is significantly over the consumption levels experienced in some developed nations. Daily per capita water consumption in the K-A region of the Republic is estimated at 105 gallons (ACTEW, 2000) compared to the high consumption levels of 79-106 gallons in North America and the exceptionally low levels of 40 gallons in Australian cities such as Melbourne (Data 360, 2010). Australia as a whole has quite high per

capita consumption – Melbourne is an exception with their “Target 155” campaign (Target 155, 2010). Outside of the K-A region, there are 15 small public water distribution systems, each of which may serve populations of between 20 and 600 people. Around 80 per cent of rural communities in Palau are served by these smaller public water systems (Kingston, 2004).

Assuming an annual increase in demand for water per year of 2% (equivalent to the assumption on population growth), total annual water demand by 2020 will be 349.6 billion gallons per year up from 300 billion gallons per year in 2010. See Section 3.4 on water demand for clarifications on assumptions made to allow for this increase in demand.

3.0 ASSESSMENT METHODOLOGY

Economic assessment of drinking water safety planning in Palau has been conducted using a standard cost-benefit analysis. Cost-benefit analysis is a technique that evaluates the benefits and costs of a project from the perspective of society (as opposed to a single individual). It involves:

- Measuring the gains and losses to the community, using money as the measuring rod for those gains and losses.
- Aggregating the monetary valuations of the gains and losses and expressing them as net present social gains or losses (Pearce 1983).

The ‘net’ value of having and implementing a DWSP – the Plan’s benefits less its costs – can be calculated by comparing the situation without a DWSP and the situation with it to determine the value of improvements. In economics, this is referred to as a ‘with and without analysis’.

3.1 With and Without Analysis

‘Without’ scenario

Hutton and Haller (2004) claim that 4 per cent of the global disease burden is due to unsafe water at a cost of 60.7 million Disability Adjusted Life Years at 2003 prices (see Glossary). The WHO (2004, document 2) claims that globally, 1.8 million people die annually from gastrointestinal diseases including cholera – 90 per cent are children under 5, mostly in developing countries. Overall, 88 per cent of diarrhoeal disease is attributed to unsafe water supply, inadequate sanitation and hygiene, resulting in 1.5 million deaths per year, most of which child deaths although there is also an important increased risk for the elderly and those without immunisation.

In Palau, as in most countries, the predominant health threats associated with drinking water quality are gastrointestinal and diarrhoeal diseases caused by pathogenic microbiological contaminants: protozoa, viruses and bacteria such as faecal coliform which are inevitably present in all surface water at some time. Such health problems would persist, and potentially worsen, without effectively implementing the DWSP and would be expected to incur costs from medical treatment. They may lead to deaths in the most at-risk sections of the population: the young, the elderly, the unwell and those most susceptible to contamination, as well as potentially resulting in days lost from work or school, leading to losses in earnings and future productivity.

Additionally, under current management arrangements, a significant amount of Palau’s water supply each year is being lost to leakages (a risk in the DWSP). Persistent leakage in water supply leads to intermittent supply and increased costs of treatment, wasting resources. Furthermore, where reserves are limited, leakage unnecessarily depletes the source, which could potentially result in an intermittent supply or even to emergency conditions unless consumers have access to safe alternative water sources.

As part of implementing the K-A DWSP it is important to manage the risks associated with water leakage, as this is a major and costly risk identified as part of the DWSP. However, as mentioned in Section 6, this will require significant further work and coordination on the part of the DWSP National Water Steering Committee, which includes the EQPB.

'With' scenario

Establishment and maintenance of the K-A DWSP would incur financial costs in the form of equipment and installation costs (fixed costs) as well as ongoing costs for maintenance of these installations and awareness (variable costs).

Following implementation of the K-A DWSP, there are likely to be a number of effects:

- Risk management actions of the DWSP can be expected to improve water quality and reduce the incidence of gastrointestinal and diarrheal health problems.
- Action points D1-D6 (see Annex 2 and 4) concerning water distribution can be expected to have a particularly significant reduction effect on leakage:
  - Increase public awareness of water conservation, water shed protection. Proposed legislation on water saving plumbing fixtures Increase in water loss from pipe breakages due to aging pipes.
  - Regular checks and maintenance/ replacement of pipes and/or fittings. Asset Management DWSP development. SOP for Mains disinfection.
  - Strengthen and enforce existing regulations; Disconnect illegal and unpermitted connections; discourage connection of private tanks to water mains. Install and legislate backflow prevention devices installed/legislated for connections, as per improvement schedule.
  - Purchase and training of reliable monitoring equipment for operators.
  - Public education/awareness about proper hygiene practices programme.
- If sound water demand strategies for K-A are developed as part of the DWSP process, implemented and sustained together with appropriate leakage reduction strategies, leakage in the K-A system could be expected to be reduced to approximately 25 per cent in a best case scenario and in line with the optimal (and realistic) expectations of leakage across PICs (Chelsea Giles-Hansen, 2010). Adequate bulk metering and universal customer metering, part of the improvement schedule of the K-A DWSP, are the first steps toward developing a K-A water demand strategy, in addition to pressure management and active leak detection and repair. Reduction in leakages would result in cost savings to the Government of Palau. Currently costs are incurred to treat and pump water which is subsequently wasted, along with revenue lost from water which is not delivered and thus not paid for. Additionally, reduced water losses might result in cost savings to consumers as they rely less on alternative sources of water (e.g., purchased bottled water). Outcomes in leakage reduction, however, will require further policy action, as mentioned in Section 6.

A summary of the general with and without scenarios for DWSP at the K-A WTP in Palau is provided in Table 1.

Table 1 Potential with and without scenarios.

