Sustainable Integrated Water Resources and Wastewater Management in Pacific Island Countries

National Integrated Water Resource Management Diagnostic Report

Papua New Guinea

Published Date: November 2007
Draft SOPAC Miscellaneous Report 643

GLOBAL ENVIRONMENT FACILITY

UNDP

SOPAC

UNEP

ACRONYMS

ADB	Asian Development Bank
ADRA	Adventist Development and Relief Agency
ANU	Australian National University
AusAID	Australian Agency for International Development
BCL	Bougainville Copper Limited
CBD	Convention on Biodiversity
CBO	Community-based Organization
CI	Conservation International
CRC	Conservation Resource Center
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAL	Department of Agriculture and Livestock
DEC	Department of Environment and Conservation
DNPM	Department of National Planning and Monitoring
DoH	Department of Health
DoW	Department of Works
DPE	Department of Petroleum and Energy
DPLLGA	Department of Provincial and Local Level Government Affairs
EDF	European Development Fund
EEZ	Exclusive Economic Zone
ENSO	El Nino Southern Oscillation
FAO	Food and Agriculture Organization
FIMS	Forest Information and Mapping System
FSP	Full-size Project
GEF	Global Environment Facility
GIS	Geographical Information System
GULLG	Goroka Urban Local Level Government
GPNG	Government of PN
ICAD	Integrated Conservation and Development
ICCC	Independent Consumer and Competition Commission
IHP	International Hydrological Program
ILG	Incorporated Landowner Group
ITCZ	Inter-tropical Convergence Zone

IWP PNG	International Waters Program PNG
IWRM	Integrated Water Resources Management
JICA	Japanese International Cooperation
LDS	Lutheran Development Services
MEA	Multi-lateral Environmental Agreements
MTDS	Medium Term Development Strategy
NCAA	National Civil Aviation Authority
NCDC	National Capital District Commission
NDO	National Disaster Office
NDR	National Diagnostic Report
NEC	National Executive Council
NGO	Non-government Organisation
NWRMP	National Water Resources Management Policy
NWS	National Weather Service
NWSP	National Water Services Policy
NWV	National Water Vision
Pacific RAP	Pacific Regional Action Plan on Sustainable Water Management
PDF	Project Development Facility
PICs	Pacific Island Countries
PNG	Papua New Guinea
PNGFA	PNG Forest Authority
PNGGS	PNG Geological Survey
PNGRIS	PNG Resource Information System
SPREP	Secretariat of the Pacific Regional Environment Program
TNC	The Nature Conservancy
ULLG	Urban Local Level Government
UNCCD	United Nations Convention on Biological Diversity
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation
WMO	World Meteorological Organization
WRM	Water Resources Management
WWF	World Wide Fund for Nature

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Tables

ACKNOWLEDGEMENTS

This report would not have been completed without the support and cooperation of officers within DEC and other important organisations whose activities are linked directly or indirectly to water and wastewater management in PNG. These organisations include DoH, NWS, PNGGS, DAL, NDC and the National Waterboard. The author would like to extend his appreciation to all the officers whose names are listed below:

DEC:	Ms. Kay Kalim, Mr. Tony Kuman, Mr. Maino Virobo, Mr. Nason Yube, Mr. Vaura Inara, Ms. Gwen Sissoiu, Mr. Dennis Ivarami, Mr. James Sabi and Ms. Aida Somake
DoH:	Ms. Anna Irumai
NWS:	Mr. Sam Maiha and Ms. Arnolie Tito
PNGGS:	Mr. Arnold Lakamanga
DAL:	Mr. Andrew Maika
NDO:	Ms. Sabina Fuluvii
PNG Waterboard:	Mr. Sibona Vavia
Eda Ranu:	Mr. Billy Imar

EXECUTIVE SUMMARY

Located south of the equator in the South-western Pacific, PNG is the largest and most populous Pacific Island nation. It consists of the eastern half of the island of New Guinea, several large high volcanic islands and numerous high volcanic islands and coral atolls. Its diverse geography gives rise to an equally diverse range of ecosystems which accommodate a wide variety of flora and fauna making up 5% of the world's biodiversity. Its population of 5.8 million people is also diverse in ethnicity, language, custom and culture. Eighty five percent of the population live in the rural areas on a subsistence lifestyle while the rest live in urban areas either as employees in the formal sector or engaged in a range of informal sector income earning activities such as market gardening, small livestock husbandry and other service based business activities. A large proportion of urban dwellers are unemployed and rely on relatives for support.

The country has a substantial amount of freshwater resources including springs, creeks, rivers, lakes, wetlands and groundwater. The main water uses are domestic consumption, hydropower generation and a wide range of industrial uses. In the rural areas the main sources of potable water are rainwater tanks, shallow hand-dug wells, springs, creeks and rivers. Only 20% of the rural population have access to improved water supply systems while the rest consume rainwater contained in tanks or water obtained directly from the source. In the urban areas 60% of the population have access to treated water reticulated to their households while the rest who reside in the peri-urban areas have to make do with water delivered through standpipes.

The story with sanitation is not as good. In the rural areas three modes of human waste disposal are used: septic toilets, pit toilets and direct defecation into the environment. An alarming 78% of the population, which is more than 4 million people, do not have access to safe sanitation services. Contaminated drinking water, lack of proper sanitation services and poor personal hygiene contribute to the high incidence of water and food borne diseases such as diarrhoea, dysentery and typhoid. Statistics in the 1996 National Health Plan reveal that diarrhoea is the number one cause of morbidity and mortality in the country at the rate of 1610 deaths per 100,000 of the population. Furthermore, 2.9% of all deaths are caused by typhoid and the current low access to potable water and safe sanitation is an ideal recipe for the incidence of cholera and other similar epidemics. Two of the main reasons for the above situation are the lack of coordination in the water supply and sanitation sector and inadequate funding by the government.

Water resources availability in terms of quantity and quality is coming under increasing threat from the pressure induced by rapid population growth as well as runoff and point source pollutant laden discharges from mining, logging, agriculture, infrastructure development and industrial processing, entering surface and groundwater bodies. While existing regulatory controls are in place to minimise these impacts, better monitoring and compliance arrangements are required to regulate these activities. In order to overcome the constraints imposed by limited regulatory funding from the government, monitoring networks involving partnerships with private sector, NGOs and local landowners should be seriously pursued.

Due to its position at the intersection of the stable Australian plate and the mobile Pacific plate, PNG is geologically young and dynamic with high seismic and volcanic activity. Its northern portion forms a part of the so called “Pacific Ring of fire” which makes the country prone to volcanic eruptions, earthquakes, landslides and tsunamis. In addition, with one of the wettest climates in the world, floods occur annually with magnitudes differing from one year to another. Even with its very wet overall climate, the topography of the country is such that there are areas which experience distinct dry seasons where droughts can develop during extended dry seasons. Global warming has led to climate change and variability which have increased the country’s vulnerability to sea level rise, tropical storms, tidal surges and saline intrusion. Global warming has also intensified the impacts of the ENSO phenomenon in both extremes yielding more frequent and severe floods and

droughts. Inadequate preparedness, adaptation and contingency planning have resulted in increasing damages and loss of life due to floods and amplified the misery associated with droughts. There is a need to improve flood and drought forecasting and expend more resources in hazard assessment and risk management by adopting precautionary and contingency measures in order to minimise damages, human suffering loss of life and fatalities.

In order to safeguard the availability of water with respect to quantity and quality to maintain ecological integrity, cater for natural and anthropogenic water uses as well as minimise impacts arising from floods, droughts and climate change, there is an urgent need to apply integrated water resources management involving all stakeholders and focusing on catchment units. Several institutional, legislative, operational, strategic, capacity, public consciousness and resource related barriers have been identified for appropriate treatment in order to achieve effective IWRM in PNG. These include the establishment of a national water committee, formulation of a national vision for water resources, development of a national water resources management policy, review and finalisation of a national water services policy, review of institutional mechanisms and capacity building in each of the thematic areas targeted in the Pacific RAP.

Furthermore, the current deficiencies with respect to water resources management, access to water supply and safe sanitation cannot be allowed to continue if the country is to achieve the corresponding targets set out under its Medium Term Development Strategy (MTDS) National Millennium Development Goal numbers six and seven on health and environmental sustainability respectively. In order to begin the process of systematically organising the sector, it is imperative that a National Water Committee is set up; comprising representatives from a wide cross-section of the society, to oversee a comprehensive sectoral review and devise a national vision for water resources management. This will then lay the foundation for appropriate legislative, policy, regulatory, institutional and capacity issues to be addressed.

1. INTRODUCTION

Water is essential for human, faunal and floral physiology. Water sustains life and is essential for climatic equilibrium, the maintenance of ecosystems, agriculture, industrial processing and hydropower. In many countries, increasing population, natural resource extraction, food production, industrial activity and other land uses are producing diffuse and point source discharges which carry a wide range of contaminants into water bodies and affect the quality and quantity of water for other uses. This situation is caused by ineffective assessment, planning, utilisation and management of water by water resources management authorities, water supply and sewage disposal service providers and other sectoral users of water resources. There is an immediate and critical need for Integrated Water Resources Management (IWRM) in a catchment unit in order to ensure the sustainable use of the available water resources.

Some PICs have begun to take remedial measures by attempting to bring about IWRM in their countries but progress has been affected by lack of resources as well as inefficient administrative and coordination mechanisms. Since 2002, SOPAC (with the assistance of the ADB and other international aid agencies) started a process of national and regional consultation to expedite and consolidate efforts to internalise and mainstream the IWRM approach within Pacific countries. The entire consultation process was aimed at helping small island country stakeholders and regional and international organisations strengthen their policies, institutional arrangements and enabling projects. The national, regional and international consultations were conducted to enhance public awareness on the need for improved water and wastewater management, exchange pertinent views and experiences and develop a mutual appreciation of policies, institutional arrangements and approaches conducive to sustainable water resources utilisation and management.

The consultation process began with an initial regional meeting held from 31 January to 1 Feb 2002 in Port Vila. This meeting was organised by ADB and SOPAC to establish the framework for regional consultation to prepare a regional paper for presentation at the 3rd World Water Forum. The meeting resolved that regional consultation should be interactive and at the highest possible level. It also identified six thematic areas based on previous evaluations which would provide the platform for the consultation process. These thematic areas were: water resources management, island vulnerability, awareness, technology, institutional arrangements and finance.

The next phase of consultations was conducted within country for the preparation of country reports addressing the six thematic areas. National discussions involved stakeholders in the government, NGO community and the private sector including all agencies concerned with water resources management, water authorities, service providers, rural development departments, health and environment agencies, and regulators. The existing national water council or committee in certain countries played a major role in the conduct of these consultations.

The outcome of the national consultations were discussed in a high level regional meeting held in Sigatoka, Fiji form 29 July to 3 August 2002. The meeting resulted in a communiqué and ministerial declaration that were both adopted on 3rd of August 2002. These outcomes were taken to the Caribbean Water and Wastewater Conference and Caribbean Dialogue on Water and Climate in October 2002 and subsequently to the 3rd World water Forum held in Kyoto, Japan from 16 to 23 March 2003.

During the last few years SOPAC submitted an application to GEF to fund a regional programme under the latter's International Waters portfolio which would attempt to address the six thematic areas in the Pacific Regional Action Plan on Sustainable Water Management in an IWRM orientated project. GEF endorsed the request for detailed project design through the UNDP. The Sustainable Integrated Water Resources and Wastewater Management Project in Pacific Island

Countries (PICs), abbreviated as IWRM project is aimed at mainstreaming the IWRM approach in governance structures within the participating countries.

The process is now in the Project Development Facility (PDF) B stage in which SOPAC is required to formulate and present a Full-size Project (FSP) GEF brief to the GEF Secretariat in 2008. It is anticipated that project implementation will then commence towards the end of 2008. The long-term objective of the project is to assist PICs to implement applicable and effective IWRM and Water Use Efficiency Plans in the Pacific Region. The main outcomes of the PDF – B stage are: establishment of a National Inter-sectoral Water Committee in each country, formulation of a demonstration project and production of a full brief through an extensive consultative process.

The purpose of this report is to describe the current situation and constraints with respect to the occurrence, uses and management of water resources in PNG and to propose remedial measures aimed at ensuring the sustainable utilisation of the available water resources in order to achieve human wellbeing and maintain environmental integrity.

2. GENERAL OVERVIEW

This section describes the nation of PNG in terms of its geography, topography, geology and geomorphology, soils, climate, vegetation, agriculture, hydrology and hydrogeology, demography, government system and socio-economy.

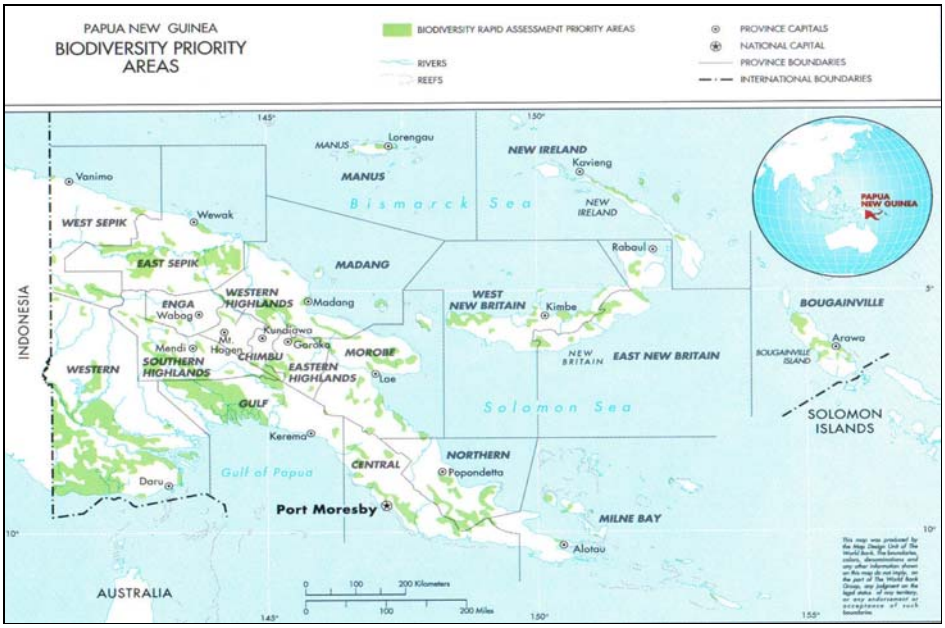
2.1 Geographical location and topography

In terms of land mass, the Independent State of Papua New Guinea consists of the eastern half of the island of New Guinea and numerous easterly located islands in the Bismarck and Solomon seas. The largest of these are Manus, New Ireland, North Solomons and New Britain in the order of increasing land area. The western portion of New Guinea constitutes the Indonesian province of West Papua. Figure 1 shows the map of the country depicting the provinces, main centres and biodiversity priority areas.

The country has a total land area of about 462,840 km². In his work on the geomorphology of PNG, Loffler (1977, 1979) identified five principal landscape categories with fourteen types of land forms as shown on Figure 2. The five landscape categories are: (i) Southern Plains and Lowlands Region; (ii) Central Range Region; (iii) Intermundane Trough Region; (iv) Northern Ranges Region and (v) Island Region. An excellent summary on this given by Bleeker (1983) is reproduced below with slight modifications.

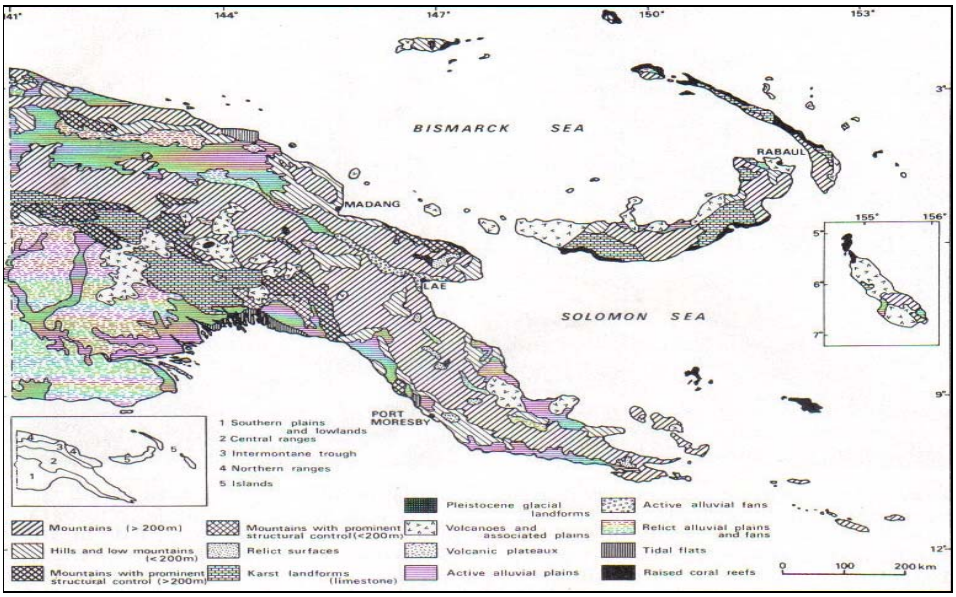
The Southern Plains and Lowlands Region covers the area from the southern coastline to the foothills of the Central Ranges. The southern portion is over 400 km wide and drained by the Fly River. The region gradually narrows towards the east where it is divided in a number of embayments by the foothills of the Central Mountain Ranges. This area is mainly a relict variously dissected alluvial plain and to a large extent situated above the flood level of its river system. South of the Fly River, the surface is mainly flat and less than 30 m above sea level. Large portions of the lower areas are flooded during the wet season. The plain extends westwards to the Digoel River, West Papua and is known as the Oriomo Plateau. Located to the north of the Fly River is another plain, which is dissected by narrow ridges and valleys with elevation ranging from 10 m in the south to 60 m in the north. The rest of the region consists mainly of poorly drained or swampy alluvial plains. These are traversed by meandering rivers with floodplains made up of scrolls or point bar complexes, oxbow lakes and swamps, which in term merge into extensive backswamps. Near the coast are large tidal flats which are interspersed with narrow bands of beach ridges and swales. On the seafront are very large mangrove swamps.

Figure 1: Map of PNG showing provinces, main centres and biodiversity priority areas



Source: PNG Environment Monitor, World Bank, 2002

Figure 2: Landforms and major landscape regions of PNG



Source: Loffler 1979

The Central Range Region extends throughout the mainland island of New Guinea with Mount Wilhelm (4509 m) being the highest peak in PNG. This region takes up almost half of the island and forms a complex of narrow ridges, V-shaped upland valleys and volcanoes. It varies in width from approximately 50 km near the Irian Jaya border and in eastern PNG to almost 200 km in its centre. The prominent features of the region are the Star Mountains in the west, through the Hinderburg, Muller, Kubor, Schrader, Bismarck and Owen Stanley Ranges in the east. Each of these components are characterised by altitudes beyond 3000 m.

The region as a whole has a high relief, and on some of its margins, where there is an abrupt break with the flanking lowlands, the relief may be over 300 m. Most of the Central Ranges have irregular branching, structureless ridges with narrow crests, long sleep slopes and V-shaped valleys. They are usually located on igneous and/or sedimentary rocks. Very prominent, though less extensive are the structural homoclinal ridges which have formed in areas where limestone or resistant sandstone alternates with soft sedimentary rocks. The Central Ranges also contains the largest area of karst in PNG, covering up to 15,000 km^2. In the centre of the region, the relief is generally lower than at the margins. This area is referred to as the highlands and is a succession of intermontane plains, broad upland valleys and a number of extinct volcanoes.

The Intermontane Trough Region is a huge structural depression extending across New Guinea. The depression is made up of plains, lowlands and swamps and in most parts flanked by steep mountains. The Sepik plains, the most extensive in PNG, are dominantly swamps, meandering floodplains and fans bordering the northern flanks of the trough. The Markham Ramu Valley also has large swampy areas, but is characterised by moderately to steeply sloping fans made up of coarse material derived from the backing, steeply sloping mountains.

The Northern Ranges Region runs parallel to the Central Ranges from which they are separated by the trough. The terrain is often very rugged and steeply sloping, and on the Huon Peninsula, these mountains rise in places to 4000 m. Mountain ridges and V-shaped valleys bordered by foothills, and underlain by sedimentary rocks, are the dominating landscape. At the coast the mountains descend steeply into a narrow, discontinuous coastal plain. The north coast is actively rising with a maximum rate of uplift of 3 m per 1000 years.

The Island Region can be subdivided into four major groups of islands. The Southern Bismarck Island Arc is a belt of active volcanoes running along the coast north of the mainland into New Britain. Numerous active volcanoes are located along the north coast of New Britain with large areas covered by ash deposits. The central and southern parts of New Britain are dominated by rugged mountains formed on sedimentary rocks, particularly limestones which have prominent karst features.

The Northern Bismarck Islands Arc includes Bougainville, Buka Island, New Ireland, New Hanover and the Admiralty Islands. Bougainville, the largest island in the Solomons Group, has a massive central mountain chain dominated by three large, active volcanoes surrounded by volcano-alluvial footslopes and fans. New Ireland is a long, narrow island, which in its southern part contains mountain ridges and V-shaped valleys underlain by igneous rocks, while the central and northern parts are dominated by limestone with well developed karst land forms. Along the north coast the island is fringed by a narrow strip of raised coral, and along the south coast by a narrow discontinuous strip of alluvium. To the west of New Ireland lie the Admiralty Islands of which Manus is the largest. It is mainly volcanic, consisting of hilly terrain and surrounded by coral reef.

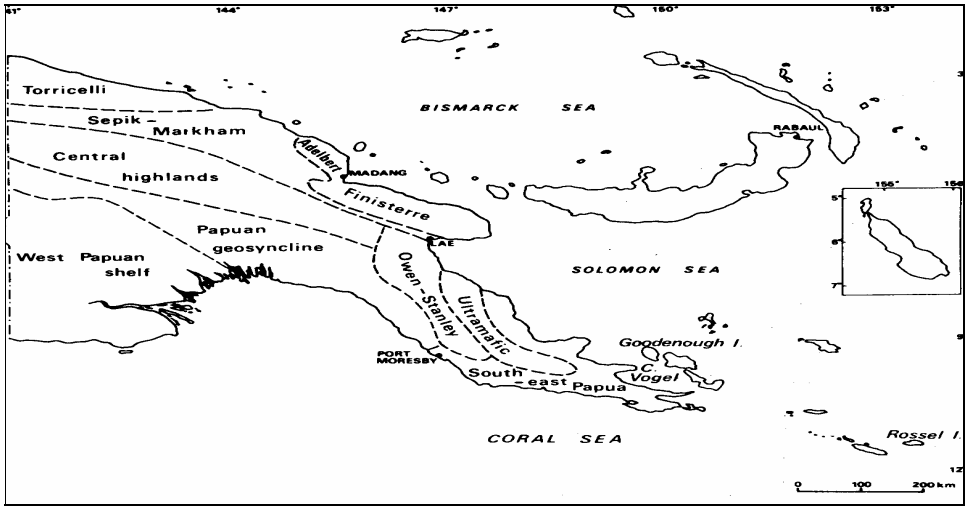
The islands near the eastern tip of the mainland form an extension of the Central Ranges Region. Both the D'Entrecasteaux Islands and the Louisaide Archipelago have rugged mountains composed mainly of metamorphic rocks and fringed by coral reefs. The Trobriand Islands lie to the north of the D'Entrecasteaux Islands. The groups consist of four islands and several small islets, all of raised coral limestone. Kiriwina, the main island has a central ridge rising to 30 m with many sharp, ragged limestone pinnacles and has a high proportion of swamps. Woodlark Island further

to the east, also has much raised coral and a core of metamorphic rocks which in places are above 400 m in height.

2.2 Geology and geomorphology

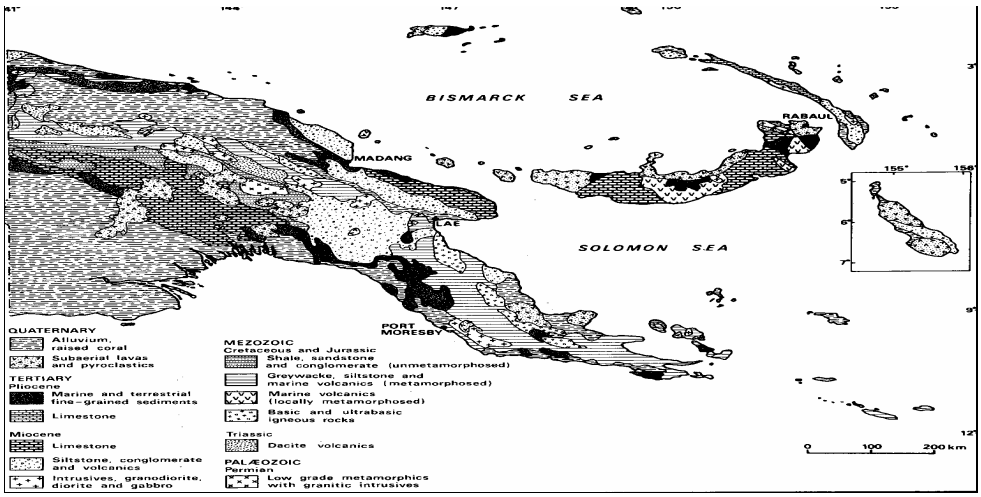
Bleeker (1983) has produced a broad summary of the geology of PNG based on the work by Ollier and Bain (1972) and Loffer (1977, 1982). This summary is accompanied by Figures 3 and 4 showing the key geological features and depicting a generalised geological map respectively.

Figure 3: Principal geological features of PNG



Source: Bleeker 1983

Figure 4: Generalised geology of PNG



Source: Loffler 1979

The mountain chain running through the centre of the mainland and islands to the south-east are dominated by metamorphic and intensive igneous rocks. This central chain can be divided into three units namely, the Central Highlands, Owen Stanley Ranges and a line of islands stretching from Goodenough Island to Rossel Island. The metamorphic rocks found in these units are composed mainly of altered sedimentary and volcanic rocks of Jurassic and Cretaceous age, while the intrusive rocks are predominantly of Miocene Age.

In the West Papuan shelf, Palaoezoic rocks form the basement, outcropping in only one isolated location on the mainland. The overlying Mesozoic and Tertiary rocks show very little folding, indicating that the area has been relatively stable. These rocks, in turn, are overlain by Quaternary deposits derived from the Central Mountain Range.

In the Papuan geosynclines, located to the east are thick sedimentary beds which have been subjected to tectonic movements. These beds were accumulated during the Mesozoic and Tertiary ages.

South–east Papua is regarded as the most geologically complicated area of PNG, containing not only metamorphosed sedimentary rocks of Cretaceous and Jurassic Age, but also many basic igneous Tertiary rocks.

North of the Owen Stanley Range is the Papuan ultramafic belt which is considered to be part of an old sea floor and mantle thrust over the continental rocks of the Owen Stanley Ranges The tertiary sediments and volcanics flanking the ultramafic belt in the Cape Vogel are largely covered by Quaternary deposits of volcanic origin.

The Torricelli, Adelbert and Finisterre Ranges are considered to be geologically different from the rest of the mainland. Pliocene fine grained marine and terrestrial sediment on a basement of metamorphic rocks are mainly exposed in the Torricelli Mountains, while the Adelbert Range consists of folded Miocene siltstone, conglomerate and volcanics overlying unmetamorphosed lower Tertiary sediments and volcanics. Further to the south-east, the Finisterre Range is mainly of Miocene limestone on a lower Tertiary volcanic basement.

Apart from a few areas of Mesozoic marine volcanics in New Britain, and the metamorphic islands of south-east Papuan coast, the major PNG islands are dominantly composed of Tertiary rocks. Bougainville and the north coast of New Britain, however, have extensive areas covered by Quaternary deposit from active volcanoes.

The structural history of PNG has been linked to the interaction between the Australian Continental Plate and the Pacific Plate. Since the late Palaeozoic period the Australian plate has been moving slowly northwards from its portion near the South Pole, with southern New Guinea forming its northern rein. During most of the Mesozoic and continuing well into the early Tertiary extensive terrestrial deposition took place on the southern part of the Pacific Block. On the northern margin of the Australian Plate, however, a large geosyncline developed during the late Triassic, in which thick beds of marine sediments were deposited. Several periods of volcanism took place during this deposition.

The landmass of PNG started to take shape during the Miocene period, but it was not until the Pliocene that it became firmly established when large vertical movements along major fault lines created most of the present day landforms. This uplift is continuing in the Northern Ranges. Widespread volcanic activity occurring in the highlands as a result of the movements formed large volcanoes such as Mount Hagen and Mount Giluwe. While large scale volcanic activity ceased in the highlands about 200 000 years BP, some deposition of ash took place until about 50 000 years ago. While on the mountain ranges above 3600 m glacial erosion took place, extensive denudation occurred at lower altitudes resulting in a strongly dissected landscape. Elsewhere, in limestone areas, typical karst features developed. Changes in the coastline, particularly in the south were brought about by glaciation in the northern hemisphere, causing lowering of the sea level by

approximately 130 m. The country's landscape is still undergoing rapid changes caused by volcanism, landslides triggered by seismic activity and heavy rainfall and various denudation processes.

2.3 Soils

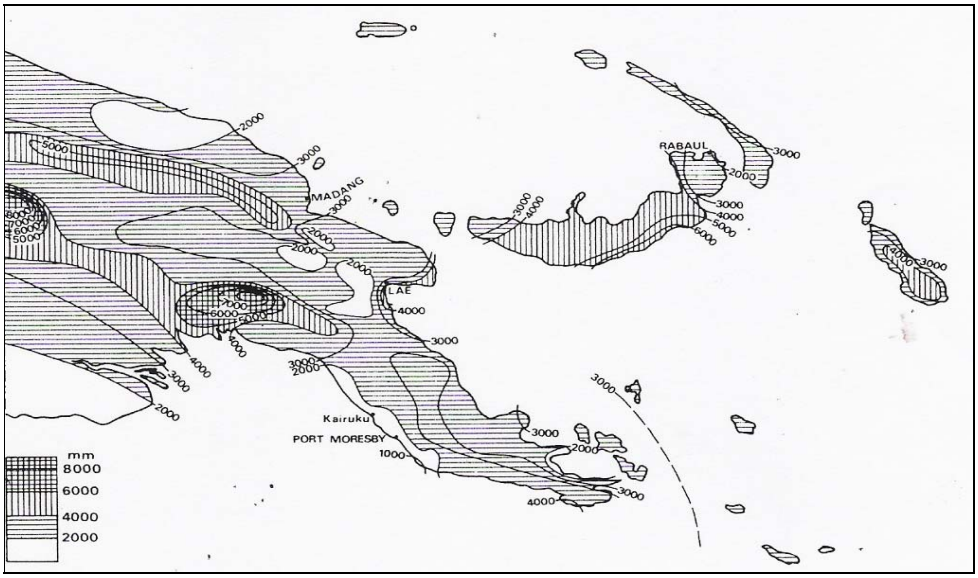
Using the 1975 version of the United States Department of Agriculture scheme for Taxonomy, Bleeker and Healy produced a soil type profile for PNG. In this exercise they identified the great soil groups and their approximate distribution across the country. The soil types are dependent on the geology, topography, vegetation and climatic factors. Volcanism, vegetation removal, as well as natural weathering and erosion processes are responsible for soil profile formation and modification at a given location. Soil distribution has been described to be very local, local, and common to very common (Bleeker 1983). Annex 1 contains a table showing the distribution of different soils types across PNG.

2.4 Climate

A detailed account on the climate of PNG is given by McAlpine et al. (1983). The two main determinants of climate in PNG are the topography and the seasonal latitudinal movements of two air streams separated by a low pressure system known as the Inter-tropical Convergence Zone (ITCZ). When the ITCZ is positioned north or south of PNG, north-westerly winds predominate from late December to mid April. These winds are also referred to as monsoons because they bring heavy rainfalls. When the ITCZ is repositioned to the north of PNG between May and October, south easterly winds blowing over the Coral Sea predominate. These winds are also known as the Trade Winds. During this period heavy rainfall occurs in areas conducive to orographic influences such as the highlands and the windward slopes of areas exposed to the south-east including New Britain, the southern face of the central Cordirella and the southern face of the Huon Peninsula. Otherwise there is generally less and irregular rainfall elsewhere. The brief periods between the two seasons, during late October and November and during late April and May, are known as the doldrums and characterised by weaker multi-directional winds.

PNG can be described in general as wet tropical, due to the generally high rainfall, with more than half on the country receiving greater than 2500 mm annually. The spatial distribution of annual rainfall ranges from 1000 mm in the Port Moresby area to 8000 mm in the northern areas of the Gulf and the Hindenburg Range is strongly dependent on topographic effects. Areas having an annual rainfall of less than 2000mm, where there is a distinct wet and dry season, are restricted to parts of the Markham Valley, Bulolo Valley, Maprik - Angoram area, Eastern highlands, and coastal areas near Cape Vogel, Port Moresby and Daru. Large areas receive over 4000 mm per year, notably the northern and southern flanks of the highlands and the south coast of New Britain. The consistently highest annual rainfall of more than 10,000 mm has been recorded in the Ok Tedi area in the Star Mountains. Figure 5 shows the mean annual rainfall distribution across the country and the tabulated figures are presented in Annex 2. These represent data for selected stations covering the whole country with duration ranging from ten to more than 50 years up to 1980. A visual assessment of the latest mean monthly rainfall figures for the 14 key National Weather Service (NWS) weather stations spread across the country shows the same general rainfall trend since 1984. The figures also reflect clearly the years during which the ENSO phenomenon was active. This data set is attached herewith in Annex 3.

Figure 5: Mean annual rainfall distribution over PNG



Source: MacAlpine et. al. 1983

High daily mean temperatures are experienced in the lowlands with little annual variation. Mean maximum readings of 28 – 34 degrees Celsius and mean minimum readings of 20 – 25 degrees Celsius are usual with daily fluctuation of approximately 7 degrees Celsius. In the highland areas mean maximum daily temperatures range from 20 -29 and mean minimum temperatures are in the region of 10 – 18 degrees Celsius.

2.5 Vegetation

There are twelve categories of vegetation classified according to zonal types, with altitude and rainfall being the main controlling factors. This classification system was devised by Johns (1977, 1993) and adopted by the Conservation Needs Assessment exercise (Saulei and Beehler 1993). The vegetation categories in approximate order of increasing altitude are coastal vegetation, mangrove forests, anthropogenic grassland, swamp vegetation, savannah, monsoon forest, lowland tropical rainforest, lower montane forest, mid-montane forest, upper-montane forest, sub-alpine forest and grassland and alpine.

These forests are characterised by very high tree species diversity when compared to other tropical forests around the world, reflecting the country's wide range of climatic, geographical and geological conditions. This variety of different tree species provides a wide range of diverse forest habitats for other flora and fauna. The forest habitats accommodate diverse and unique animals, plants and micro-organisms. Most of these have not been properly investigated (Sekran and Miller 1994). Owing to their apparent distinctiveness in contrast to the known natural world, they probably represent a rich source of genetic and other bio-resources that may not be available elsewhere.

2.6 Hydrology and hydrogeology

The hydrological cycle in PNG is determined by the topography and climatic conditions. The two major air streams discussed earlier provide different sources of moisture at different times during a year. The southeasterly trade winds from May to August are accompanied by noticeable windward and leeward rainfall effects brought about topographic effects. From December to April, during the southern summer, the ITCZ is over PNG and heavy rainfalls are caused by winds coming form both

the north and south to most of PNG. Topographic conditions interact with the two air streams to determine the rainfall patterns over the country. Condensation is caused by the elevation of moist air stream due to topographic relief and conventional uplift. This gives rise to generally high rainfall with low variability in the highlands and higher variation in the lowlands. Most of the land area in PNG is under forest vegetation cover and interception rates can be very high in catchments with major influences on runoff. Evapotranspiration is amongst the highest in the world owing to high solar radiation and moisture supply in high rainfall areas.

