COUNTRY HYDROMET DIAGNOSTICS

Informing policy and investment decisions for high-quality weather forecasts, early warning systems, and climate information in developing countries.

December 2023

Papua New Guinea Peer Review Report

Reviewing Agency: Bureau of Meteorology, Australia

Australian Government
Bureau of Meteorology

WORLD METEOROLOGICAL ORGANIZATION

Alliance for Hydromet Development

Copyright

Authorisation for release of this report has been received from the Peer Reviewing Agency and the Country NMHS.

 Dr Andrew Jones General Manager International Development Bureau of Meteorology GPO Box 1289, Melbourne VIC 3001 Australia	 Mr Kevin Luana, Deputy Secretary Technical Services, Department of Transport, Enga Haus, Airways Road, 7 Mile, Port Moresby, Papua New Guinea

Acknowledgements

This report was prepared alongside work for the Systematic Observations Financing Facility (SOFF) initiative, and with UNDP as the implementing entity. We gratefully acknowledge the assistance of the National Weather Service, partner agencies, and key users in preparing this report. In particular, we wish to acknowledge the management team of the NWS in planning and facilitating an in-country visit in November 2023.

Table of contents

List of acronyms

ACCESS	Australian Community Climate and Earth-System Simulator (model)
AFTN	Aeronautical Fixed Telecommunications Network
AWS	Automatic Weather Station
AWOS	Automated Weather Observing System
CADIP	Civil Aviation Development Investment Program
CASA	Civil Aviation Safety Authority
COSPPac	Climate and Oceans Support Programme in the Pacific
CREWS	Climate Risk and Early Warning Systems
ECMWF	European Centre for Medium-Range Weather Forecasts (model)
ENSO	El Niño–Southern Oscillation
FTE	Full Time Equivalent (staffing positions)
GBON	Global Basic Observing Network
GFS	Global Forecast System (model)
ICAO	International Civil Aviation Organization
ISO	International Organization for Standardization
ICT	Information and Communications Technology
NMHS	National Meteorological & Hydrological Service
NWP	Numerical Weather Prediction
(PNG) NWS	(Papua New Guinea) National Weather Service
SOFF	Systematic Observations Financing Facility
RIMES	Regional Integrated Multi-Hazard Early Warning System
SOFF	Systematic Observations Financing Facility
SOP	Standard Operating Procedure
UNDP	United Nations Development Programme
WRF	Weather Research and Forecasting (model)
WIGOS	WMO Integrated Observing System
WMO	World Meteorological Organization

Executive Summary

Papua New Guinea is located north of Australia and between Indonesia and the Solomon Islands in the equatorial western Pacific. The country is noted for its remarkable linguistic diversity, extraordinary geography and abundant natural resources, including for food cultivation and for extractive industries. The population of over 10 million is spread across the country, but is densest in the Highlands and the eastern coastal areas of the mainland.

Climate and weather intelligence is critical for Papua New Guinea, with rain, drought, riverine and flash flooding, severe storms, tropical cyclones, tsunamis and coastal inundations all affecting the country. The country is also very geologically active, with earthquakes and volcanic eruptions being major hazards as well as potential sources of tsunamis. Hydrometeorological and geophysical hazards also interact to form compound hazards such as landslides, volcanic ashfall and lahars (volcanic mudslides). These hazards affect transport (aviation, marine and land), agriculture, resource industries and public safety in general, and profoundly influence Papua New Guinea's development and economy.

Papua New Guinea is also highly exposed to climate change, with sea level rise, increase in rainfall and tropical cyclone intensity, temperature changes, and any variation in seasonal drivers such as ENSO particularly important.

The National Weather Service has been responsible for hydrometeorological forecasting (except for flood warnings) since Papua New Guinea's independence in 1975. Throughout that period, its budget and relative capacity has tended to decline. The observations network and supporting infrastructure is currently in a strongly deteriorated condition with few reliable surface observations and no upper air observations performed.

Forecasting services have low visibility within the country and are compromised by the state of the observations network, as are numerical modelling approaches, which lack ground, sea, or upper air validation. Given the strong influence of the island of New Guinea itself on the weather and climate of the surrounding region, this situation also affects forecasting skill in neighbouring countries.