	Without drinking water safety planning	**With drinking water safety planning**
Costs	• Health costs for treatment of gastrointestinal health impacts induced by unsafe water • Loss of water through leakage	• Installation of equipment as part of improvement schedule • Maintenance costs of new equipment installed

	• Purchase of alternative sources of water	• Education and awareness-raising costs • Change to pro-active approach of risk assessment and management
Benefits	• No immediate investment in IS so would seem as saving	• Reduced health care costs • Reduced purchases of alternative sources of water

3.2 Valuing Benefits and Costs

A cost-benefit analysis (CBA) measures the social benefits and costs of an activity, not merely its financial costs. This distinguishes economic analysis from financial analysis. Financial analyses reflect only the flow of expenditure but do not reflect the full resource cost or 'opportunity cost' of an activity (such as socio-environmental damage) or broader resource benefits (such as socio-environmental improvement). As a result of this, valuing benefits and costs under a CBA may not be straight forward.

Some of the effects related to water safety can be described using monetary terms. For instance, costs associated with establishing and running the DWSP can be described using financial costs. However, other costs may be difficult to evaluate. For instance, the medical impacts of poor or improved sanitation are not commonly described using monetary values, even less so in small developing nations such as Palau where information is frequently unavailable. These 'non market' values remain important even though they are not easily described. As a result, proxies will be used to describe, as far as is practical, the value of such items.

Some benefits are intangible and will be duly noted. *Intangible benefits* describe those benefits that cannot be measured in economic terms. Those of particular pertinence to this study include:

- The benefit of peace of mind at a national level from knowing that with the DWSP in place, there should be no surprises and the water should be safe.
- Improved diligence of WTP staff, notably improving inspections, monitoring, maintenance and following standard operating procedures.
- The DWSP may indirectly lead to a change in public/community behaviour, such as increased water conservation and improved hygiene practices. The associated *costs* of individuals pursuing such behaviour change are also intangible (see Section 4.3).

Although these intangible costs and benefits cannot be valued within the scope of this study, they go hand in hand with the tangible economic costs and benefits of DWSP.

Treatment of time

The benefits and costs of an activity like DWSP occur over time, usually with costs occurring earlier in the first years when the DWSP is being established and benefits of at least an improved water quality not being realised in the immediate future. Tangible benefits, such as the improved health of the population which is the ultimate benefit will take considerable time. In the time between, few tangible benefits would be detected as generated by the K-A DWSP such as systematic analysis of risks and identification of control measures, savings from optimised use of treatment chemicals, development of improvement schedule to guide investments, some changes in monitoring or inspection regimes. Understandably, the time lags between costs and benefits complicate assessing the value of implementing the DWSP approach.

People generally have a preference for financial paybacks sooner rather than later. This 'positive time preference' is accommodated in cost-benefit analysis by weighting earlier monetary values of costs and benefits more heavily than later monetary values of benefits and costs. The total values

of costs and benefits over time are then presented as present-day values. The procedure to convert the values of gains and losses generated over time to present-day values is termed 'discounting'. The expected value of benefits from the DWSP will therefore be discounted over time to generate an overall pay off to Koror and Airai states of the system in current-day values. Appropriate selection of a discount rate is crucial for CBA and has important implications for economic payoffs, of which sustained health improvements are the most important.

The rate at which later values should be discounted in comparison to earlier ones has been under debate for some time in economic literature and is unlikely to be resolved (see Pearce et al. 2003 for examples). Holland (2008) indicates the range of discount values used in PICs in recent years varies between 3 and 12 per cent. Consistent with other SOPAC analyses, discount rates of 3, 7 and 10 per cent will be used in this CBA to reflect development aims from a variety of perspectives. Values reported will be at a discount rate of 10% unless stated otherwise.

3.4 Assumptions

Lifespan and scope of the CBA

The life span of the equipment and inputs used in the K-A DWSP vary widely from a few years (in the case of valves) to as many as several decades (for example in the case of major equipment such as rainwater tanks and other piping equipment). As an example, New Zealand Ministry of Health (2007) suggests that the normal life spans of water supply equipment are as given in Table 2.

Most of the improvements mentioned in the K-A DWSP improvement schedule refer to pumps, valves, meters and similar equipment. These have a maximum lifespan of 20 years. For representativeness, the economic analysis has thus been conducted over the span of 20 years.

Table 2. Lifespan of water supply equipment.

Equipment	Normal lifespan (years)
(1) Buildings, concrete or steel structures, buried pipes	50–100
(2) Pumps, valves, switchboards, meters and similar equipment	15–20
(3) Instruments and controls	10–15

Source: New Zealand Ministry of Health (2007).

Demand for water

In order to accommodate changes in the consumption of water over time, expected changes in population and water demand need to be considered. The ADB (2009) claims that population growth in Palau was 1.4 per cent in 2009. It is assumed that the amount of water produced by the K-A WTP will increase by at least the rate of population growth. Additionally, tourism has increased steadily in recent years (see Table 3). On the basis of this, an increase in the demand for water has been assumed at 2 per cent per year. This assumption holds if the water demand management will be conducted effectively to improve WTP capacity and efficiency and further reduce water losses. This assumption provides an effective backdrop for DWSP whereby no construction or expansion will be required to allow for the assumed increases in demand for water. For illustrative purposes, it is assumed that water supply and demand (where demand in this case accounts for both consumption and leakage) are equivalent, and therefore that demand for water is equivalent to the 300 billion gallon per year supply of water from the K-A WTP.

Table 3. Tourism population growth over time.

Year	Total	Tourist	Business	Employment	Other
2001	54,111	45,866	2,930	5,315	-
2002	58,560	50,513	3,431	4,458	158
2003	68,296	59,851	3,472	4,679	294
2004	94,895	83,041	4,422	5,361	2,071
2005	86,124	76,180	4,398	5,322	224
2006	87,206	78,252	4,150	4,557	247
2007	93,031	84,566	3,610	4,641	214
2008	83,114	75,829	3,407	3,678	200

(Source: European Union, 2007).