The central Cordirella serves as the major divide causing all river systems to drain either north into the Bismarck Sea or south into the Coral Sea. The northern side of the mainland is mainly drained by the Sepik, Ramu and Markham rivers while the main drainage channels in the southern side are the Fly, Purari and Kikori as well as numerous other smaller rivers. The bigger islands east of the mainland are drained by several large rivers. The heavy rainfall in the interior of the country, high altitude and steep slopes produce fast flowing rivers with high erosive capacity. Flow rates drop significantly in the lower reaches of the larger mainland rivers where seasonal floods are a normal feature. Annex 4 shows the natural surface drainage of the country.

Infiltration and therefore soil moisture and groundwater are dependent on rainfall, topography, vegetation cover, soil type and geological conditions. The availability of soil moisture and groundwater is locality based. Groundwater is present in both confined and unconfined aquifers with the amount and quality varying form one location to another. Alluvial fans in valleys and coastal plains and in close proximity to surface water bodies appear to contain most of the groundwater resources while large limestone areas provide underground channels and storages for groundwater. Hydrogeological studies have only been carried out in certain parts of the country and there is a need to carry out detailed groundwater assessments in all the catchments in the country if the sound integrated management of water resources is to be attained.

2.7 Demography

The last full scale national was conducted in 2000 and recorded a total population of 5.2 million. The ratio of males to females was 1:2 and population density was 11 people/km^2. In terms of regional population distribution, the Highlands recorded the highest at 38%, followed by Momase at 28%, Southern at 20% and Islands at 14 %. There were 1,008, 969 households with an average size of 5 persons. Most of the populace is rural based with only 15% residing in urban centres. At an annual growth rate of 2.7% the current total population is estimated to be around 5.8 million (PNG 2000 National Census Report 2003).

PNG is one of the most diverse nations on earth with over 850 indigenous languages and at least as many tribes and traditional societies. Each group has its own tribal structure, architecture, costumes, songs, music, dances, art and traditional beliefs. Ninety-five percent of the population is Melanesian, 3% are Polynesian, 2% are Micronesian or citizen and expatriate Asians, Caucasians and Africans. There are three official languages namely English, Tok Pisin and Motu. English is the official language of government, business and instruction in schools. Tok Pisin is commonly spoken in the New Guinea side while Motu is spoken in the Papua side. Tok Pisin is gradually establishing itself as a truly national and dynamic language.

In the 2000 census, 96% of citizens claimed to be Christians however many combine their faith with traditional and indigenous spiritual and witchcraft practices. The Christians are members of the Roman Catholic Church and numerous protestant denominations including the Lutheran Church, United Church, Seventh-Day Adventists, Pentecostal, Evangelical Alliance and Anglicans, Baptist, Salvation Army, Mormons and other minority churches. The non-Christians are atheists, Bahai, Muslims and Buddhists.

2.8 Agriculture

With more than half of the country receiving 2500mm of rainfall annually, most of the subsistence and commercial agriculture is rainfed. Eighty five percent of the population are rural dwellers who depend entirely on shifting subsistence cultivation, fishing and hunting. The traditional cultivated food crops as sweet potatoes, taro, yam, cassava, banana, breadfruit, sugarcane and aibika. In addition, a wide variety of vegetables including pumpkins, corn, carrots, capsicums, beans and tomatoes are cultivated for domestic consumption and sale in local markets. Cash tree crops are grown in large plantations and in nucleus type estates. Such crops include coffee, copra, cocoa, tea, rubber and oil palm. Most of the livestock farming is done in large cattle farms, piggery and poultry operations. There are also a small number of goats and sheep farms. Crop and livestock production is dependent on locality suitability in relation to altitude, rainfall, topography, soil fertility and moisture content.

2.9 Government

PNG has a Westminster system of government comprising the executive, legislature and the judiciary. Executive power is vested in the National Executive Council which is headed by the Prime Minister who is the leader of the majority party in the single chamber national parliament. The British monarch has been adopted as head of state and is represented by the Governor General who is a citizen of PNG. The executive government is supported by a bureaucracy that delivers government services to the public. The legislature consists of the national parliament and the provincial and local government assemblies. The national parliament debates and passes legislation for the entire country while the provincial and local level assemblies deal with legislation having jurisdiction within their respective boundaries. National elections for political representatives in the Local Councils and the National Parliament are held every five years. The judiciary is headed by the Chief Justice and consists of a court system from Village Courts, District Courts, National Courts and the Supreme Court.

In terms of administration there are three levels of executive government consisting of local government councils, provincial government and national government each supported by a bureaucracy. There are 20 provinces and 89 districts. The political head of a province is known as a governor who is elected by the province and is a member of the National Parliament. Each provincial bureaucracy is headed by an Administrator and each district bureaucracy is looked after by a District Manager.

2.10 Socio-economy

The vast majority (85%) of the population are rural dwellers that live a subsistence lifestyle. A proportion of the rural population is involved in commercial agriculture where cash crops both food and non-food are cultivated either in smallholder farms or large commercial agricultural estates. Approximately 15% of the population lives in urban areas or in logging, large commercial agricultural and mining townships. A large and growing proportion of urban dwellers live in peri-urban settlements and are mainly rural immigrants in search of employment and access to better education and health services.

Since independence, the major impediments to social and economic advancement in PNG have been a complex land tenure system, inadequate and costly infrastructure development and maintenance, poor governance and deteriorating law and order. Only 3% of the land is owned by the state. The rest is communally owned through a variety of clan structure systems. In most parts of the country, land ownership follows patrilineal lineages while in some areas matrilineal descendency is followed. The advantages of this customary land ownership system is that the age old man-to-land connection is retained and a subsistence livelihood practiced over thousands of years in the country is maintained. However, conflicts arise when land is required by the State and developers for the construction of public infrastructure and major resources extraction, agricultural, industrial and commercial projects. A number of mechanisms such as the Incorporated Landowners

Group (ILG) system have been devised to allow local landowners to organise themselves, and register their land before negotiating with the project developers and the State for such undertakings. The main intention has always been to protect the interest of all parties. Last year the current government set up a Land Reform Task Force to review the land management system in the country and propose improvements. The task force report to the National Executive Council (NEC) was recently approved and directions were issued for the immediate implementation of the major recommendations.

The complex geography of the country is a natural hindrance to the development and maintenance of road infrastructure. Landowner negotiations are time consuming and invariably wind up with huge compensation payments before construction can commence. In addition, inappropriate planning, mismanagement and poor coordination between national and provincial administrations, as well as political interferences have led to diversion of road funding to other activities. This has resulted in delayed work on new developments and lack of maintenance of existing facilities. This in turn has affected the rural population who cannot get their garden produce and cash crop to markets as well as the delivery of goods and services such as health, education and agricultural extension from administrative centres to outlying villages.

Over the years, through the normal process of government planning at all levels and in collaboration with NGO and donor community, successive elaborate development plans have been formulated, but funds have continued to be diverted to other areas and consequently key social, health and economic development indicators and targets remain elusive. Within the last two parliamentary terms, the government has introduced radical changes to public planning and expenditure incorporating appropriate checks and balances and heavy penalties to discourage and eliminate corruption at all levels of government.

Over the last 32 years of independence, the population has doubled from 2.5 million to about 5.8 million. More than half of the population is under the age of 30 and large numbers of students graduate every year from schools, colleges and universities without adequate jobs in the formal sector. The current government has taken steps to encourage growth in the informal sector, lure investment and diversify economic activity to produce more employment opportunities in the private and informal sector. At the same time, vocational, technical, high school, college and university education and training being reviewed to produce graduates who are able to be self-employed and productive members of the society rather than becoming displaced and resorting to illegal means of survival in urban centres.

Major agricultural exports include coffee, tea, rubber, oil palm. Other expert commodities are whole, filleted and canned fish, logs, processed timber, gold, copper, silver and both crude oil and processed oil. Although mineral production export has been very high there has not corresponding increase in development indicators such as literacy, infant mortality and child-birth mortality. In addition, exports in the agriculture sector have been outweighed by the growing importation of food grain products particularly rice and wheat.

The country also possesses rich mineral resources including gold, copper, silver, nickel, cobalt, petroleum and natural gas. The exploitation of these resources over the last 30 years has provided the country with substantial foreign earnings, infrastructure, training and employment. The mining and petroleum sector continues to be of major economic importance, contributing approximately 75% (PGK1,064.5 million) of the total value of merchandise exports (PGK1,410 million) in the September quarter of 2002 (Bank of Papua New Guinea 2002). Mineral export receipts, excluding crude oil, made up 49% of total merchandise exports in this quarter, whilst receipts from crude oil exports accounted for 26% of the total merchandise exports during this period.

During the last decade, successive governments have worked hard to promote good governance, legislate for government stability, redirect public expenditure on critical priority areas and provide a favourable social and fiscal environment for foreign investment. With the stability provided by the

Law on the Integrity of Political Parties, for the first time since independence, the current Somare government will have served a full five year term in office by July 2007. This tenure and stability in office has enabled the government to implement its economic recovery policies and provide investor confidence for the private sector. In addition, stringent public fiscal management and improved commodity prices, have contributed towards noticeable growth in the local economy, employment opportunities and annual revenue over the last three years. Consequently debt retirement has progressed steadily and funding for social services, particularly health and education, and infrastructure development and maintenance has increased.

3. IWRM IN PNG – CURRENT STATUS, CONSTRAINTS AND POSSIBLE REMEDIES

In this section, the current situation with respect to the six thematic areas under the Pacific Regional Action Plan on Sustainable Water Management (Pacific RAP) is described, constraints are identified and corrective actions proposed.

3.1 Water resources management

3.1.1 Types of freshwater resources

In any area, the type of water resources available at any given point in time depends on the local rainfall pattern and the availability of collection capability of the geology in forming surface water bodies and groundwater aquifers within a catchment. There is an abundance of water resources with immense potential for development in the country. The following are some water resources in PNG that can be harvested for economic and domestic use.

i. Surface fresh water from streams, rivers, lakes, ponds, reservoirs, estuaries and swamps;

ii. Subsurface freshwater from confined and unconfined aquifers;

iii. Surface and subsurface brackish water showing varying degrees of salinity; and

iv. Effluent water, which can be treated and recycled.

Papua New Guinea receives an average annual rainfall of about 3000 mm per year. Most of this rainfall is experienced outside of the capital Port Moresby especially in the Western Province where in Tabubil, the average is about 4000 mm per year, the wettest in PNG. Other distribution is along the coastal and island Provinces. This makes Papua New Guinea one of the wettest regions in the world. Surface water is the most common source of water readily available to people in PNG. Rainfall is depended upon for consumption almost in every part of PNG except in Port Moresby where rainfall is experienced only between October or November and March or April while shallow groundwater is mainly available to coastal areas and low-lying coral islands.

Surface water resources including springs, streams, creeks, rivers and lakes can be found anywhere in PNG. Some of the largest rivers of PNG include the Fly River, Sepik River, Markham River, Purari River and Kikori River. Others of similar characteristics but a small in catchments include Busu River, Bumbu River, Gogol River, Zokozoi River, Hargy River, Ambogo River, Lakekamu River, Brown River, Laloki River, Vanapa River and Kemp Welsh River (to name a few). With numerous major rivers and streams, flooding is a problem faced everywhere in PNG and flash flooding in small tributaries is common in the northern regions of PNG and the highlands due to steep terrain. PNG has some exotic lakes such as Lake Kutubu (Protected Area) and Lake Murray at the lower Fly River region. There are also number of volcanic springs perched up in the high altitude mountains like Mt. Wilhem and Mt. Giluwe in Chimbu Province and Mt. Lamington in the

Northern Province. There are vast water resources in the swamps and brackish water is distributed across PNG especially in the northern parts of PNG and the Gulf Province. Surface water resources are readily available for economic development in terms of mining and logging activities in PNG due to their abundance.

Groundwater is another water resource that is heavily depended upon in the coastal communities and especially the island atolls. Most of the communities along the coastal regions of PNG especially in the southern region depend on shallow groundwater wells for domestic consumption. Major Provincial towns like Lae, Vanimo, Rabaul and Kavieng depend on groundwater for their residents due to no major surface water close by or to avoid contamination of the source.

Although rainwater on the other hand is harvested from residential rooftops in most of the rural communities and some urban residents who do not have access to town supply, it is limited in Port Moresby and its surrounds. Wastewater reuse is practiced in a minority of instances where agricultural developments especially in oil palm are encouraged to construct ponding systems to treat oil palm waste effluent and applied as irrigation water in the plantations during dry season or treated sewage effluent and applied on golf courses in urban areas. A few commercial establishments in the drier areas of the country operate small desalination plants to supplement their water supply during the dry seasons. The potential for large-scale inter-catchment water transfer schemes is significant and may become necessary in the future.

3.1.2 Types of freshwater uses

The main water use in PNG is for domestic purposes for washing, cooking, bathing, and aquatic resource gathering in the rural communities. In the urban areas, the main use is for domestic and industrial purposes. Other uses of freshwater include hydropower generation, mode for transportation and small scale irrigation.

3.1.2.1 Drinking water. In PNG there are a number of agencies dealing with water supply schemes. Some are privately owned and most are operated and managed by the PNG Waterboard who has been mandated to build, operate and manage water supply and wastewater treatment systems.

The PNG Waterboard operates all reticulated water supply systems in PNG except for Port Moresby (operated by Eda Ranu) and Goroko (operated by Goroka Town Authority). The Waterboard uses both surface and groundwater sources for supplies for the rest of the 17 Provinces. In the rural communities, the Department of Health provides small-scale water supply systems that can be managed by the community. The rest of the rural community depends on rainwater, shallow wells or direct use of streams for domestic purposes.

3.1.2.2 Industrial use. Industrial usages vary from province to province. In Port Moresby and Lae (2 bigger cities), the industrial use is more than 50% of processed town supply. Other uses in the agriculture sector is more in the rural areas with small reticulation systems constructed for both domestic and industrial purposes for coffee, coconut, rubber and oil palm processing.

Mini agricultural irrigation systems are also in place especially for agricultural experimental station and research activities including forestry. However the mineral sector for both mining and petroleum take up the biggest portion of water uses for processing, domestic and waste disposal (domestic and industrial including tailings).

3.1.2.3 Hydropower. Hydropower in PNG has a very big potential when dealing with climate impacts. PNG has big hydropower stations in Rabaul (Warangoi), Kainantu (Yonki) and Port Moresby (Rouna 1 & 3, Rouna 2 and Rouna 4 stations). Aside from these there are small hydropower stations like Aibe Creek (Mendi), Pauanda (Mendi), Ru Creek (Kimbe), Hargy-Bialla Hydro (Kimbe), Yuk Creek (Ok Tedi), PNG Forests (Bulolo); and micro hydro

schemes such as those run by the Catholic Diocese that has a number of them throughout PNG. There remains big potential for additional hydropower schemes.

3.1.2.4 Transportation. The major rivers in PNG provide mode for transport and it is common for big barges to travel up and down major rivers like the Fly and Sepik. Smaller rivers provide for outboard motors, canoes and kayaks for travel.

Other common freshwater uses are for food gathering especially for communities who depend on waterways to sustain their living. Edible fish, molluscs and aquatic weeds are gathered from the wetlands all around PNG.

3.1.3 Major issues and concerns

The overriding challenge in most situations is to deliver water at the right quantity and quality for a given use. In rural PNG, only 20% of the population have access to an improved water supply which includes public standpipes, boreholes, protected wells or springs (PNG Waterboard Strategic and Medium Term Corporate Plan 2006). For the rest of the population, water is directly taken from the source. In the urban areas which PNG Waterboard services, 91% have access to treated and reticulated water but only 60% of these households get piped water directly into their houses. The other 'urban' households are located in squatter and peri-urban settlements where reticulated water is provided at public standpipes and wastewater management is a problem.

While the water resources available in a catchment is initially subject to natural climatic and geophysical conditions, various land uses and waste disposal linked to population growth is also affecting the capacity to supply in terms of quantity and quality to cater for ranges of water uses. Currently, there are few catchments that are directly accessible to the main urban towns and cities in PNG. The development of these sources to sustain the demand is difficult with settlers settling in critical areas like at headwaters causing concern for pollution to the original source etc. Landuses such as agriculture, cultivating crops that consume more water deprives other users to benefit from the same source.

Catchments such as Laloki (proposed demonstration site), Wahgi and Bumbu are over stressed with poor quality yields and high demand from various users.

Under the current Environment Act 2000, the Department of Environment and Conservation (DEC) is charged with the responsibility of managing the nation's water resources. This legislation is linked to all development planning and natural resource extraction regulatory instruments through which DEC liaises with various agencies to ensure that environmental impacts including those on water resources are either prevented or minimised at an acceptable level. As the management and monitoring agency, DEC's operation is hindered by lack of resources, an ineffective monitoring and enforcement system and the uncoordinated development and land use planning system in the country.

There is currently little to no hydrological data collection around PNG except in areas with resources development like mining. Knowing how much yield from a catchment is not possible until the situation for raw data collection is improved.

One of the main prerequisites for sound natural resources management is the collection and maintenance of reliable natural resources database. Data is required on all aspects of the ecosystem including climate, geography, and geology, topography, biodiversity and water resources for integrated natural resources management. Natural resources data collection in PNG commenced during the colonial administration with CSIRO[1] being one of the key participants. In fact a large proportion of the natural resources databases and published texts are a result of the large input of resources by the Australian administration into data collection across the country. Over the last decade dwindling financial resources has reduced capacity to continue to collect this

[1] Commonwealth Scientific and Industrial Research Organisation

data. With the slow but steady recovery in the economy, adequate support should be given to the respective organisations to resume their data collection programmes.

Additionally, there no proper catchment management plans that would dictate the landuse type in the area and equally distribute water resources. The constant increase in population has pushed communities and settlements to move into catchments that could not support different agricultural landuses causing stress to environment and water resources. Clearing of riverbanks are causing increasing erosion and depositing them into waterways.

The other main concern is to develop a policy to regulate activities within critical catchments and provide for equal distribution of the resources to all users.

A number of natural resources databases have been constructed and developed over the last twenty years. The most widely known is the PNGRIS system, which has grown in scope and utility over the years. It is the first and probably the only database so far to incorporate and integrate a range of ecosystem parameters. In parallel with PNGRIS other sector specific databases have been established over the years. These include DEC's hydrometric and biodiversity data base, Department of Agriculture and Livestock (DAL) land use and soil data base, Forest Information and Mapping System (FIMs), climatic and geological databases. A major upgrade of the PNGRIS is currently underway at UPNG with EU funding. It is generally agreed that the upgraded version of PNGRIS should be used as the basis for integrated catchment management planning. However its full potential may not be harnessed since some custodians of sector specific data are reluctant to allow the inclusion of "their" data due to concerns regarding commercial confidentiality and profiteering from the sale of data by unscrupulous persons.

The continued availability of trained and competent officers in all the disciplines required for integrated catchment management is critical. Ideally a catchment planning team providing advice to a management committee will be headed by a qualified and experienced catchment planner. A number of trained and experienced DEC officers in this field have left the public service but the level of replacement and training has been incommensurate.

3.1.4 Measures to manage impacts and concerns

The routine collection of hydrometric and water quality data is essential for the sound management of water resources. Given the long period of disuse, it can be assumed that the entire system has been either vandalised or beyond repair. There is an urgent need to revive and establish a basic representative hydrometric network taking into consideration the latest technology, as well as installation and operational costs. The inclusion of in-situ instantaneous measurement of physical water quality parameters would be an advantage.

The surface hydrological data collected by DEC is not combined with hydrogeological data for catchment water budgeting and allocation for various uses. At present, limited hydrogeological data is collected by the PNG Geological Survey (PNGGS) and there is very little interaction between the two organisations in terms of data collection, exchange and analysis. PNGGS also needs the surface hydrological data that DEC collects and the two agencies should work towards integrating their databases and conducting joint data collection exercises. This collaborative working arrangement could be one way of dealing with the limited annual operational funding allocated to the respective organisations by the government.

Funding limitations has drastically reduced the area of hydrometric coverage, therefore a coordinated approach using the landusers in the catchment is currently been promoted. Water quality data is not collected routinely but only in response to pollution complaints, which may warrant specific water sampling and analysis exercises to authenticate such allegations and take remedial actions.

Under the environmental permitting system of the Environment Act 2000, companies and corporations involved in large-scale natural resources extraction, infrastructural development and

industrial activities are required to collect and submit hydrological and water quality data at specified intervals. DEC is supposed to incorporate the information into its database but the current database capacity can only accommodate hydrometric data. An additional difficulty with the hydrometric data is the use of different incompatible database software. When this technology is improved DEC should be able to store all the data provided.

A permit holder is required to undertake monitoring for various parameters and report at regular intervals to DEC in compliance to the permit condition. The samples for compliance monitoring are collected in duplicate with one set dispatched to an accredited independent laboratory for analysis. A copy of the laboratory's results is sent directly to DEC to eliminate suspicion of data tempering. DEC is also required to undertake compliance monitoring including audit sampling for analysis by an independent laboratory. If there is any evidence of non-compliance, the permit holder is instructed to take corrective action within a specified time period or face prosecution.

All expenditures are now taken by the developer under the Use Pay Policy that is practiced and promoted under the Environment Act 2000. The costs for laboratory analysis are very high and DEC's ability to carry out audit sampling is restricted. Funding for routine compliance inspections is limited and in most cases, permit holders assist with airfares, accommodation, transportation and subsistence expenses for DEC officers to carry out their duties. The public do not consider this practice acceptable, particularly those in the vicinity of the permitted operation who may be affected by an act of non-compliance.

There are no community based water quality monitoring programmes but most people in rural communities are well aware of who to approach when they observe discernible changes in water appearance and taste experience, ill health or notice sudden as well as inexplicable deaths of people, aquatic flora and fauna. In a number of cases expensive compensation agreements had to be negotiated between the offenders and the parties affected. One such situation could not be resolved amicably and resulted in a ten year armed insurgency on the island of Bougainville. The compensation claim was for environmental damages caused to the Panguna Watershed and the Empress Augusta Bay by direct disposal of overburden and tailings from the Bougainville Copper Mine. This conflict marked an historical turning point in terms of environmental awareness and management in PNG. It highlighted the direct dependence of man on the environment in a rural subsistence cultivation based lifestyle and the extent to which the people can go to protect their livelihood. A lot of useful lessons emerged from the Bougainville uprising and since then in negotiating with local landowners, the national government and resource developers have tried to prevent similar situations from deteriorating into violent confrontations.

Other water resources related data are collected by the National Weather Service (NWS) which is part of the National Civil Aviation Authority (NCAA) and the PNG Geological Survey (PNGGS), Department of Mining. Rainfall and climate data is collected by the NWS while PNGGS collects hydrogeological data. DEC has an excellent working relationship with the NWS and both organisations share the rainfall data collected under their respective networks. The same cannot be said of DEC and PNGGS and although both organisations have worked together on a few assignments, there is a need to improve and strengthen this connection as well as exchange data. This is crucial because a complete integrated water resources management plan for a catchment requires data on both surface and groundwater hydrological parameters.

While, water conservation becomes critical in both rural and urban centres during prolonged low flow and drought conditions, a large amount of wastage can occur as a result of leakage and misuse especially with reticulated systems. During drought situations in urban areas, the service provider applies a stepwise response strategy relative to the declining capacity of supply to meet demands. The strategy includes use restrictions accompanied by fines, temporary increase in fees to discourage misuse and rationed distribution throughout the serviced area. In addition, all service providers undertake regular monitoring and maintenance of reticulated systems in order to reduce

unnecessary wastage and operational costs. In rural areas during drought conditions, people are forced to restrict potable water usage and use brackish or seawater for non-consumptive purposes.

With regard to water pollution prevention in catchments, DEC currently has in place a number regulatory tools including water supply watershed protection and codes of practices for municipal solid waste landfills, as well as industrial, logging, agricultural, mining and infrastructure development. These tools specify implementation of the various activities with respect to erosion control, protection of biodiversity, provision for traditional subsistence gardening and proper disposal of solid and liquid waste. Most companies have complied with these requirements but there have been many instances where major destruction of watersheds has occurred. DEC requires more funding to effectively perform its regulatory duties and it should also devise an effective compliance monitoring strategy with the private sector and involving landowner and public participation.

The Environment Act 2000 contains a provision that restricts certain land uses within a surface water catchment or a groundwater bore field to prevent contamination of the water and to conserve water for priority uses during prolonged dry seasons and drought situations. In a surface water catchment, restrictions may be imposed on removal of vegetation, gardening, buffer zones, drainage and waste disposal. Similarly, over a bore field area, vegetation clearance, waste disposal and barriers to effective recharge are the main considerations. This provision is difficult to apply over customary owned land since getting the people's consent is invariably impossible. In a number of cases watershed protection for water supply purposes has been indirectly secured where landowners have organised themselves and requested the area to be declared a Wildlife Management Area under the Fauna Protection Act for biodiversity conservation, maintenance of environmental integrity, prevention of commercial logging and promotion of ecotourism. In some critical situations an outright purchase of the headwaters area of a catchment may have to be negotiated with landowners. Public education and awareness and the provision of alternative revenue generation measures is therefore essential to acquiring landowner support and cooperation.

The low rate of access to potable water in the rural areas, increasing pollution and vulnerability of water resources to natural disasters and climate variation all highlight the critical need for integrated water resource assessment, planning and management. An effective inter-sectoral coordination mechanism involving the public sector, private sector, NGOs and landowners must be established in each catchment to ensure that all development and natural resource exploitation activities are undertaken in a sustainable manner.

An important component of the national catchment management strategy must be the formulation of training and development program for climatologists, hydrographers, hydrologists and hydrogeologists, who can interact with other experts such as biologists, agriculturalists, engineers, sociologists and economists to devise and implement all inclusive catchment management plans. The involvement of a wide range of expertise is critical because each individual can also act within his/her sector to ensure that any planned activity for the catchment can be sustainably accommodated within the plan.

3.2 Island vulnerability

3.2.1 Types of disasters

Many parts of PNG are vulnerable to the effects of natural disasters. The natural disasters that have severe adverse effects on the lives of people and economy in PNG include the following:

- Cyclone generally in the Milne Bay islands but Tufi in Oro Province has been hit previously;
- Volcanic eruptions in East and West New Britain, Oro and Madang Provinces;

- Tsunami in Aitape of West Sepik Province;
- Major landslides in Morobe and Highlands Provinces;
- Flooding in parts of PNG;
- Droughts resulting from El Nino phenomenon;
- Frost in the Highlands.

Other related disasters include; sea level rise, coastal erosion, saltwater intrusion, earthquakes and tidal surges. Man-made disasters include deliberate and unplanned water pollution.

3.2.1.1 Flooding. With annual rainfall ranging from 950 mm in the lowlands to 10,000 mm in the highlands, most areas across the country experience floods in almost every wet season. In the highlands where there is little variation in rainfall, severe floods are experienced in the wetter months. Floods are common in the lowlands during heavy rainfall in the wet season because of the flat catchment plains that allows for the overflows.

In 1985, Lae experienced a major flooding of the Bumbu River that removed the two bridge connections to the city and washed away permanent houses along the banks. Settlers residing along the bank were also victims when flood waters settled in their residential homes. Similar situations have been on-going in the Laloki catchment where flooding is always experienced during wet season between November and May. Food gardens, residences and government institutions like Bomana Correctional Services always remain alert. During these floods, most prisoners escape and this costs the government thousands of Kina to recapture them.

The Sepik River normally overflows and remains inundated for over couple of months. This allows people along the river to collect their building materials etc. However in recent times this trend increased to more than six months in 2001 which raised concern on food security. Further on in the Wau-Bulolo area of the Morobe Province, flooding has been experienced frequently. In 2006, a massive one destroyed the only highway that links the town and Lae city. In the process a landslide buried a village and hamlet with several people washed away or buried.

Further into the coastal plains, flooding causes severe erosion with mudflows and overflowing rivers heavily laden with sediments causing havoc on downstream settlements and agricultural land. Frequent flash flood in major streams happens due to sudden change from steep topography to flat plains. In the lowlands, floods with heavy loads of silt and debris physically damage coastal ecosystems such as estuaries, tidal flats, mangroves and coral reefs.

The cost of damage can be severe in heavily populated areas and urban areas with infrastructure located close to watercourses. Inundation of water resources affects availability of potable water for drinking and cooking as well as water for ablution. It also leads to the incidence of waterborne diseases such as skin rashes, scabies, diarrhoea, dysentery and typhoid.

3.2.1.2 Landslide. Most of the high mountainous regions of the country experience landslides, which destroys villages and gardens and major infrastructures. In 1986 a major landslip caused by a perched lake in the mountains of Morobe Province buried a whole village of 1000 people. Continuous slips are experienced in the highlands of PNG and are impacting on the Highlands Highway after heavy rainfall. These two events occur regularly and cost the government millions of Kina on rebuilding the roads and aiding the victims.

3.2.1.3 Droughts. Prolonged dry seasons and droughts occur in some parts of the country, which have noticeable wet and dry season. Such areas include the Southwestern plains,

Central Province plains, Cape Vogel area, Markham valley, Bulolo valley, Maprik – Angoram area, and some areas on the Eastern Highlands and Madang Provinces (McAlpine et al. 1983). Extended dry seasons and drought affect vegetation growth, encourage bush fires, restrict food crop production and result in the drying up of most creeks, streams and large wetland areas that depend on rainwater to recharge the catchment.

PNG experienced droughts in 1992 (mild) and a major one in 1997/98. It was obvious during this period that PNG did not have a disaster response plan on droughts. During this period frost was also experienced in the Highlands that wiped out most of the sweet potato gardens and food was in short supply.

3.2.1.4 Pollution. Water pollution becomes an issue when there is insufficient water in rivers to dilute wastewater discharges. The DEC hydrological database has historical records of floods and droughts for most river systems going back to the early 1950s but it has to be extracted from the annual discharge data. According to the NWS, the incidences of these events have increased in frequency and severity recently due to the ENSO phenomenon. Annex 5 shows the types of disasters and number of occurrences in PNG between 1997 and 2002.

3.2.1.5 Cyclone, storm surges and salt water intrusion. PNG is fortunate to be just outside of the tropical cyclone activity region but its southern tip is occasionally hit by cyclones that originate close to the area. The last major cyclone raged through the area in the early seventies and caused substantial damage. Nevertheless, during the cyclone season in the region, the southern coastline of the mainland and the Milne Bay islands experience unusually strong winds and rough seas. In some instances these strong winds and rough seas have destroyed houses built over the sea and on low-lying coastline areas.

In 2005 a freak wave washed away more than ten houses at Barakau village less than 10 km out of Port Moresby. A similar incident also happened in Madang and Lihir in 2006 with no casualties but houses along the beach were washed out.

Saltwater intrusion has been reported in low-lying coral atolls and in some coastal rivers. A study was carried out along the Binaturi River in the Western Province after people claimed their freshwater trees were dying. It was confirmed that after the drought in 1992 and with impact from the climate change, saltwater did travel up in this flood plain and inundated forest more than15 km inland.

3.2.1.6 Sea Level Rise. The Katarets island of PNG and the Motlocks are experiencing first hand the impacts of sea level rise. These atolls close to the Solomon Island are very flat and most of their land is under water. Survival is mostly from coconut fruit. The experience there is obvious and a USA film crew made a documentary on it in early 2007. This documentary will soon be aired on the Discovery Channel.

Sea level monitoring has been carried out in PNG since the late eighties and some data on horizontal land movement is collected and monitored by the PNGGS. However under the Delimitation Project and for the claiming of the Continental Shelf, the data are been reviewed and have not been released yet.

3.2.1.7 Earthquakes and volcanic eruption. Earthquakes and volcanic eruptions cause landslides, tidal surges and tsunamis which have resulted in alteration of watershed morphology, sedimentation of watercourses, shoreline erosion, saline intrusion, costly damage to property and loss of human lives.

An offshore earthquake triggered tsunami with devastating consequences hit the Aitape area in the West Sepik Province in 1998 where more than four villages located along the

shoreline were swept away with heaps of destruction to the environment. This is one experience PNG still remembers.

In addition, volcanic eruptions caused large-scale destruction of vegetation and contamination of water bodies as experienced in East New Britain and West New Britain in 1994 and 2001 respectively. Similar eruptions in Madang, has displaced number of villages on Manam Island who are currently re-settled at Bogia mainland. This relocation is causing government lots of money to support the people. No exact costs were made available but East New Britain is still rebuilding itself from that disaster and have physically relocated provincial headquarters to a new location.

Where drinking water has been affected, alternative sources of water had to be located. This is easier on the mainland as opposed to atolls where larger roof rainwater catchments and storage tanks had to be provided.

3.2.1.8 Manmade disaster. The disposal of mine tailings into water bodies is a major source of water pollution and sediment build up downstream in the catchments where mines are located. With the mines located in the interior on the mainland, it is prohibitively expensive and structurally risky to build large impoundment structures or pipelines to convey tailings down to the coast and into a deep submarine outfall such as the now closed Misima Gold mine and currently operating Lihir Gold mine. Similar situations occurred in Panguna mine where tailings were discharged into the river system causing pollution and build up of riverbed sediment and instigated the civilian riots on Bougainville Island in 1989.

A number of relatively minor chemical and oil spills have occurred mainly in petroleum and mining project sites. Fortunately, in all cases the impacts have been minimal due mainly to the relatively small quantity of substance involved and the rapid clean up response by the operator. To date there has not been any major oil spills in the maritime ports or in PNG's EEZ waters.

3.2.2 Major issues and concerns

There are two main issues in relation to disaster management. The first one is disaster preparedness where we need to know in advance when an event is likely to happen and what necessary preparatory action needs to be done. At the same time an assessment of the extent of the event to prevent loss of life and damage to infrastructure etc. the risk reduction is important. The other is the adaptability to disasters where what can be done to sustain life after a disaster has struck to minimise further loss of life.

The NDO's National Disaster Management Plan has a nationwide response network and implementation strategy. However, this Plan lacks the communication component of the network in disseminating information to the general public. A recent alarm in early 2007 triggered by the tsunami in the Western Province of the Solomon Island clearly displayed the inadequacy of communication in PNG for disaster preparedness. Information is not readily available for NDO to use in informing the public on types of disasters and when it is expected. The communication between the provinces and Port Moresby requires a lot of improvement. The NDO is also not equipped in predicting disasters because the office is not adequately supported with trained personnel in this area. However information is collected from other responsible agencies before disseminating which is a concern and delays the process.

Information sharing is a concern especially when respective government agencies dealing with disasters operate separately from the NDO. The NWS is tasked to predict climate variability using their data however; it does not have direct linkage with the DEC's hydrological database to complete the predictions especially with respect to flooding which is a common disaster in PNG. Current flood and drought warning systems overseen by the NWS are too general and need to fine tuned through the development of river specific flood and drought analysis with assessment,

prediction and warning systems. Appropriate adaptive measures can then be devised and implemented.

DEC needs to improve its water resources assessment system in order to collect near real time data to produce flood management manuals that are updated every five years. This has to be done in collaboration with the NWS using their rainfall data. On the few sea level monitoring systems that were put in place under a project executed by SPREP, only one in Lorengau Naval Base is in operation however collection of data is not known. The reduction of personnel in the Water Resources Management Branch and especially in the Hydrological Unit of DEC has also contributed to the loss of data where in the past, this section collected tidal data from all major sea ports managed by the PNG Harbours Board (now referred to as PNG Ports Limited).

Since PNG is considered one of the wettest countries in the world, it has been perceived, perhaps wrongly, that there will always be water available. There has been little dialogue on water and climate. The El Nino phenomenon has indeed brought the water and climate relation in to focus.

On hand for the man-made disasters, the government has an EIA and pollution regulatory system built into the Environment Act 2000 which regulates activities but DEC is not adequately funded to carry out the compliance monitoring work on defaulters. With particular reference to the mining sector, in spite of the negative impacts caused by river disposal of mine tailings, it is unlikely that the present permitting arrangement will be changed. Most NGOs argue that unless mines are able to construct tailing impoundment structures they should not be allowed to operate. However the government is forced to make the sacrifice in order to curtail the level of national debt and dependency on foreign aid funding.

3.2.3 Measures to manage impacts and concerns

Since the major drought in 1997 - 1998, PNG has shifted from crisis management to planning and management. The tsunami in Aitape was also a challenge for an office to be established to deal with such disasters in the country.