There are no effective flood warning arrangements in Papua New Guinea, following the decline and collapse of the extensive river monitoring network in the 1990s due to a lack of resources for ongoing maintenance.

All sectors mentioned above are affected by the challenges faced by the National Weather Service, but particular mention should be made of marine safety. In 2012, the devastating Rabaul Queen sinking occurred in heavy weather with great loss of life[1], and many improvements to marine safety have been made since. However, there are frequent and increasing incidents with small craft ('banana boats') around the archipelago, with over one-hundred lives considered still lost at sea from September 2023 alone (during a period of strong winds – see discussion in main body of report). Improved daily weather intelligence is critical for improving the decision-making of small boat operators as well as other essential sectors such as the aviation industry.

The quality of services has directly contributed to a downgrading of quality certification periods granted by the Civil Aviation Safety Authority, with the NWS only certified for meteorological services to aviation for three-month periods at the time of writing (the desired and maximum period of certification is five years). Improved quality and availability of weather observations and forecasts would directly assist the quality and

[1] https://www.thenational.com.pg/lest-we-forget-rabaul-queen-tragedy/

safety of aviation services. The quality of climate services to the population is also affected by the observations issue, although cooperative efforts have been made to develop and issue seasonal outlook products.

In 2014, a diagnostic review of the NWS was conducted under peer-review 'twinning' arrangements between Papua New Guinea and Australia, with a focus on transport services. The overall situation in 2023 has not changed greatly since then, with further deterioration in the observational network and budgetary situation, and an acute need for professional training for less experienced staff. The physical facilities of the NWS have also continued to deteriorate, and NWS staff have articulated this as a major concern that is impacting NWS operations, morale and staff security – the latter having an impact additionally on and likely contributing directly to gender imbalance. Lack of access to observing sites at some remote stations is also a critical issue.

However, the NWS have now developed a progressive Strategic Plan, which strongly emphasises partnerships as well as restoration of services. Evidence of this reinforced partnership approach was clear to the diagnostic team. Following the first three years of this Strategy, it is also very positive to note that, under the newly released Medium-Term Development Plan 2023-2027, the Papua New Guinea Government is planning substantial investment in infrastructure, which, if funded, would significantly improve the viability and sustainability of internationally-funded investment projects in observations and forecasting activities.

Noting the increasingly pressing needs of all weather and climate-sensitive sectors and the current quality and service gaps, consideration could be given to increasing the priority of reform of legislative and budgetary mechanisms relating to the National Weather Service, in particular to establish a stand-alone agency with stronger capacity to manage its own budget, and transparently cost-recover aviation and other commercial services. Such legislative reform could be considered together with the disaster management priorities of the Medium-Term Development Plan 2023-2027, which has an integrated early warning system as a key investment area, and also with the need to consider current challenges in flood and geohazard warning arrangements in that context.

A closer integration of national multi-hazard arrangements would also be of practical benefit in encouraging external capacity-building partnerships to support Papua New Guinea's efforts, consistent with the UN 'Early Warnings For All' initiative and related projects. In the longer term, well integrated and effective multi-hazard early warnings at the national level will substantially assist progress towards the Papua New Guinea Vision 2050, as well as supporting progress towards the Sendai Framework for Disaster Risk Reduction 2015-2030 goals.