Fuel, labour and maintenance costs

There are large electricity costs involved in the production and distribution of safe drinking water by the WTP. Kumar (2010) observes that fuel prices in Palau are currently at levels indicated in Table 4.

Table 4. Fuel prices in Palau.

	Petrol	Diesel	Kerosene
(US$ per gallon)	$3.66	$3.96	$6.95
(US$ per litre)	$0.97	$1.05	$1.84

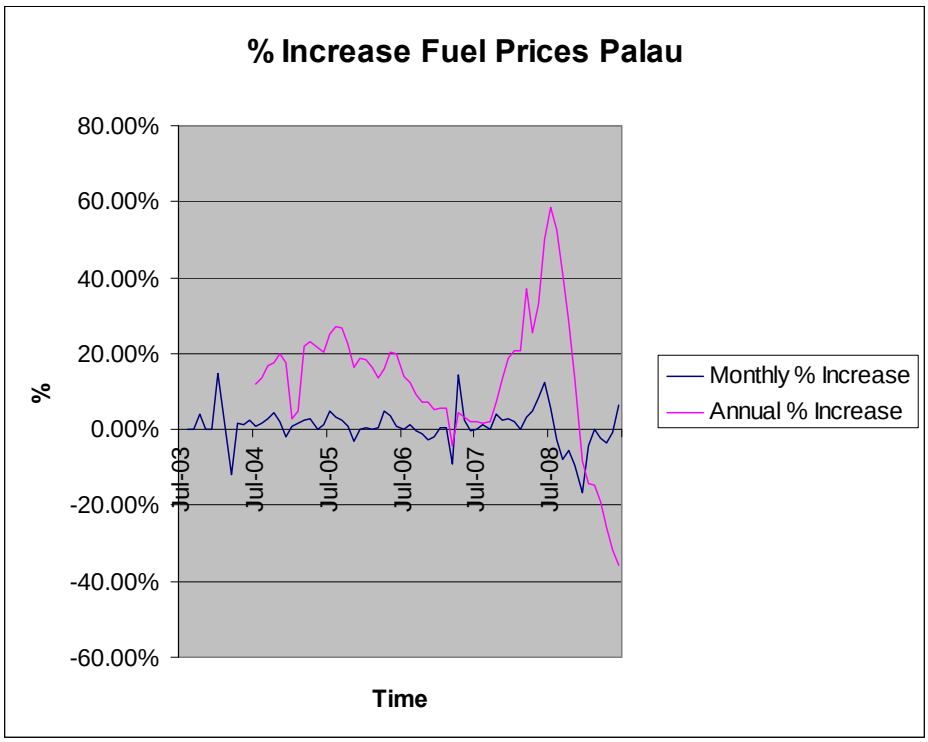

Figure 3. Fuel increases in Palau.

At the K-A WTP, diesel is used to generate electricity. Figure 3 illustrates the monthly and annual percentage increases in diesel fuel price in the Republic. Some abstract indicative forecasts can

be made using the information available. According to the US Energy Information Administration, world oil consumption will grow by 1.5 million barrels per day (bbl/d) in 2010 and 1.6 million bbl/d in 2011. This growth is the result of an expected recovery in the global economy, with world gross domestic product (on an oil-weighted basis) assumed to rise by more than 3 per cent per year. Oil price globally is forecast to average at US$81.06 per barrel in 2010 (Forexyard, 2010) but to continue to increase in the long term. Accordingly, world fuel prices can be expected to drive an increase in Palau's fuel prices. Based on discussions with SOPAC energy staff, it is understood that the average annual increase in diesel price over the past 4 years has been 13.2 per cent. However, given the lack of modelling available, it is difficult to forecast the fuel price changes for the Republic over time. Estimated fuel price changes will thus be imputed as part of the maintenance costs for the implementation of the improvement schedule.

Labour costs in Palau can also be expected to increase over time although it is not possible at this point to determine how high labour rates for implementing the DWSP will be in the future compared to now. Potential increases in labour costs for the implementation of the DWSP will be built into the maintenance costs.

Equipment to be replaced or upgraded as a result of risks identified in the DWSP must be maintained over time. Maintenance costs are likely to increase as time progresses and equipment requires new parts or more attention. In the absence of better information, maintenance costs – including changes in fuel costs and labour costs per annum – are assumed for illustrative purposes at 3 per cent of improvement schedule costs (in line with Singh, forthcoming), increasing annually in line with the inflation rate suggested by ADB (2009) of 2 per cent per year, as well as increasing 2 per cent per year to compensate for depreciation of the equipment.

4.0 DATA

4.1 Data Availability and Sources

Data used in this document have been procured from four main sources:

- Directly interviewing EQPB personnel *in situ* in Palau.
- Internet-based research. The data collected here is not always tailored exactly to the nature of this work and was adopted or extrapolated in most cases to suit the country specifications of Palau.
- Past SOPAC reports.
- SOPAC/WHO water safety/water quality team.

Data availability for the analysis is highly limited, for example information on the incidence of gastrointestinal illnesses in Palau was difficult to secure during field visits or by remote contact likewise. Information regarding age of current equipment, education and time elapsed (e.g. since new equipment was installed in the WTP and the projected DWSP education expenditure plan) was not available.

4.2 Health Issues

The risk to public health is the most important issue to be addressed by water safety planning, especially bacterial or protozoal contamination related to human or animal waste, although some chemical contaminants can be significant in certain special circumstances (Freshwater, 2010).

By default, all surface water supplies and shallow underground sources without sanitary surveys and DWSPs in place should be considered unsafe and subject to contamination at any time.

Although DWSP implementation can lead to improved health, it is assumed that improvements in sanitation and hygiene must continue in the background, as these issues cannot be separated from working towards safe drinking water (Freshwater, 2010).