The National Disaster Office was created through an Act of Parliament: The National Disaster Management Act to basically coordinate disaster risk preparedness and response in partnership with relevant government agencies and NGOs. The Office is administered by the National Disaster Committee chaired by the Secretary for the Department of Provincial and Local Level Government Affairs. In 2005, NDO launched a National Disaster Mitigation Policy. This policy is based on “One Step ahead” approach promoting proactive planning and implementation of mitigation in disaster and risk management. All stakeholders including the National Disaster Committee, the National Disaster Office and disaster management stakeholders at the national, provincial and community will implement this policy.

Routine hazard risk monitoring is undertaken by specialised government entities depending on the nature of the disaster. Monitoring and forecasting of droughts and floods is done by the NWS, while advice on the possible extent of damage is provided by DEC. Geotectonic monitoring for earthquakes, land subsidence, tsunamis and volcanic eruptions is conducted by the PNGGS. Monitoring information is provided constantly to the NDO which issues warnings when necessary and activates its response procedures when the disaster takes place. In the case of water related disasters, the key government agencies involved are National Weather Service, PNGGS, Department of Health (DoH), DPLLGA, DEC and the relevant provincial government. PNG has a National Oil Spill Response Plan that is coordinated by the Department of Transport's Marine Transport Division in close collaboration with NDO and DEC. Other agencies involved are PNG Ports Ltd. and National Fire Service. The NDO is required to ensure that these processes and systems are functioning, reviewed and updated regularly.

There is need for relevant agencies in the water resources sector to liaise and work closely with the NDO to ensure that this approach is adopted and implemented. This strategy will be promoted in

the proposed IWRM Demonstration project. This particular aspect of the project will build on the work done in the First National (Climate Change Situation and Adaptation) Communication report and will be linked to the other related projects listed in Table 2, section 3.5. It is especially encouraging because all these activities will be taking place over the same period and should complement each other so every effort should be made to achieve maximum synergy.

Effective communication of disaster response, relief, and rehabilitation and adaptation measures to the general public is absolutely critical in normal circumstances and especially during a disaster. Unless the public is informed in a timely and accurate manner, the adverse consequences will not be minimised. Under normal situations, an effective campaign using appropriate media and targeting different gender and age groups should be formulated and implemented. It is important that the correct message is relayed so as to avoid unnecessary fear and panic.

The government regulates all river disposals of tailings from mines such as Porgera and Kainantu Gold through permit conditions. Each company is also required to provide monetary and in-kind compensation including the provision of alternative water supplies for any negative downstream impacts. The mill effluent and other waste streams from each operating mine have to meet site specific standards prior to disposal into the river system. Heavy fines are applied for any major and continuous breaches of these standards. PNG is doing away with self regulatory system to allow regulators to monitor mining operators fully. It is worth noting that Panguna river system that received Bougainville Copper Limited's (BCL) tailings has recovered remarkably well since the forced closure of the mine in 1989. Although being the major single revenue earner for the government coffers, the Fly River into which Ok Tedi tailings are discharged is contaminated by heavy metals and sedimentation.

Capacity building will be required to ensure that there is stable pool of experts who can carry out the hazard assessment and risk management work. This applies to climate, geological and man made hazards. Training programmes and career development paths should be designed for a pool of national experts on climatology, geology, hydrology, hydrogeology, disaster management and resources should be secured to provide the necessary training.

3.3 Awareness

3.3.1 Types of awareness campaigns and advocacy initiatives

Awareness on watershed protection, sustainable water resources management, potable water supply and proper sanitation is undertaken by several organisations. They include public sector agencies, NGOs and community based organisations (CBOs). Some of these activities are funded by donor organisations. The targeted audiences are school children, the general public, public sector organisations, the NGO community, politicians and donors.

In primary and high school environment curricula, the need for watershed conservation, clean water supply and environmentally acceptable methods of human waste disposal are taught. The Live and Learn NGO are concentrating on preparing educational curricula for schools and promoting them by circulation to schools and Education Department. The DoH has publicity materials on rural water supply and sanitation. Additional material have been provided by WHO's Healthy Island Program which promotes village cleanliness, personal hygiene, clean and safe potable water, proper sanitation and nutrition. These materials are supposed to be distributed and promoted through participatory village livelihood improvement programmes using the provincial divisions of Health. The materials used are pamphlets, education charts and posters. Some of the DoH material is used by NGOs in addition to their own products. NGOs are heavily involved in project specific local and general education and awareness activities.

Urban service providers Eda Ranu and PNG Waterboard conduct regular awareness on water conservation for their customers through newspaper and TV advertisements, radio, posters, pamphlets and stickers. PNG Waterboard has also taken the lead in coordinating the observance of

World Water Day every year. Eda Ranu has been targeting the population in the capital with some participation of the DEC.

DEC carries out general public awareness during government awareness broadcasts on Karai National Radio, international environment and conservation observance days including World Environment Day. Awareness is also carried out by officers during fieldtrips to provinces when they meet with communities to address the relevant environmental issues in the area.

Since 1980, there has been a growing number of donor funded and NGO initiatives aimed at promoting conservation of natural resources and sustainable development. The initiatives were designed to increase education and awareness on the impact of uncontrolled large-scale extraction of natural resources, promote environmentally-friendly, less destructive alternative means of utilising natural resources for income generation and emphasise the need for proper sanitation and waste disposal.

Such initiatives included the UNDP/DEC/CRC integrated conservation and development (ICAD) project in New Ireland and Madang Province in the early eighties. The initiatives trialled a variety of approaches in educating, monitoring, engaging and empowering local people to develop their locally available natural resources in a sustainable manner. These projects were followed by many interventions by environmental NGOs such as the WWF, The Nature Conservancy (TNC) and Conservation International (CI) as well as smaller CBOs. Some of these involved private sector and NGO partnerships such as the Chevron Niugini/Oil Search and WWF Kikori ICAD project. Two current projects which have benefited from the experiences and lessons learned from their predecessors include TNC's integrated coastal zone management project in Kimbe Bay of West New Britain Province and WWF's national eco-region based biodiversity and wetlands conservation project.

3.3.2 Major issues and concerns

While there is a reasonable level of communication within the water resources management, water supply and sanitation sector, not everyone has a good handle of developments and events as they occur. A lot more can be achieved if there is improved interaction and cooperation where necessary. Public awareness is done by individual organisations and in many cases other important stakeholders are not involved.

The cost of production and dissemination of awareness materials is an important constraint. Most of the bigger organisations are able to employ full time professionals to concentrate on their publicity activities. However, there seems to be little if any interaction between these persons. The effectiveness on the materials produced and the mediums used should be evaluated regularly and improved as required.

The high level of illiteracy (44% from the 2000 National Census) must be considered in the design and delivery of awareness programmes. Direct verbal awareness through meetings, rallies, workshops and drama performances are more effective. Any opportunity for direct interaction with the audience should be utilised. This should be subsequently complemented by radio, TV and printed material awareness. Dissemination of awareness material can be hampered by poor transport and communication infrastructure. This is where networking with provincial and district administrations, the NGO network and the private sector can be helpful.

The biggest issue with natural resources management and biodiversity conservation in PNG is land ownership. Ninety-seven percent of the land in PNG is customarily owned. Under their constitutional rights, landowners can basically do whatever they want with their land and natural resources with the exception of water. While they have the right to access water resources within their boundaries, they cannot construct permanent dams or diversion structures or indiscriminately discard waste material, which will affect the availability of water to downstream users. All natural resources extraction and development legislation are therefore deliberately designed to involve

landowners in the planning and implementation phases. The legislation complements each other to: (i) maximise economic benefits to the landowners, the country and resources developer and (ii) to maintain the environmental integrity of the area.

Any external intervention aimed at promoting sustainable resource use will not succeed without the consent and support of landowners. As long as the people are adequately educated on the value of the natural resources and the importance of responsible environment management, they will in most instances opt for development activities with minimum environmental impact. In most projects, the use of influential people such as politicians and church leaders as champions of sustainable development has contributed massively to gaining community support and participation.

In many communities throughout PNG, women are responsible for ensuring there is sufficient water and firewood in the house. This usually involves carrying large water containers from nearby wells, creeks and rivers while firewood is collected and carried in large bundles from nearby bushes and forests. Women also do most of the garden work. In the coastal communities, it is the women that collect shellfish and crabs from estuaries and mangrove areas. Women are therefore important in integrated water resources management and their participation cannot be overlooked.

Access to clean, safe and reliable water supply and proper disposal of solid and human waste are essential for healthy and productive individuals, an entire community and society in general. All members of the society use water and interact with the environment in various ways but not everyone is fully knowledgeable of the actions which may be detrimental to the sustainable utilisation of natural resources. Any awareness programme must be designed to include all age and gender groups to ensure understanding and encourage appropriate behavioural change. These may involve classroom-based activities in schools and workshops within communities.

Apart from the relevant components on responsible environmental management taught in schools throughout the country, general public awareness on water resources and wastewater management is done in an uncoordinated and fragmented manner with uneven coverage across the country. Improved public participation can be achieved if there is a sustained, deliberate, structured and cohesive campaign involving all stakeholders to promote responsible water use and wastewater management. This undertaking should be overseen by the proposed National Water Committee.

3.3.3 Measures to manage impacts and concerns

Inadequate awareness on the status and impact of the unsustainable water resources, water and wastewater in the country could be one reason for the low level of access of the population in the rural areas to potable water supply and safe sanitation. The focus of a structured national awareness campaign should be to highlight the importance of improving the situation amongst the general public, politicians and the donor community. This should lead to better coordination, attract additional funding and enhance support for currently operating projects and national initiatives in addressing the situation.

Experience from many community centred infrastructure development and resources management projects has shown that effective communication from the outset and throughout the life of the project is vital. The local people must be accurately advised about the objectives and scope of the project, unnecessary expectations should not be raised and any misunderstanding should be clarified. The people should then decide whether to proceed with the project. This will give them a sense of responsibility and ownership for the commencement, operation and long-term sustainability of the project. Over the last few years this approach has been included as an essential requirement of water supply and sanitation projects. In these arrangements community support in cash and kind has been built into project agreements. Where people expend time, funds and effort into any community development project they are more likely to ensure that it is maintained and continues to be of service to the community. In addition the operation of the water

and sanitation committees in the villages should be improved. This should be done by clearly defining their individual and collective roles and functions and supported by a training programme for villagers to provide assistance in the maintenance and construction of water and sanitation facilities. This approach should be applied nationwide.

A national communication plan should be formulated to promote awareness on sustainable water and wastewater management at all levels in the society. The plan should have a clearly articulated vision, objectives and outcomes over a five year time frame with specified targets and progress indicators. The audiences must be identified, the messages clearly expressed and effective production as well dissemination strategies must be devised. The roles of all stakeholders must be clearly explained. Some possible outcomes of this plan should be capacity building for effective education and awareness, production of quarterly newsletter, establishment of a national information centre and an annual competition for the community with the best water supply and sanitation system in the country.

An important avenue that must be considered in the National Communication Plan is to review the contents of the environment education component in both primary and high school curricula to ensure that sustainable water and wastewater management is adequately covered. This could be supplemented by video shows and take home pamphlets, posters and stickers.

3.4 Technology

3.4.1 Types of water supply systems

The PNG Waterboard provides treated reticulated water supply to the provincial towns it is operating in. It has gradually extended to provide this vital service to the Districts within these provincial towns. In urban settlements, the Waterboard has been providing public standpipes for community consumption rather than individual households. Most of these systems are subsidised by the operating agency like the PNG Waterboard or the Eda Ranu in Port Moresby. Information on the PNG Waterboard water supply establishment in urban and District areas and their method of extraction can be found in Annex 7.

Table 1: Population in the major urban centres with access to safe water and adequate sanitation

Town/City	Population:(2000)
Port Moresby	252 469
Lae	78 038
Madang	27 394
Wewak	19 724
Mt. Hagen	27 782
Goroka	18 617
Kundiawa	8 147
Mendi	17 119
Wabag	4 062
Vanimo	9 809
Kimbe	14 656
Rabaul/Kokopo	8 885
Kavieng	11 560
Alotau	10 025
Daru	12 879

Popondetta	19 556
Kerema	5 116
Buka	6 443
Lorengau	5 829
TOTAL	**558 120**

Source: PNG Waterboard 2002.

In most rural communities, water for domestic use is obtained directly from surface water bodies, wells and rainwater tanks. In some communities, the raw water is pumped from a surface or groundwater source into an elevated storage tank or reservoir from which it is distributed by gravity to standpipes located throughout the community. In other communities, the reticulated system is entirely gravity fed from the intake structure situated upstream in the watershed. There are also community water tanks around the country and especially on small atolls for rainwater collections.

The Department of Health in its attempt to provide simple but manageable water supply to the rural communities has provided 30% coverage. It is further implementing a project to increase this coverage as planned in the 10 year National Health Plan. The Rural Water Supply and Sanitation project with the Department of Health is also providing this service to the communities through various contracts. The design of the infrastructure to be used is intended to ensure sustainability by;

- Basing projects upon real needs expressed by communities,
- Engendering ownership by communities through participation throughout the decision-making process and the commitment of cash and in-kind contributions towards the overall cost of the project, and
- Projects designed to be in reach of community technical and financial capacities.

Other appropriate technologies used are provided by the University of Technology and some NGO groups like World Vision, Save the Children Fund and church organisations such as Adventist Development and Relief Agency (ADRA) and Lutheran Development Services (LDS) who support water supply and sanitation activities. The information on the technologies used was not available for documentation. Departments of Works and Provincial and Local Level Government provide planning and designing for most of the rural water supply developments.

3.4.2 Types of wastewater/sanitation systems

The Eda Ranu Limited operates the National Capital District wastewater and sanitation systems. It comprises of biological lagoons and sewerage system with treatment of wastewater prior to direct discharge into marine at depths below 125m below surface of water. The PNG Waterboard operates all systems outside of Port Moresby with combinations of biological lagoons and sewerage systems for treatment and direct disposal into marine environment at various levels below surface water. In the ten towns that the PNG Waterboard operates, there are individual treatment systems for wastewater and sanitation. For more information please refer to Annex 8.

It is important to note that although the PNG Waterboard is operating in most of urban centres, it does not have the full coverage of the towns with sewerage systems. Lae, Kimbe, Kavieng still have a majority of residents using a septic system, which is of concern since they depend on groundwater for water supply. Large residential compounds have small biological waste treatment units constructed to manage the wastewater and sanitation produced. In Madang, residents in the New Town area still use pan toilets that are regularly collected and disposed of at a designated site for treatment and eventual discharge. Major educational institutions all depend on small sewerage treatment system servicing only their set-ups. The exception is for institutions in the National

Capital District where all are connected to the town system. In squatter settlements within and on the fringes of urban areas, most people use standard, poorly constructed pit toilets.

In rural areas pit toilets or direct disposal into the environment (land/marine) is the means of removing human waste. Most rural toilets are pit latrines of the standard variety with minimum allowance for odour and fly control. Most incidences of diarrhoea, dysentery and typhoid are directly linked to the poorly designed and constructed pit toilets and improper personal hygiene.

The following basic process is used in most reticulated systems. The waste is either: (i) channelled to a fabricated package or pond system for treatment before disposal into a surface water body or (ii) screened, macerated and discharged at depth into the sea through a sub-marine outfall. In major mining, logging and agriculture development camps and towns, reticulated water supply and sewage disposal and treatment facilities are provided.

3.4.3 Major issues and concerns

The current situation with regard to sanitation is very serious because 78% of the population or more than four million people do not have access to safe sanitation services. Statistics in the 1996 National Health Plan revealed that diarrhoea is the number one cause of mortality and morbidity in the country at the rate of 1610 deaths per 100,000 of the population. Furthermore, 2.9% of all deaths are caused by typhoid and the current low access to potable water and safe sanitation is an ideal recipe for the incidence of cholera and other similar epidemics (PNG Waterboard Strategic and Medium Term Corporate Plan 2006). The government needs to reorganise the water supply and sanitation sector in order to improve service delivery and eliminate the high incidence of these preventable diseases.

The type of technology used in rural and urban areas is largely determined by availability of the freshwater source in terms of quantity and quality and the cost of installation, operation and maintenance of appropriate infrastructure. In rural areas, where it is possible to establish standalone household facilities, the burden on communal systems is reduced. The main setback for the rural sector is the absence of an institutional structure at the provincial and district level focusing solely on providing technical support to local communities on the construction, operation and maintenance of water supply and sanitation systems. In urban areas, the type of system and extent of coverage and leakage reduction is dependent on the costs involved and the operational systems.

Whether it is a rural or urban setting, the ability of supply to meet demand depends on the natural availability of water and the delivery capacity of the water supply system. In the rural areas with very wet and wet climates, the amount of water is able to meet the demand however in some locations quality may be an issue if the water is taken directly from a surface water source with economic developments upstream. Even in areas where there is a long distinct dry season supply is able to cope with demand except in an ENSO prolonged dry season. This is the time where cities such as Port Moresby are forced to impose water restrictions. In reticulated systems especially in large urban centres, wastage through leakages is a principal concern for service providers. Every effort is made to identify leakages and carry out repairs directly as well as public awareness to encourage users to check for leakages within their household and take corrective action immediately. In its nationwide urban water supply network the PNG Waterboard has succeeded in reducing unaccounted for water from the 1987 level of 50% to the present level of 31%. During prolonged dry seasons people in rural areas resort to groundwater wells and water carted from nearby urban centres.

PNG Waterboard is responsible for the appropriate provision of water supply and sewage disposal facilities in all urban centres in the country. At present only Port Moresby and Goroka are outside of the PNG Waterboard network. The water and sewage disposal facilities in Port Moresby is run by another state owned enterprise known as Eda Ranu while the facilities in Goroka are run by the municipal council. In accordance with its legislation and mandated national responsibility, the PNG

Waterboard should manage and oversee all urban water supply and sanitation facilities either on its own or in partnership with other private sector and non-government organizations. Annex 9 presents a map outline of the current PNG Waterboard establishment of water supply and sewage facilities in the urban areas throughout the country and development targets for the next decade. Ideally, in the urban scenario, Port Moresby and Goroka facilities should be brought under the PNG Waterboard. The inclusion of these facilities will expand its revenue considerably and enable it to re-invest some of the money into improving water supply and sanitation facilities throughout the country. At present it is not clear as to who should be responsible for the planning, monitoring and management of rural water supply and sanitation facilities.

The level of wastewater produced in a catchment depends on the population density, nature of landuses and the level of industrial activity. Most of the catchments experiencing problems with wastewater discharges are those with large urban centres, mining, logging and major agricultural projects. Increased sediment, bacterial and chemical pollution from untreated waste streams and improper solid waste management will continue to cause destruction of aquatic flora and fauna and affect the health of people downstream use and users.

3.4.4 Measures to manage impacts and concerns

Over the last ten years, DoH, PNG Waterboard, IWP PNG, some churches and a number of community development oriented NGOs have vigorously promoted the use of ventilated improved toilets across the country. The adoption rate has been lower than expected and a lot of awareness still needs to be carried out to convince local people to expend more time and resources to build better rural toilets, stop defecating directly into the local environment and improve personal hygiene. Pit latrines are not suitable for areas with high watertables and other alternatives such as compost toilets should be promoted. Attempts by DEC to introduce an Environment Policy on Waste Disposal (human waste) fell short when it was realised the extent it would have to cover. The policy would have been divided into categories dealing with pit latrines, over the sea latrines and septic. PNG needs to pursue this as priority in the future.

For the rural sector, institutional arrangements and capacity development should be reviewed and strengthened at the provincial and district level with appropriate funding and logistical support. This may require the establishment of an entity dedicated wholly to planning, installing and maintaining water supply and sanitation facilities throughout each province. Such a mechanism is critical to improving access to potable water and safe sanitation and improving the health status of individuals and communities in the rural sector.

As a first major step towards improving water supply and sanitation, a draft National Water Service policy has been formulated by the PNG Waterboard. This policy presents the case for the creation of a National Water Authority, which will be responsible for overall planning, regulation, compliance, licensing and regulation of the industry. Service delivery agencies such as PNG Waterboard Operations, Eda Ranu and Goroka ULLG can continue to operate independently. At the same time community service obligation activities would be separated from profit making operations.

The government through DEC has an environmental impact assessment (EIA), permitting and monitoring system under the Environment Act 2000. All major resource extraction and development projects have to go through a rigorous impact assessment process involving public awareness, scrutiny and consultation. When the permits are granted these operators are expected to adhere to certain standards with respect to wastewater treatment and the impact on the receiving water body following discharge. Companies risk heavy fines or closure of operations if the expected standards are not met.

Water source protection can be applied under the Environment Act 2000. Using these clauses certain activities can be prohibited in a surface water catchment or a groundwater borefield to protect water quality especially for domestic water supply. Water conservation measures are only utilised during low flow situations to promote responsible water use and ensure available supplies

are properly managed to last throughout the dry season. The measures imposed would differ between rural and urban centres. The typical measures are to use restrictions, increased fees, rationing and use of brackish water for general non-consumptive purposes.

There are number of databases containing water related information and housed in different government agencies and academic institutions. These include the hydrological database in DEC, PNGRIS in DEC/DAL, meteorological database with NWS, Forest Information Management System (FIMs) with PNG Forest Authority (PNGFA) and hydro-geological database with PNGGS. In order to facilitate IWRM, the establishment of databases incorporating relevant GIS and other data from the aforesaid existing databases will be crucial.

Organisational audits, dedicated individual focused capacity building as well as introduction of updated technology where required to improve performance and operation should be carried out with current and proposed stakeholders in both the rural and urban sectors.

3.5 Institutional arrangements

3.5.1 Types of institutional arrangements

The main government agencies that are mandated by law to carry out water resources management, water supply and sanitation services are DEC, PNG Waterboard, Eda Ranu Limited, DoH and Geological Services. The Department of Works is responsible to assist in providing infrastructure to the development of water resources and the Department of Planning and Monitoring is mandated to facilitate funding to implement water resources management, supply and sanitation projects.

3.5.1.1 Department of Environment and Conservation. The Fourth National Goal and Directive Principle under the PNG National Constitution declares "PNG's natural resources and environment to be conserved and used for the collective benefit of all, and be replenished for the benefit of future generations."

The Department was established to serve the people of PNG in upholding this Fourth Goal and is mandated to manage and monitor the environment and its components including the water resources of PNG using six different legislations. The Environment Act 2000 is responsible for the protection and sustainable use of the nation's water resources and to ensure that the quality of water resources is maintained at an acceptable level and that there is sufficient water in time and space to cater for various uses. There are other legislation administered by the Conservation Division that requires protection of wetlands and declaring protected areas for conservation purposes around PNG. This also includes marine protected areas and lakes etc.

The Environment Act 2000 is a management tool used to provide protection and sustainable management of the environment and its various components and ecosystems in particular. It has been framed in an enabling format allowing for the development of legally binding policies and regulations to cater for various components of the environment (e.g. water, air and marine), and resource extraction activities (e.g. forestry and mining). The policies, supported by operational procedures, include the identification of the beneficial values of the environment so that development activity can be measured against impacts on the identified values of the environment. It also provides for the establishment of the Environment Council, which is an independent body that evaluates the environmental impacts of major policies and developments and makes appropriate recommendations to the Minister for Environment and Conservation.

3.5.1.2 PNG Waterboard and Eda Ranu Limited. The PNG Waterboard administers the National Water Supply and Sewerage Act 1986 and is responsible for the provision of water supply and sewage disposal in urban centres throughout the country based on a user pays

policy. At present it is running water supply and sewage disposal facilities in all the main urban centres apart from Port Moresby and Goroka. The PNGWB provides information on all water bodies they intend to develop prior to development by utilising the Water Investigation Permits under the Environment Act 2000. They provide necessary funding where possible and collect water quality data for water bodies they use.

The PNGWB is governed by a Board and its membership of Directors as provided in the National Water Supply and Sewerage Act consists of a representative each from PNG Institution of Engineers, PNG Institute of Accountants, PNG Chamber of Commerce and Industry, PNG Institute of Management and the three Departmental Heads of Works, Health and Finance. The Board by its membership brings into the water industry a diverse range of expertise at its meetings, which in itself is an ongoing consultative process.

The very highly professional and ethical conduct of the Board in the discharge of its duties through consultation has earned the respect of the Government, private sector, and the community at large and aid donors.

Eda Ranu Limited also operates with Board of Directors and they provide water supply and sewerage system to the National Capital also under an Act of Parliament. This entity was established after the Government noticed the importance of having a separate body to manage water supply and sewage in the city. The Eda Ranu collects water quality information on Waigani Swamp that forms part of the treatment process for the inland lagoon systems; and provide support in terms of finance for monitoring groundwater within the city limits and nearby areas.

3.5.1.3 Department of Health. The DoH administers the Public Health Act and is responsible for ensuring that all potable water supplies meet public health untreated and treated drinking water quality standards. Along with the DoW, it also provides technical support for the construction of rural water supply and sanitation facilities.

The Drinking Water Standards are adopted from the WHO Drinking Water Guidelines and has been revised to adopt the 1998 Guidelines. The Department of Public Health is responsible for the administration of the Drinking Water Quality Regulation that has been prepared under Public Health Act.

3.5.1.4 Geological Services of PNG. They operate under the Mining Act of 1992; and are mandated especially to monitor seismic activities with respect to volcano and earthquakes. They are also mandated to carry out groundwater investigations to provide technical support to the mining developments in PNG thus dealing with groundwater investigation directly. They also assist in providing data on shallow groundwater wells when needed and are also part of the National Water Supply and Sanitation Committee.

3.5.1.5 Department of National Planning and Monitoring (DNPM). Although this Department is not mandated to manage or monitor water sector activities, it plays a major role in the implementation of various national and provincial water projects. The Department makes sure that the Public Investment Programmes for water sector are funded through the government or allocate the government counter funds. The development of Water Supply and Sanitation is a priority activity under the Government's Infrastructure Medium Term Development Strategies (MTDS).

This Department also prepares the MDTS that is used for budgeting purpose. Overall government planning for service delivery and enforcement of national legislation is undertaken through the annual monitoring, planning and budgetary process coordinated by DNPM. Development and expenditure priorities are outlined in the MTDS which is updated every five years or when deemed necessary by the government. The present MTDS 2005 to 2010 addresses good governance, effective financial controls, prioritised expenditure on

social services, development of the renewable resources sector and infrastructure development. The national MDG goals are outlined in Annex 14. The ones that relate to the water resources sector are MDG 6 (Health) and 7 (Environmental Sustainability). The specific targets set for these goals will not be achieved unless there is coordination and networking within the sector. It is essential that any institutional, policy, planning and legislative changes do not deviate markedly from attaining these outcomes.

3.5.1.6 National Water Supply and Sanitation Committee (WASCOM). This most significant consultative Committee was formed in 1990 and continues to be the main consultation forum on Water Supply and Sanitation especially in the rural or District towns and Local Level Government areas. The Chair is currently held by the Department of Health. The Committee consists of Department of National Planning and Rural Development, Department of Health, Department of Environment and Conservation, National Disaster and Emergency Services, WHO, UNICEF, AusAID, European Union, PNG Waterboard, National Weather Service, Department of Mining, Department of Provincial and Local Level Governments, National Capital District Commission (NCDC), PNG University of Technology, Department of Works, EDA Ranu and various NGOs have attended (Red Cross, Lutheran Development Service, Adventist Development and Relief Agency).

The National WASCOM has proven its value and usefulness as the main consultation forum on matters relating to water supply and sanitation. The Provincial Governments in each province have been encouraged to set up Provincial Water Supply and Sanitation Committees consisting of all stakeholders for consultation. Many provinces have strong Provincial WASCOM while others need strengthening.

3.5.1.7 PNG International Hydrological Programme (IHP) Committee. This Committee is the oldest in PNG established under IHP in conjunction with UNESCO working closely with the regional office in Jakarta dealing with hydrological and water resources matters affecting the country. The member of the committee consists of UNESCO Chairperson in the Department of Education, the PNG Waterboard, University of Technology, University of PNG, National Research Institution and Department of Environment and Conservation.

The Committee's focus is on water resources management through data collection, processing, archiving and the management of the resources in both quality and quantity. The use of raw and processed hydrological data is the primary function for this committee. The IHP supports country research in collaboration with other IHP activities in the region in producing information through publications in the region on hydrology.

3.5.1.8 Policies. The DEC is using the Environment and Conservation Policy to operate under. However this policy is quite old and needs review to cater for the current changes globally. In order to improve the water quality aspect of the water sector, DEC has in place a first draft Environment (Waters of PNG) Policy that is yet to be finalised due to lack of funds to complete the consultation process. The PNG Waterboard is currently finalising the National Water Supply and Sanitation Policy which addresses the following:

- Integrating management of sector to coordinate investment within the sector and reduce duplication
- Strengthening sector regulation by effective and efficient enforcement
- Improving information databases to provide a basis upon which regulatory and investment decisions can be made
- Strengthening capacity, skills, training and awareness education
- International cooperation

- Integrating Eda Ranu
- Sustainable funding of rural and non-commercial water and sanitation services
- Donor aid, NGOs and Public Private Partnerships
- Future governance and decentralisation

It is overdue for PNG to have such a policy and after the Millennium Development Goals were endorsed and accepted by PNG as National Actions, the National Executive Council directed the PNGWB to develop this policy.

The Public Health Policy oversees the management and monitoring of water quality with respect to health and this are all complemented by the Environment Act and its Regulations on the overall protection of water resources, wastewater and sanitation disposal and handling.

3.5.1.9 Other support. The government gets a lot of support from environmental NGOs in carrying out water resources assessment and water quality testing. These NGOs also provide sustainable small water supply systems to remote areas. The educational institutions like the University of PNG and University of Technology assist in providing advice on engineering, scientific and technical support in terms of models etc. in managing and developing water.

3.5.2 Major issues and concerns

There is an urgent requirement for improved water supply and safe sanitation services throughout the country and many NGOs are actively involved in providing these services and should be commended for their participation. However, the DoH and PNG Waterboard, who have been given the responsibility to plan as well as monitor installation and operation of these facilities either do not have the capacity to do so or are simply disregarded.

Unlike the PNG Waterboard, which generates its own operating revenue, monitoring, enforcement and compliance work by DoH and DEC is largely limited by the level of funding received from the government. DoH is required to carry out monitoring of potable water sources for compliance to the drinking water quality standards. Regular testing of urban water supplies particularly for microbiological parameters is carried out in conjunction with the central Public Health Laboratory. The logistics and costs for doing likewise for all rural water sources would be simply overwhelming. In many cases the, hydrogen sulphide test (H2S) is used as qualitative indication of the suitability of the water for drinking and cooking. As a further precautionary measure people using untreated water are always reminded to boil the water before drinking. This further amplifies the need for watershed and water sources protection.

The national vision in PNG for sustainable water resources management as adopted by DEC is, “To effectively monitor and manage PNG’s water resources in an efficient and sustainable manner for equal benefit between the industries and the citizens and for the protection of the environment.” The Department of Health’s vision is to provide proper water supply and sanitation to more than 50% of the population by year 2015. Water supply and sewerage regulators have their own vision to commission all infrastructure prior to being used and to provide good portable water to all small rural district towns.

The absence of a national vision on water resources is probably the main reason for the institutional, planning, legislative and enforcement deficiencies in the sector. While each organisation is striving to perform its functions within resource constraints, there is a need to carry out a complete overview and chart a clear vision for the sector. With this in place, it should be relatively easier to determine the necessary institutional, legislative, policy and capacity requirements to bring about effective and efficient water and wastewater management throughout

PNG. The country also needs a National Water Resources Management policy and National Water Services Policy.

The present Environment Act retained important legislative provisions covering all aspects of water resources management from one of its precursors, the Water Resources Act. These provisions deal with issues such as overall State control over the flow, use and management of the nations' water resources, customary landowner rights to use water within their boundaries without restricting its availability to other users, collection of hydrological and water quality data, an elaborate EIA process for large scale developments that have the potential to cause severe environment impacts, permitting system for non-customary landowner water abstractions, damming and diversion structures, wastewater discharges and watershed management.

However, most of those activities have not been implemented as in the past. The downgrading of the Water Resources Management Division to only a Branch is making it difficult in implementing them because of time it takes for approval and priorities are diverted away from water activities.

DEC is also constrained by lack of capacity to carry out compliance monitoring for all permitted water abstractions and waste stream discharges throughout the country. All permit holders in the private sector carry out the required sampling and submit independently tested results to DEC. At regular intervals audit samples are collected and dispatched to an accredited laboratory for analyses. The results are submitted directly to DEC for evaluation. In most cases the audit compliance monitoring trips are funded by the permit holder and this places DEC as the regulatory agency in a questionable situation.

The main operational constraints to effective water resources management are lack of funding for hydrological and water quality data collection, compliance monitoring and ineffective catchment planning and management. Although the existing legislative aspects are adequate in content and clarity, they need to be supported by a clear national vision complemented by appropriate policies, regulations and guidelines. A planning mechanism should be organised to allow integrated planning and development to enable sustainable development and use of water resources. This mechanism must be consistent with and complementary to the planning and budgetary process coordinated by the DNPM.

PNG has acceded to a number of MEAs which in one way or another have a bearing on water resources and wastewater management. These include CBD, Ramsar Convention, Waigani Convention, UNFCCC, Kyoto Protocol, Apia Convention, and UNCCD. Table 2 shows the specific requirements of these instruments and the shortfalls PNG has in fulfilling them.

Table 2: Specific requirements of MEAs and the shortfalls PNG has in fulfilling them

MEA	***Requirements***	***Shortfalls***
CBD	• Conservation of the nation's ecosystems and the faunal and floral biodiversity that they contain.	• Lack of resources for baseline inventories and monitoring investigations. • Biodiversity data stored in different locations. • Conservation interests clashing with development needs. • Lack of integrated planning and management. • Lack of promotion of the nation's biodiversity for eco-tourism and bio-prospecting. • Unsustainable resource extraction

		practices.
Apia Convention	• Regional convention on the sound management of the environments of member countries.	• Experiences the same shortfalls as for CBD
Ramsar Convention	• Conservation and sustainable use of wetlands.	• Experiences the same shortfalls as for CBD
Waigani Convention	• Regional convention on the proper disposal of wastes and prevention of water pollution.	• Lack of resources for effective monitoring and enforcement. • Ineffective partnerships with stakeholders.
UNFCCC	• Convention on the management of climate variability and change.	• Ineffective monitoring, forecasting and preparedness. • Ineffective implementation of management and adaptive responses.
UNCCD	• Convention on the prevention of land degradation, maintenance of eco-system integrity and prevention of desertification.	• Ineffective and uncoordinated landuse planning. • Unsustainable landuse practices. • Ineffective implementation of management and adaptive responses.

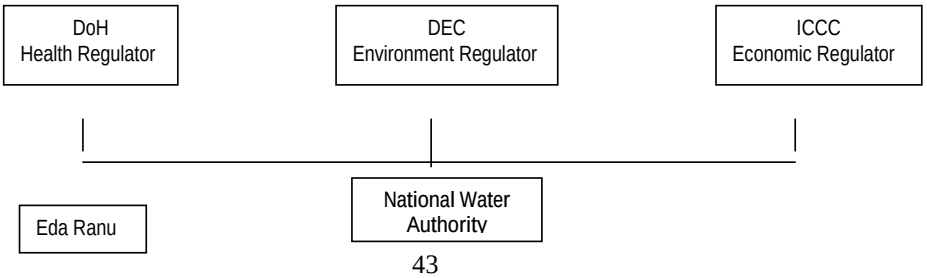
The priority needs for compliance to these conventions are improved regulatory tools, better data collection and management approaches. This may entail strengthening of partnerships with the private sector, NGOs and local landowners.

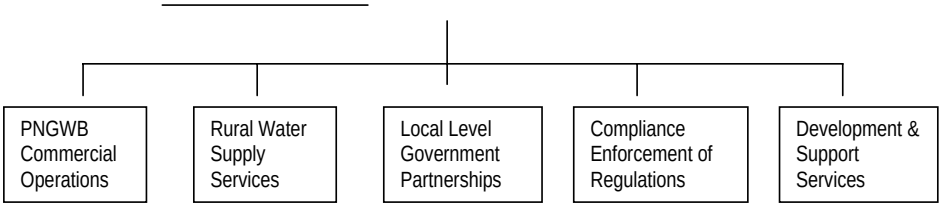
3.5.3 Measures to manage impacts and concerns

With regard to the water supply and sanitation sector there is definite need to review the sector, develop a national water supply and sanitation policy and make appropriate legislative and institutional changes. These changes should be aimed at expediting the provision of improved water supply and safe sanitation services throughout the country. This is what PNG Waterboard through a direction from the NEC is doing. It is hoped that under this new policy, there would be a sector organisation such as a National Water to coordinate and manage all the sector activities.