Summary of assessed ratings for Country Hydromet Diagnostics elements

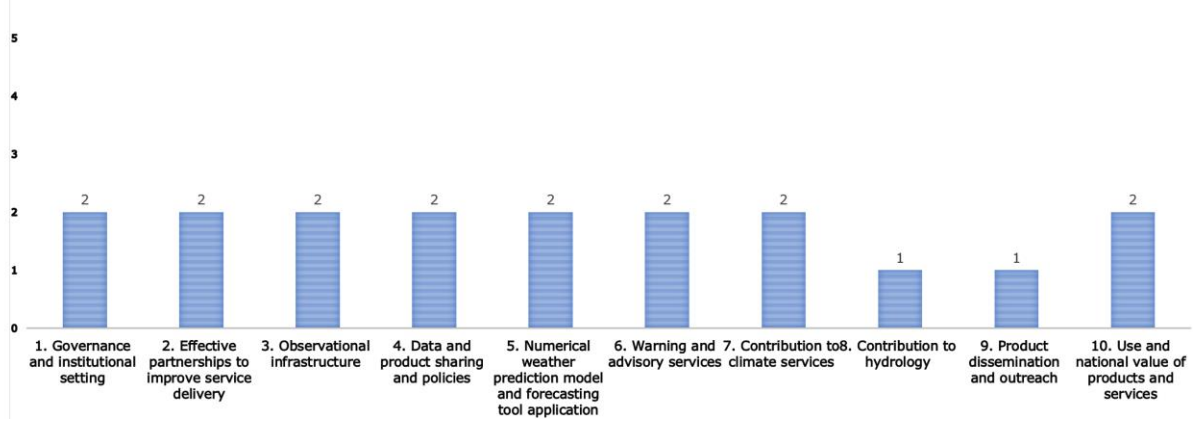

Figure 1 - Summary of assessed ratings for the ten Country Hydromet Diagnostics elements. Each rating is out of five, with five reflecting a relatively high degree of maturity.

Element	Maturity level score
1. Governance and institutional setting	2
2. Effective partnerships to improve service delivery	2
3. Observational infrastructure	2
4. Data and product sharing and policies	2
5. Numerical weather prediction model and forecasting tool application	2
6. Warning and advisory services	2
7. Contribution to climate services	2
8. Contribution to hydrology	1
9. Product dissemination and outreach	1
10. Use and national value of products and services	2

Table 1 - As for Figure 1, in tabular form

Chapter 1: General information

Introduction

Papua New Guinea occupies the eastern half of the large island of New Guinea and an archipelago to the east towards Solomon Islands in the southwest equatorial Pacific Ocean. Its land mass of 462,840 km² comprises approximately 600 offshore islands together with the mainland. New Guinea itself is famous for its extreme topography, with rugged mountain ranges towering over coastal plains and a dominant central spine rising above 4,500 m on the Papuan side and even higher over the border in West Papua. The major offshore islands to the east of New Guinea (New Britain, New Ireland, Bougainville) are also mountainous.

The Exclusive Economic Zone of Papua New Guinea is 2,402,288 km^2 (16th largest in the world) and extends slightly north and south of the Solomon Islands. To the south lies the continent of Australia, which is relatively flat by comparison.

The warm equatorial oceans and topographic influences combine with fertile soil to create an environment suitable for intense cultivation over multiple climate zones, with a great variety of produce grown, particularly in the highlands. The overall population is approximately 10,000,000, although there is some speculation that it may be considerably higher[2]. A census is planned for 2024 to produce an updated official figure. There is great cultural and linguistic diversity amongst the people, with over 800 languages spoken.

Papua New Guinea has a real GDP per capita of approximately USD $3700 (depending on the population estimate used), and an overall GDP of approximately 37 billion USD (130th in the world). The population is highly rural and is concentrated most in the highlands and the eastern lowlands.

Weather, climate, and geohazards

The east-west towering spine of New Guinea exerts a significant influence on weather and climate in the region. Widespread moist convection is frequently present, particularly during the October – April period, and generally follows a strongly diurnal cycle with inland thunderstorms developing during the afternoon, migrating to the coasts and offshore during the night and early morning. Papua New Guinea is very sensitive to seasonal climate influences such as ENSO, with severe drought tending to occur during strong El Nino episodes. Short-term hydrometeorological hazards include tropical cyclones in the south of the country, flash flooding, riverine flooding, strong winds, tsunamis (from geohazard sources), seas and swell causing coastal inundation at high tides, and even hail[3].

As Papua New Guinea sits on the western part of the Pacific Ring of Fire, it is frequently subject to earthquakes. It also has 56 historically active volcanoes, with the worst in recent history being the eruption of Mt Lamington in 1951 with the loss of 2492 lives[4]. Volcanic hazards include pyroclastic flows, tsunamis, ashfall, ash hazards to aviation and shipping, and toxic gases.