WHO (Hutton and Haller, 2004) claims that improved water supply reduces diarrhoea morbidity by between 6 to 25 per cent, if severe outcomes are included. Improved sanitation reduces diarrhoea morbidity by 32 per cent. Hygiene interventions including hygiene education and promotion of hand washing can lead to a reduction of diarrhoeal cases by up to 45 per cent (Hutton and Haller, 2004). Improvements in drinking-water quality through household water treatment, such as chlorination at point of use, can lead to a reduction of diarrhoeal episodes by between 35 per cent and 39 per cent (Hutton and Haller, 2004).

Health cost data for the Republic of Palau was difficult to obtain given the lack of readily available records. Information on the number of gastrointestinal and diarrhoeal disease incidents in Palau could not be secured, making it impossible to estimate more precise financial costs of the currently low levels of water safety. Given this lack of data, only broad estimates can be made based on a slightly similar study by Hajkowicz and Okotai (2006). As a point of comparison, Hajkowicz and Okotai (2006) estimates that health costs in Palau due to solid waste related pollution are most likely to be around US$697,000 per year, calculated based on productivity losses due to days off work, as well as costs of medical treatment.

Whilst these figures are based on solid waste-related pollution, they represent the closest information available on current health costs related to pollution in Palau. They are therefore used for indicative purposes to illustrate potential health benefits from implementing DWSP in Palau. It can be assumed that, in the absence of the DWSP, this level of health cost would persist in Palau. By comparison, full implementation of the DWSP might be expected to generate a reduction in diarrhoea morbidity by between 6 to 25 per cent (as per Hutton and Haller 2004). Annual health costs due to water quality are thus assumed to be US$697,000 for the without scenario and US$588,965 for the with scenario assuming an average reduction in diarrhoea morbidity of 15.5 per cent (the average of 6 to 25 per cent). By subtracting these two figures, the value of the actual health improvements made (or benefits of the DWSP) is US$108,035 in 2010. The value of health improvements has been adjusted for population growth of 2 per cent per year and for annual inflation of 2 per cent (ADB, 2009).

4.3 DWSP Costs

Costs to be covered to implement the K-A DWSP are summarised in Table 5. The improvement schedule implementation is expected to be completed in 2012 (if on track) and major capital upgrades are not expected to be necessary until 2032. Meter installation is included under the improvement schedule, in the form of bulk meters installed at the WTP and the water source.

Table 5. Fixed and Variable costs (including new investments).

Fixed costs	**(US$) 2010**
Total cost of improvement schedule implementation (2010)[1]	85,000
Variable costs per year	
Maintenance in 2010 [2]	2,550
Education in 2010 onwards [3]	5,000

[1] Improvement schedule

[2] Calculated as 3% of improvement schedule costs, increasing annually by 2% for inflation and 2% for depreciation over time.
[3] Estimate for illustrative purposes, increasing by US$1000 per year.

Not all costs could be estimated, for example the intangible costs of individuals changing their behaviour regarding water conservation and hygiene following the implementation of the DWSP. Furthermore, although it is known that US$10,000 was contributed by SOPAC to the EQPB in 2009 for education/awareness, it was not possible to obtain information on the cost of awareness-raising activities that would be needed to implement the plan. Awareness-raising activities and education will increase annually by US$1000.

NB: The education/awareness expenditure mentioned is assumed to be a once-yearly short campaign as opposed to an ongoing programme, in which case such expenditure would be higher.

4.4 Alternative Sources of Water for Consumption

Alternative sources of water in Palau are rainwater catchment tanks, dispensed water and bottled water. The 2000 Palau Census (Hajkowicz, 2006) found that residents obtain drinking water as follows:

- 55 per cent from rain supplies (e.g. rainwater tanks);
- 13 per cent from public mains supply;
- 10 per cent from bottled water; and
- 3 per cent from a mix of rain and bottled water (Hajkowicz, 2006).

In contrast, the Director of Public Works in the Republic, Techur Rengulbai (2010), cited a figure of 70 per cent when referring to the percentage of the population in Babeldaob owning rainwater tanks, claiming they were used mainly to buffer the odd period of drought.

Theoretically, a successfully implemented DWSP could reduce local reliance on alternative water sources such as bottled water. At this stage, it is difficult to predict the long-term shift of consumers away from rainwater tanks and bottled water due to a safer water supply. Improvement in the reliability of water supplies would have a limited impact on a decreased reliance on rainwater tanks over the time span of 20 years. This is because rainwater tanks have an expected life of 50-100 years according to the New Zealand Ministry of Health (2007) and would largely not need to be replaced during the 20 year period of the DWSP assessed in this report (see Table 2). In the short term, however, it is possible that consumers in Koror and Airai states might rely less on the purchase of bottled water. For illustrative purposes, and assuming the figures available from 2008 can be extrapolated to 2009 and onwards, a reduction in the purchase of bottled water of 5 per cent would represent savings of US$21,451 in 2010. This value has been adjusted for changes in demand and inflation (as per Section 4.3).

4.5 Summary of Values Associated with DWSP in the K-A Water Supply in 2010

Table 6. Summary of the present non-discounted benefits and costs associated in DWSP in Palau.

Without DWSP (US$)	With DWSP (US$)	Change due to DWSP (US$)
• Health costs 697,000 in 2010[a] • Purchase of alternative sources	• Health costs 589,000 in 2010 • Education of 5,000 in 2010 • Remaining bottled water expenditure 407,600 in 2010	• Health benefits at 15.5% improvement = 110,200 in 2010 • Education costs = 5,000 in 2010 • Reduction in alternative water

of water of 429,000 in 2010 based on 2008 data • No immediate investment of dollars	• Installation, equipment and ongoing maintenance costs: - 68,000 fixed costs in 2009 (although back-spending is ignored for the purposes of this review) - 85,000 fixed costs in 2010	purchases = 21,500 • Installation , equipment and maintenance costs: - 68,000 fixed costs in 2009 (although back-spending is ignored for the purposes of this review) - 85,000 fixed costs in 2010

[a] Hajkowicz *et al* (2006).