The proposed Sector Organisation Structure (below) would be promoted to implement all activities done by PNGWB, DEC, DoH etc.

Figure 6: Sector Organisation Structure





As part of this review, capacity building requirements should be identified for inclusion in a comprehensive and adequately supported training program designed to produce a sustainable pool experts in various disciplines critical for sound integrated water resources management and the delivery of essential water services.

Public participation provisions are built into all the relevant clauses in the Environment Act. Wider and more active involvement of the public is essential for sustainable water resources management and can be achieved through an overarching vision for sustainable water resources management and supported by a national water resources management policy. Both instruments should be based on and consistent with the relevant provisions of the Environment Act 2000 and other related legislations, regulations and policies. Advisory support for the implementation of the policy could be provided by a National Water Resources Management Committee and similar sub-committees, and immediately should report to the Environment Council. The latter is the supreme entity under the Environment Act that scrutinises and deliberates on major environment policies, standards, regulations and Environment Permit applications and advises the Minster for Environment and Conservation. Its members are drawn from various backgrounds within society.

The roles and functions of the existing National Water Supply and Sanitation Committee should be revised to make it more effective in the planning for and provision of potable water supply and safe sanitation. Like the proposed National Water Resources Management Committee, this may require a clearly specified connection to a relevant legislation such as the National Water Supply and Sewerage Act. The proposed National Water Authority, if established, would play a major role in coordinating all water resources management, supply and sanitation activities in PNG and should be supported.

Sufficient funds should be allocated to DEC to carry out an adequate level of compliance monitoring of permitted activities throughout the country. At the same time adequately trained and competent personnel should be based at the local level in the provinces to carry out compliance monitoring and sampling at reduced costs. At present DEC has a Compliance Monitoring officer based at the Lihir Gold Mine. There is also one vacant position for the Porgera Gold Mine. This arrangement does not apply to the OK Tedi Copper mine as it is excluded from the jurisdiction of the Environment Act.

While there is consultation between government agencies in relation to extraction of natural resources and landuses there needs to be a more integrated approach which will enable coordinated resource extraction and maintenance of the physical integrity of a catchment. There should be a planning and monitoring mechanism through which all relevant agencies can participate in the implementation of landuse and development activities in a catchment which will result in minimum impact on biodiversity, maintenance of ecosystem integrity and optimal use of the available water resources.

3.6 Finance

3.6.1 Types of financing arrangements

Funding for the construction and installation of rural water supply facilities is obtained from several sources including the national government, donor agencies, churches and NGOs. The beneficiaries are then required to pay user fees to the local water committee to cover operational and maintenance expenses. Provincial governments are also required to subsidise annual maintenance costs for these facilities. Apart from meeting the cost of demonstration toilets which are usually located within local health centre or community schools; villagers are encouraged to provide their own funding. A decent ventilated improved pit latrine using minimum modern materials will cost around PGK500.

In the urban centres, water supply and sanitation services are provided at a cost to customers. Aside from Port Moresby and Goroka, water supply and sewage schemes in the urban areas are run mainly by PNG Waterboard. The tariff structures for the operators are set by ICCC and differ between the three service providers. The tariff structure for PNG Waterboard is seen in Annex 10. According to the organisation, 11 of the 15 centres are not profitable but the revenue generated from the other three large centres is sufficient to cover all operational costs and generate some profit. Nevertheless, the level of profit is not enough to carry out large-scale expansion or development of new infrastructure. To meet such expenses, grant funding has been provided by AusAID and JICA and concessional loans have been sourced from lending institutions such as ADB. The government does not subsidise annual operational costs but counterpart funding and loan guarantee is provided as required for major infrastructure developments.

Similar operating arrangements apply to the service providers for Port Moresby (Eda Ranu Ltd) and Goroka (Goroka Urban Local Level Government). The scope and quality of service as well as the tariff structure varies between the three service providers. It would be nationally beneficial if this scenario was rationalised so that only one entity is responsible for the provision of urban water supply and sanitation facilities in the country.

3.6.2 Major issues and concerns

In many villages, the funding arrangements overseen by the Local Water and Sanitation committees have not been sustained due to lack of cooperation and mismanagement. The situation is exacerbated when Provincial Governments fail to allocate annual complementary funding and consequently many facilities fall into disrepair and the community is left to revert to traditional water sources. A better system of operation and management is needed to reverse this unacceptable and avoidable trend.

Recently a number of donor funded projects, NGOs and the PNG Waterboard have been promoting the use of ventilated pit toilets. Most of the design variations of these toilets require the use of modern materials which have to be purchased from hardware shops. Villagers are encouraged to at least build pit toilets using bush materials if necessary. Other alternative environmentally friendly low cost toilets should be promoted in the rural areas. As noted earlier people need to appreciate the importance of improved sanitation on human health and the environment and to assume responsibility in taking positive remedial measures.

Some of the funding difficulties faced by PNG Waterboard are: (i) inadequate revenue raised for large infrastructure developments in the sector, raising dependency on donor funding; (ii) donors are moving from concessional lending to normal lending increasing pressure on local counterpart requirements; (iii) grant aid funding through bilateral arrangements is not readily available mainly because low priority is given to water and sanitation sector; (iv) low income generation from 11 of the 15 urban centres; (v) ever increasing tariff due to rising costs of goods and services for new developments or replacement of existing assets; (vi) government's inability to subsidise community service obligations and (vii) future business growth areas (smaller provincial towns and district centres) unlikely to be economically feasible, as a result of small customer base, lack of support facilities and high capital cost.

3.6.3 Measures to manage impacts and concerns

With regard to rural water supply and sanitation facilities, funding arrangements should be critically reviewed to ensure individual and communal responsibility as well as continued provincial government subsidy. In addition rural micro-financing institutions should be assisted to fund the construction and installation of communal or individual household water supply and sanitation facilities. One proposal that has been floated around for some time is to streamline the entire water and sanitation sector under one coordinated institutional system so that the funding generated and capacity developed can be used to improve water and sanitation facilities throughout the country.

In the urban sector, the Independent Consumer and Competition Commission (ICCC) approved 5-Year tariff structure (2005-2009) of PNG Waterboard and Eda Ranu respectively based on development plans, revenue generation assumptions and projected CPI fluctuations. Elaborate water supply and sanitation development plans have been prepared but external funding needs to be secured for implementation. In order to maximise use of the revenue that can be generated within the sector two initiatives have been taken. One concerns a draft Consumer Service Obligation (CSO) Policy seeking approval for reinvestment of profits into CSO activities instead of dividend payments to the State. The other relates to the need for an institutional review and formulation of a National Water Policy as discussed in section 3.4 on technology and section 3.5 on institutional arrangements.

4. LINKAGES TO OTHER AREAS

As an essential and versatile resource, a sustainable integrated approach to water resources management within a catchment must also take into consideration all the other potential and existing uses as well as the natural ecological water requirements. The relationship with other water related uses and issues is discussed in this section.

4.1 Landuse and agriculture

Landuse varies between catchments and is dependent on the size of the area, topography, human population, infrastructure, agricultural potential and the available natural resources. PNG does not have an overall landuse policy providing guidelines for development planning, human settlement and utilisation of natural resources. Instead there are many sectoral policies which incorporate environmental safeguards applicable to their respective activities. In the absence of an integrated planning system, conflicts do arise between different landuses and where there is a large concentration and variety of landuses, the combined adverse environmental impact on the catchment can be significant. The main landuses in most of the catchments are human settlement, infrastructure development and subsistence and cash crop farming. Large scale commercial agricultural development and logging is undertaken in many catchments while commercial and artesanal mining is carried out in catchments with sizeable mineral deposits.

Comment: Check spelling

Increased shifting cultivation involving riverside gardening and lack of sedimentation and erosion control measures and commercial agriculture involving the use of artificial fertilisers, pesticides and herbicides, are contributing to increased contamination of the receiving surface and groundwater. In many logging areas, water quality has deteriorated due to non-compliance to standards relating to drainage and erosion management as well as solid waste and sewage disposal. In catchments where mining is undertaken the impacts vary between large-scale and artesanal mining. These include sedimentation and contamination of water bodies from runoff and various organic and inorganic based point discharges including mine tailings and waste dump leachates. The impacts of land clearance, agriculture, forestry, mining and petroleum developments on water resources are discussed below.

(a) Land clearance

The main environmental impacts that can be caused by land clearance are: direct loss of habitat(s), dismantling of habitat ranges, provision of an access route for invasive pioneer and alien species and increased soil erosion. Road and other land clearances can have a measurable effect on the integrity of animal and plant communities by limiting their range, migration or distribution passages.

Land clearances can allow also provide access for invasive pioneer and alien species such as feral dogs and cats, and human intrusion into previously remote or inaccessible habitats. The latter can lead to an increased hunting, gathering and collecting of plant and animal products, including timber for construction purposes, and clearance of undisturbed areas for gardening and housing. The removal of surface vegetation also exposes surface soils to water and wind abrasion that can substantially increase the rate of erosion, resulting in significant soil loss and the silting of downstream catchments. In keeping with good agricultural practice, soil conservation measures are incorporated in the clearance program, including non-clearance of sloping or heavily saturated ground, and immediate replanting of cleared areas with soil-holding ground-cover plants. Vegetation removal can also result in lowering of infiltration rates and enhancing of overland flow and soil erosion. During high intensity rainfall this can lead to sudden elevation river water levels causing surge flows and flash floods. These can result in river channel erosion and destruction to riverside habitats, human settlements and infrastructure.

As a function of catchment size, the extent of soil erosion into surface waters, significant silting (deposition, re-suspension/remobilisation, and re-deposition of silts and sediments) can occur in the calmer waters of the middle and lower catchments. This can lead to modifications to bed morphology, river alignment and water-levels, altering the depth and extent of inundation in the floodplains and wetlands, and adjusting local habitat conditions. Biological communities are accustomed to a certain degree of variation in a range of habitat parameters, which if exceeded may be detrimental for some species. A number of coastal water habitats which are breeding areas for the juvenile stages of many marine species, are especially vulnerable to silting and high nutrient levels. If these nursery areas are polluted the local fisheries and marine ecosystems could be badly affected (Nichols 2003).

(b) Agriculture

Approximately 200,000 hectares of forested land (predominantly of secondary regrowth vegetation) is cleared annually in PNG for subsistence agriculture (Sowei et al. 2002). Increasing rural populations, improvements in transport infrastructure and government rural development policies will allow greater opportunities for income generation from cash crops and consequently result in more land being converted to agricultural and garden use, particularly along roadsides and riversides where access is easier. These pressures are likely to result in shorter fallow periods and intensive farming systems to maximise harvests. This is likely to lead to loss of soil fertility, declining crop yields and cultivation of new forested land. In upland areas many of the streams and rivers carry large quantities of silts and soil sediments either through natural landslips and erosion, or steep slope gardening. The cultivation of more marginal areas will only worsen erosion and downstream siltation. This trend can be halted if better agricultural practices and alternative crops are introduced.

Massive tracts of forested land have been converted into large-scale commercial oil palm estates in West New Britain, Oro and Milne Bay Provinces. Recent increases in the international market price of palm oil and the government's push for more export-orientated agricultural development in the rural sector could lead to more land conversions over the next few years.

It has been estimated that approximately 25,000 hectares of pristine previously undisturbed natural forest are cleared annually for both plantation agriculture and infrastructure

construction purposes (Sowei et al. 2002). Annex 12 shows the areas with agricultural potential. Unlike subsistence shifting agriculture clearances where secondary re-growth takes place during a fallow period, plantation and infrastructure clearances become ecologically alienated areas causing habitat fragmentation and hindering natural species mobility.

(c) Agricultural developments

All agricultural activities generate organic wastes. These wastes can be divided into two categories, field wastes from weeding, pruning and harvesting, and process wastes resulting from the processing of the harvested crop, such as palm oil and coffee beans.

In large-scale commercial operations with intensive cropping and high yields, the amount of field wastes produced may generate organic and nutrient loads in excess of the soil's assimilative capacity, so that runoff over waste storage areas may contain significant concentrations of organic matter and nutrients. Where this runoff discharges into water bodies (streams, wetlands or lagoons), nutrient enrichment and eutrophication may occur. This has been noted in intensively cropped oil palm estates, where discarded fruit bunches (from the processing) are returned to the plantations as composts or mulches and where the crop is regularly irrigated to maintain soil water levels. The extent and severity of this nutrient enrichment has not been adequately assessed.

In comparison, process wastes are more likely to exert a greater environmental impact on downstream watercourses because of the higher organic content. Natural degradation of the waste in the water may lead to depleted dissolved oxygen levels downstream. This would be compounded by the release of soluble phosphates and soluble nitrates which would establish eutrophic conditions which will cause loss of aquatic flora and fauna.

Oil palm is the most important export cash crop in Papua New Guinea today, and is a critical component of the government's agricultural exports policy, as well as being the largest employer and revenue source in the provinces that have large oil palm developments. In the oil palm processing operations, the process waste is a watery sludge, referred to as Palm Oil Mill Effluent (POME). It contains high concentrations of organic wastes with a very high Biochemical Oxygen Demand (BOD_5), approximately 100 times as polluting as domestic sewage. Most of this waste consists of sludge, fibre, oil and other components of plant origin. The very high concentration of organic material in POME requires several stages of treatment before it can be safely discharged or used for irrigation purposes in oil palm nurseries and plantations (Department of Environment and Conservation 1997).

The treatment process comprises residual oil removal, temperature equilibration, buffering, anaerobic and aerobic treatment in a pond system designed to produce a final effluent BOD_5 concentration of less than 100 mg l^{-1}, for river discharge. This would still require a minimum 5 to 10 times dilution to meet the normal ambient BOD_5 range for lowland streams and rivers. In addition, this sacrificial dilution usage of the receiving water through the mixing zone strategy may require compensation for loss of downstream uses.

A number of the oil palm estates have reduced river disposal by applying a large proportion of the POME for irrigation in nursery areas. When used as an irrigant, POME only requires a BOD_5 concentration of approximately 5000 mg l^{-1}, which eliminates the need for a large area of treatment ponds. The usage of partially-treated POME for irrigation can cause surface water and/or groundwater contamination and it is therefore important that the irrigated area is prepared beforehand to ensure that the risk of contamination is reduced. In addition, the oil palm industry has recently switched from the use of artificial fertilisers to the application of empty fruit bunches (EFBs) recycled from the milling process and other waste vegetable matter. The industry is also developing an enhanced composting technique using

the EFBs and partially treated POME to produce richer and more readily absorbed compost. The impact in the receiving water bodies in terms of the nutrient concentration of plantation runoff waters will need to be examined.

Coffee is the second most important export cash crop in Papua New Guinea and produces wastes with high BOD and nutrient composition. Most of the larger commercial coffee wet factories have primary treatment systems which remove solid organic pulp from the effluent, but these still leave a very high concentration of dissolved organics in the effluent. Only a few factories have secondary treatment to reduce the concentrations of dissolved organics in the discharge.

The situation is worse in the smallholder sector in which about 65% of the country's coffee is grown and processed. Most of the smallholders do not have the resources or the skills to install and operate effluent treatment systems (Sowei et al. 2002). As a consequence, it is likely that up to 65% of the raw coffee effluent is discharged directly into the streams and rivers that flow through the coffee growing areas. During the coffee season many of these waterways are badly polluted with coffee wastes. There is a need for education and awareness as well as development of basic organic waste separation and treatment for smallholder wet coffee mill operators (Sowei et al. 2002).

There is some use of fertilisers and biocides (pesticides and herbicides) in the agricultural industry, but this appears to be mainly limited to the large commercial operations such as oil palm and sugarcane. However to date, contamination of water bodies or algal blooms have not been reported.

Under the Food and Agriculture Organization (FAO) food security evaluation scheme, PNG despite its huge potential in agricultural production, is still classified as a low income deficit food insecure country. The main reasons for this are its high annual rice and wheat flour imports and the relatively high level of malnutrition in some areas of the country. In these areas, although the quantity of local staples is adequate all year round, fresh protein is not readily available and the resulting unbalanced diet is leading to malnutrition.

In collaboration with FAO, the government of PNG through the Department of Agriculture and Livestock ran a pilot project focusing an improving food production for household use and sale of excess for income to cover basic expenses and the cost of other items. The pilot project was implemented in the Huon and Kaiapit districts of Morobe Province. The activities included land preparation, drainage and irrigation, rice growing and rotational cropping to maintain soil fertility and production on the same block of land. More than 1500 people went through the training and extension programme which were conducted on several demonstration farms in a number of selected local villages. The pilot project ran from 1996 to 2001. In 2004, the governments of PNG and the Philippines entered into an agreement based on the FAO sanctioned South-South Cooperation program for agricultural experts from the Philippines to assist in the replication of the pilot project into districts in six other provinces. This project is in progress but implementation is hindered by inadequate financial and logistical support from the participating provinces. In the meantime, FAO and the government of PNG have engaged a team of national consultants to develop a national food security programme. This programme will be formulated to achieve two objectives: (i) to have high impact food security activities in each of the 89 districts in the country by 2012 and (ii) to eliminate hunger and malnutrition by 2015.

One of the key ingredients of the up-scaling program is to maximise the use of the available water resources to boost food and agricultural production across the country. The requirements for drainage and irrigation agriculture will differ from one location to another depending on climatic, topographical, geological, soil conditions, crop suitability, aquaculture and livestock husbandry. The availability of surface and groundwater would

have to be assessed on a catchment basis through which a water budget and allocation strategy can be developed. The considerable success of the irrigated agriculture production in the pilot project has demonstrated the need to introduce it in other areas that experience a distinct wet and dry season.

(d) Forestry

There are approximately 36 million hectares of closed natural forest in Papua New Guinea comprising 77% of the total land area of 46.3 million hectares. Approximately 15 million hectares of these forests could be designated as production forests (forests with a commercial value) of which more than 50% occur in the lowlands. Under current regulations, between 6 million to 8 million hectares of the production forest is suitable for logging (Sowei et al. 2002) and approximately half (3.5 million hectares) had been logged by the end of 1998. Although not officially confirmed, it is currently estimated that between 150,000 to 180,000 hectares are selectively logged annually. At this rate, the remaining forestry resource will be logged within 25 years (Sowei et al. 2002). The following concerns are notable for the sector: (i) application of an unsustainable cut cycle of 35 - 40 years; (ii) inadequate enforcement of environmental regulations; and (iii) ecologically sustainable use of forest resources.

Existing regulations and the PNG Logging Code of Practice prescribe measures to protect soils, natural waters, and the residual tree stock. However, the national government or local governments are unlikely to have the resources to successfully conduct effective field monitoring and enforcement in the near future. Consequently, alternative ways of achieving this purpose must be developed. One possible approach could be to raise the level of environmental awareness amongst the landowners and empower them to actively participate in the monitoring and enforcement process. This is an innovative shift in strategy and will require provision of appropriate training in critical aspects such as basic compliance monitoring, negotiation, collaboration, conflict resolution and enforcement.

(e) Mining

Environmental impacts can occur at all stages of the mining cycle depending on the methods used and degree of activity. These phases include exploration, construction, operation, closure and rehabilitation. Local environmental disturbance may occur during the early stages of exploration as a result of seismic exploration and test drilling. These can easily be reduced by minimising the area of activity along seismic lines and around drill rig sites, and by utilising strict management controls on drilling mud during drilling operations and rehabilitation of drilling sites. More severe environmental impacts may occur later in the exploration cycle as a result of trenching and the drilling of rock shafts, which can cause pollution of downstream waters. This can be reduced with the use of effective control mechanisms including stormwater separation and treatment systems, environmentally secure containment and management of all hazardous materials and wastes, and implementation of sound rehabilitation measures.

The construction of mine sites and related infrastructure may include roads, camps, workshops, ore processing plants and related facilities such as tailings impoundments (ponds and dams) and treatment facilities, assay labs and hazardous materials storage, handling and end-use facilities. The scale of these constructions may pose more widespread threats to the environment, particularly the surrounding and downstream habitats and human communities. The impacted area can often extend several kilometres beyond the mine site perimeter (Nichols 2003).

Strict imposition of environmental management controls and environmental protection systems throughout all stages of the construction phase are crucial to minimising these threats. The key strategy is to minimise or prevent loss or movement off-site of any: (i)

waters that may be contaminated with soils, rock sediments, wastes, chemicals or other materials; (ii) soils, rock sediments, wastes, chemicals or other materials and (iii) toxic, noxious or odorous aerial emissions. Each mine construction site should have a comprehensive integrated environmental management system that is specifically designed to suit the local construction requirements and ambient conditions.

Potentially, the operational phase consists of the most environmentally devastating period of a mine's history. By its very nature, open-cut mining involves the stripping of huge quantities of overburden before the ore bearing material can be mined. This overburden has to be placed in a stable and secure area that is under long-term environmental management to ensure that it does not pose a threat to the adjacent and downstream catchments. These management measures include waste characterisation, stormwater controls, soil conservation and ground stabilisation measures, landscaping and continual re-vegetation of new deposits with appropriate species.

Ore processing involves crushing the ore rock to maximise the surface area and subsequent chemical treatment. The latter may involve application of extreme heat or pressure to concentrate the ore (copper concentrate from Ok Tedi Mine) and ultimately extract the purified metal (gold at Porgera, Lihir and Tolukuma Mines) from the treated ore mix. The waste product from this chemical treatment is called "tailings" and is generally a slurry composed of at least 50% water, with high residual concentrations of the treatment chemicals and metals mobilised from the host rock during the extraction process. Raw tailings are extremely toxic and often corrosive and are therefore treated prior to discharge.

The treatment of tailings depends on the nature and composition of the tailings slurry. A number of the critical steps are temperature regulation, pH adjustment to a neutral or slightly alkaline condition to stabilise metal concentrations and oxidation with compressed air, oxygen or chlorine to extract metal residues from solution as precipitates or flocs. Treated tailings can be disposed off in impoundments (dams), which are designed and constructed for secure long-term storage. However, in locations where secure containment is impractical and risky owing to limited storage area, ground instability, or high rainfall, treated tailings may be discharged directly into high discharge rivers or via long outfalls into the marine environment, where the high dilution capacity is utilised.

Due to the conditions stated above, tailings dams could not be built at the existing mines and the treated tailings are discharged into receiving waters, utilising the mixing zone principle. This strategy requires the receiving water containing the tailings discharge to reach prescribed water quality standards at the boundary of the mixing zone which may be many kilometres downstream or surrounding the end of a submarine outfall. However, even beyond the mixing zone, any residual toxicity and turbidity of these waters can pose an environmental threat to aquatic habitats, and may extend into the coastal and marine habitats depending on their proximity to the mixing zone boundary. Heavy metal contamination and turbidity are significant threats to coral reefs. Sedimentation smothers and asphyxiates the benthic communities in inland and coastal waters, severely disturbing food webs and the production and recycling of organic material and nutrients. Inshore coastal waters are important spawning and nursery grounds for many key subsistence and commercial species. Destruction of these ecosystems by sediments or toxic materials will have a significant impact on a wide range of marine species.

The heavy metals that may be present in residual concentrations in tailings discharges are known to increase in concentration in the food chain so the ingestion of these metals by edible fisheries species poses a significant threat to regular fish consumers. This can easily be a serious threat as fish is part of the staple diet of many coastal people.

The potential environmental impacts that may arise from mine closure are ongoing contamination of surface and groundwaters, soil erosion and downstream siltation from unstable or exposed ground surfaces and habitat fragmentation from inappropriate landscaping or re-vegetation programmes. These impacts can be minimised by ensuring effective progressive environmental rehabilitation measures are implemented during and up to final mine closure. These measures should be consistent with a collectively (developer, State and landowners) endorsed landuse plan employing best available technology and best available practice. Some of the important measures include backfilling and re-contouring of the landscape to a stable form, including water courses and water bodies where feasible, and planting of local native plant species. In addition, restrictions on use and access should be enforced to allow full recovery of the area.

Monitoring and regulation of medium and large-scale operations. Mining in PNG has a history of serious environmental and social impacts (Sowei et al. 2002). The most notable is the now defunct Panguna Mine on Bougainville which over a ten-year period dumped more than 360 million tons of tailings and waste rock into the Kawerong/Jaba River system. This resulted in the entire loss of fish from the 480 kilometre catchment and associated declines in coastal fish stocks and local wildlife populations (Sowei et al. 2002). In the early 1980s local landowners protested against these disastrous impacts, but received little support. When negotiations collapsed in 1988, the landowners decided to take matters into their own hands and closed down the mine. This led to a state of civil war on the island that ended a decade later with the granting of autonomous government to the North Solomons Province.

Similar environmental impacts threaten the Fly River system in the remote west of the country (see Section 2.4). The Ok Tedi Mine, which is the world's largest copper mine has been disposing its tailings and waste rock into the Ok Tedi River (a tributary of the Fly River) since the mid 1980s, at an average rate of 65 million tons per year (Sowei et al. 2002). The accumulation of natural and mine-derived sediments in the river system has produced flooding of the Ok Tedi and Fly Rivers, depositing these sediments across a wide area of the floodplains. This is believed to be one of the primary causes of the extensive vegetation dieback observed on the floodplains, together with the loss of food gardens, fish habitats and reduced fish populations (Sowei et al. 2002).

Ever since the late eighties it has become increasingly difficult for the government to provide funding for regular site assessments and effective monitoring of the mining industry. As a result a self-regulatory arrangement has been established with the industry. To formalise and facilitate this process, DEC and the mining industry are working together in developing a code of environmental practice for the industry which will be administered under the Environment Act 2000. Taking its own initiative, the main mining companies have enhanced their environmental performance through greater publicity and easier access to information (Sowei et al. 2002).

In addition the government, through the Department of Mining has overseen the: preparation of a Sustainable Development Policy and Sustainability Planning Framework for the Mining Sector in Papua New Guinea and preparation of a Mine Closure Policy, addressing mine decommissioning and rehabilitation. Both documents focus on the planning and management of mining projects so that their benefits can contribute more in practical and effective ways to the long-term sustainable development of the local communities and the country.

*Small-scale artisanal mining. S*mall-scale alluvial mining for gold is estimated to employ approximately 80,000 Papua New Guineans (Sowei et al. 2002), a much greater number than those directly employed in the highly technical and capital-intensive large scale mining operations. While some of these artisanal mining areas are in the vicinity of old, worked out

goldfields such as around Wau and Bulolo and others are located close to existing mines such as Porgera and Tolukuma, the majority are not located near any old or current mines.

Most operations are located in stream and creek beds and are run by the local landowner families using shovels and occasionally mechanical diggers mounted on agricultural tractors to mine the streambed and sandbanks along the side of the river. The simple portable screens are usually set up on the riverbank or a sandbank close to the diggings, and are fed by a small water pump extracting directly from the stream. The highly turbid screen-waters are discharged directly back into the stream or small river, creating severe turbidity and high sediment loads downstream. In areas where alluvial gold occurs, there are usually many small artisanal operations, often in the same small river or stream, and consequently these rivers and streams are severely impacted for considerable distances by the high sediment loads (Nichols 2003).

Mercury is used to extract the gold from the river sediments but unfortunately the process is not carried out properly mainly because the miners are unaware of the serious health and environmental and health risks. Although yet to be evaluated, high mercury contamination of downstream waters is likely to be a major problem in these catchments.

The Department of Mining has conducted a number of awareness exercises but regular monitoring to ensure that appropriate technology and occupation health issues are taken into consideration is difficult. Given the nature of the situation, there is a critical need for a vigorous environmental awareness, education and training program which should empower the local people to operate a self-regulatory system that will promote safe mining practices and reduce the level of pollution of local water resources.

(f) Petroleum and gas

The petroleum and gas sector is a major contributor to the national economy, and is the second most important contributor to foreign export earnings after the mining sector However, as with the mining sector, its contribution to the national workforce is small. At the present time the petroleum and gas sector in PNG is limited to extraction and upstream processing of crude oil and natural gas from the petroleum fields in the Southern Highlands province. By the nature of these operations, they have a smaller and more localised environmental impact than mining. These impacts are limited to: (i) land clearance during the construction of access roads, well sites, oil and gas transport pipelines and upstream processing facilities; (ii) waste management, mainly arising from camp and workshop wastes as the produced water and unused gas is re-injected into the petroleum bearing strata to maintain pressures for oil extraction; and (iii) some localised disturbance to adjacent habitats as a result of normal working operations, including flaring of gas (particularly at night) and traffic movements.

(g) Need for integrated land and water use planning in a catchment

As indicated earlier, DEC has operational guidelines for agricultural, mining, forestry, industrial activities as well as solid and liquid waste disposal. These are all designed to minimise environmental degradation and protect biodiversity. Whenever there is funding available, monitoring by DEC officers is undertaken directly. In addition, self-monitoring forms a key feature of environment permit conditions and members of the public are urged to report any visible signs of pollution or environmental damage to the nearest government authority who is then required as a matter of public service to advise DEC immediately for appropriate action. It is critical that a planning and monitoring system is established to ensure integrated land and water use management in each catchment so that environmental degradation is minimised and sustainable development is achieved.

4.2 Habitats and ecosystems

Given its geology, topography and climate PNG has a variety of terrestrial, coastal and marine ecosystems ranging from glacier covered high mountain peaks, through humid tropical forests and swampy lowlands to pristine coral reefs. The main coastal and terrestrial ecosystems are: coastal beach ridges and flats, coastal saline and brackish swamps, lowland fresh water swamps (0-50 m); lowland alluvial plains and fans (0-500 m); foothills and mountains (below 1000 m); lower montane zone (1000-3000 m) and upper montane zone (3000-4000 m) (Paijmans 1976).

Forest cover is the dominant vegetation in Papua New Guinea. Forests cover 360,000 km^2 (78 %) out of a total land area (Sekran and Miller 1994). These forests are characterised by very high tree species diversity reflecting the wide range of climatic, geographical and geological conditions in the country. This species richness is the principal reason why Papua New Guinea is positioned highly on the world's biodiversity ratings. The large number of different tree species provides a wide range of diverse forest habitats for other flora and fauna.

(a). Vegetation of PNG

The twelve categories of vegetation described below are classified according to zonal types, primarily based on altitude and rainfall. This classification system is based on Johns (1977, 1993) as used by the Conservation Needs Assessment (Saulei and Beehler 1993). The bulk of the following material is a modified version of the summary prepared by Nichols, 2003 in the *Priority Environmental Concerns of PNG* and based on the *Papua New Guinea Country Study on Biological Diversity* edited by Sekhran and Miller (1994). The vegetation categories are presented in approximate order of altitude from coastal habitats, continuing through lowland and middle-altitude vegetation to the alpine habitats of the highland summits and ridge-tops.

Mangrove forest

These coastal and estuarine tidal forests are inundated daily by salt or brackish water. They are widespread and extensive in the deltas of many of the rivers that drain the southern side of PNG, notably the Fly, Kikori and Purari Rivers, and many of the smaller rivers that drain the southern slopes of the Owen Stanley Range and discharge into the sea along the Central Province coastline.

Mangrove trees have a very close-knit and extensive network of robust and binding aerial roots which trap and hold the tidal mud and river sediments brought down into the tidal reaches during flood events. This combination of the close-knit network of aerial roots and the deep layers of organically rich sediment that have accumulated between them provides a unique and highly varied habitat for a remarkably diverse aquatic and semi-aquatic coastal marine community. Species diversity ranges from the myriad small invertebrates that inhabit the many surface niches on the aerial roots and other tidal zone surfaces, to the numerous open-water fish and larger invertebrate species for which these tidal mangrove habitats are the principle nursery areas for the young and larvae.

The microbial communities on the surface of, and within, the mud sediments are a key component of the wider coastal ecosystem. These communities decompose much of the water borne organic debris and detritus which settles out in the quieter waters amongst the aerial root networks of the mangrove trees. This debris and detritus comes in every day on the tide, and periodically from inland catchment areas following high river flows which carry their sediment loads into these tidal reaches. The high concentrations and richness of this organic matter result in high levels of productivity and nutrient recycling within mangrove forest areas, and importantly, the retention of these within the tidal and shoreline communities.

Coastal vegetation

This vegetation occurs on the succession of well-drained ridges and slopes aligned parallel to beaches that are relatively common in many coastal areas of PNG. The vegetation ranges from the pioneering herb and grass beach communities occupying the harshest environments closest to the beach, through the beach scrub communities which occur behind the pioneers, to the inland mixed

forest which occupies the well drained ridges and slopes. The pioneering communities consist mainly of beach grasses and ground-hugging plants that are adapted to the typically poorer sandy soils adjacent to the beach. These species characteristically propagate by vegetative growth, often exhibiting adaptations to water stress such as the thick leaf surfaces of the herbaceous plants and long thin leaves of the grasses. Behind these the stunted saline-resistant beach scrub communities gradually give way to the inland mixed forests that occupy the richer and structured soils of the ridges and slopes behind the coastal strip.

Anthropogenic Grassland

This vegetation covers much of the dry hilly country along the north-east coast, and is the main vegetation in many populated highlands valleys. In most cases these grasslands are artificially maintained by man-made fires, without which they would probably revert to woodland.

Swamp Vegetation

Swamps are areas of ground that are inundated for part of the year. Swamp vegetation varies considerably in species composition and community structure depending on the varying regimes and patterns of inundation, and on the soils and vegetation of the surrounding catchment, which supply much of the sediment and organic matter that make up the swamp bed. Although of highly varied composition, the trees are more widely separated than they would be on drier ground resulting in a broken and open canopy, beneath which an understorey of broadleaf species such as palms and *Pandanus* typically occur. Swamp grasses and reeds form the dominant species in the herbaceous layer, which also varies markedly in composition between different swamp regimes and catchments.

Savannah

Mixed savannah, found in the monsoonal south-west of PNG, varies in composition and structure according to the local relief, drainage and frequency of burning. The dominant tree species include *Eucalyptus*, *Albizzia* and *Melaleuca*. This vegetation also occurs on waterlogged plains and some dry hill slopes up to 500 metres at other locations elsewhere in PNG.

Monsoon Forest

This forest type occurs mostly in areas near the coast with an annual rainfall of less than 2,500 mm and a prolonged dry season such as the areas to the north-west of Port Moresby, some parts of Western Province and the Safia-Pongani region in the southeast of the country. The dominant tree species include *Bombax, Erythrina, Tetrameles, Albizzia, Acacia* and *Mangifera*. In some areas, such as around Port Moresby, the monsoon forest grades into savannah woodland with *Eucalyptus*, *Albizzia* and *Melaleuca* trees.

Lowland Tropical Rainforest

This forest type occupies much of lowland PNG that lies below 1,000 metres and receives more than 2,500 mm rainfall per annum. It is probably the richest vegetation type for plant diversity in PNG (Saulei and Beehler 1993), and although it covers large areas of the country, it is probably also the least studied forest type. This type of forest is separated into two sub-categories: (i) Lowland Wet Forest, below 500 metres with more than 3,500 mm rainfall per annum and (ii) Lowland Humid Forest, occurring below 1,000 metres with between 2,500 and 3,500 mm rainfall per annum.

Lower Montane Forest

Occurring between 1,000 and 2,000 metres elevation, this common forest type is quite variable in composition and structure. Typically dominant tree species include *Araucaria* and *Castanopsis* species, but different dominant species do occur in this forest type. This forest type is the category most impacted by subsistence agriculture. Forests at this elevation that receive over 3,500 mm

rain per annum have been separated into a sub-category, Lower Montane Wet Forest, by Saulei and Beehler (1993).

Mid-Montane Forest

Sometimes called "cloud forest", this forest type occurs at elevations between approximately 2,000 and 2,500 metres and is typically ever-wet (perhumid), with fogs, mist and clouds ever present and almost daily rainfall producing luxurious growing conditions. These forests are rich in epiphytes (such as orchids and bromeliads), with broken, open and uneven canopies. Typically dominant tree species include *Nothofagus*, *Phyllocladus* and other podocarps.