5.0 ECONOMIC PAYOFFS OF K-A DRINKING WATER SAFETY PLANNING IN PALAU

5.1 Net Present Value

Discounted over 20 years, and using a 10 per cent discount rate, the total cost of establishing and implementing the K-A DWSP is estimated to be US$ 0.2 million. By comparison, the total value of benefits over time is expected to be US $1.34 million (see Table 7 and Annex 1 for calculations).

The expected net benefits of the implementation of the water safety planning in Palau are thus estimated at US$ 1.11 million – a return of US$ 5.9 on each dollar invested.

Table 7. Expected net benefits from a water safety planning in Palau over 20 years.[1]

Present Value of Benefits (million)	Present Value of Costs (million)	Net Benefits (million)	Benefit: Cost Ratio
1.34	0.229	1.11	5.9:1

[1] Discount rate of 10 per cent; calculations available from the author upon request.

5.2 Sensitivity Analysis

Predicted payoffs from DWSP are sensitive to assumptions concerning the discount rate applied, the percentage improvement in health, maintenance costs and growth in water demand. Detailed values generated during sensitivity analyses for a variety of parameters, as well as a brief explanation of discounting, are provided in Annex 1.

Discount rates

Estimated payoffs should worsen with a lower discount rate. The most likely net present value from the DWSP at a discount rate of 3 per cent would be US$ 1.92 million, with US$ 6 payback for every dollar spent, and at a discount rate of 7 per cent would be US$ 1.38 million, also with US$ 6 payback for every dollar spent. It is clear that this analysis is not significantly sensitive to assumptions on the discount rate.

Health benefits

Estimated net benefits from the DWSP are sensitive, in both directions, to assumptions in the impact of the DWSP on health. If percentage improvement in the incidence of gastrointestinal and diarrhoeal health problems due to the DWSP implementation was only 6 per cent (Hutton and

Haller, 2004) expected net benefits would fall from US$ 1.34 million to US$ 0.5 million. By comparison if health improvements are assumed to be larger (where DWSP reduces morbidity by 25 per cent), expected net benefits could rise from US$ 1.34 million to US$ 1.9 million (see Annex 1).

Maintenance costs

When the maintenance cost assumption is adjusted to 3 per cent total plant management costs of US$ 2,542,026, the benefit:cost ratio for the DWSP is 1.15:1 – or US$ 0.15 saved for every dollar invested in the DWSP. This is a much lower payback than with the original assumption of maintenance costs at 3 per cent of only the improvement schedule costs. This lower payoff underlines then importance of adequate maintenance cost assumptions.

Growth in water demand

Water demand is intrinsically linked to population growth (see Section 3.4) and is currently assumed at 2 per cent per year. According to Table 3, there has been a growth in visitor arrivals between 2001 and 2008 of 7.4 per cent, such that annually, there are currently around 4 times as many visitors to Palau as there are residents. Although tourists typically stay in the country for a short length of time, this growth in tourism evidently has a large impact on water demand, especially under the assumption that visitors tend to use up to 50 per cent more water on a per day basis than do residents (Kim and Konan, 2004). For these reasons, and given the potential uncertainties involved in finding out exactly the significance of tourist water usage, a sensitivity analysis has been done on this subject. In conclusion, whether water demand growth is assumed at 2.5 per cent per year or at 3 per cent per year makes no significant difference to the benefit cost ratio, with payback per dollar expenditure remaining around US$8 for both these demand assumptions, only two dollars higher than with the original assumptions.

6.0 POLICY IMPLICATIONS

It would appear that the potential benefits to be gained from implementing the K-A DWSP are greater than the costs. A high estimated benefit: cost ratio of 5.9:1 would suggest that investment in establishing and implementing the K-A DWSP would justify its support from a socio-environmental perspective. The benefits of this Plan rely on ongoing support for maintenance and awareness. Without this, potential benefits from the Plan could be expected to decline over time as equipment deteriorates and awareness of safe water falls.

Ultimately, delivery of high quality water to users will require ongoing funding activities. According to ADB (2009, document 2), a flat rate of US$10 per month is presently imposed in Palau on all connections in areas with no meters and there are no changes proposed to this charge. The Bureau of Public Works is keen to remove the need for flat rate charges altogether, by installing meters for all households and charging US$0.85 per 1000 gallons water usage (see Section 2.1). This, however, is a separate project, even though it falls within the DWSP umbrella, and funding options are currently being explored. Given the significant shortfall with current water charges, and given previous recommendations from both ACTEW (2000) and ADB (2009), further consideration of water usage charges should be made in order to lend further support to effective DWSP implementation (and water demand management under DWSP).

Related to this, the scale of leakage in the K-A water supply system is uncertain but likely to be high with the last assessment by ACTEW (2000) estimating leakage to be in the order of 60 per cent (or approximately 2.4 mega-gallons per day). ACTEW (2000) estimated that approximately half of this leakage is attributed to system leakage, and the other half from household piping. If

leakage could be fixed, funding requirements to maintain water supply services could be substantially reduced.

6.1 Recommendations for Further Action and Future Analysis

Data to conduct this analysis was scarce and the resulting figures are necessarily preliminary. To improve assessments in the future, it will be valuable to improve access to data such as State-by-State daily consumption of water and health data on the incidence of gastrointestinal disease. At an operational level, improved data on the proportion of water supply and maintenance costs of the K-A WTP equipment would be beneficial, as these are not currently available (and had to be presumed in the report). It will also be important to obtain the water education expenditure plan.

It is recommended that more research be conducted in the area of the past and future values of identified current costs and benefits, in order for a detailed discounting exercise to be conducted.

7.0 CONCLUSION

The total cost of establishing and implementing the K-A DWSP, discounted from 2010 over 20 years using a 10 per cent discount rate, is estimated to be US$ 0.2 million. By comparison, the total value of benefits over time is expected to be US$ 1.34 million.

The expected net benefits of the implementation of the K-A DWSP water safety planning in Palau are thus estimated at US$1.11 million – a return of US$ 5.90 on each dollar invested.

The CBA for implementing the K-A DWSP demonstrates that the benefits gained are greater than the costs. A high estimated benefit: cost ratio of 5.9:1 would suggest that investment in establishing and implementing the K-A DWSP would justify its support from a socio-environmental perspective. The majority of this benefit would be expected to accrue to the people of Palau who suffer most from water-induced gastrointestinal illnesses: the young, the old and those with compromised immune systems.

8.0 REFERENCES

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ANNEX 1 SENSITIVITY ANALYSIS

The Net Present Value (NPV) investment begins one period before the date of the value cash flow and ends with the last cash flow in the list. The NPV calculation is based on future cash flows. If your first cash flow occurs at the beginning of the first period, the first value must be added to the NPV result, not included in the values arguments. See the formula below.

If n is the number of cash flows in the list of values, the formula for NPV is:

$$\Sigma R_t / (1 + i)^t$$

Where: R_t = the original investment value
i = the selected discount rate
t = the time of cash flow

The present value of benefits of the Koror-Airai DWSP has been calculated using the following values (see Table 7, Section 5.1):

R_t = US$ 135,309.90 in the base year 2010 (year 0)
i = 10%
t = the number of years that have passed since initial improvement schedule investment. For the base year, the value of t is 0. For 2011, the value of t is 1, and so on.

The values that result per year will then be summed to reach the final present value of benefits of US$1.34 million after the 20th year in 2030. The same discounting procedure is followed for the present value of costs.

Expected returns with varying discount rates.

Discount rate	Present Value Benefits (millions)	Present Value Costs (millions)	Net Present Benefits (millions)	Benefit: Cost Ratio
3%	2.28	0.365	1.92	6:1
7%	1.65	0.272	1.38	6:1

Expected returns with varying impacts on health (at 10% discount rate).

Discount rate	Percentage Health Cost Reduction following WSP	Present Value Benefits (millions)	Present Value Costs (millions)	Net Present Benefits (millions)	Benefit: Cost Ratio
10%	6%	0.730	0.228	0.501	3.2:1
10%	25%	2.18	0.228	1.95	9.5:1

*Expected returns with maintenance/labour/fuel costs based on total WTP management costs of US$*2,542,026.16 as opposed to based on the improvement schedule costs.

Discount rate	Present Value Benefits (millions)	Present Value Costs (millions)	Net Present Value (millions)	Benefit: Cost Ratio
10%	1.34	1.16	0.178	1.15:1

Expected returns with population growth (and thus also water demand) at 2.5% and at 3%.

Discount rate	**Population Growth (water demand growth)**	**Present Value Benefits (millions)**	**Present Value Costs (millions)**	**Net Present Value (millions)**	**Benefit: Cost Ratio**
10%	2.5%	1.78	0.230	1.55	7.7:1
10%	3%	1.86	0.231	1.63	8:1

ANNEX 2 KOROR-AIRAI WATER SUPPLY IMPROVEMENT SCHEDULE

Nº	Improvement	Risk	Priority	Agency	Stages/Actions	Time Frame	Estimate Cost
IS1	Establish/identify a back-up Intake and/or storage system for drought events	**C1**	1	BPW	• Investigate the cost/feasibility secondary pipeline from Dam to WTP • Investigate alternate sources for supplementation	2010 2012	$25,000
IS2	Improve land use/planning within Drinking Water Catchment Areas	**C2**	2	BPW/ EQPB	• Design regulations to designate drinking water catchment zones and permitted activities • Implement Sanitary Survey programme	2011 2009	
IS3	Investigation and survey of dam assets	**C7**	1	BPW	• Source suitably qualified person/organisation to provide condition report on dam, including sediment controls	2010	$25,000
IS4	Purchase and training of reliable monitoring equipment for operators	**T1**	1	BPW	• Source quotes from suppliers of suitable monitoring equipment for supply including- - Portable Colorimeter(s) - Portable/static Turbidity meter(s) - Replacement Turbidity meter for WTP • Source training from suppliers of equipment • Purchase 3 flow meters - Ngerikiil River - Ngerimel Dam - Outlet of the wet well	2009	 $5,000 $18,000
IS5	Develop contingency/emergency plans for all highlighted risks	**T2**	1	BPW/ EQPB/ NEMO	• Priority of security of water quality to be complete first • Industry best practice to be used • Plans to include entire water system	2009	
IS6	Standard Operating Procedures to be designed for water supply.	**T2**	1	BPW EQPB	Water system procedures should include best practice for: - Catchment Management - Treatment - Distribution Each Procedure to have a check sheet for verification and audit purposes. Verification Process to be design for WSP	2009 2009	

IS8	Storage tanks for finished water	**T2**	2	BPW	• Investigation needs to be carried out on daily demand to acquire data on storage requirements. • Feasibility and concept report required to be completed for options.	2009 2009	$15,000 $30,000
IS9	Provide justification for annual maintenance and operations funding	**T4**	1	BPW	• Design Preventative Maintenance Programme for Water Supply • Develop Asset Management DWSP including budgets	2009	
IS10	Construction of fences around the storage tanks	**T8**	3	BPW	• Design and request quotes • Write security procedure for sites	2010	
IS11	Increase public awareness of water conservation and water shed protection. Leak detection programme Demand Management Study	**D1** **D3**	2	EQPB	• Develop water conservation and awareness campaign • Develop campaign of water hygiene practice in schools • Engage suitable resources to quantify water loss through leak survey • Engage suitable resources to perform demand study	2009 2010 2010	 $15,000 $20,000
IS12	Strengthen existing regulations and enforcement	**D4**	2	EQPB	• Set up working group to review all current water regulations and legislation and provide recommendations	2010	
IS13	Design of integrated Disaster Management Plan	**D3**	2	NEMO/ PW	• Assessment on Natural Hazards to Palau and effects on the water assets need to be carried out	2010	

ANNEX 3 WSP IMPROVEMENT SCHEDULE

The following information is taken from the Koror-Airai drinking water safety planning from 2008 (total cost of US$153,000 by 2012).