Upper Montane Forest

This forest type occurs between 2,500 and 3,200 metres, and forms the high altitude "cloud forest" that is characterised by a simpler forest structure of low canopy gymnosperm tree species heavily encrusted with mosses or moss-like epiphytes. These hang from the tree branches absorbing water from the almost permanent mists and fogs that characterise these high altitude forests.

Sub-alpine Forest and Grassland

This vegetation type occupies the uppermost slopes and summits above 3,200 metres up to approximately 3,900 metres elevation. Here the harsh climate (depressed temperatures, often falling to near zero during the night, and constant high winds) and thin, poor soils severely limit the composition and structure of the plant communities. The sub-alpine forests usually contain very few different species, and are structurally simple with a canopy height of eight to twelve metres. Often the canopy is closed up, with the canopy branches of adjacent trees intertwined together to form a close mesh of upper branches providing some protection against the prevailing winds and harsh climatic conditions. Such low, closed canopy forests are often dominated by a single species such as *Dacrycarpus*.

Alpine

In Papua New Guinea, the tree-line (the limit of growth of trees) is generally at about 3,900 metres, although this does vary locally dependent on local climatic factors such as prevailing winds, shelter and local minor temperature variations. Above the tree-line, shrubs gradually decrease in height and frequency up to approximately 4,400 metres (the limit of most plant growth in PNG). Above 3,900 metres, rosette and cushion herbs, mosses, lichens and low ferns become progressively more abundant.

(b) Natural Biodiversity

In terms of flora, the forest trees provide habitats for an extraordinarily large number of epiphytes, ranging from vines and other climbing plants to lichens in the cloud forests and orchids and bromeliads in the lowland and lower montane forests. It is estimated there are between 15,000 and 20,000 native plant species, of which possibly 60% are endemic (Johns 1993 in Sekran and Miller 1994). There are over 3,000 species of native orchids alone (Howcroft 1992, in Sekran and Miller 1994), including the world's largest orchid, *Grammatophyllum papuanum*. The klinkii pine (*Auraucaria hunsteinii*) which occurs as one of the predominant species in the Lower Montane Forests between 1,000 and 2,000 metres altitude, is recognised as the world's tallest tropical tree. PNG is also home to the world's largest banana, *Musa ingens*, which can grow up to 12 metres.

With respect to fauna, the country's high diversity of birds, reptiles and insects is well documented. PNG's rich avian fauna has been well studied compared to other animals with 405 of the total 762 native species being considered endemic (Sekran and Miller 1994). The most prominent are the exotic birds of paradise, bowerbirds and cassowaries. PNG accommodates the largest number of parrot species including the world's smallest parrot (*Micropsitta spp*), the world's largest pigeon (*Goura victoria*) and the world's only poisonous bird (*Pitohui spp)* which carries a toxin similar to that found in the poison arrow frogs of Central and South America (Sowei et al. 2002).

The reptilian fauna includes two species of crocodile (an endemic freshwater species and the widely distributed salt-water crocodile), 13 species of turtle of which 7 are freshwater species (3 of these are endemic), 195 species of lizards (including the world's longest lizard (*Varanus salvadorii*) and 98 species of snakes, of which about 60% are endemic. There are 197 described species of amphibians, the majority of which are endemic, and include the world's largest tree frog (*Litoria infrafrenata*) (Sekran and Miller 1994).

It has been estimated that there are 300,000 native insect species in PNG, including the world's largest butterfly (*Ornithoptera alexandrae*) the Queen Alexandra's birdwing butterfly, and one of the world's largest moths (the Hercules moth, which has the largest wings of any moth in the world). Although less than 200 species of mammals occur in the country, these include approximately 70 species of marsupials, of which 60% are considered to be endemic (Sekran and Miller 1994), and two species of monotremes, including the long-beaked echidna which is the world's largest monotreme. PNG is home to 75 species of bats, including the world's largest bat, *Pteropus neohibernicus*. The Bismarck flying fox, can have a wingspan of over five feet (Sekran and Miller 1994).

PNG is surrounded by three seas and a major gulf, the Bismarck Sea to the north, the Solomon Sea to the north and east, the Coral Sea to the south and east, and the Gulf of Papua to the south, lying between Papua New Guinea and Australia. Papua New Guinea has a total sea area (EEZ) of 3,120,000 square kilometres and 17,110 kilometres of coastline (Sowei et al. 2002). This huge area encompasses a diverse array of marine environments including reefs (fringing, patch and barrier reefs); seagrass beds; mangroves; sand and mud shorelines and inter-tidal flats; barrier dunes and their associated coastal lagoons; deltaic floodplains and estuaries; rocky shorelines; reef walls and drop-off areas of the continental slope; sea mounts. (Sekran and Miller 1994). The country is renowned for the diversity and pristine quality of its coral reefs and coastal environments, but its waters extend beyond the coastal shelves to include deep unexplored ocean basins.

PNG ranks in the top 20 most biologically diverse countries in the world, with a wide range of remarkably diverse environments that support a great variety of different habitats rich in species. Between 5 and 7% of the world's total number of animal and plant species are found in Papua New Guinea, even though it occupies less than 1% of the world's total land area (DEC 2002b). Some of the forests in PNG are amongst the richest in the world in terms of their biodiversity and represent an important natural gene pool for future generations of PNG, particularly as many of these species are endemic to the country, or the island of New Guinea.

The coastal and marine environments of Papua New Guinea are likely to be at least as biologically rich and diverse as the terrestrial environments, but are much less studied. The process of cataloguing and describing the range of habitats and the organisms therein has so far been minimal. The country's coral reefs are amongst the most diverse in the world and are also important as the principal source of protein for the majority of coastal dwellers. This may pose a threat to their biodiversity unless sustainable fishing practices and conservation measures can be implemented effectively.

Other globally important coastal habitats within Papua New Guinea's territorial waters include the seagrass beds in the shallow waters of the western Gulf of Papua and Torres Strait that are home to one of the world's last remaining dugong populations. The extensive mangrove forests that characterise the major river deltas along the southern coast of Papua New Guinea such as the Kikori and Purari Rivers are also of global biodiversity significance and in need of further more intensive study if their global importance is to be more accurately assessed and effective conservation measures implemented. In regard to the largely unknown deeper waters that surround Papua New Guinea, recent reports in the media have indicated that the Bismarck Sea has a globally significant population of sperm whales, hitherto undetected.

(c) Protected areas

Depending on the main purpose for protection, a terrestrial or marine area can be placed under a protected system in accordance with a number of legislation administered by DEC. This legislation includes: Environment Act 2000, Fauna (Protection and Control) Act (1982, Conservation Areas Act (1978) and National Parks Act (1982). Apart from the Environment Act which has been described above brief outlines of the other legislation are given below. Annex 13 shows the areas currently under some form of legislated protection. It is easier to declare a protected area if it is located within the 3% of land under the jurisdiction of the State. The process is more involved when the area is on customarily owned land. Intensive awareness and consultation leading to majority endorsement by landowners is essential before the legal formalities can be completed.

The Fauna (Protection and Control) Act (1982) provides for the conservation and management of fauna, particularly through the establishment of Wildlife Management Areas (WMA), administered by local interest groups through a Wildlife Management Committee. The Act allows protection of fauna through the declaration of protected fauna (e.g.: dugong and leatherback turtle), protected areas, wildlife management areas and sanctuaries. The Minister is obligated to consult landowners and local government prior to declaring an area as a WMA under terms that are more demanding than those required for the establishment of conservation areas under the Conservation Areas Act, reflecting the application of WMA to private land. The intent of WMAs is for the management and protection of fauna whereas Conservation Areas and National Parks can be created for aesthetic and cultural values. Under the Act, the Conservator of Fauna may, on application, grant permits for approved scientific or zoological organisations to take protected fauna from the wild.

The Conservation Areas Act (1978) provides for the establishment of conservation areas by the Head of State. The Minister responsible, in response to approaches by individuals or interest groups, may declare a conservation area. A management committee, representing landowner and local interests, may be established to manage the area through the development and implementation of management plans and the provision of direction to local rangers. Though drafted in 1978, the Act has not been implemented. A National Conservation Council, provided for under the Act, has not been established.

The National Parks Act (1982) provides for the establishment, on State-owned or leased land, for national parks for the preservation of particular scenic, scientific or cultural significance. As the legislation does not make specific reference to marine habitats, it is uncertain if this legislation can be applied to marine conservation areas.

(d) Integrated planning for the maintenance of ecosystems

The main threats to these interconnected ecosystems are activities such as commercial logging, commercial agriculture, subsistence agriculture, road clearance, mining and petroleum developments, industrial and sewage effluents as well, as indiscriminate solid waste disposal. Runoff and point source discharges carry a cocktail of particulate, chemical and bacterial contaminants into water courses which can transport them further into the coastal estuary and marine ecosystems. In catchments where there is a high concentration of such activities and human population, the trail of destruction is clearly discernable from the actual activity high in the watershed down to the mangrove and coral reef ecosystems on the coast and out in the sea. It is absolutely crucial that the adequate safeguards are imposed and enforced to minimise the extent of damage caused. As highlighted above since most of the land is under customary land ownership, public awareness and education is paramount in ensuring the sustainable management of natural resources within catchment boundaries.

4.3 Health and hygiene

The health impacts related to watershed and wastewater management are linked to consumption of contaminated water and aquatic food items. The preceding sections have highlighted the adverse impacts on water resources in a catchments arising from landuses such as road construction,

agriculture, logging, mining as well as improper disposal of solid and human waste. This is major cause for concern as 60% of the rural population obtain drinking water directly from a natural source. Although they are reminded to boil the water before consumption, poor hygiene still gives rise to the waterborne diseases such as diarrhoea, dysentery and typhoid[2]. Because the water is untreated water-washed diseases such as scabies and other skin infections occur as well. Food contamination can result from pesticide and chemical contamination of the food items either directly or through the use of contaminated water in food handling and preparation. The DoH Healthy Islands Program has been promoting better hygiene, improved sanitation and proper solid waste disposal throughout the country but it needs the support of other government agencies, provincial and local level governments as well as NGOs and CBOs.

The impact on watersheds by tourism is minimal mainly because the concentration of rural based eco-tourism facilities and the annual volume of incoming tourists is relatively low. Currently, there is a steady growth of such facilities and the Tourism Promotion Authority in collaboration with DEC has and will continue to run courses on environmentally friendly eco-tourism activities to minimise negative environmental impacts. There needs to be a Code of Practice to regulate such activities so that all stakeholders conform to a uniform set of requirements across the country.

4.4 Watershed and coastal management

A suite of pollutants and particulate matter in contaminated runoff and point source discharges into watercourses within a catchment can eventually end up in coastal areas. The degree of impact will depend on the nature, concentration and volume of the contaminants and the distance from the point of origin to the coast. Major extractive developments and urban centres in several catchments have clearly demonstrated that the coastal areas are sinks for untreated and uncontrolled waste generated in the watershed. In situations where major industrial and infrastructure developments and effluent discharges are located in coastal areas, the added input of waste material from the watershed may amplify the level of impact on the recipient ecosystems. It is now acknowledged that an entire watershed should be assessed and developed as a unit in order to eliminate negative impacts and maintain its natural integrity and productivity.

From a national government planning perspective, a medium term development strategy with a five year timeframe sets the overall direction and targets for development planning. This document is prepared by the public sector through the Department of National Planning in consultation with the private sector, NGOs and the donor community. District development plans are then developed in line with the MTDS but incorporating the specific needs of the locality (MTDS 2005).

However, to date national and district development planning has been conducted without adequate reference to, or consideration of the physical constraints of the natural environment to absorb and support the extent and scale of existing and proposed human activity. A growing number of catchments are being threatened by increasing resource extraction, infrastructure development, population growth and poor waste management. In order to promote sustainable development and utilisation of natural resources, there should be an integrated and coordinated approach to planning and service delivery on the basis of catchments at the district levels.

The current practice where resources extraction and infrastructure projects are evaluated as individual ventures should be replaced by one where every new development and activity is assessed relative to other landuses and the natural conditions in the entire watershed. The response of the watershed to the introduced changes can then be evaluated and appropriate management measures can be taken.

At present resource extraction and development is mainly done in isolation with inadequate inter-sectoral consultation and collaboration. In most cases each natural resource regulatory agency or

[2] Latest disease incidence figures could not be obtained at the time of writing. Data recording at Rural Health Centres and collation at the district, provincial and national level needs to be improved.

development proponent applies for environmental clearances from DEC but they do not necessarily exchange information or interact actively with other government agencies having jurisdiction over other activities in the catchment. These inter-linkages should be clearly defined, strengthened and implemented through a system where all relevant parties actually account for their respective components so that sustainable development is achieved within a catchment unit.

5. STAKEHOLDER ENGAGEMENT

Table 3 lists the organisations that were consulted. Questionnaires were formulated using the NDR report template provided by SOPAC and these were discussed with stakeholder representatives in interview sessions. Most questionnaires had to be left with these persons to insert additional information. In addition, all written materials on PNG's participation in the dialogue process leading to the compilation of the Pacific RAP were collected and perused. A review of relevant literature to extract relevant information for the report was also undertaken.

Table 3: Organisations consulted

Institution	Stakeholders – interests and responsibilities	Relevance to IWRM and reason for inclusion	Role in the consultation process
Department of Health	• Responsible for sustainable management of the nations water resources.	• Coordinate the introduction of IWRM in PNG. • Hydrological data is essential for water resources planning and management.	• As the IWRM focal point for PNG it facilitated the consultation process with all stakeholders.
PNG Waterboard	• Responsible for the oversight and provision of water supply and sanitation facilities and services in the country.	• Water supply and sanitation is the biggest water related activity in PNG. • Sanitation facilities must not cause water pollution.	• Interviewed and provided additional data as per issued questionnaire.
National Weather Service	• Responsible for hydrometeorological data collection and weather forecasting.	• Hydrometeorological data is essential to water resources planning and management.	• Interviewed and provided additional data as per issued questionnaire.
PNG Geological Survey	• Responsible for the collection hydrogeological data.	• Hydrogeological data is essential to water resources planning and management.	• Interviewed and provided additional data as per issued questionnaire.
Department of Agriculture and Livestock	• Responsible for agricultural land use planning in the country.	• Land uses within catchments can affect the availability of water in terms of quantity	• Interviewed and provided additional data as per issued questionnaire.

		and quality.	
Department of Petroleum and Energy	• Responsible for the oversight and provision of hydropower facilities in the country.	• Hydropower generation within a catchment must be catered for relative to other priority water uses.	• Interviewed and provided additional data as per issued questionnaire.
National Disaster Centre	• Responsible for disaster management in terms of relief and rehabilitation.	• Effective risk assessment, preparedness and response for flood and droughts are essential.	• Interviewed and provided additional data as per issued questionnaire.
Department of National Planning and Monitoring	• Responsible for national development planning and monitoring.	• Overall planning must be sustainable and consistent with national development priorities.	• Interviewed and provided additional data as per issued questionnaire.

6. PROGRAMMES, PROJECTS AND ACTIVITIES RELATED TO IWRM

One of the key reverberating messages in this document is the current compartmentalised sectoral infrastructure development and resources extraction planning still being practised in the country. Most of these sectoral plans promote sustainability as a fundamental underlying principle but they all fall short in making those crucial linkages with other related sectors in order to achieve sustainability of their initiatives. Such sectoral plans include road infrastructure, commercial agriculture, selective logging, plantation forestry, mineral exploration and mining, hydropower, health services and water supply and sanitation. Although all the agencies concerned are required by law to consult with each other in the formulation of their development and implementation plans the degree of interaction and cooperation needs to be improved to so that all planned activities in a given area contribute towards overall sustainable development. The proposed National Planning Act may be able to facilitate this level of planning and execution but in the interim the IWRM approach offers an opportunity for all agencies to come together on a catchment basis and collectively decide on what development activities should be undertaken for the maximum benefit of the people but within the pertinent physical environmental constraints.

In addition to normal government planning and implementation noted above, a number of projects on IWRM have been undertaken in the past but have not been continued because of lack of funding and general unwillingness to adopt new planning and development strategies. These include preliminary catchment management plans that were drafted in 1992 for the Wahgi, Ramu and Lihir catchments under the WMO Water Resources Management Strengthening Project. Although these were draft documents they provided crucial training for the officers involved. Some of these officers are still with DEC, while others have joined the private sector and NGOs and are still able to make some contribution towards the implementation of IWRM in the country.

The level of environmental consciousness has increased considerably since then especially in relation to global warming, climate change and the ENSO phenomenon. It can also be noted from the recent surge in inter-sectoral cooperation that the time is probably right to consolidate IWRM as the tool to undertake development planning and service delivery for the future. There are several

projects current and planned that should assist in establishing and consolidating IWRM in PNG. These are listed in Table 4. It will be noted that the aspects covered are climate change situation analysis and adaptation under UNFCCC (two projects), sustainable land management under (UNCCD), national disaster management, hydrometric station rehabilitation and flood forecasting. Most of these pilot sites for these projects will be located in the Laloki catchment making it the logical choice for the IWRM pilot project.

Table 4: Current and planned projects supporting IWRM

Title	**Second National (Climate Change Situation and Adaptation) Communication**	**Sustainable Land Management**	**Pacific Islands Adaptation to Climate change**	**National Disaster Management Project**	**Ramu River Hydrological Stations Rehabilitation**	**Flood Forecasting (Pacific HYCOS)**
Executing Organisation	UNDP/DEC	DEC/UNDP	SPREP, UNDP, DAL	NDC, PNGGS, DEC	SOPAC and DEC	SOPAC and DEC
Funding source	GEF, GPNG	GEF ,IFAD, GPNG	GEF	European Development Fund (EDF)	European Development Fund (EDF)	World Meteorological Organization (WMO)
Value of project	US$405,000	PGK3 million (GEF-USD500,000)	US$750,000	€6.2 million	PGK100,000-200,000	
Start and finish dates	3 years from March 2007	Mid 2007-mid 2010	2008 – 2013	2007 - 2010	2007	2007-2009
Focus of project	Enhance capacity to develop the 2nd national communication	Capacity building	Adaptation in food production in selected sites in PNG	Improved disaster management with particular focus on hazard assessment and risk management.	Revive the three hydrometric and two rainfall stations along the Ramu River catchment: (a) For environment protection and management. (b) To ensure sustainable resource development. (c) To monitor the climatic conditions.	(a) Revive hydrometric stations of national significance and economical value. (b) Install remote sensing capabilities to collect and disseminate near real time data for forecasting and warning. (c) To ensure that operators of major infrastructure such as hydropower and water supply schemes are given adequate advance warning of

						imminent dangers.
Key activities and outcomes	GHG Inventory –established data management V&A programmes Mitigation measures	Training of key relevant personnel in GIS monitoring	Rehabilitate drylands Low technology irrigation systems Construct water reservoirs	• Improved disaster monitoring and reliable warning systems for all types of natural disasters nationwide. • Improved disaster risk management, preparedness, relief and rehabilitation	Plans to acquire the monitoring instruments are already in place. Allocation of resources for construction and installation is in progress.	
Contact persons	Bernard Suruman – DEC Mika Andrew, Stanley Oa – DAL	Dennis Ivarami – DEC	Taito Nakalevu – SPREP Bernard Suruman – DEC	PNGGS - Arnold Lakamanga, NDC - Kaigabu Kayamana and DEC - Kay Kalim	SOPAC: Michael Bonte DEC: Maino Virobo	SOPAC/WMO: Llyod Smith DEC: Maino Virobo
Areas of overlap with GEF IWRM	Inventory data Water resources info in relation to hydro energy potential Adaptation priorities and strategies	Data management, monitoring	Water resources technology and management	Upgrading of existing hydrometric stations or installation of new stations.	Water level, flow and rainfall observed over time will be used to project activity trends and will be useful in helping to design and planning for sustainable resource development and environment management.	
Resourcing needs	Staff, Inventory database equipment, technical experts	Two technical assistants, Vehicle, computer, office space, stationeries	Project personnel, equipment,	SOPAC to purchase equipment and fund training. GPNG – provide personnel and all other in country logistical support	DEC will provide personnel for construction, installation and routine data collection. Project is to provide instrument, logistic support and funding. DEC to provide field vehicle.	

The environment and conservation NGOs in PNG are very active in the natural resources inventory, environmental awareness and education, adaptation to climate change, sustainable revenue generating activities and integrated conservation and development. Wherever possible they work closely with government agencies to promote sustainable development in all sectors. The

bigger NGOs such as Green Peace, CI, TNC and WWF are involved in antipollution campaigns in the mining, forestry and fisheries sectors. WWF in particular has an active wetlands conservation program that is being implemented through its eco-regions concept. On of the main outcomes of this program is to increase the number and area of protected sites throughout the country. It would therefore be inadvisable for the IWRM project in PNG to exclude these NGOs as partners with much to offer in terms of technical support and public mobilisation.

In the water supply and sanitation sector, the draft national waters services` policy should be revised seriously and finalised so it can form the basis of the sectoral review and reorganisation. This is absolutely critical because the current level of service delivery will deteriorate further if no corrective action is taken. The national water committee should take this as one its main priorities and lobby for the necessary support from within the public service, broader civil society and political circles.

7. CAPACITY DEVELOPMENT NEEDS FOR REMOVING BARRIERS

Capacity development in the water resources and wastewater management sector is required in all the thematic areas. Human resources development is an important component and will be required at different levels and include a range of disciplines and professions. In the rural areas, local people will need to be educated on the need for sustainable water resources management, construction and installation and maintenance of water supply and sanitation facilities and basic water quality monitoring. At the more technically advanced level, people will need to be trained in hydro-meteorological data collection and installation, construction and maintenance of water related structures. At the professional planning, supervisory and advisory level, training is needed in a variety of disciplines including, hydrology, hydrogeology, civil engineering, accounting, economics, sociology and law.

While PNG has adequate training and educational institutions to produce the required manpower some areas of technical training and specialist professional training will have to be acquired at regional organisations or elsewhere. Two such areas include training in advanced hydrography and processing, analysis and forecasting of hydrometerological data for effective water resources management and disaster risk assessment and management. Other specialist courses may include preparation, monitoring and implementation of catchment management plans. Such specialist training may be provided through job attachment or official courses.

Apart from human resources development, Table 5 in section 8 lists a range of capacity improvement requirements in water resources management, vulnerability assessment and hazard management, awareness, technology, institutional arrangements and financial mechanisms. Most of the capacity development requirements are common to all thematic areas while some are specific to a single area. They include improved biophysical and socio-economic data collection systems, overall sectoral review, clear vision and policy direction, legislative and institutional reforms, better inter-agency coordination, vigorous community awareness, empowerment and engagement, reliable multi-stakeholder partnerships and improved operational and financial management systems. These requirements should be addressed in a systematic manner through regular government processes and with project assistance.

8. AN INTEGRATED APPROACH TOWARDS BARRIER REMOVAL

In the preceding sections, the main hindrances to sustainable water resources and wastewater management in PNG have been discussed. They include: sectoral rather than integrated planning and implementation; lack of coordination and networking; lack of specialist technical and

professional expertise; inefficient bureaucracy; lack of resources; poor governance and lack of political will. In order to eliminate these hindrances, the following actions should be taken:

(i) establish a national water resources committee,

(ii) devise a national water vision,

(iii) formulate a national water resources management policy and national water services policy;

(iv) compile a catchment management policy,

(v) identify capacity building requirements across all thematic areas and organise appropriate training locally, within the region or elsewhere;

(vi) by employing a participatory approach, devise a series of catchment management plans across the country which will address water resources and wastewater management issues and cater for all water uses.

All stakeholders will be represented in the National Water Committee and will participate in all aspects of vision setting, policy formulation and catchment management planning and implementation.

An IWRM pilot project in a selected catchment will serve as the demonstration site in the development and examination of these policies and plans as well as water resources and wastewater management systems, processes and mechanisms. All stakeholders in the government and private sectors as well as the public will have to be fully engaged in these activities. The current legislation on water resources and wastewater management should be examined to determine the functions and responsibilities of the National Water Committee and where and how it should be established and accommodated in terms of secretarial support. The priority tasks for the committee should be to oversee the formulation of a national water vision, a national water resources management policy, a national water services policy and a catchment management policy. The other actions identified above should then follow within and between organisations with performance and suitability being assessed in the demonstration catchment.

When replicating from the pilot site, the introduction of IWRM will require as crucial prerequisites, effective networking and cooperation at all levels. Apart from within government collaboration, the private sector and NGOs must be treated as important partners in order to share resources, increase coverage and maximise impact. IWRM as an effective development planning and management strategy will also need to be promoted in all sectors of society, the general public and amongst politicians. Significant advances can be made if politicians are convinced of the environment, social and economic benefits of IWRM over the short, medium and long term.

Table 5 gives a list of the current barriers to IWRM in PNG and the suggested remedial measures. This information was used to update the PNG National Action Plan on Sustainable Water Management which is presented in a matrix in Annex 11. The original version was compiled in 2003 after the adoption of the Pacific RAP.

Table 5: Current barriers to IWRM in PNG and suggested remedial measures

	Thematic area	**Barriers to IWRM**	**Proposed IWRM remedial measures**
1	Water resources management	• Inadequate access to clean and reliable water supply for human consumption.	• Review and reorganise sector to improve planning, construction, maintenance and management of water supply and sanitation services.
		• Lack of resources to operate a minimum density hydro-meteorological data	• Secure required resources to establish a representative and manageable minimum density hydro-meteorological

		collection network.	data collection network.
		• Lack of coordination between hydrological and hydro-geological data collection services.	• Build and strengthen cooperation and data exchange between DEC Hydrosurvey Unit and PNGGS Hydrogeological Unit.
		• Uncoordinated landuse, natural resource extraction, infrastructure development and water resources planning and management.	• Establish National Water Committee to begin the process of applying IWRM in PNG with full participation of all stakeholders.
		• Absence of ongoing specialist training in hydrography, hydrology, hydrogeology, landuse and water resources planning and management.	• Develop a training and career development program to produce and maintain a sustainable pool of qualified and competent national experts.
2	Island vulnerability	• Too much emphasis on reactive disaster management.	• Apply holistic disaster management from hazard assessment and risk management to provision of efficient relief and rehabilitation.
		• Ineffective and insufficient attention on hazard assessment and risk management.	• Improve hazard assessment and risk management involving all stakeholders.
		• Absence of flood and drought management plans in every catchment.	• Develop flood and drought management plans for every catchment.
		• Ongoing specialist training in climatological, hydrological and geological analysis and forecasting as well as hazard assessment and risk management.	• Develop a training and career development programme to produce and maintain a sustainable pool of qualified and competent national experts.
3	Awareness	• Uncoordinated awareness campaigns and stakeholders working in isolation and not aware of events and developments in the sector.	• Develop a national framework for awareness on water resources and wastewater management.
		• Ineffective awareness strategies and minimum use of media and education system.	• Utilise effective awareness strategies and make use of all forms of media, the education system and NGO networks. • Provide appropriate training to relevant personnel as well as NGO, CBO and community representatives. • Develop and implement a National Communication Plan based on the

			above.
4	Technology	• Too many organisations involved in water supply and sanitation in both rural and urban areas.	• Review and reorganise sector to improve planning, construction, maintenance and management of water supply and sanitation services.
		• Ineffective use of available resources.	• Rationalise use of available resources.
		• Mismanagement of most rural water supply facilities.	• Improve community participation and management of these facilities. • Provide training on operation and maintenance of rural water supply systems.
		• Poor rural sanitation in most areas.	• Undertake major campaign to improve rural sanitation including the provision of alternative toilet facilities. • Provide training on the construction, use and maintenance of various alternative rural household toilets.
		• Inefficient water conservation of and leakage reduction.	• Improve conservation campaigns and leakage reduction strategies
		• Ongoing specialist training on demand projection analysis, facility design and construction, as well as operation and maintenance of water supply and sewage disposal facilities.	• Develop a training and career development program to produce and maintain a sustainable pool of qualified and competent national experts.
5	Institutional arrangements	• Lack of National Water Vision and complementary policies.	• Establish National Water Committee and develop these priority policies immediately. • Undertake legislative and institutional reviews and make necessary adjustments.
		• Lack of coordination between agencies.	• Improve coordination as per the above policies, legislation and institutions.
		• Lack of resources to conduct monitoring and enforcement.	• Improve the implementation of these activities in conjunction with other government agencies, the private sector, NGOs and the general public.
		• Ongoing inter-disciplinary training on integrated water resources management.	• Develop a training and career development program to produce and maintain a sustainable pool of qualified and competent national experts.
6	Finance	• Heavy dependency on donor finding for rural water supply and	• Advise government to increase funding of these facilities and make communities more responsible with fee

		sanitation facilities.	collections. • Provide appropriate financial management training.
		• Substantial potential combined revenue from urban water supply and sanitation facilities not readily available for reinvestment for the improvement and expansion of services throughout the country.	• Advise government to rationalise the sector and place all water and sanitation facilities under the PNG Waterboard or another single structure establishment with appropriate partnership arrangements.

9. CONCLUSION

Although PNG is blessed with an abundance of freshwater resources, there are many issues that need to be addressed if these resources are to be used for the wellbeing of its citizens and to maintain the country's natural biodiversity. Urgent attention is required to improve access to potable water and safe sanitation for eighty percent of the population. The high rainfall and topographically influenced local climate is such that floods and droughts occur regularly. Global warming has increased climate variability and the country's vulnerability to severe and frequent floods, droughts, tropical storms, sea level rise and saline intrusion. The high seismic and volcanic activity can also affect water availability through events such as earthquakes, landslides and tsunamis. Disaster relief and rehabilitation has been implemented through a largely reactionary approach and the costs involved have been considerable. Adequate advance preparedness and risk management will ensure that the cost of damages and loss of life is minimised or prevented. In addition, diffuse and point source discharges arising from human settlements, infrastructure development, agriculture, forestry, mining and other landuses can affect the quantity and quality of water within a catchment to cater for its various uses. Monitoring and enforcement will have to be improved in order to minimise water pollution.

Water is a vital renewable resource and its availability at the right quantity and quality for a multitude of uses as well as the satisfactory handling of its negative impacts can be achieved if it is managed in a holistic and integrated manner. This can only be achieved at each local catchment and across the nation with an appropriate legislative, policy, institutional, participatory and financing framework supported by adequate resources and competent personnel. At the same time, since it is mans interaction with the environment that causes a whole range of adverse impacts, sustained public education and awareness to encourage responsible behaviour is essential.

10. REFERENCES

Bleeker P. 1983: *Soils of Papua New Guinea*, CSIRO, MacArthur Press for Australian National University Press, Canberra, Australia: 1-5 and 18 – 21.

Department of Environment & Conservation 2002b. *PNG Country Program Strategy. Operational Phase III GEF - SGP (July 2002)*. A report prepared for the UNDP GEF - Small Grants Program.

Nix HA et al: 1996: *The BioRap Toolbox National Study of Biodiversity Assessment and Planning for PNG,* World Bank.

Loffler E. 1977. *Geomorphology of Papua New Guinea*, CSIRO, Australian National University Press, Canberra, Australia.

Loffler E. 1979. *Papua New Guinea*, Hutchinson, Australia.

MacAlpine J, Keig G. and Falls R. 1983. *Climate of PNG,* CSIRO, Australian National University Press, Canberra, Australia: 1 – 88.

Nichols, S: 2004. *Priority Environmental Concerns of PNG*, SPREP, Apia, Samoa.

PNG Waterboard, 2006. *Strategic and Medium Term Corporate Plan*.

Paijmans K. (ed), (1976): *New Guinea Vegetation*, CSIRO, ANU Press, Canberra: 23 – 105.

Saulei S. and Beehler B. 1993. *Biodiversity and Conservation of Humid Forest Environments of Papua New Guinea, in Beehler B. (ed.) Papua New Guinea Conservation Needs Assessment, Volume 2.* Department of Environment and Conservation, Boroko, Papua New Guinea

Scott D, Overmars M, Falkland T and Carpenter C. 2003. *Pacific Dialogue on Water and Climate Synthesis Report*, SOPAC.

Sekran N. and Miller S. (eds), 1994. *PNG Country Study on Biological Diversity*, DEC, Conservation Resource Centre and Africa Centre for Resources and Environment.

SOPAC 2003.: *Pacific Regional Action Plan on Sustainable Water Management*, ADB.

Sowei J, Koi H, Mamae H and Sivusia-Joyce B. 2002. *Papua New Guinea Environment Monitor 2002.* Report prepared by a team from National Research Institute, Papua New Guinea for the World Bank.