WSP Improvement Schedule		**2010**	**Onwards**
Establish/identify a back-up Intake and/or storage system for drought events (15-20 years)			25000
Improve land use/planning within Drinking Water Catchment Areas	Design regulations to designate drinking water catchment zones and permitted activities	2010	
	Implement Sanitary Survey programme		
Investigation and survey of dam assets			25000
Purchase and training of reliable monitoring equipment for operators (10-15 year lifespan)	Source quotes from suppliers of suitable monitoring equipment for supply Source training from suppliers of equipment	5000	
	Purchase 3 flow meters (Ngerikiil River, Ngerimel Dam, Outlet of the wet well)	18000	
Develop contingency/emergency plans for all highlighted risks			
Standard Operating Procedures to be designed for water supply			
Storage tanks for finished water (15-20 years)	Investigation needs to be carried out on daily demand to acquire data on storage requirements	15,000	
	Feasibility and concept report required to be completed for options	30,000	
Provide justification for annual maintenance and operations funding		2010	
Construction of fences around the storage tanks (lifespan 15-20 years)			2010
Leak detection programme	Engage suitable resources to quantify water loss through leak survey		15000
Demand Management Study	Engage suitable resources to perform demand study		20000
Strengthen existing regulations and enforcement.			2010
Design of integrated Disaster Management Plan			2010

Detailed costing for the management of the Koror-Airai Water Treatment Plant.

Cost (yearly average, US$)	**2006**	**2007**	**2008**	**2009**
Ngerikiil Pump Station				576,642
Ngeruluobel WTP A				685,453
Ngeruluobel WTP B				144,674
Ngermid Pump Station				2,609
Total Yearly Average Electricity Costs				**1,409,379**
Aluminium sulphate				182,520
Soda ash				132,264
Powder activated carbon (pac) 30bgs/mo				14,479
Chlorine (granular) 31 pails				64,148
Chlorine (Tablet) 30 pails				39,236
Total chemical cost				**432,647**
Staff costs				700,000
Total Cost				**2,542,026.16**

ANNEX 4 KOROR-AIRAI DWSP RISKS

Catchment & Intake

	Risks to Water Quality	Control Measures	Risk Priority
C1	Drying up of the Ngerimel Dam due to drought events	None	*High* – Although not frequent the loss of water has a high impact on the system and population
C2	Contamination from agricultural chemicals	None (Ngerikiil River Intake)	*Medium* – Risk has potential but currently not quantified
C3	Increased turbidity due to deforestation e.g. for agriculture or wild fires or clearing for development	None	*High* – Not likely to occur on a regular basis. However, the impact of such an event would have a devastating affect on the water supply and population
C4	Contamination from road runoff e.g. from oil and petrol leaks/spills	None	*Medium* – Not likely to occur on a regular basis. Therefore urgent action is probably not warranted, however, a emergency/contingency plan should be prepared to deal with this risk in the long-term especially with the new Compact Road opening soon
C5	High Sediment load from flooding during periods of heavy rainfall	None	*Medium* – Occurs over a great period of time
C6	Contamination from human and animal faeces due to open access to Intake for people and animals especially at Ngerikiil River	None	*Medium* – it is a risk but one that is not so significant, therefore urgent action is probably not warranted, however, an emergency/contingency plan should be established to deal with the risk in the long-term
C7	Damage to dam infrastructure	None	*High* – Structural integrity of the dam is a cause of concern and related pipe work age
C8	Faecal Coliform contamination from residential/recreational activities within the catchment and intake areas	None	*Low* – Restricted access to catchment areas
C9	Power outage	Yes back-up generator on-site to continue operations during power outage	*Low*

Treatment & Storage

Risks to Water Quality		Control Measures	Risk Priority
T1	Monitoring equipment	None	*High* – Monitoring equipment is old and not calibrated
T2	Increased turbidity loading from source	Partially Routine tests to ensure correct dosing	*High* – Plant unable to perform with high turbidity levels
T3	Increased Coliform levels due to inadequate dosing and monitoring of chemicals such as Chlorine	Partially Chlorine is dosed and FAC tested – accuracy variable	*Medium* – Procedures in place, but monitoring equipment upgrade required
T4	Insufficient funds to buy relevant equipment, carry out repairs and maintenance etc	None	*High* – Ineffective preventative maintenance programme
T5	Not enough chemicals in stock (running out of chemicals such as Chlorine etc)	Yes. Proper stock control procedures in place to avoid the problem of running out of chemicals	*Low*
T6	Contamination or damage to infrastructure due to sabotage and/or vandalism	Yes. The treatment area is well fenced and there are water operators onsite at all times	*Low*
T7	Damage to storage tanks due to aging Infrastructure	Yes. Regular monitoring of infrastructure conditions and maintenance when needed	*Low*
T8	Damage to storage tanks due to vandalism	None	*High* – Access to needs to be restricted
T9	Power outage	Yes. A back-up generator on-site to continue operations during power outage	*Low*