Annex 1: Table showing the distribution of soil types in PNG

Distribution	Great Group	Description
Very Local	Cryorthents	Slope soils
	Ustorthents	Colluvial soils
	Cryofolists	Alpine peat
	Cryohemists	Alpine peat and humus soils
	Cryofibrists	Alpine peat and humus soils
	Halaquepts	Alpine peat and humus soils
	Cryoquepts	Skeletal and peaty soils
	Cryumbrepts	Alpine peat and humus soils, skeletal soils
	Cryumbrepts	"
	Pellusterts	Dark cracking clay soils
	Natrustolls	Shallow black earth, Texture Contrast Soils
	Calceistolls	Texture contrast soils
	Arguirestolls	Brown clay soils
	Haplustolls	Dark cracking clay soils; Beach soils
	Natrustolls	Texture contest soils
	Natrustalf	Alkaline reddish clay soils
	Rhodudalfs	Brown forest soils
	Haplohumox	Highly melted red
	Acrohumox	Brown clay soils
	Haplorthox	Acid red to brown clay soils
	Eutnorthex	Granuler dark red uniform heavy clay soils
Local	Andaquepts	Humic olive ash soils; Unweathered sandy volcanic soils with black topsoils
	Ustropepts	Brown Clay soils
	Pelluderts	Alluvial black clay soils, Black earth
	Argiaquolls	Dull meadow podzolic soils, meadow podzolic soils
	Haplustolfs	Texture contrast soils, brown clay soils
	Rhodudalfs	Terra rossas
	Albaquults	Meadow prodzolic soils;Lateritic and gleyed latosals
	Plinthohumults	Lateritic and gleyed latosals
	Rhodudults	Acid red to brown day soils
Common	Tropofibrists	Peaty soils; Organic soils
	Troposaprists	Peaty soils; Organic soils
	Tropaquepts	Gleyed plastic heavy clay soils; Meadow soils; Dark soils of heavy texture;
	Haplaquolls	Meadowpodalic soils
	Arguidolls	Well drained old alluvial soils; Immature brown soils on sedimentary rocks; Dull meadow podzolic soils; Meadow podzolic soils
	Hapludolls	Young alluvial soils; well drained oil alluvial soils; old alluvial soils; alluvial black clay soils
	Plinthaqualfs	Meadow podzolic soils; meadow soils
	Tropaqualfs	As above, but also including gleyed plastic heavy clay soils and weathered glayed soils
	Plinthaquults	Meadow postzolic soils; podzolised grey laterites
	Tropaquults	Meadow soils; Meadow podzolic soils; Gleyed plastic heavy clay soils; Humic brown and red latosols; Strongly weathered red and brown clay soils

	Plinthudults	Red and yellow earths; Meadow podzolic soils
	Tropudults	Acid red to brown clay soils; Dull meadow podzolic soils
Very Common	Sulfaquents	Saline pests and muds; Mangrove soils
	Hydraquents	Young alluvial soils; Very purely drained alluvial soils
	Fluvaquents	Alluvial soils; Young alluvial soils; Recent alluvial soils
	Tropaquents	Alluvial soils; Young alluvial soils; Recent alluvial soils
	Troporthents	Lithosals, skeletal soils
	Hydrandepts	Humic brown clay soils (on volcanic ash)
	Vitrandepts	Unweathered sandy volcanic soils with black top soils
	Eutrandepts	
	Dystrandepts	Moderately weathered brown ash soils; Moderately to litter weathered brown ash soils
	Humitropepts	Humic brown clay soils
	Eutropepts	Brown forest soils; Darks alluvial soils; Shallow dark clay soils; Reddish clay soils
	Dystropepts	Strongly weathered red and brown clay soils; Acid red to brown clay soils; Acid brown forest soils; Uniform red and yellow clays; Reddish clay soils
	Hapludolls	Young alluvial soils; Well drained old alluvial soils; Old alluvial soils; Alluvial black clay soils
	Tropudalfs	Dull meadow podzolic soils; Brown forest soils; Immature brown soils on sedimentary rocks

Annex 2: Mean monthly and annual rainfall for representative stations (10 to 50 years prior to 1980)

Source: MacAlpine et al. 1983

MEAN MONTHLY AND ANNUAL RAINFALL (MM)
FOR STANDARD PERIOD 1956-1970

STATION NAME	STATION NO.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AIOME	200291	681	727	737	606	403	211	228	194	276	347	456	561	5642
AITAPE ST.ANNA	200002	242	270	292	210	216	191	181	134	175	173	214	310	2581
AIYURA	200003	197	246	263	183	111	85	96	131	132	177	187	268	2076
AMBUNTI	200004	277	260	311	265	211	132	163	187	196	217	233	240	2727
ANGORAM	200006	200	210	228	201	142	84	84	84	92	126	225	212	1882
AWELKON	200166	602	692	530	390	247	252	273	286	220	234	233	444	4402
BAINYIK	200169	147	181	197	181	113	76	82	90	108	156	171	173	1684
BAIYER RIVER	200170	281	343	364	261	170	91	101	122	181	205	204	310	2633
BAMU RIVER	200171	296	361	435	363	410	297	179	152	207	211	204	277	3391
BANIARA	200015	271	264	272	207	121	93	44	35	61	78	74	168	1698
BEREINA	200174	204	225	207	135	42	30	18	26	60	51	50	145	1193
BOGIA/AWAR	200175/165	240	235	287	243	140	92	68	53	81	145	201	299	2084
BULOLO FORESTRY	200178	132	125	158	137	127	88	103	111	129	145	156	184	1604
BWAGAOIA	200084	236	248	223	285	223	249	123	172	231	254	237	242	2779
DARU	200024	271	237	302	293	158	133	71	53	51	62	131	184	1891
DOGURA	200025	246	218	217	143	75	80	62	42	80	93	68	122	1447
ERAP	200187	150	158	168	86	60	78	87	104	75	87	77	146	1271
ERAVE	200188	294	328	330	271	258	254	320	307	322	292	236	298	3511
FINSCHHAFEN	200035	146	96	135	332	535	631	681	556	478	489	292	249	4619
GARAINA	200192	233	284	311	241	200	138	140	173	222	310	277	280	2808
GIZARUM	200194	398	436	355	230	126	124	119	121	88	106	150	298	2551
GOROKA A/S	200197	215	237	263	184	110	59	53	78	131	167	170	273	1939
HENGANOFI	200312	232	266	300	172	88	43	29	67	97	171	153	229	1847
ITIKINUMU	200316	290	316	333	327	295	151	98	173	287	296	279	352	3241
KAIAPIT	200043	257	277	356	253	139	63	54	82	127	172	229	357	2366
KANDRIAN	200210	119	98	152	179	327	596	671	631	425	298	158	151	3860

MEAN MONTHLY AND ANNUAL RAINFALL (MM)
FOR STANDARD PERIOD 1956-1970

STATION NAME	STATION NO.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
KAVIENG	200048	347	281	326	303	261	230	217	208	211	279	236	395	3282
KEREMA	200051	227	286	299	288	452	360	416	348	421	325	179	237	3826
KIKORI	200054	329	355	338	463	683	598	663	597	646	483	273	270	5635
LAE A/S	200065	291	225	332	361	451	447	519	544	463	441	307	373	4753
LUMI	200234	265	247	315	251	191	108	120	166	199	253	249	299	2658
MADANG A/S	200235	382	287	343	436	332	204	172	151	144	324	378	404	3558
MENDI	200339	229	259	286	215	214	195	261	258	266	276	194	226	2806
MENYAMYA	200238	151	181	182	145	121	96	80	100	153	176	175	174	1752
MINJ	200240	236	272	296	214	182	117	130	174	208	205	198	284	2509
MOMOTE	200241	274	253	277	281	224	327	372	314	277	245	230	309	3382
MT. HAGEN	200243	252	264	295	236	190	115	138	168	212	234	190	270	2564
POMIO	200251	223	151	233	268	462	856	1291	1187	723	477	240	235	6195
POPONDETTA	200272	311	263	295	239	171	121	78	101	158	190	235	346	2482
PT. MORESBY A/S	200286	199	239	217	143	41	41	16	31	57	37	48	145	1214
RABAUL A/S	200340	235	233	253	194	93	124	118	122	111	126	184	249	2014
SAIDOR	200253	402	480	398	327	175	131	119	100	119	167	167	275	2742
SAMARAI	200123	160	174	228	305	206	257	133	170	230	213	134	149	2312
SOHANO	200018	338	303	341	271	168	121	183	182	168	185	199	249	2692
TAPINI	200255	229	268	282	184	128	67	51	77	141	172	162	240	2002
TARI	200256	229	251	285	247	242	156	178	187	238	261	230	250	2754
TUFI	200262	381	458	324	305	295	206	108	66	106	164	238	311	2963
VANIMO (ARMY)	200259	271	257	336	232	182	184	203	157	171	188	201	327	2673
WABAG	200265	293	308	353	295	206	134	137	202	276	277	254	325	3056
WAU GOLD RIDGES	200274	183	197	197	169	117	69	104	96	115	176	169	215	1806
WEWAK A/S	200160	143	128	155	173	219	203	184	195	206	225	207	147	2189

MEAN MONTHLY AND ANNUAL RAINFALL (MM)
FOR SELECTED STATIONS FOR ALL YEARS OF RECORD

STATION NAME	STATION NO.	YRS. OF RECORD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ABAU	200000	15	141	162	205	225	250	215	206	197	210	113	108	145	2211
AIOME	200291	8	681	727	737	606	403	211	228	194	276	347	456	561	5642
AITAPE ST.ANNA	200002	29	256	263	274	246	208	175	172	153	139	156	206	270	2531
AIYURA	200003	29	230	263	265	225	121	90	102	131	135	161	195	241	2156
ALOTAU	200543	6	148	175	196	261	356	329	308	342	501	375	112	121	3199
AMAZON BAY	200446	8	273	196	249	272	234	204	236	154	183	149	67	113	2197
AMBOIN	200456	3	611	582	688	448	282	327	367	277	475	455	492	457	5214
AMBUNTI	200004	16	245	253	298	246	181	119	150	178	205	241	273	276	2554
ANGORAM	200006	13	210	218	235	221	145	87	80	81	88	150	219	239	2101
ARONA	200164	15	208	272	280	180	74	63	73	73	91	162	193	289	1978
AWELKON	200166	21	578	670	562	396	275	275	272	268	221	216	243	407	4444
BAIBARA	200168	14	210	190	231	227	206	270	205	216	245	139	76	161	2491
BAINYIK	200169	17	160	186	204	176	110	81	78	95	120	147	180	176	1721
BAIYER RIVER	200170	16	290	334	370	274	160	90	100	126	174	195	222	304	2614
BALIMO A/S	200297	11	258	323	326	269	243	160	108	70	129	130	132	277	2476
BANIARA	200015	34	268	288	258	206	143	107	71	60	64	88	122	179	1813
BEREINA	200174	14	210	220	210	131	42	28	21	26	55	53	43	172	1182
BUBIA	200176	17	217	193	243	230	263	265	351	325	288	257	185	202	3025
BUIN COAST	200017	15	277	258	308	224	270	318	563	465	366	313	235	205	3776
BULOLO HOSPITAL	200019	27	122	151	180	160	117	73	94	98	117	126	150	179	1544
BUNA BAY	200022	28	329	320	344	294	233	181	133	101	147	211	337	369	3048
BWAGAOIA	200084	35	252	318	269	292	299	248	181	221	237	260	255	227	3012
CAPE NELSON	200023	29	397	466	410	344	295	209	126	101	107	186	309	325	3327
DARU	200024	57	280	258	325	321	223	108	93	52	42	55	111	204	2063

MEAN MONTHLY AND ANNUAL RAINFALL (MM)
FOR SELECTED STATIONS FOR ALL YEARS OF RECORD

STATION NAME	STATION NO.	YRS. OF RECORD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
DOGURA	200025	44	232	221	222	149	91	93	76	65	77	79	88	120	1493
ERAP	200187	16	149	149	179	87	60	78	98	99	68	77	76	135	1248
ERAVE	200188	14	297	335	314	274	257	250	309	292	331	289	238	299	3405
ESA'ALA	200189	14	185	199	233	260	207	203	170	139	199	217	134	134	2272
FINSCHHAFEN	200035	25	140	95	135	301	464	589	655	568	531	402	297	227	4417
GARAINA	200192	22	227	296	291	251	195	131	148	166	220	282	300	303	2806
GASMATA	200036	21	140	143	175	239	646	811	867	1071	827	512	303	192	6051
GIZARUM	200194	23	397	456	404	223	124	132	118	118	94	94	156	284	2562
GOBARAGERE	200049	33	195	174	196	211	108	78	46	51	61	78	129	166	1521
GOROKA A/S	200197	19	230	254	266	204	113	54	49	74	121	154	171	243	1921
HENGANOFI	200312	14	232	266	305	172	88	43	29	67	97	167	142	230	1828
IALIBU	200314	13	331	351	381	297	228	191	258	288	369	373	312	343	3752
ILOLO	200205	28	287	328	305	287	193	123	87	121	174	222	196	258	2575
IOMA	200041	27	446	412	398	344	260	207	160	195	250	292	448	456	3927
ITIKINUMU	200316	39	322	286	363	357	267	166	114	176	230	283	322	338	3255
KAGUA	200319	12	263	272	316	235	209	171	207	233	315	330	223	285	3080
KAIAPIT	200043	26	264	271	363	292	140	64	65	79	121	165	243	335	2425
KAINANTU A/S	200208	16	235	252	285	170	103	69	58	95	116	150	194	267	2037
KAIRUKU	200044	36	240	277	226	134	46	44	28	14	40	40	54	133	1282
KALILI	200045	22	521	383	472	325	275	308	459	419	337	337	340	468	4737
KANDRIAN	200210	15	123	115	142	184	350	556	697	630	468	277	164	140	3885
KEREMA	200051	44	231	232	264	289	437	386	347	331	336	299	209	209	3612
KIETA	200053	27	259	259	301	295	233	250	259	243	210	250	242	233	3020
KIKORI	200054	43	314	330	360	441	750	718	652	556	610	473	329	301	5772
KOKODA	200056	39	336	333	365	328	259	187	180	224	273	321	407	362	3596

MEAN MONTHLY AND ANNUAL RAINFALL (MM)
FOR SELECTED STATIONS FOR ALL YEARS OF RECORD

STATION NAME	STATION NO.	YRS. OF RECORD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
KOKOPO	200057	33	219	189	221	170	120	121	168	148	111	116	162	230	1946
KOMPIAM	200218	12	281	350	398	343	245	165	176	205	308	292	315	348	3421
KOROBA	200328	13	263	267	321	288	328	246	248	289	319	291	219	261	3331
KUNDIAWA	200182	13	249	239	288	241	152	97	84	117	182	200	185	224	2249
KWIKILA	200116	41	156	131	176	149	79	51	44	43	58	50	66	110	1147
LAE A/S	200065	30	267	231	324	403	424	414	501	517	473	386	346	332	4617
LAKE KUTUBU	200226	11	370	412	367	453	446	297	356	364	487	454	299	385	4735
LORENGAU	200075	37	325	297	307	333	275	335	398	367	281	279	285	294	3881
LOSUIA	200069	37	425	431	380	337	332	306	306	270	271	257	239	268	3942
LUMI	200234	15	275	249	311	269	183	107	111	162	198	253	266	285	2646
MADANG AGRIC.	200070	42	340	314	373	439	378	235	176	123	152	267	376	375	3533
MENDI	200339	13	231	267	277	222	213	183	239	253	284	269	204	219	2800
MENYAMYA	200238	16	156	182	175	170	128	84	80	96	151	158	175	186	1769
MINJ	200240	14	245	269	289	217	181	114	127	174	215	191	186	271	2485
MOMOTE	200241	20	270	260	305	287	215	308	335	291	257	230	240	311	3341
MOROBE	200086	18	159	180	179	230	265	244	236	215	265	233	276	255	2769
MT. HAGEN	200243	20	264	271	285	253	184	119	131	171	221	221	208	258	2586
MUMENG	200244	16	176	143	153	130	86	64	84	81	98	114	156	204	1471
NAMATANAI	200088	25	438	407	418	341	211	173	187	154	125	189	299	407	3431
NOMAD RIVER	200484	8	496	522	601	252	313	228	236	309	266	322	262	454	4272
POPONDETTA	200272	14	291	268	294	240	195	112	85	99	171	177	264	335	2482
PT. MORESBY A/S	200286	25	169	221	191	167	51	40	20	34	40	40	69	156	1197
PT. MORESBY KONEDOBU	200108	42	177	199	170	103	62	30	29	16	26	31	49	105	995
RABAUL A/S	200340	23	230	244	256	209	129	114	104	103	94	118	173	238	2003

Annex 3: Latest mean monthly rainfall for the 14 NWS weather stations

Source: (NWS, 2007)

Station Name:	Daru W O		
Lat:	9.08	South	
Long:	143.20	East	
Elevation:	6.0	Metres	

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1981	278.6	260.2	213.0	334.2	34.2	59.8	95.0	14.2	39.2	97.2	147.8	448.0	2021.4
1982	260.6	199.0	493.2	220.8	141.8	36.2	46.8	67.4	1.6	4.6	16.8	25.4	1514.2
1983	196.2	182.8	237.6	289.9	292.4	89.4	78.4	56.4	155.2	40.2	9.2	260.8	1888.5
1984	156.6	294.2	333.2	65.1	321.0	65.6	27.8	35.4	10.6	19.0	29.8	303.0	1661.3
1985	392.8	272.0	328.4	615.6	314.0	78.4	84.6	91.6	46.4	104.0	156.8	102.2	2586.8
1986	176.4	403.2	393.8	659.8	105.2	32.6	49.2	29.4	18.2	29.6	9.6	196.8	2103.8
1987	223.4	379.4	270.0	374.6	78.6	13.6	55.8	32.0	28.2	3.4	5.2	336.0	1800.2
1988	175.6	510.8	431.8	145.0	77.4	162.4	118.4	46.0	108.6	27.8	72.6	148.4	2024.8
1989	221.0	162.0	299.2	248.4	207.6	211.6	88.4	37.8	29.4	50.6	157.2	130.6	1843.8
1990	229.8	107.6	335.8	90.0	653.0	374.8	160.0	29.4	36.4	5.0	59.0	55.8	2136.6
1991	324.6	195.8	187.4	559.8	67.6	38.6	50.0	137.2	10.8	24.6	55.6	205.8	1857.8
1992	169.0	183.6	280.8	415.6	911.6	44.0	63.8	11.8	2.4	5.6	1.0	241.4	2330.6
1993	238.8	371.8	103.2	608.6	72.6	49.2	35.8	22.6	14.0	3.8	5.8	255.8	1782.0
1994	201.2	265.2	362.6	463.4	620.8	58.0	130.4	44.0	8.0	12.0	0.0	25.8	2191.4
1995	380.0	249.4	197.4	560.6	188.8	89.4	30.6	50.0	40.0	111.8	89.2	237.6	2224.8
1996	197.0	375.6	314.2	385.2	246.2	22.2	45.0	82.2	30.4	331.6	27.0	173.0	2229.6
1997	223.0	530.4	110.8	32.2	37.0	31.4	42.0	14.2	4.8	0.0	0.0	93.2	1119.0
1998	214.0	269.0	261.4	129.2	276.0	134.2	15.8	44.8	20.2	75.2	350.0	276.0	2065.8
1999	180.0	226.0	165.0	335.6	500.0	228.0	66.0	33.0	11.0	9.0	191.0	220.0	2164.6
2000	145.0	342.0	424.0	227.0	664.0	74.0	28.0	25.0	21.0	95.0	35.0	400.0	2480.0
2001	242.2	255.4	211.0	795.8	231.6	55.0	31.0	20.0	13.0	13.0	125.0	140.0	2133.0
2002	213.0	44.0	262.0	583.6	189.0	143.0	45.0	13.0	14.8	24.0	40.0	153.0	1724.4
2003	490.2	205.2	151.0	623.2	147.2	67.0	136.8	19.4	18.8	48.2	65.2	210.4	2182.6

2004	276.0	315.0	389.0	192.0	276.0	60.0	42.0	12.0	25.0	8.0	10.6	61.0	1666.6
2005	399.0	191.6	328.4	471.6	36.0	41.0	38.2	22.2	10.8	11.6	127.2	202.2	1879.8
2006	252.6	154.0	314.2	459.8	203.8	99.4	64.2	24.8	93.8	12.6	19.2	50.8	1749.2

Station Name: Goroka
Lat: 6.04 South
Long: 145.23 East
Elevation: 1572.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	217.0	347.0	448.0	296.0	109.0	43.0	129.0	75.0	51.0	261.0	281.0	121.0	2378.0
1974	165.0	444.0	197.0	132.0	46.0	112.0	55.0	24.0	21.0	158.0	176.0	151.0	1681.0
1975	201.0	350.0	230.0	225.0	225.0	75.0	23.0	109.0	40.0	35.0	116.0	272.0	1901.0
1976	212.0	181.0	133.0	132.0	100.0	45.0	70.0	64.0	115.0	174.0	130.0	132.0	1488.0
1977	317.0	215.0	111.0	193.0	146.0	80.0	86.0	108.0	83.0	275.0	116.0	147.0	1877.0
1978	142.0	171.0	208.0	266.0	140.0	49.0	60.0	74.0	53.0	148.0	34.0	184.0	1529.0
1979	158.0	152.0	254.0	128.0	109.0	42.0	28.0	52.0	28.0	187.0	280.0	239.0	1657.0
1980	388.0	177.0	164.0	184.0	115.0	36.0	71.0	175.0	68.0	15.0			
1981													
1982													
1983													
1984													
1985													
1986													
1987													
1988													
1989													
1990	258.6		113.2	222.6	73.0	106.4	73.2	124.2	175.6	274.4	174.4	172.8	
1991	224.6	323.2	83.0	141.2		62.0	45.4	155.6	29.4		198.4	198.4	
1992	119.6	309.4	305.0	193.2	82.2	89.0	16.4	44.8	36.4	158.2	55.6	285.2	1695.0
1993	301.0	141.4	215.2	124.0	63.0	46.4	77.4	45.2	37.0	97.6	215.2	404.0	1767.4

1994	310.2	115.0	100.6	141.0	153.4	83.2	126.6	150.0	96.6	115.0	119.0		
1995	237.2	265.0	320.8	214.8	83.6		22.0	15.8					
1996													
1997													
1998													
1999	63.4	141.4	272.2	150.4	167.6	64.6	45.6	0.0	154.2	141.0	143.4	171.6	1515.4
2000	152.4			67.0	237.5	43.8	157.6	105.4					
2001	50.2	268.8	208.2	268.4	212.2	43.2	104.2	32	28	4.8	111.2	221.2	1552.4
2002	181.4	128.6	399.2	201.0	61.0	79.2	111.8	22.4	38.6	123.2	215.2	161.8	1723.4
2003	152.6	267.2	368.4	101.2	131.2	7.4	48.0	49.2	212.8	168.2	159.2	150.8	1816.2
2004	153.4	268.6				106.2	50.4		114.8	103.2	145.6	109.6	1051.8
2005	295.2	181.0	279.4	215.4	191.2	21.4	101.2	145.6	245.2	191.4	358.4	154.6	2380.0
2006	306.6	162.6	96.0	237.0	106.4	87.2	66.2	48.4	146.0	105.2	133.6	837.8	2380.0

Station Name: Gurney W O
Lat: 10.32 South
Long: 150.33 East
Elevation: 20.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1988													
1989									314.8	103.4	138.0	91.6	
1990	323.8	71.6	245.8	182.8	339.0	115.8	296.0	34.6	239.6	217.4	148.4	192.2	2407.0
1991	162.4	253.2	203.6	292.6	232.8	272.4	359.0	191.6	266.8	122.0	247.0	108.4	2711.8
1992	148.8	274.8	151.2	169.8	355.4	129.2	178.6	53.8	2.6	33.8	121.0	283.6	1902.6
1993	127.4	250.4	219.8	347.0	532.0								
1994										366.4	53.0	12.2	
1995	141.8	95.0	352.0	249.0	266.4	250.8	79.0	512.4	174.0	201.8	328.4	131.8	2782.4
1996	159.0	152.6	192.4	125.0	124.0	124.6	403.8	248.6	282.0	690.6	128.6	86.6	2717.8
1997	198.4	164.2	161.6	128.2	67.6	72.8	176.2	44.2	61.8	255.8	91.6	18.0	1440.4
1998	150.0	115.6	465.4	67.4	236.8	116.6	301.2	350.8	479.8	221.4	271.6	310.4	3087.0

1999	77.0	122.0	114.0	22.0	137.0	359.0	426.0	261.6	113.0	125.6	241.0	208.0	2206.2
2000	215.0	118.0	230.0	223.0	216.0	526.0	90.0	207.0	420.0	267.0	72.0	186.0	2770.0
2001	49.2	145.2	207.4	301.6	110.8	373.0	101.0	106.0	454.0	222.0	398.2	89.0	2557.4
2002	119.0	219.0	180.0	236.0	229.0	266.0	133.0	42.4	58.4	128.0	224.0	85.6	1920.4
2003	107.0	44.2	219.0	317.2	191.2	229.2	182.2	98.8	135.2	113.4	362.8	163.4	2163.6
2004	97.0	146.0	300.0	269.0	299.0	289.0	42.0	23.0	86.0	210.0	194.6	106.0	2061.6
2005	162.0	131.0	337.2	210.8	192.2	93.6	152.6	135.2	20.6	229.4	143.2	133.8	1941.6
2006	218.8	98.2	191.4	330.2	121.2	292.0	101.6	113.0	151.4	61.2	266.4	82.8	2028.2

Station Name: Hoskin W O
Lat: 5.47 South
Long: 150.4 East
Elevation: 8.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1983			760.8	422.8	354.2	205.8	131.8	122.0	154.4	173.8	437.0	455.4	3218.0
1984	119.6	203.6	617.6	235.2	86.6	102.6	115.6	38.8	157.4	109.2	250.2	608.6	2645.0
1985	673.6	376.2	663.0	114.6	271.8	130.8	161.0	99.6	172.4	165.0	317.0	326.8	3471.8
1986													
1987													
1988													
1989													
1990													
1991													
1992													
1993													
1994													
1995			198.4	582.2	110.6	128.2	109.6	113.4	50.0	149.4	103.8	176.8	1722.4
1996	392.4	120.4	310.4	112.6	142.6	100.8	89.8	177.4	163.4	252.2	67.8	295.4	2225.2

1997	412.0	578.4	401.0	115.6	208.0	74.6	74.4	0.0	88.0	29.8	174.6	270.4	2426.8
1998	608.0	876.6	684.2	452.0	321.8	295.0	215.0	155.0	11.8	162.2	389.4	392.4	4563.4
1999	531.0	1044.0	393.0	165.0	97.6	238.8	161.2	118.6	113.0	270.0	226.0	328.0	3686.2
2000	480.4	135.8	555.4	274.4	520.8	74.2	77.2	289.8	88.6	165.4	223.6	413.8	3299.4
2001	146.0		439.0	262.8	191.8	282.4	242.4	139.8	112.4	85.8	289.2	700.0	
2002	540.0	904.0	592.0	303.2	106.0	257.0	178.2	0.0	44.4	251.4	153.2	267.6	3597.0
2003	581.8	677.8	723.8	388.2	201.6	66.8	123.4	159.8	114.4	189.8	72.6	484.0	3784.0
2004	659.0	521.0	839.0	170.0	291.0	164.0	129.0	44.0	135.0	172.0	101.8	44.8	3270.6
2005	616.4	615.2	729.2	839.4	154.0	49.0	125.4	116.6	140.0	120.2	260.4	413.2	4179.0
2006	463.4	740.4	498.6	455.8	92.0	203.6	189.8	175.2	289.6	17.0	158.4	239.0	3522.8

Station Name: Kavieng W O
Lat: 2.35 South
Long: 150.48 East
Elevation: 7.0

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	309.0	353.0	568.0	481.0	154.0	322.0	110.0	346.0	151.0	71.0	267.0	172.0	3304.0
1974	68.0	248.0	279.0	154.0	106.0	202.0	156.0	204.0	86.0	131.0	361.0	228.0	2223.0
1975	487.0	408.0	438.0	213.0	104.0	151.0	77.0	228.0	62.0	244.0	200.0	162.0	2774.0
1976	338.0	163.0	435.0	355.0	129.0	206.0	302.0	126.0	146.0	212.0	196.0	397.0	3005.0
1977	223.0	314.0	439.0	484.0	246.0	200.0	301.0	300.0	106.0	401.0	192.0	245.0	3451.0
1978	314.0	261.0	383.0	212.0	204.0	157.0	218.0	198.0	237.0	414.0	453.0	260.0	3311.0
1979	96.0	141.0	367.0	326.0	354.0	291.0	302.0	262.0	193.0	295.0	315.0	258.0	3200.0
1980	523.0	306.0	342.0	332.0	318.0	261.0	324.0	311.0	258.0	394.0	156.0	247.0	3772.0
1981	362.0	232.0	575.0	469.0	101.0	192.0	304.0	240.0	179.0	458.0	211.0	348.0	3671.0
1982	362.0	305.0	604.0	297.0	177.0	207.4	92.0	32.0	74.0	102.0	164.0	357.0	2773.4
1983	422.0	174.0	356.0	430.0	429.0	315.0	362.0	174.0	151.0	314.0	270.0	189.0	3586.0
1984	55.0	176.0	203.0	167.0	162.0	159.0	206.0	72.0	153.0	135.0	267.0	302.0	2057.0
1985	373.0	295.0	382.0	151.0	185.0	265.0	339.0	206.0	334.0	289.0	251.0	387.0	3457.0
1986	342.0	245.0	131.0	301.0	237.0	220.0	201.0	100.0	190.0	217.0	319.0	317.0	2820.0

1987	376.4	298.8	305.4	179.0	329.0	155.0	119.0	173.8	171.6	142.0	257.8	402.0	2909.8
1988	235.4	296.2	468.4	275.4	307.4	187.2	160.4	162.4	186.2	304.8	437.2	232.8	3253.8
1989	312.6	302.4	250.4	476.6	367.6	184.8	83.8	207.8	174.4	431.6	271.0	297.6	3360.6
1990	274.4	187.2	238.0	309.4	267.2	247.4	397.0	221.6					
1991	344.8	311.4	255.6	208.0	222.0	258.4	281.6	276.0	220.4	215.6	85.0	207.0	2885.8
1992	268.8	212.0	371.6	188.8	237.2	161.2	159.8	202.0	115.2	352.0	233.4	269.2	2771.2
1993	311.8	229.2	206.8	298.2	297.0	429.6	251.2	19.2	52.8	160.0	168.0	159.4	2583.2
1994	179.6	413.0	312.6	349.0	296.6	196.0	373.2	239.2	115.6	134.4	81.0	340.2	3030.4
1995	358.8	166.8	393.4	448.2	167.0	192.4	160.2	156.0	228.8	360.2	276.0	411.6	3319.4
1996	338.2	163.4	434.8	355.4	128.0	205.6	301.7	125.8	146.2	212.2	195.4	397.0	3003.7
1997	256.2	218.0	92.4	176.0	243.0	120.0	150.6	12.0	29.4	72.8	67.4	202.0	1639.8
1998	256.2	504.4	157.6	246.0	253.0	400.2	167.0	206.2	141.0	155.6	133.6	220.4	2841.2
1999	119.0	239.2	147.2	39.2	141.6	311.4	279.0	261.0	94.2	70.4	225.4	218.2	2145.8
2000	161.0	13.6	133.0	156.0	313.0	180.0	305.0	280.0	150.0	195.0	341.0	228.6	2456.2
2001	131.0	504.6	365.8	389.0	385.8	547.8	412.2	258.2	126.6	137.8	180.6	401.0	3840.4
2002	405.0	236.8	390.8	431.2	228.2	303.2	98.0	86.6	30.8	167.8	161.0	350.8	2890.2
2003	467.4	285.4	326.8	274.6	345.4	215.8	327.8	243.6	356.2	277.8	309.2	334.4	3764.4
2004	283.4	325.0	239.2	275.0	273.0	282.6	219.2	84.0	262.0	209.4	203.0	238.4	2894.2
2005	661.2	355.0	313.0	345.6	161.0	278.0	343.6	192.8	464.4	422.2	168.0	283.0	3987.8
2006	317.2	264.6	326.0	482.6	347.8	323.2	493.8	223.8	288.4	112.8	122.4	731.9	4034.5

Station Name: Kiunga W O
Lat: 6.08 South
Long: 141.18 East
Elevation: 8.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1981	459.4	432.4	416.0	245.2	427.4	616.2	706.6	168.6	432.8	342.0	232.2	442.0	4920.8
1982													
1983													
1984													

1985	437.4	245.8	380.4	641.8	489.6	428.8	264.0	474.4	432.2	330.4	373.2	549.8	5047.8
1986	662.0	601.8	718.8	626.4	254.4	556.6	674.0	263.6	119.2	244.2	330.4	336.2	5387.6
1987	703.8	341.8	539.2	264.4	288.6	154.2	67.2	144.6	582.8	179.2	351.0	492.6	4109.4
1988	570.2	240.4	621.6	308.8	358.8	261.0	730.2	403.0	524.4	432.8	461.4	498.0	5410.6
1989	666.6	175.2	606.6	406.0	417.6	273.0	338.6	373.6	492.6	546.8	355.0	483.8	5135.4
1990													
1991													
1992													
1993												446.4	
1994	355.4	420.4	567.6	400.2	598.0	317.2	198.0	343.2	276.8	410.2	250.6	289.2	4426.8
1995	438.8	669.6	418.0	240.4	336.4	235.8	246.6	404.8	570.2	250.0	485.6	108.0	4404.2
1996	561.4	496.0	257.2	506.0	356.2	71.8	211.0	353.8	538.8	1300.2	203.6	326.4	5182.4
1997	482.4	402.2	220.0	254.4	156.8	94.6	329.4	4.4	140.0	66.8	295.8	356.2	2803.0
1998	159.4	579.2	311.2	644.4	606.8	471.2	322.6	298.4	562.4	477.6	325.2	452.8	5211.2
1999	650.0	494.0	1060.0	520.4	222.0	561.0	380.0	233.6	194.0	275.6	625.0	794.0	6009.6
2000	565.0	560.6	439.0	501.6	554.0	395.4	235.0	284.0	216.0	656.0	446.0	540.0	5392.6
2001	716.8	413.0	692.2	787.8	456.8	380.0	243.0	36.0	259.0	453.0	320.0	390.0	5147.6
2002	503.0	348.0	597.0	463.0	209.0	420.0	211.0	179.0	307.2	224.0	268.0	502.0	4231.2
2003	434.8	588.4	459.4	556.8	428.4	107.0	481.2	141.6	481.6	495.8	266.4	433.8	4875.2
2004	369.0	385.0	429.0	158.0	627.0	148.0	105.6	40.6	324.0	192.8	422.0	439.0	3640.0
2005	447.6	357.8	685.4	538.6	542.0	218.6	407.8	131.6	340.8	268.0	394.8	656.0	4989.0
2006	495.2	381.0	747.8	515.4	287.6	237.4	452.6	141.8	377.6	93.4	185.6	302.8	4218.2

Station Name: Madang W O
Lat: 5.22 South
Long: 145.8 East
Elevation: 4 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	465.0	228.0	366.0	396.0	425.0	204.0	191.0	76.0	224.0	250.0	463.0	174.0	3462.0
1974	87.0	398.0	409.0	434.0	306.0	368.0	84.0	133.0	96.0	265.0	279.0	488.0	3347.0

1975	384.0	450.0	352.0	306.0	302.0	349.0	183.0	443.0	242.0	614.0	234.0	350.0	4209.0
1976	345.0	231.0	277.0	549.0	329.0	126.0	197.0	159.0	22.0	122.0	259.0	271.0	2887.0
1977	244.0	285.0	536.0	211.0	480.0	216.0	58.0	64.0	79.0	215.0	178.0	612.0	3178.0
1978	451.0	502.0	315.0	436.0	361.0	215.0	139.0	99.0	244.0	85.0	320.0	382.0	3549.0
1979	285.0	419.0	326.0	456.0	175.0	104.0	32.0	122.0	13.0	277.0	201.0	520.0	2930.0
1980	346.0	248.0	142.0	298.0	333.0	53.0	279.0	70.0	62.0	255.0	422.0	423.0	2931.0
1981	202.0	216.0	255.0	330.0	294.0	323.0	144.0	94.0	37.0	373.0	189.0	565.0	3022.0
1982	364.0	484.0	546.0	494.0	187.0	186.0	101.0	29.0	3.0	200.0	225.0	216.0	3035.0
1983	381.4	450.4	409.0	255.4	347.4	141.8	84.8	0.4	119.2	209.4	274.0	289.4	2962.6
1984	84.0	185.0	325.0	396.0	440.0	288.0	47.0	118.0	173.0	269.0	401.0	626.0	3352.0
1985	356.0	208.0	384.0	246.0	343.0	497.0	241.0	178.0	208.0	313.0	370.0	183.0	3527.0
1986	424.0	309.0	161.0	692.0	350.0	235.0	116.0	177.0	206.0	271.0	170.0	400.0	3511.0
1987	678.0	290.4	313.8	372.8	318.4	13.4	238.6	34.4	6.6	58.8	280.4	440.8	3046.4
1988	306.4	475.4	284.2	378.4	241.4	280.8	149.4	122.6	192.0	575.0	363.4	283.0	3652.0
1989	334.8	204.8	396.6	596.0	566.0	439.0	220.8	225.8	300.6	538.8	344.4	456.0	4623.6
1990	461.0	319.4	171.4	626.0	322.4	206.4	123.0	58.2	82.6	67.4	372.8	524.6	3335.2
1991	139.2	258.2	363.2	200.6	126.0	131.4	105.4	193.2	108.4	195.0	339.0	294.6	2454.2
1992	454.2	240.8	320.4	339.8	93.8	22.2	30.4	32.4	10.2	314.0	209.8	183.8	2251.8
1993	349.4	500.6	343.6	580.2	71.4	110.4	3.2	2.0	3.4	97.2	273.8	405.2	2740.4
1994	247.0	245.8	256.2	312.2	451.4	119.6	171.2	140.8	33.2	44.8	213.4	358.2	2593.8
1995	234.2	292.0	400.8	260.4	548.2	127.2	134.6	6.0	185.2	392.4	305.6	489.8	3376.4
1996	336.6	197.0	234.8	218.8	454.0	497.6	51.2	75.0	290.0	253.8	309.6	519.2	3437.6
1997	415.8	343.6	166.0	787.6	300.4	36.8	163.8	14.6	3.4	180.2	80.2	289.6	2782.0
1998	253.2	448.6	410.8	583.4	327.2	99.8	94.8	134.2	142.6	529.4	430.6	407.4	3862.0
1999	81.0	305.0	337.0	188.0	396.0	493.0	217.0	334.0	58.0	312.0	248.0	273.0	3242.0
2000	290.4	184.0	306.0	432.0	541.0	225.4	354.0	86.0	23.0	170.0	485.0	663.0	3759.8
2001	327.2	214.8	376.0	414.0	391.2	170.0	183.0	72.0	24.8	206.0	322.0	343.0	3044.0
2002	375.8	230.6	329.0	339.6	532.0	228.4	103.8	142.8	29.4	239.2	280.2	345.0	3175.8
2003	590.6	378.8	208.6	590.0	497.4	147.0	26.2	116.0	374.2	195.4	374.6	435.0	3933.8
2004	394.2	300.0	618.0	461.0	467.0	125.0	327.8	40.6	60.4	211.6	141.4	268.0	3415.0
2005	497.4	293.4	466.6	389.4	238.0	75.0	236.2	114.0	73.8	120.2	453.0	382.0	3339.0

2006	279.4	439.2	699.6	230.8	198.2	391.6	354.8	18.6	153.2	214.2	265.2	311.8	3556.6

Station Name: Misima W O
Lat: -10.41 South
Long: 152.50 East
Elevation: 6.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973	165.0	442.0	215.0	199.0	199.0	211.0	75.0	114.0	143.0	370.0	219.0	333.0
1974	525.0	279.0	481.0	447.0	153.0	486.0	866.0	165.0	301.0	536.0	723.0	379.0
1975	293.0	492.0	636.0	351.0	766.0	300.0	479.0	94.0	355.0	440.0	325.0	237.0
1976	324.0	486.0	223.0	554.0	443.0	199.0	268.0	171.0	224.0	25.0	165.0	154.0
1977	420.0	207.0	372.0	350.0	92.0	94.0	311.0	97.0	152.0	298.0	236.0	32.0
1978	173.0	412.0	200.0	159.0	330.0	57.0	201.0	73.0	28.0	91.0	145.0	106.0
1979	352.0	212.0	73.0	344.0	119.0	46.0	70.0	7.0	68.0	298.0	119.0	332.0
1980	175.0	377.0	384.0	108.0	141.0	9.0	31.0	151.0	38.0	46.0	85.0	210.0
1981	440.0	238.0	81.0	194.0	109.0	97.0	335.0	78.0	145.0	236.0	123.0	160.0
1982	298.0	301.0	225.0	423.0	392.0	149.0	139.0	87.0	23.0	26.0	143.0	104.0
1983	227.0	191.0	262.0	216.0	171.0	226.0	58.0	14.0	245.0	128.0	192.0	224.0
1984	96.0	211.0	345.0	221.0	285.0	186.0	41.0	75.0	285.0	479.0	18.0	256.0
1985	362.0	259.0	585.0	242.0	500.0	430.0	190.0	412.0	214.0	262.0	440.0	327.0
1986	460.0	381.0	203.0	479.0	99.0	119.0	172.0	79.0	98.0	50.0	78.0	325.0
1987	147.6	416.2	126.4	125.4	92.8	58.2	54.8	7.8	61.0	46.0	25.0	602.2
1988	476.6	183.4	158.0	351.0	141.0	312.0	191.8	328.6	363.4	390.6	90.6	219.4
1989	244.6	185.8	304.0	1162.8	450.8	353.8	354.0	560.8	341.0	326.8	91.4	196.8
1990	253.4	124.0	379.0	148.4	370.2	226.0	341.2	108.4	557.0	164.6	163.0	310.0
1991	199.6	179.8	254.4	275.0	497.0	88.2	32.4	191.0	84.8	350.0	178.0	33.6
1992	157.0	349.0	111.6	268.0	323.2	38.8	108.2	11.4	39.6	20.6	65.4	221.0
1993	103.6	304.4	133.4	207.8	146.0	17.4	30.6	6.6	28.8	22.8	72.2	297.0
1994	412.6	466.2	223.6	177.2	271.4	140.2	37.8	183.4	108.6	175.2	44.4	73.6
1995	111.4	119.0	192.0	295.4	145.2	323.0	31.6	329.0	201.4	110.2	164.4	205.6

1996	372.2	155.2	253.8	136.8	192.4	282.2	145.8	109.6	315.0	596.8	319.6	294.0
1997	166.4	290.4	755.6	235.8	72.8	113.8	199.7	18.4	44.0	61.4	124.8	94.4
1998	137.4	157.4	273.0	38.0	155.4	63.8	48.4	249.6	311.2	183.8	181.0	213.0
1999	311.0	404.0	252.0	216.6	290.0	119.0	269.8	141.0	65.0	296.0	210.0	421.0
2000	314.0	415.0	429.0	308.0	339.0	507.0	91.0	207.0	23.0	165.0	208.0	220.0
2001	308.4	464.8	266.6	487.8	93.0	338.4	127.0	42.0	378.0	78.0	190.0	333.0
2002	158.0	418.0	359.0	152.0	228.8	105.0	85.0	27.0	247.2	303.0	435.0	119.0
2003	50.2	271.2	213.8	226.4	272.0	284.4	70.0	8.0	85.6	119.8	538.6	209.8
2004	151.0	278.0	409.0	580.0	174.0	160.0	43.0	6.0	41.0	138.0	167.4	298.0
2005	499.0	79.6	294.0	474.2	277.4	125.4	131.8	49.8	39.0	47.0	736.0	332.8
2006	327.2	148.2	23.7.8	546.8	439.8	517.6	79.8	107.2	79.0	36.6	127.2	241.4

Station Name: Momote W O

Lat: 2.03 South

Long: 147.3 East

Elevation: 4 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	384.0	298.0	541.0	430.0	204.0	245.0	358.0	312.0	139.0	81.0	268.0	183.0	3443.0
1974	77.0	389.0	328.0	365.0	247.0	281.0	367.0	179.0	117.0	112.0	440.0	341.0	3243.0
1975	321.0	339.0	362.0	264.0	179.0	243.0	254.0	187.0	209.0	147.0	161.0	235.0	2901.0
1976	333.0	206.0	253.0	287.0	144.0	207.0	193.0	221.0	164.0	261.0	193.0	411.0	2873.0
1977	404.0	219.0	356.0	381.0	384.0	273.0	396.0	402.0	341.0	365.0	363.0	339.0	4223.0
1978	273.0	143.0	334.0	291.0	199.0	95.0	279.0	256.0	330.0	391.0	385.0	233.0	3209.0
1979	121.0	197.0	420.0	306.0	491.0	332.0	201.0	240.0	276.0	220.0	173.0	287.0	3264.0
1980	216.0	414.0	347.0	96.0	189.0	676.0	604.0	528.0	214.0	350.0	214.0	395.0	4243.0
1981	247.0	236.0	262.0	264.0	126.0	223.0	314.0	274.0	213.0	434.0	292.0	426.0	3311.0
1982	488.0	263.0	289.0	180.0	230.0	216.0	141.0	175.0	39.0	64.0	288.0	288.0	2661.0
1983	253.0	80.0	478.0	127.0	261.0	312.0	696.0	320.0	225.0	209.0	317.0	144.0	3422.0
1984	109.0	150.0	275.0	183.0	458.0	105.0	351.0	234.0	157.0	309.0	115.0	453.0	2899.0
1985	334.0	372.0	333.0	83.0	141.0	221.0	338.0	301.0	293.0	256.0	252.0	389.0	3313.0

1986	250.0	221.0	281.0	445.0	350.0	206.0	312.0	150.0	278.0	148.0	443.0	334.0	3418.0
1987	319.0	107.0	247.0	203.0	270.0	231.0	259.0	121.0	126.0	402.0	199.0	279.0	2763.0
1988	250.0	284.0	416.0	137.0	207.0	212.0	373.0	160.0	252.0	346.0	292.0	352.0	3281.0
1989	187.0	221.0	208.0	436.0	228.0	188.0	225.0	193.0	180.0	265.0	446.0	307.0	3084.0
1990	333.0	380.0	291.0	290.0	199.0	432.0	458.0	412.0	195.0	294.0	192.0	243.0	3719.0
1991	247.0	428.0	286.0	219.0	242.0	281.0	599.0	754.0	191.0	266.0	172.0	251.0	3936.0
1992	185.0	245.0	321.0	192.0	183.0	330.0	324.0	160.0	120.0	266.0	158.0	204.0	2688.0
1993	305.0	89.0	258.0	156.0	223.0	293.0	479.0	50.0	238.0	211.0	190.0	396.0	2888.0
1994	106.0	265.0	169.0	288.0	391.0	380.0	714.0	280.0	179.0	133.0	147.0	381.0	3433.0
1995	394.0	172.0	198.0	285.0	196.0	314.0	305.0	383.0	254.0	266.0	140.0	282.0	3189.0
1996	157.0	251.0	275.0	259.0	445.0	178.0	434.0	232.0	235.0	183.0	147.0	208.0	3004.0
1997	305.8	355.8	103.6	192.8	255.2	46.2	349.2	62.8	14.4	125.8	319.6	392.6	2523.8
1998	312.0	117.0	167.0	339.0	238.0	296.0	335.0	342.0	250.0	175.0	149.0	446.0	3166.0
1999	180.0	333.0	110.0	280.0	230.0	252.0	316.0	478.0	155.0	111.0	259.0	297.0	3001.0
2000	280.0	62.0	255.0	228.0	314.0	312.0	414.0	326.0	88.0	316.0	253.0	213.0	3061.0
2001	146.0	504.0	581.0	367.0	307.0	269.0	516.0	418.0	308.0	220.0	197.0	233.0	4066.0
2002	275.4	177.4	345.2	192.6	139.8	324.2	314.6	97.8	175.4	107.4	350.6	282.8	2783.2
2003	226.4	219.0	362.4	362.0	263.4	71.6	287.0	520.0	588.0	215.8	401.2	205.0	3721.8
2004	135.0	418.0	336.0	321.0	271.0	523.0	339.0	163.3	482.0	226.0	239.0	289.0	3742.3
2005	557.0	169.4	313.4	453.0	257.0	261.8	543.2	225.4	358.6	219.4	321.6	246.4	3926.2
2006	318.8	178.0	269.0	307.8	225.0	264.4	411.8	774.6	394.2	195.8	202.2	260.4	3802.0

Station Name: Nadzab W O
Lat: 6.55 South
Long: 146.2 East
Elevation: 70.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973										123.0	152.0	44.0	
1974	74.0	222.0	142.0	102.0	17.0	176.0	309.0	32.0	208.0	101.0	188.0	77.0	1648.0
1975	206.0	273.0	214.0	225.0	56.0	38.0	157.0	111.0	89.0	34.0	124.0	231.0	1758.0

1976	156.0	110.0	143.0	96.0	73.0	18.0	37.0	47.0					
1977	112.0	47.0	18.0	107.0	76.0	81.0		85.0	121.0	194.0	135.0	263.0	1239.0
1978	191.0	126.0	117.0	117.0	62.0	16.0	198.0	114.0	134.0	107.0	126.0	98.0	1406.0
1979	196.0	100.0	267.0	206.0	66.0	180.0	127.0	92.0	104.0	90.0	21.0	112.0	1561.0
1980	185.0	81.0	88.0	83.0	53.0	22.0	48.0	249.0	70.0	21.0	78.0	194.0	
1981	56.0	194.0		70.0	62.0	209.0	121.0	48.0	122.0	114.0	73.0	196.0	1265.0
1982	114.0	200.0	309.0	204.0	73.0	138.0	63.0	94.0	10.0	69.0	10.0	128.0	1412.0
1983	145.0	134.0	186.0	88.0	88.0	62.0	94.0	221.0	147.0		105.0	154.0	
1984	6.0	68.0	145.0	102.0	152.0	111.0	117.0	101.0	20.0	71.0	34.0	232.0	1159.0
1985	149.0	84.0	236.0	134.0	137.0	64.0	125.0	282.0	57.0	47.0	165.0	157.0	1637.0
1986	226.0	153.0	217.0	220.0		71.0	54.0	58.0	95.0	279.0	42.0		
1987					22.8	8.8	4.8	7.4	55.8	15.0	11.6	124.0	
1988	283.0	169.0	225.0	103.8	57.2	34.6	165.4	181.6	124.4	190.2	80.4	69.6	1684.2
1989	141.6	236.0	92.8	204.8	84.4	126.0	42.4	80.8	57.6	64.0	84.2	188.8	1403.4
1990	130.2	64.8	158.8	204.2	81.2	106.0	98.2	90.8	146.4	102.4	143.2	165.0	1491.2
1991	245.0	266.0	129.4	79.8	72.2	36.6	28.8	165.6	15.4	119.8	120.6	168.2	1447.4
1992	93.8	245.4	226.2	188.4	150.0	21.6	292.0	186.2	23.0	97.4	57.0	291.4	1872.4
1993	172.0	64.2	79.4	103.8	58.6	183.0	64.2	19.2	29.6	9.2	106.8	240.6	1130.6
1994	167.6	95.6	141.0	120.2	216.0	43.8	121.8	121.8	186.0	80.0	25.2	172.2	1491.2
1995	147.2	131.6	233.0	84.4	66.6	192.4	115.2	190.6	186.0	140.2	105.4	236.8	1829.4
1996	182.6	69.6	163.4	87.4	103.6	63.2	47.4	118.4	111.2	179.6	50.0	27.4	1203.8
1997	170.2	223.2	33.4	38.0	32.4	1.6	64.6	3.8	20.8	0.0	54.8	107.6	750.4
1998	363.2	158.6	236.4	65.2	130.8	81.8	258.0	172.8	150.2	135.6	180.6	144.8	2078.0
1999	56.8	112.2	68.4	93.2	102.8	72.8	18.4	121.0	44.2	81.0	83.4	178.4	1032.6
2000	142.6	35.8	221.2	36.0	171.6	117.0	186.0	267.2	25.0	53.0	171.0	295.0	1721.4
2001	35.2	174.4	140.0	78.0	19.4	182.8	95.0	58.0	45.0	14.4	81.0	147.0	1070.2
2002	124.8	152.0	237.0	103.0	49.0	120.0	119.0	25.0	39.2	80.6	105.0	37.0	1191.6
2003	203.2	96.8	146.2	61.4	99.0	12.6	148.0	134.2	113.8	84.0	42.6	77.8	1219.6
2004	57.0	147.0	252.0	74.0	170.0	27.4	38.4	15.8	46.4	91.2	91.4	38.0	1048.6
2005	303.0	188.0	304.0	137.0	153.4	81.2	43.4	279.8	54.8	143.0	141.4	28.8	1857.8
2006	148.0	186.0	114.6	46.0	15.2	121.4	94.0	31.0	132.8	27.0	698.8	712.4	2327.2

Station Name:	Port Moresby W O			
Lat:	9.45	South		
Long:	147.20	East		
Elevation:	42.0	Metres		

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	246.0	109.0	233.0	41.0	162.0	57.0	21.0	15.0	5.0	9.0	283.0	240.0	1421.0
1974	321.0	335.0	49.0	108.0	74.0	22.0	25.0	3.0	56.0	9.0	6.0	53.0	1061.0
1975	153.0	141.0	280.0	125.0	139.0	260.0	3.0	23.0	63.0	77.0	135.0	228.0	1627.0
1976	378.0	162.0	137.0	104.0	159.0	145.0	8.0	12.0	0.0	129.0	97.0	206.0	1537.0
1977	227.8	219.0	123.2	178.0	131.2	18.6	106.6	35.8	66.6	39.6	3.2	74.6	1224.2
1978	187.0	186.0	107.0	54.0	48.0	1.0	69.0	24.0	21.0	1.0	217.0	92.0	1007.0
1979	233.0	105.0	321.0	125.0	64.0	7.0	74.0	0.0	1.0	19.0	9.0	41.0	999.0
1980	256.0	123.0	150.0	6.0	0.0	2.0	1.0	17.0	5.0	0.0	8.0	212.0	780.0
1981	303.2	82.8	153.8	155.6	56.2	50.0	14.2	23.0	7.6	49.6	52.4	291.4	1239.8
1982	266.0	88.4	326.2	45.8	68.6	1.0	2.8	134.8	0.0	0.6	0.4	3.2	937.8
1983	53.2	101.4	162.6	91.6	77.2	16.8	24.8	10.4	25.2	46.4	32.0	161.0	802.6
1984	207.4	288.4	155.8	55.8	18.2	45.4	27.2	31.6	5.2	41.8	20.8	126.0	1023.6
1985	129.2	114.0	498.4	105.6	50.4	97.6	23.6	2.8	52.0	49.2	174.8	65.4	1363.0
1986	99.0	140.2	186.2	320.4	10.8	71.8	3.6	6.8	8.2	44.0	0.6	45.8	937.4
1987	215.0	207.2	161.4	105.4	0.0	0.0	2.6	0.0	17.4	7.4	4.8	129.0	850.2
1988	188.4	95.8	220.4	81.6	148.4	82.6	12.0	5.0	27.2	17.2	154.4	160.0	1193.0
1989	88.0	118.4	275.6	228.6	42.8	19.0	89.0	44.6	25.2	129.0	127.2	138.2	1325.6
1990	421.4	149.0	366.2	63.2	31.2	174.2	15.0	58.6	62.2	12.8	31.2	49.4	1434.4
1991	322.4	104.6	100.4	50.6	114.4	3.6	2.4	43.8	5.6	31.4	45.4	68.2	892.8
1992	127.2	91.8	83.6	83.6	12.4	27.8	18.4	3.0	14.4	7.0	7.8	162.0	639.0
1993	192.2	86.6	49.8	86.8	108.2	0.6	4.4	0.0	8.2	30.8	7.8	78.8	654.2
1994	78.8	270.2	152.2	105.4	403.6	3.4	7.8	78.8	0.2	1.6	4.4	14.8	1121.2
1995	130.2	308.8	288.6	219.6	114.4	2.4	3.0	41.2	33.6	109.2	13.8	134.0	1398.8
1996	206.2	173.6	194.0	128.2	120.0	1.4	111.8	3.2	18.2	86.4	46.2	291.2	1380.4

1997	181.6	221.0	205.2	48.0	52.6	1.2	21.6	0.0	7.8	0.0	0.0	88.8	827.8
1998	81.0	105.2	263.0	87.8	61.2	1.4	25.6	60.8	7.2	40.0	201.4	162.0	1096.6
1999	137.8	125.8	253.2	238.0	51.0	10.4	90.2	10.2	18.8	25.0	191.4	117.0	1268.8
2000	146.0	242.0	350.0	326.0	304.6	43.4	31.0	9.2	7.6	11.6	49.6	50.4	1571.4
2001	270.2	293.4	281.8	201.0	5.0	60.4	30.8	32.2	5.0	9.0	74.0	103.0	1365.8
2002	86.0	139.0	188.8	162.2	31.0	24.0	133.0	0.0	7.0	6.0	32.0	27.0	836.0
2003	182.0	245.0	117.0	105.6	95.0	50.0	14.0	12.0	10.6	14.2	129.4	168.2	1143.0
2004	195.0	296.0	160.0	61.2	44.0	456.2	0.4	0.4	41.0	71.8	40.0	97.6	1463.6
2005	290.4	93.8	271.6	309.8	57.8	11.2	4.0	1.2	29.0	1.0	24.0	177.2	1271.0
2006	296.0	181.6	231.6	220.6	88.6	23.8	5.6	1.2	66.6	0.0	45.6	12.2	1173.4

Station Name: Tokua W O

Lat: 4.33 South

Long: 152.2 East

Elevation: 10.0 Metres

YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
1995	**235.4**	135.4	170.4	240.0	205.6	100.8	102.6	118.8	344.2	84.4	102.4	177.2	2017.2
1996	106.2	135.4	275.6	198.0	288.2	91.4	149.4	104.8	79.4	157.4	108.8	141.8	1836.4
1997	256.2	274.6	370.6	145.4	175.2	68.4	186.4	76.6	153.2	98.6	2.8	126.4	1934.4
1998	60.2	135.8	229.0	199.8	258.4	238.6	246.2	269.2	193.4	120.2	158.8	200.0	2309.6
1999	63.6	181.4	75.0	46.0	178.0	279.0	251.6	274.2	85.0	88.0	147.0	340.0	2008.8
2000	120.0	54.0	88.0	57.0	226.0	185.0	213.0	161.0	103.8	159.0	225.0	218.0	1809.8
2001	174.0	575.6	326.6	343.4	190.6	143.0	347.0	170.8	84.0	232.0	198.4	127.0	2912.4
2002	126.0	125.0	179.0	135.4	213.0	268.0	238.0	33.0	89.4	186.2	347.0	119.0	2059.0
2003	363.0	247.0	269.0	227.4	346.0	100.0	200.8	457.2	460.4	175.8	116.2	180.6	3143.4
2004	188.6	342.0	209.0	143.0	315.0	276.0	418.0	204.0	89.8	93.0	69.0	92.0	2439.4
2005	216.4	65.4	48.4	328.8	129.6	49.0	115.6	183.4	149.2	108.0	91.8	320.0	1805.6
2006	164.8	244.4	196.4	230.2	152.2	223.0	391.8	454.4	184.6	51.8	148.4	200.0	2642.0

Station Name: Vanimo W O

Lat: 2.70 South
Long: 141.30 East
Elevation: 3.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1996	97.0	182.4	194.4	198.8	290.0	267.4	112.0	187.4	193.0	212.6	272.2	96.8	2304.0
1997	197.0	361.6	527.8	183.0	154.8	143.4	262.8	38.0	41.2	141.2	164.0	112.8	2327.6
1998	26.4	596.6	431.2	389.0	425.2	218.8	140.8	304.0	192.6	245.0	350.0	192.6	3512.2
1999	149.8	308.6	265.0	381.0	323.0	296.2	244.8	212.2	155.8	153.2	366.6	277.4	3133.6
2000	176.6	85.4	295.2	278.2	423.4	223.6	174.0	162.6	80.0	290.6	170.4	288.6	2648.6
2001	41.4		286.4	234.8	194.2	195.4	65.4	89.4	99.8	132.8	278.0	560.0	
2002	203.0	251.0	236.0	200.0	379.0	216.0	182.0	193.0	292.0	68.8	201.0	103.6	2525.4
2003	278.6	270.2	104.2	300.2	114.0	309.4	245.0	185.2	148.2	194.4	202.0	214.8	2566.2
2004	321.0	270.0	125.0	176.0	276.0	283.0	219.0	149.0	151.6	98.8	218.0	181.0	2468.4
2005	351.2	151.2	383.6	403.0	169.2	168.4	270.6	344.0	429.4	100.6	199.8	254.6	3225.6
2006	395.2	162.2	363.0	314.0	205.8	194.4	203.4	182.2	106.8	243.4	138.0	90.2	2598.6

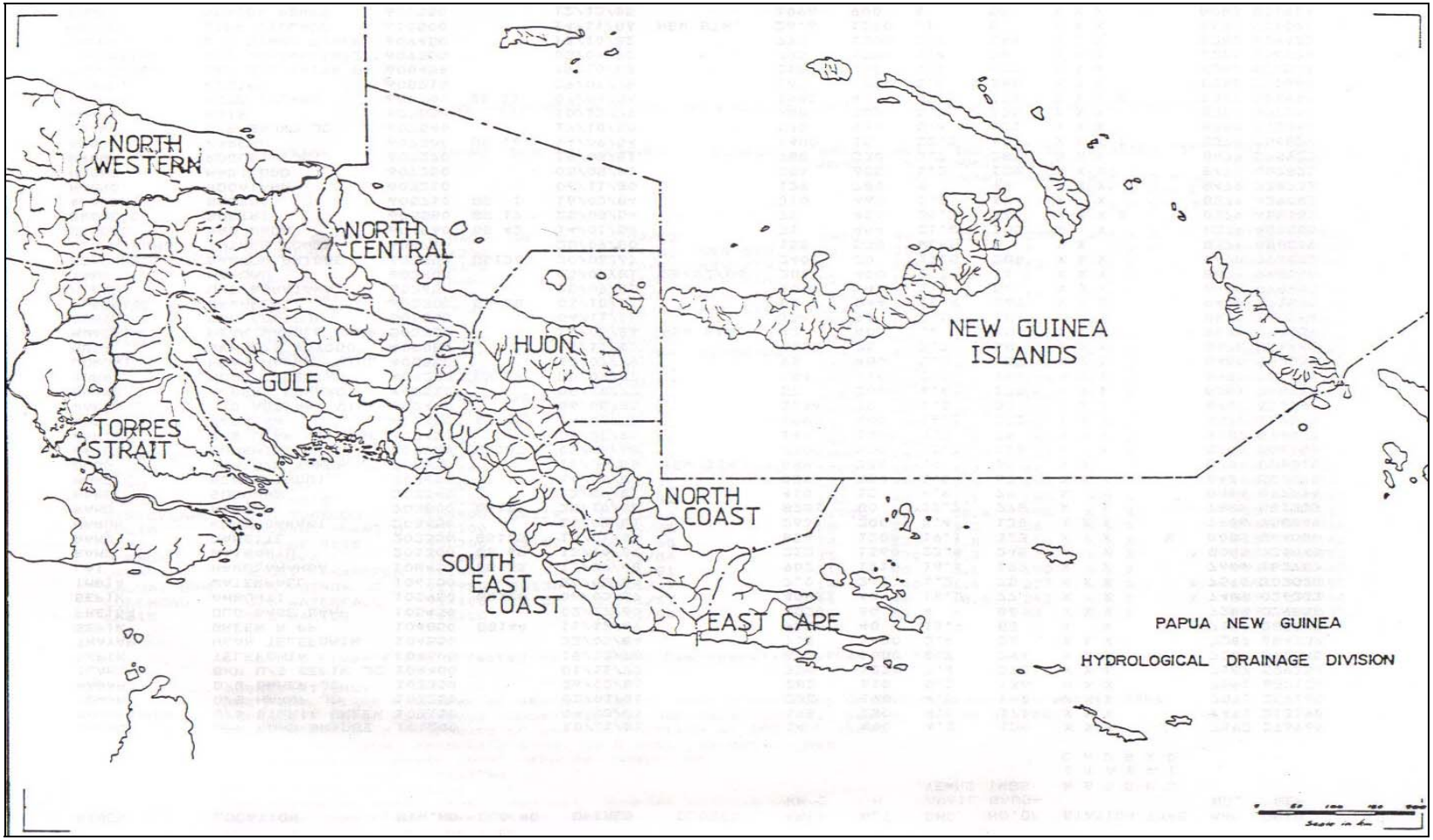
Station Name: Wewak W O
Lat: 3.58 South
Long: 143.67 East
Elevation: 5.0 Metres

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1973	144.0	154.0	144.0	239.0	339.0	336.0	282.0	117.0	234.0	291.0	290.0	191.0	2761.0
1974	89.0	197.0	290.0	292.0	195.0	277.0	307.0	109.0	171.0	225.0	188.0	120.0	2460.0
1975	141.0	117.0	223.0	142.0	267.0	190.0	175.0	212.0	205.0	359.0	313.0	148.0	2492.0
1976	208.0	216.0	49.0	158.0	117.0	172.0	191.0	374.0	141.0	330.0	104.0	232.0	2292.0
1977	102.0	132.0	173.0	87.0	219.0	180.0	130.0	80.0	57.0	175.0	93.0	121.0	1549.0
1978	163.0	40.0	331.0	129.0	273.0	204.0	138.0	128.0	180.0	292.0	285.0	180.0	2343.0
1979	136.0	96.0	189.0	207.0	226.0	125.0	127.0	97.0	193.0	169.0	325.0	162.0	2052.0
1980	57.0	200.0	193.0	204.0	273.0	184.0	297.0	112.0	193.0	147.0	186.0	179.0	2225.0
1981	134.0	80.0	133.0	229.0	220.0	272.0	257.0	232.0	185.0	96.0	240.0	129.0	2207.0
1982	73.0	182.0	169.0	167.0	252.0	219.0	198.0	185.0	211.0	176.0	114.0	103.0	2049.0

1983	132.0	168.0	187.0	385.0	109.0	101.0	70.0	41.0	89.0	324.0	220.0	104.0	1930.0
1984	28.0	125.0	172.0	271.0	310.0	189.0	155.0	220.0	186.0	233.0	110.0	160.0	2159.0
1985	164.0	157.0	103.0	136.0	150.0	228.0	200.0	247.0	197.0	197.0	262.0	108.0	2149.0
1986	194.0	33.0	213.0	181.0	55.0	177.0	126.0	255.0	206.0	278.0	273.0	143.0	2134.0
1987	142.2	127.4	56.0	101.6	55.6	103.2	33.0	39.6	180.4	117.4	352.0	136.6	1445.0
1988	77.8	115.4	184.8	84.0	307.4	251.8	106.4	407.4	235.6	394.6	110.6	227.4	2503.2
1989	157.4	108.2	164.8	198.4	192.6	209.6	260.2	293.6	147.2	249.0	153.2	77.8	2212.0
1990	241.2	82.6	132.0	163.0	249.4	255.4	251.6	251.2	201.4	348.2	253.8	183.0	2612.8
1991	119.4	142.6	71.6	256.0	97.6	142.6	386.6	92.6	55.0	180.2	129.8	110.8	1784.8
1992	35.8	215.0	115.8	136.8	165.8	67.0	168.0	120.2	149.4	301.2	195.6	115.8	1786.4
1993	148.6	227.4	66.8	134.8	38.6	356.6	53.8	104.0	28.6	197.2	114.8	206.2	1677.4
1994	12.8	67.0	104.6	145.8	112.6	97.6	150.2	64.4	131.6	116.2	150.8	305.0	1458.6
1995	110.2	74.4	175.6	124.6	211.2	212.8	210.0	91.6	32.4	311.6	236.8	271.8	2063.0
1996	7.6	240.6	205.4	267.8	242.4	180.8	272.0	181.8	248.2	212.6	140.8	172.2	2372.2
1997	165.2	91.0	159.8	510.4	277.6	219.0	278.2	121.4	11.2	170.6	141.4	135.4	2281.2
1998	92.4	311.6	173.6	395.0	356.4	229.0	167.0	141.4	128.8	236.2	299.8	165.8	2697.0
1999	146.8	123.0	181.0	351.4	451.0	226.0	169.0	408.0	114.0	271.0	249.0	61.0	2751.2
2000	122.0	90.0	156.0	219.0	209.0	307.0	269.0	263.0	44.0	239.0	247.0	240.0	2405.0
2001	130.0	248.4	95.0	288.8	191.0	192.0	450.0	146.0	156.0	178.0	212.0	219.0	2506.2
2002	87.0	84.0	301.0	354.0	283.0	190.0	183.0	121.0	118.0	109.6	189.0	35.0	2054.6
2003	151.0	63.0	94.6	134.0	177.2	164.6	243.6	184.2	198.6	285.8	152.2	304.2	2153.0
2004	189.0	75.0	85.0	174.0	241.0	247.0	52.0	44.2	176.0	134.0	193.8	236.0	1847.0
2005	111.2	127.4	170.2	230.6	313.4	118.6	177.8	98.8	257.6	204.0	125.0	142.6	2077.2
2006	172.2	210.8	204.8	186.4	136.0	243.9	206.4	162.0	220.6	283.8	177.6	169.2	2373.7

Annex 4: Surface hydrology map of PNG

Source: Nix H.A. et al. 1996



Annex 5: NDO Table showing Natural Disasters in PNG - 1997 to 2002

Source: NDO Library

REFLECTION MAJOR DISASTERS IN FIVE YEARS (1997 – 2002)					
ID No	Disaster (Calamity)	No. of Occurrence	Population Affected	Lives Lost	Estimated Humanitarian Response & Rehabilitation Cost in Kina
01	Volcanic Activities	4	46,358		4,058,870
02	Floods	22	480,517		13,709,4423
03	Landslides	22	19,707	128	1,090,000
04	Searise	1	3,227		620,000
05	Famine	1	2,000		200,000
06	Earthquakes	4	221,282	2	18,674,000
07	Cyclone	1	158,780		4,960,760
08	Drought & Frost	1	2,326,830		29,073,496
09	Disease Outbreak	2	196	11	?
10	Hailstorm	3	2,259		250,000
11	Tsunami	1	12,427	2,227	6,008,100
12	Chemical Spill	1	750		46,000
13	Kerosene Explosion	1	39	5	35,826
14	Total	63	3,274,375	2,373	K78,728,475

Annex 6: Questionnaire response from NWS

			Hydrometeorological Data Collection					
1.0	**Describe the current meteorological data collection network throughout the country.**							
	Location	**Site**	**Latitude**	**Longitude**	**Elevation**	**Data**	**Types of**	**Reporting**
	Name	**Number**	**(south)**	**(east)**	**(metres)**	**Collector**	**Parameters**	**frequency**
	Madang W. O	10003	05.22	145.78	4.0	Mr. Augustine Kuanangi	1.Maximum Temperatures	24 hourly
						Mr. Graham Mamo	2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							5.Evaporation	24 hourly
							6. Terrestrial Minimum Temperatures	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Momote W.O	15003	02.05	147.42	4.0	Mr. Himson Waffi	1.Maximum Temperatures	24 hourly
						Mr. Tadi Baras	2.Minimum Temperatures	24 hourly
						Ms. Myra Selan	3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							5.Evaporation	24 hourly
							7.SLP	3-hourly

							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
							15.Upper Air Winds	9am & 3pm
	Kavieng W.O	20001	02.58	150.8	7.0	Mr. Gabriel Kunal Olua	1.Maximum Temperatures	24 hourly
						Mr. Charles Saupaii	2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							6. Terrestrial Minimum Temperatures	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Goroka W.O	25002	06.07	145.38	1587.0	Mrs. Daisy Siraba	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							7.SLP	3-hourly

							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Nadzab W.O	30045	06.56	146.72	70.0	Mr. Yaeng Busop	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Hoskin W.O	35043	05.47	150.42	8.0	Mr. Allan Mihen	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly

							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Tokua W.O	40056	04.38	152.37	10.0	Mr. Brian Sirip	1.Maximum Temperatures	24 hourly
						Mr. John Wiringa	2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Misima W.O	50033	10.67	152.83	6.0	Mr. McDonald Sideni	1.Maximum Temperatures	24 hourly
						Mr. Konsy Konaberi	2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							5.Evaporation	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly

							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Gurney W.O	50059	10.32	150.33	20.0	Mr. Steve Adarei	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							5.Evaporation	24 hourly
							6. Terrestrial Minimum Temperatures	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Port Moresby W.O	55006	09.45	147.2	42.0	Mr. Eminon Sowape	1.Maximum Temperatures	24 hourly
						Mr. Kila Sam	2.Minimum Temperatures	24 hourly
						Mr. Gabriel Tuno	3.Rainfall	24 hourly
						Mrs. Elizabeth Virobo	4.Sunshine duration	24 hourly
						Ms. Boge Morea	5.Evaporation	24 hourly
						Mr. Ben Enos	6. Terrestrial Minimum Temperatures	24 hourly
						Ms. Mary John	7.SLP	3-hourly
						Mr. Sakumai Kanawi	8.MSLP	3-hourly
						Mr. Eddie Besi	9.Wind Direction	3-hourly

							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
							15.Upper Air Winds	9am & 3pm
	Daru W.O	65029	09.08	143.2	6.0	Mr Peter Warupi	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							5.Evaporation	24 hourly
							6. Terrestrial Minimum Temperatures	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Kiunga W.O	65061	06.08	141.18	8.0	Ms Posa Kavora	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							7.SLP	3-hourly

							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Wewak W.O	80002	03.58	143.67	5.0	Mr Cornelius Gembod	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							4.Sunshine duration	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly
							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Vanimo W.O	85012	02.70	141.3	3.0	Mr Francis Anuma	1.Maximum Temperatures	24 hourly
							2.Minimum Temperatures	24 hourly
							3.Rainfall	24 hourly
							7.SLP	3-hourly
							8.MSLP	3-hourly
							9.Wind Direction	3-hourly

							10.Wind speed	3-hourly
							11.Dry & wet bulb temperatures	3-hourly
							12.Dewpoint temperatures	3-hourly
							13.Total cloud cover	3-hourly
							14. Relative Humidity	3-hourly
	Remark:	**Legend Keys**						
	W.O	Weather Office						
	SLP	Station Level Pressure						
	MSLP	Mean Sea-Level Pressure						

2.0	**List other additional data available to NWS through satellite imagery**					
		1. GMS				
		2. GOES				
		3. METSAT				

3.0	**List types of data processing, analysis and forecasting work carried out at NWS**								
	Data Processing		Data Analysis				Reporting services/Publications		
	1. Manual EDP in spreadsheet		1. Correlation				1. 3-monthly rainfall outlook		
			2. Normals						
	2. Software based EDP using		3.Standard deviation				2. 3-monthly seasonal outlook??		
	Climsoft, SCOPIC , instat,		4. Interpolation						
	GIS rainman		5. Anomalies						
			6. Mean						
			7. Frequency						
			8. Median						

4.0	**What inter-linkage does NWS have**							

	with Government and NGOs?							
	Organisation		Nature of relationship		Liaison frequency			
	National Disaster Centre		National Disaster Awareness & preparedness committee		Bi-monthly			
	Eda Ranu		Monthly Seasonal Outlook		Monthly			
	NARI		Seasonal Outlook Briefing		Monthly			
	Water Board		Climate Briefing		Quarterly			

Annex 7: PNG Waterboard Current Water Supply Establishment

	Location	Source	Method of Extraction	Degree of Treatment	System Production Capacity	No. of Households served	Future plans within next 10 years
1	LAE	Groundwater – 7 Bores at Taraka	Submersible Pumps	Chlorination only	36 ML/day	7,600	Source augmentation and system expansion. (after 2010)
2	MADANG	Gum River	River Intake / Pumping	Sedimentation Filtration and Chlorination	15 ML/day	2,600	Expansion of distribution system to new service areas
3	WEWAK	Brandi River	River Intake / Pumping	Sedimentation Filtration and Chlorination	6.5 ML/day	2,200	Source and Treatment Works to be upgraded.
4	MT.HAGEN	Wara Kum	River Intake / Pumping	Sedimentation Filtration and Chlorination	6.5 ML/day	3,100	Source and Treatment Works to be upgraded.
5	RABAUL / KOKOPO	Groundwater	Submersible Pumps	Chlorination only	3.0 ML/day	1,600	Rabaul – System Rehabilitation Kokopo – Rehabilitate E&M Assets
6	KIMBE	Groundwater	Submersible Pumps	Chlorination only	1.5 ML/day	1,600	Rehab source and distribution
7	KAVIENG	Groundwater	Submersible Pumps	Chlorination only	1.5 ML/day	1,100	Rehab source and distribution
8	LORENGAU	Lorengau River	Gravity-fed from intake pond	Sedimentation Filtration and Chlorination	2 ML/day	300	Expand system to growth areas
9	ALOTAU	Goilawaligena River and Groundwater	Gravity fed from river & Submersible bore pumps	Chlorination only	2.2 ML/day	1220	- Possibly abandon river source and maximise groundwater source capacity - Rehab distribution system

10	POPONDETTA	Banguho River	River intake / Pumping	Sedimentation Filtration and Chlorination	1.0 ML/day	850	Alternative source – groundwater and asset rehabilitation

	LOCATION	**SOURCE**	**Method of Extraction**	**Degree of Treatment**	**System Production Capacity**	**No. of Households served**	**Future plans within next 10 years**
11	DARU	Binaturi River	River intake / Pumping – via submarine pipe	Filtration and Chlorination	1.0 ML/day	900	Asset Rehabilitation and upgrading through partnership with PNG Sustainable
12	KUNDIAWA	Ur Spring	Gravity fed to treatment plant	Chlorination	1.5 ML/day	900	Asset Rehabilitation
13	BEREINA	Borehole	Solar submersible pump with diesel backup	Chlorination	0.2 ML/day	60	Asset Rehabilitation
14	KWIKILA	Borehole	Submersible pump	Chlorination	0.2 ML/day	100	Asset Rehabilitation
15	MUTZING	Borehole	Submersible pump	Chlorination	0.2 ML/day	100	Asset Rehabilitation

Note: All water supply systems listed above have fully reticulated distribution systems with storage facilities and all service connections are individually metered.