Distribution

Risks to Water Quality		Control Measures	Risk Priority
D1	Loss of water due to water wastage	None	*High*
D2	Increase in water loss from pipe breakages due to aging pipes	None, lack of equipment	*High*
D3	High water loss due to unattended and/or un-reported leakages in the distribution lines	None	*Medium*
D4	Backflow contamination and/or cross contamination from household/rainwater storage tanks connected to water mains	Partially – regulations exist but not enforced.	*High*
D5	Incorrect analysis data due to uncalibrated laboratory equipment	Regular calibration of analytical equipment; cross-check/validation of data by EQPB	*High*
D6	Point of use contamination due to improper hygiene practices	None	*High* – Mitigation of some of this risk can be achieve through actions of D4

Catchment Risk Management Plan – High Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
C1	Drying up of the Ngerimel Dam due to drought events	Establish/identify a back-up Intake and/or storage system for drought events	**IS1**	- Visuals Inspections - Monitoring of dam Levels		Water restrictions	
C3	Increased turbidity due to deforestation e.g. for agriculture or wild fires or clearing for development	Improved land use management/planning within the catchment Sanitary survey BMP Agricultural practices around watersheds	**IS8**	- Visual Inspections - Sanitary Inspections		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	
C7	Damage to dam infrastructure	Investigation and survey of dam assets	**IS3**	- Visual Inspections		- Water restrictions - Implantation of emergency plan	

Catchment Risk Management Plan – Medium Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
C2	Contamination from agricultural chemicals	Establish buffers (vegetation) between agricultural land and intake areas (river/stream) Create legislation	**IS2**	- Water chemistry monitoring programme - Sanitary Survey		Shut off the system, flush the system out; place public messages over local media advising consumers to take precautionary measures	
C4	Contamination from road runoff e.g. from oil and petrol leaks/spills	Improve drainage around roads to divert runoff away from the intake areas	**IS2**	- Water chemistry monitoring programme - Sanitary Survey		Shut off the system, flush the system out; place public messages over local media advising consumers to take precautionary measures	
C5	High sediment load from flooding during periods of heavy rainfall	Increase reservoir capacity Better filtration system in place to remove suspended solids	**IS3**	- Monitoring programme - Sanitary Survey		Public Notices to collect water will be broadcasted over the media during heavy rainfall	
C6	Contamination from human and animal faeces due to open access to Intake for people and animals especially at Ngerikiil River	Fencing off the intake area; place warning signs for the public Assess alternative locations and existing intakes	**IS2**	- Water chemistry monitoring programme - Maintenance and monitoring of Cl levels in distribution system - Sanitary survey		Place public messages over local media advising consumers to take precautionary measure	

Treatment & Storage Risk Management Plan – High Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
T1	Monitoring equipment	Purchase and training of reliable monitoring equipment for operators	**IS4**	- EQPB Monitoring for verification			
T2	Increased turbidity loading from source	Create Contingency Plan for an event Auditing process for WTP SOPs Investigate alternate source water Investigate extra finished water storage	**IS1** **IS5** **IS6** **IS8**	- Water chemistry monitoring - Sanitary Survey		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	
T4	Insufficient funds to buy relevant equipment, carry out repairs and maintenance etc	Provide justification through design of asset management/sustainability plan for funding	**IS9**	- Monitoring Programme - Verification EQPB		If an event occurs; place public messages over local media advising consumers to take precautionary measure e.g. boiling	
T8	Damage to storage tanks due to vandalism	Construction of fences around the storage tanks	**IS10**	- Visual Inspections		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	

Treatment & Storage Risk Management Plan – Medium Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/Emergency Plan	Plan Nº
T3	Increased Coliform levels due to inadequate dosing and monitoring of chemicals such as Chlorine	Create Standard Operating Procedures (SOP) Auditing process for WTP SOPs	**IS6**	- Monitoring Programme - Verification EQPB		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	

Distribution Risk Management Plan – High Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
D1	Loss of water due to water wastage	Increase public awareness of water conservation, water shed protection Proposed legislation on water saving plumbing fixtures	**IS11**	- Flow monitoring		Decrease water pressure	
D2	Increase in water loss from pipe breakages due to aging pipes	Regular checks and maintenance/replacement of pipes and/or fittings Asset Management Plan development SOP for Mains disinfection	**IS9**	- Demand and Pressure Surveys		Decrease water pressure	
D4	Backflow contamination and/or cross contamination from household/rainwater storage tanks connected to water mains	Strengthen existing regulations and enforce Disconnect illegal and unpermitted connections; discourage connection of private tanks to water mains	**IS12**	- Inspection Programme		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	
D5	Incorrect analysis data due to uncalibrated laboratory equipment	Purchase and training of reliable monitoring equipment for operators	**IS4**	- Regular calibration of analytical equipment; cross-check /validation of data by EQPB		Public Messages	
D6	Point of use contamination due to improper hygiene practices	Public education/awareness about proper hygiene practices programme	**IS11**	- Property Surveys		Place public messages over local media advising consumers to take precautionary measure e.g. boiling	

Distribution Risk Management Plan – Medium Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
D3	High water loss due to unattended and/or un-reported leakages in the distribution lines	Leak detection programme Investigation and design of asset replacement/renewal programme	**IS11**	- Repairs sheets - Distribution procedures - Pressure testing programme		Place public messages over local media advising consumers to take precautionary measure and conserve water	

General Risk Management Plan – High Risks

Worksheet Nº	Identified Risk	Improvement Identified	I/Schedule Nº	Monitoring and Management Activity	Procedure Nº	Contingency/ Emergency Plan	Plan Nº
G1	Unforeseen or out of the ordinary events	Design of Disaster Management Plan with NEMO	**IS13**	- Monitoring and Management by NEMO/EQPB/PW		Assistance from outside Palau	