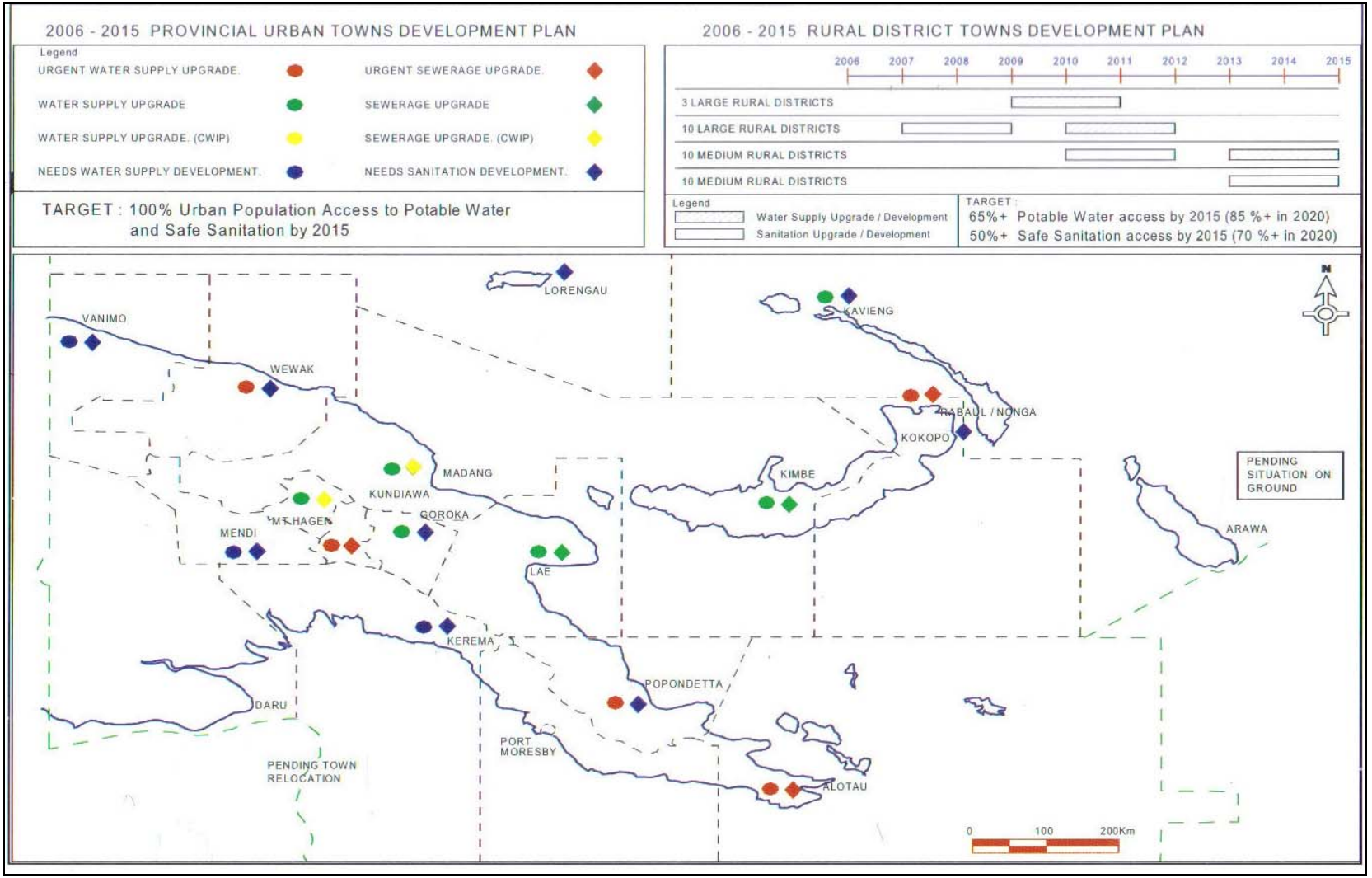
Annex 8: PNG Waterboard Current Sewerage Establishment

	Location	Collection system	Degree of Treatment before disposal	Receiving waters	No. of Households served	Future plans within next 10 years
1	LAE	Reticulated Sewerage system - Partial coverage	(1) Sewage Lagoons (2) Coarse screening prior to sea outfall	(1) Bumbu River (2) Ocean – Huon Gulf	1,500	- Expand reticulation and improve treatment – particularly treatment system prior to sea outfall - Ensure better management of treatment systems & monitoring of quality.
2	MT.HAGEN	Reticulated Sewerage System	Sewage Lagoons with Chlorination of effluent	Wara Kum	365	- Current project in the pipeline to upgrade treatment works - Proposed expansion of system to cover whole town
3	KUNDIAWA	Limited Reticulation	Trickling Filter (Deteriorated)	River discharge	30	Upgrade sewage treatment works and expand reticulation
3	KIMBE	Reticulated Sewerage limited to School and Hospital	Sewage Lagoons	River discharge	150	Upgrade sewage treatment works and expand and/or develop new reticulation system to other parts of town
4	ALOTAU	Limited Reticulation	Large septic tanks on shore front	Ocean outfall	130	Current proposal for CBD sewerage development (ADB-Funded project) on-hold due to various factors
5	POPONDETTA	Limited reticulation for Hospital	Sewage Lagoons	Banguho river	15	Increase treatment capacity & expand system to other areas within town.
6	RABAUL	Limited reticulation for volcano-affected area	No treatment (after volcano) Direct discharge to sea	Sea – Blanche Bay	20	Installation of suitable treatment options for Rabaul and seek funding for development of Kokopo Sewerage

Note: Current work in progress includes the following:

- ⇒ Low Cost Sanitation Programme (Japanese Fund for Poverty Reduction (with some ADB funding) - Provincial Towns WS&S Project)
  - o VIP Latrines for urban fringe areas in Lae, Mt.Hagen, Alotau and Wewak involving LLG, community and beneficiary participation
  - o Septic Tanks developed in Madang – also involving LLG, Communities and beneficiaries.
- ⇒ New Sewerage developments
  - o Madang Sewerage – Currently under construction – ADB Provincial Towns WS&S Project
  - o Mt. Hagen Sewage Treatment Ponds – to be upgraded under the same project
  - o Alotau Sewerage Development – on hold, pending.

Annex 9: Map showing PNG Waterboard urban water and sanitation establishment and targets for the next decade



Annex 10: Questionnaire response from PNG Waterboard

Financial Management

1.0 How does the organisation derive the tariffs that are imposed on customer?

In the year 2005 – ICCC developed a 5 year price path for PNG Waterboard (and a separate one for Eda Ranu as well). The price path was developed taking into account operational cost-recovery, return on investment as well as affordability of customers. The current agreed price path formula for PNG Waterboard is 7.8 x CPI – applied annually from 2005 to 2009. Currently there are three tiers. The first tier being a flat rate for consumption up to 12 KL This is referred to as a "Lifeline Tariff" – which addresses the basic needs of low income consumers. The next two tiers are gradually increased rates as a measure towards encouraging people to save water and save money. The tariff is a Uniform National Tariff – i.e. the same tariff is applied in all operational centres, regardless of operational cost variations. (This allows for cross-subsidisation between larger profitable centres and smaller non-profit centres)

2.0 What are the current tariffs for water supply and sewerage?

The 2007 - Tariff is as outlined below:

1.0	**Water Supply**	
1.1	**Consumption Charges**	
1.1.1	Up to 12 Kilo Litres	PGK 7.20 Minimum Charge
1.1.2	13 to 30 Kilo Litres	PGK 2.145 Per Kilo Litre
1.1.3	Above 30 Kilo Litres	PGK 2.46 Per Kilo Litre
1.2	**Water Tankers**	
1.2.1	Up to 10 Kilo Litres	PGK 25.00
1.2.2	Above 10 Kilo Litres	PGK 2.50 Per Kilo Litre
2.0	***Sewerage Services***	
2.1	**Non Industrial Customers**	
2.1.1	Up to 12 Kilo Litres	PGK 6.60 Minimum Charge
2.1.2	Above 12 Kilo Litres	PGK 0.65 Per Kilo Litre
2.2	**Industrial Customers**	PGK 1.10 Per Kilo Litre (Flat)
2.3	**Sludge Tankers**	
2.3.1	Up to 10 Kilo Litres	PGK 6.60
2.3.2	Above 10 Kilo Litres	PGK 0.66 Per Kilo Litre
3.0	***Connection Fees***	
3.1	Standard Connection – Water	Free
3.2	Non Standard Connection – Water	As Per Quotation
3.3	Standard Connection – Sewerage	As Per Quotation
3.4	Non Standard Connection – Sewerage	As Per Quotation

3.5	Reconnection – Water	PGK32.00 per reconnection
4.0	***Standby Fees***	
4.1	Water	PGK 1.10 Per Kilo Litre
4.2	Sewerage	PGK 0.65 Per Kilo Litre

3.0 As a statutory body, does PNG Waterboard receive any Government funding to supplement the revenue raised?

PNG Waterboard has never received any subsidy support from the Government to supplement recurrent operational budget. The only funding assistance made available is counterpart funding specifically for donor funded development projects.

4.0 What economic instruments has PNG Waterboard used to obtain external/international funding for major expansion of existing facilities or new infrastructure?

All Donor/International funding for development purposes is facilitated through the Department of National Planning and Monitoring. The main donor over the years has been the Asian Development Bank – This is in the form of Concessional Loans for infrastructure development and Technical Assistance Grants for capacity building studies and project preparatory studies. The Government is the Guarantor in all these loan agreements. Recently, the Governments of Japan and Australia have separately provided grant aid assistance for development projects – which have since been completed successfully.

The European Union has also initiated arrangements for grant aid funding for proposed developments in selected District Centres.

The Asian Development Bank has commended PNG Waterboard for prudent management of its business affairs, the ability to earn a rate of return and successful project implementation (*which includes implementation of recommended institutional reforms to improve performance*).

5.0 What difficulties is the organisation facing with the current financing arrangements?

(a) Inability to reinvest in the business due to relatively low ROI; hence heavy dependence on donor funding. Additionally, donors are indicating a shift from consessional lending to normal lending, with increased demands for local counterpart (State) funding inputs.
(b) Grant Aid funding through bilateral relationships is not readily available – due to low priority being accorded to the water and sanitation sector.
(c) The burden of managing 11 out of 15 centres which are non-profitable (out of goodwill) - drags down the Waterboard's bottom line.
(d) The rising cost of goods and services – for new developments or replacement of existing assets, necessitates continuous tariff increase.
(e) Community service obligations require Government subsidy – which has not been available.
(f) Future business growth areas (smaller provincial towns and district centres) are not expected to be economically feasible, due to the small customer base and lack of support facilities as against the high cost of capital.

6.0 How can the current financial hindrances be overcome?

- The ICCC approved 5-Year price path (2005-2009) locks down the tariff structure and revenue generation assumptions up to year 2009. It takes into account development.
- Whilst water supply and sanitation development programmes are in place, the challenge is in securing external funding (ideally grant aid or concessional loans), for implementation.
- A proposed CSO Policy seeks approval for reinvestment of profits into CSO activities, in lieu of dividend payments to the State.
- A Draft National Water Policy has been drawn up which looks at creation of an Apex body to regulate the sector – as a separate entity from the service delivery agencies.
- The apex body – to be known as the National Water Authority would then be responsible for regulation of the industry, overall planning, compliance and licensing and other non-operational activities.

- Service delivery agencies such as WB – Operations, Eda Ranu, Goroka-ULLG, and other private operators would be allowed operate independently.
- CSO activities would be separated from purely commercial operations, to eliminate conflicting objectives.

Annex 11: Updated PNG National Action Plan on Sustainable Water Management

PAPUA NEW GUINEA NATIONAL ACTION PLAN ON SUSTAINABLE WATER MANAGEMENT Updated April 2007

THEMES	KEY MESSAGES	ACTIONS REQUIRED	RESPONSIBLE AGNECIES	STATUS
1.0 WATER RESOURCES MANAGEMENT	• There is a critical need for improved capacity to collect, process and analyse hydrological, hydrogeological and meteorological information for the sound management of water resources to cater for its various uses under normal conditions and in times of water related disasters.	• Upgrade and implement a nation wide hydrological, meteorological and water quality data collection network using models such as Pacific Hydrological Cycle Observing System (HYCOS)	• DEC; NWS; PNGGS; DoH; PNGWB & PNG Power; DPLLG; Resources Developers; SOPAC with support from international agencies like WMO and UNESCO.	HYCOS project will assist in this endeavour. The PNG component will involve upgrading of the hydrometric network in the Laloki catchment and improved flood and drought forecasting and mitigation.
		• Develop career development paths and training programmes for Hydrographers, Hydrologists, Hydrogeologists and Climatologists, identify suitable courses and job attachments locally, within the region and internationally and secure funding to cover the associated expenses.	• DEC; NWS; DoH; PNGGS; PNGWB & PNG Power; DPLLG; Service Providers; SOPAC with support from international agencies such as WMO and UNESCO.	One person from PNG has already participated in a SOPAC run regional course on Hydrography.
		• Facilitate public participation in water quality testing programmes as a useful vehicle to raise environmental awareness in local communities.	• DEC; DoH; DPLLG; Communities; NGOs; CBOs; Private Sector; Donors (funding); Regional Organisations	To be trialled in the Laloki Catchment Demonstration project.

	Policies and strategies must be developed and implemented to improve the management of water resources and surface and groundwater catchments to cater for all uses and to maintain environmental integrity.	• Introduce sound catchment management practices in all watershed areas involving all stakeholders including regulators, developers and communities	▪ DEC; NWS; PNGGS; PNGWB; DPLLG; Communities; NGOs; Private Sector; Donors (funding)	To be trialled under the Laloki Catchment Demonstration project.
2.0 PNG VULNERABILITY	▪ Shift the focus for disaster management from disaster response to hazard assessment and risk management.	• Design and implement a capacity-building program to improve coordination between NDES, NWS, DEC, PNGGS, and other relevant national and provincial agencies to establish effective disaster warning, preparedness, relief and rehabilitation systems.	▪ NDES; NWS; DNPRD; DEC; DoF; SOPAC with support from international agencies like WMO; Donors (funding); International agencies like WMO and National Institute of Water and Atmospheric research, New Zealand (NIWA)	Laloki project will also address partnerships and dialogue in hazard assessment and risk management.
		▪ Establish a system for effective information sharing between DEC, National Weather Services & NDO on hydrology, climate variability & weather.	▪ DEC; NWS; NDES; Service providers; Resource Developers; Donors (funding); SOPAC with support from international agencies like IHP, WMO, UNESCO	Pacific Environment Information Network is currently being installed by SPREP and will look at information sharing.

		• Use appropriate technologies for small islands and remote inland areas, which will withstand prolonged natural disasters such as droughts.	▪ DNPRD; DPLLG; Communities; PNGWB; other service providers. NGOs; Donors (funding); SOPAC, SPREP	Laloki project will also look into groundwater management and data collection.
		• National Government to provide adequate resources to NDES and NWS to better assess and manage disasters	NWS; NDES; DNPRD; DOM; Donors (funding)	National budgetary support is insufficient.
3.0 AWARENESS	▪ There should be a clear strategy at the national and local level to enable open participation of all communities in sustainable water and wastewater management.	▪ Design and implement a national communication strategy on sustainable water and wastewater management. ▪ The above strategy must ensure community participation during planning and implementation of water related projects to strengthen ownership and ensure sustainability	▪ DEC; NWS; PNGWB & PNG Power; Resources Developers; International and Regional Donors	

	▪ Information on sustainable water use and management should be readily accessible to all sectors of the society and the general public.	▪ Improve communication and coordination of all stakeholders in sustainable water and wastewater management. ▪ Review and improve information compilation and provision to the public. ▪ Encourage equal participation by all women in all water related issues. ▪ Provide training public education and awareness.	▪ DEC; DoH; NWS; PNGGS; PNGWB;DNPRD;DYSW; Communities; NGOs; Donor (funding) • As above	Commenced in the mining project areas on wastewater concerns and women participation
	▪ Water and sanitation education should be integrated into the formal education system.	▪ Included water resources management and sanitation into the primary education curriculum.	▪ DNPRD; DE; Institutions; NGOs; Donors; Regional Organisations	A video is being planned for the Laloki Demonstration project.

4.0 TECHNOLOGY	▪ There should be appropriate institutions, infrastructure, and information to support sustainable water and wastewater management.	▪ Encourage the use of appropriate technologies for water supply and sanitation services to urban and rural areas taking into account affordability and long-term sustainability of systems.	▪ DEC; NWS; PNGWB & PNG Power; Service Providers; HP, WMO and Regional Organisations and Donors	A major EU funded rural water supply sanitation project is currently underway.
		▪ Provincial and Local Level Governments and Communities to plan for provision of water supplies to rural communities with assistance from Line Agencies, utilities, NGOs and Donors.	▪ DEC; DoH; DPLLG; Communities; NGOs; Donors; Regional Organisations	
		▪ Develop Urban and Rural Sanitation programmes through a participatory approach to ensure sustainability.	▪ DNPRD; DoH; PNGWB;DEC; DPLLG; Service Providers; Donors; NGOs; Communities	
		▪ Develop programmes and provide funding for or solicit donor assistance towards provision of water supply to District Centers	▪ DoH; DoW; PNGWB; DNPRD; Resource Developers; Service providers; Communities; NGOs; Donors; Regional Organisations	
		▪ Review and update current standards for water and sanitation technology to keep in pace with developments in the rest of the world.	▪ DoH; PNGWB; Service Providers; DEC	
		▪ Specific training programmes should be developed, resulting in sustainable levels of skilled and knowledgeable people and communities within the water and wastewater sector.	▪ As above.	

	▪ Minimisation of leakages and wastages will improve sustainability of utilities and reduce the need for developing new water resources.	▪ Undertake capacity building in the management of Unaccounted for Water through national and regional training programmes.	▪ Utilities; Private Sector; Regional and International Donors; National and Regional Industry partners	
5. INSTITUTIONAL ARRANGEMENTS	▪ There is an urgent need for the formulation of a National Water Policy for the sustainable management of the nation's water resources.	▪ Establish a National Water Policy linked to Medium Term Development Strategy through a consultative approach. ▪ Recognize and share the water resources management knowledge and skills of all stakeholders at the national and local level in the process of developing and implementing the national vision.	▪ DNPRD; DEC; PNGWB; DPLLG; NGOs; CBOs; Donors (funding); Regional Organisations	DEC has a draft policy in place that needs revisiting before consultation.

	• Within the framework of the NWP a range of supporting instruments including legislation, regulations, policies and plans should be developed taking into account the particular social, economic, environmental and cultural circumstances.	▪ Review sector framework to ensure good governance, better coordination, planning and implementation. ▪ Develop appropriate legislation, regulations, policies and implementation strategies. • Promote and establish appropriate institutional arrangements resourced sufficiently to enable effective management of water resources and the provision of appropriate water services. • Develop career development paths and training programmes for professionals in a wide range of disciplines which are essential and conducive to the sound and holistic management of water and wastewater, identify suitable courses and job attachments locally, within the region and internationally and secure funding to meet the associated expenses.	▪ As above. ▪ DNPRD; DEC; DoH; PNGWB; NWS; PNGGS; NGOs; Provincial and Local Level Governments; Donors; • As above.	

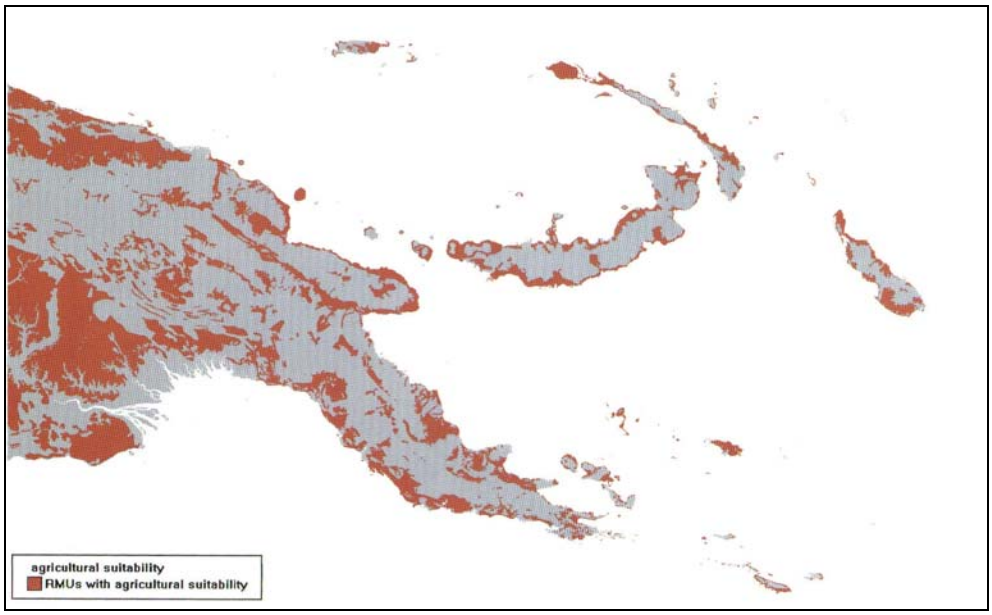
6.0 FINANCE	▪ Financially-viable enterprises for water and sanitation should be established by developing appropriate financial and cost-recovery policies, tariffs, billing and collection systems, and financial and operating systems.	• Create a better and sustainable environment for investment by both the public and private sector, by developing and implementing national, sector, and strategic plans that identify the economic, environmental, and social costs of different services and develop pricing policies, which ensure the proper allocation of resources for the water sector. ▪ Develop master plans, business plans, financial plans, and financially sustainable cost recovery strategies. ▪ National Government to commit to sector financing requirements based on approved master plans and annual budgets. ▪ Assess options for contracting out particular functions to the private sector for improved service delivery. ▪ Reduce costs through improved operational efficiency, by benchmarking, development of water-loss reduction programmes, better work practices and sustainable capacity building.	▪ DoH; PNGWB; Eda Ranu; DPLLG; DNPRD; GTC; DoE; Resource Developers	

	• Appropriate financing arrangement should be set in place to achieve sustainable rural water and sanitation services throughout the nation.	▪ Ensure access for all to potable water and safe sanitation services by developing appropriate policies and delivery mechanisms that include affordable tariff structures and sustainable subsidies.	• DoH; DPLLG; PNGWB; DoW; DNPRD; DEC.	

DEC (Department of Environment and Conservation); DJAG (Department of Justice and Attorney General); DLPP (Department of Lands and Physical Planning); DNPR (Department of National Planning and Rural Development); DoE (Department of Education); DoF (Department of Finance); DoH (Department of Health); DoM (Department of Mining); DPLLG (Department of Provincial and Local Level Government); DYSW (Department of Youth and Social Welfare); GTC (Goroka Town Council); NDES (National Disaster and Emergency Services); NWS (National Weather Services); PNGWB (Papua New Guinea Waterboard).

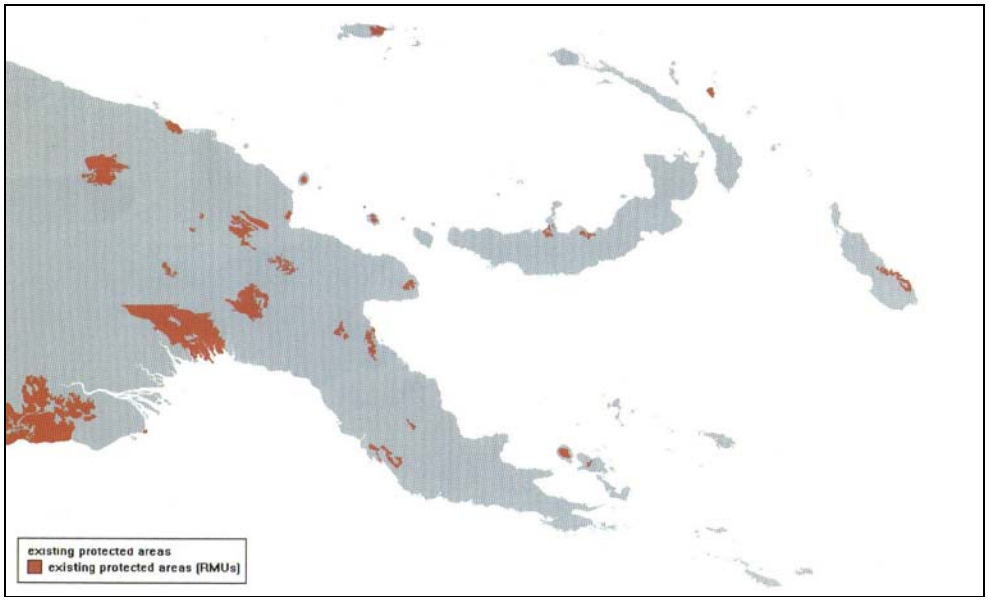
Annex 12: Map of PNG showing areas with Agricultural Potential

Source: Nix H.A. et al.1996



Annex 13: Map of PNG showing Protected Areas

Source: Nix H.A. et al.1996



Annex 14: PNG National MDG Goals in MTDS 2005 - 2010

GOAL 1 ERADICATE EXTREME POVERTY AND HUNGER	
TARGETS	INDICATORS
Target 1 Decrease the proportion of people below the poverty line by 10 per cent by 2015, using the 1996 national average figure of 30 per cent below the lower poverty line as the benchmark figure	1. Percentage of people below the lower poverty line (using the headcount method) 2. Poverty gap ratio (incidence x depth of poverty) 3. Share (percentage) of poorest quintile in national consumption 4. Gini coefficient
Target 2 By 2015, increase by 10 per cent the total amount of agriculture commercially produced and by 34 per cent the amount of subsistence agriculture production	5. Underweight births as a percentage of total births 6. Percentage of underweight children under five years of age 7. Percentage of people below minimum level of dietary energy consumption 8. Percentage of total deaths associated with malnutrition 9. Percentage of children under age 5 with height-for-age z-score below minus two 10. Percentage of children under age 5 with weight-for-age z-score below minus two
GOAL 2 ACHIEVE UNIVERSAL PRIMARY EDUCATION	
Target 3 Achieve a gross enrolment rate of 85 per cent at the primary level by 2015	11. Gross Enrolment Rate (percentage) in Grade 1 (pre-reform structure)
Target 4 Achieve a Cohort Retention Rate of 70 per cent at the primary level by 2015	12. Cohort Retention Rate between Grade 1 and Grade 6 (pre-reform structure)
Target 5 Achieve an (indirectly measured) Youth Literacy Rate of 70 per cent by 2015	13. Indirectly measured Youth Literacy Rate (age 15-24) (percentage) 14. Indirectly measured Adult Literacy Rate (over age 15) (percentage)
GOAL 3 PROMOTE GENDER EQUALITY AND EMPOWER WOMEN	
Target 6 Eliminate gender disparity at the primary and lower secondary level by 2015, and at the upper-secondary level and above by 2030	15. Sex ratio (males per 100 females) of students in primary, secondary and tertiary education 16. Sex ratio (males per 100 females) of literate 15-24 year olds 17. Sex ratio (males per 100 females) of literate adults (over age 15) 18. Percentage of persons aged 10 and over in wage employment in the non-agricultural sector that are women 19. Percentage of persons age 10 and over with money income from any source that are women. 20. Percentage of seats in National Parliament held by women.
GOAL 4 TO REDUCE CHILD MORTALITY	
Target 7 To reduce the Infant Mortality Rate to 44 per thousand by 2015	21. Infant mortality rate (per 1000 live births) per year
Target 8 Reduce the Under Five Mortality Rate to 72 per thousand by 2015	22. Under Five Mortality Rate (per 1000 live births) per year 23. Percentage of 1year old children immunized against measles per year 24. Percentage of 1 year old children immunized with Triple Antigen (3rd dose) per year

GOAL 5 TO IMPROVE MATERNAL HEALTH	
Target 9 Decrease the Maternal Mortality Rate to 274 per 100,000 live births by 2015	25. Maternal Mortality Rate per 100,000 live births by year 26. Percentage of pregnant women attending antenatal clinics 27. Percentage of births attended by skilled health personnel including village birth assistants
GOAL 6 COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES	
Target 10 Have controlled by 2015, and stabilised by 2020, the spread of HIV/AIDS.	28. Incidence rate of HIV/AIDS per 1,000 per year by sex 29. Prevalence rate (per cent) of HIV/AIDS by sex 30. Prevalence rate (per cent) of HIV/AIDS for persons aged 15-49 by sex 31. Case fatality rate (per cent) of AIDS by sex 32. Prevalence rate (per cent) of HIV/AIDS for 15-24 year old pregnant women 33. Number of children under age 15, orphaned by HIV/AIDS per year.
Target 11 Have controlled by 2015, and either stabilised or reversed the incidence of pneumonia, malaria and other major diseases by 2020	34. Incidence rate of pneumonia, TB and malaria per 1,000 per year by sex 35. Prevalence rate (per cent) of pneumonia, TB and malaria by sex 36. Prevalence rate (per cent) of pneumonia, TB and malaria for persons aged 15-49 by sex 37. Case fatality rate (per cent) of pneumonia, TB and malaria by sex 38. Prevalence rate (per cent) of pneumonia, TB and malaria for 15-24 year old pregnant women 39. Number of children under age 15, orphaned by pneumonia, TB and malaria per year.
GOAL 7 ENSURE ENVIRONMENTAL SUSTAINABILITY	
Target 12 Implement the principles of sustainable development through sector specific programs by 2010 and no later than 2015	40. Percentage of land area covered by primary forest 41. Primary forest depletion rate (percentage) per year 42. Re-forestation rate (percentage) per year 43. Percentage of land area protected to maintain biological diversity 44. Percentage of marine area protected to maintain biological diversity 45. Percentage of land area rehabilitated to ensure biodiversity (mines) 46. GDP per unit of energy use (as proxy for energy efficiency) 47. Carbon dioxide emissions (per capita)

Target 13 By 2020, increase commercial use of land and natural resources through improvements in environmentally friendly technologies and methods of production.	48. Percentage of land used for commercial purposes 49. Percentage of cultivable land used for agricultural production 50. Agricultural exports as a percentage of all exports 51. Value of agricultural exports as a per cent of total GDP 52. Value of non-agriculture exports as a per cent of GDP 53. Percentage of commercial operations using sustainable practices
Target 14 Increase to 60 per cent the number of households with access to safe water by 2010 and to at least 85 per cent by 2020 (as per definition from DOH)	54. Percentage of districts that have implemented a water policy 55. Total meters of operating water pipes 56. Total number of clean water storage tanks and wells in use 57. Number of water pumps per district 58. Litres of water supplied to users 59. Percentage of households with sustainable access to safe water source 60. Percentage of households connected directly to safe water supply (pipe/tank)
Target 15 By 2020, to have achieved a significant improvement in the lives of disadvantaged and vulnerable groups in urban areas	61. Rural to urban net migration rate (percentage) 62. Percentage of households with access to electricity, safe water and sanitation, health and education services, by geographic sector, as well as by census unit (CU) type in urban areas 63. Unemployment rate (percentage) by geographic sector and by sex 64. Urban crime rate (percentage) including prostitution and drug trafficking 65. Ratio of urban/peri-urban households with access to secure tenure 66. Percentage of population classified as vulnerable or disadvantaged by geographic sector 67. Percentage of households using wood as their primary energy source, by geographic sector.

Questions for Papua New Guinea

General: What is the correct way to write kina currency? It is written in the report as PKG, PGK and simply K.

Section Two

S2.7 The population percentages don't add up: *Ninety-five percent of the population is Melanesian, 3% are Polynesian, 2% are Micronesian and the rest are citizen and expatriate Asians, Caucasians and Africans*.

S3.1.3 What is SIM? *These include DEC's hydrometric and biodiversity data base, Department of Agriculture and Livestock (DAL) land use and soil data base, Forest Information and Mapping System (FIMs), SIMs, climatic and geological databases*.

S3.2.2 Can you please clarify what agency the Water Resources Management Branch falls under - is it the DEC?

S3.2.3 What is the DPLLGA, in reference to membership of the water related disaster response team? Not in acronyms.

Name of mining company BCL?

S3.4.4. What is FIMS with PNGFA in regards to meteorological databases?

S3.5.1.6 What is the NCDC in the *National Water Supply and Sanitation Committee.*

S3.5.2: Table two, ditto is recorded as shortfalls for the Apia and Ramsar Conventions. Does this mean they experience the same shortfalls PNG experiences complying to the Convention on Biological Diversity

S3.5.3 Sector Organisation Structure what is the ICCC economic regulator? Independent Consumer and Competition Commission

S4.1 To clarify that figures are correct. In (b) it states, Approximately 200,000 hectares of forested land is cleared annually in PNG for subsistence agriculture (Sowei et al. 2002). Then a couple of paras. Later it states, It has been estimated that approximately 25,000 hectares of natural forest are cleared annually for both plantation agriculture and infrastructure construction purposes (Sowei et al. 2002). Which figure is correct?

ANNEXES/FIGURES

Missing the following (pictures too big to import??) Can you please send if possible. Thanks.

Annex 2: Mean monthly and annual rainfall for representative stations (10 to 50 years prior to 1980, MacAlpine et al. 1983)

Annex 4:Surface hydrology map of PNG (Nix HA et al: (1996)

Annex 5:NDO Table showing natural disasters in PNG - 1997 to 2002 (NDO Library)

Annex 9:Map showing PNG Waterboard urban water and sanitation establishment and targets for the next decade

Annex 12 Map of PNG showing areas with Agricultural Potential (Nix HA et al: (1996)