Many of the geohazards are also impacted by atmospheric or ocean processes and are also affected by climate-change related changes to these processes. These include tsunamis (affected by sea level and sea-level rise), landslides (usually triggered by rain), lahars

[2] https://www.lowyinstitute.org/the-interpreter/png-needs-census-not-more-population-estimates
[3] For example, a hailstorm at Mt Hagen affected 1800 people in 2020 https://reliefweb.int/report/papua-new-guinea/papua-new-guinea-hailstorm-mt-hagen-dg-echo-national-disaster-centre-echo.
[4] Johnson, R. Wally, 'Roars From the Mountain', ANU Press. http://doi.org/10.22459/RM.2020 https://press.anu.edu.au/publications/series/pacific/roars-mountain

(volcanic mudslides, also frequently triggered by rain), volcanic dome collapse (sometimes triggered by heavy rain), and volcanic ashfall (affected by wind and atmospheric stability). These compound hazards require joint processes between hydrometeorological and geohazard agencies to manage seamlessly within a multi-hazard early warning system.

Country Hydromet Diagnostics methodology

This report has been prepared using the methodology described in the 2022 update of the Country Hydromet Diagnostics. An initial desktop review was performed, using information supplied from the National Weather Service, World Meteorological Organization, and other partners. An in-country visit was then undertaken, followed by report revision and approval. The in-country visit included meetings in Port Moresby and extensive discussion with National Weather Service staff and some stakeholders.

This report has also been informed by a 2014 'Mini-Diagnostic' report commissioned through the Papua New Guinea Transport Sector Safety Programme, and conducted by the Australian Bureau of Meteorology with assistance from the International Civil Aviation Organization and the PNG Department of Transport. The 'Mini-Diagnostic' collected extensive stakeholder feedback, particularly from the transport sector, and also used a checklist methodology to examine aviation safety concerns. The evidence collected during the 2014 process had a large degree of overlap with that required under the Country Hydromet Diagnostics process, and so creates an opportunity for time-longitudinal comparison.

As an example of the strength of concern expressed previously, the 2014 Mini-Diagnostic noted that:

> *"Discussions with NWS management, NWS staff, Department of Transport staff, heads and senior staff of companion agencies, representative panels of transport clients, and key individual clients reveal an almost unanimous concern about the current state of the NWS. The observations made, and concerns raised, are entirely consistent with the direct observations of the subject matter experts in the mini-diagnostic, with the results of a just-concluded audit by the PNG CASA, with other documents made available from various sources, and with previous representations by the NWS in international fora. From the early 2000s onwards, the NWS appears to have deteriorated to the point where its basic service provision is on the point of collapse, and is already at the point where it has lost the trust of its major stakeholders. There are several points on which the NWS can be specifically commended and which demonstrate hope for the future, as detailed in the next section, but on balance it is unlikely that the concerns raised can be fully addressed by the NWS solely using its current financial and intellectual resources."*[5]

The Mini-Diagnostic has been quoted extensively in this report where relevant, as many of the observations and findings remain valid.

[5] Tupper, A., Dunda, P, White, P, and Ataia B. A. 2014, NWS Mini-diagnostic

Chapter 2: Country Hydromet Diagnostics

Element 1: Governance and institutional setting

1.1 Existence of Act or Policy describing the NMHS legal mandate and its scope

Prior to PNG gaining Independence in 1975, the PNG National Weather Service (NWS) was a part of the Australian Bureau of Meteorology. The NWS is now established under the Civil Aviation Act (2000, amended 2010 and 2016). The Departmental Head has accountability for the following functions:

> *(a) maintaining and operating a service to be called the National Weather Service; and*
>
> *(b) ensuring the provision of a meteorological warning service in Papua New Guinea; and*
>
> *(c) arranging for the provision of, and the making of and issuing of forecasts of the weather; and*
>
> *(d) arranging the making, collection, recording, archiving, analysis and dissemination of meteorological information and observations; and*
>
> *(e) engaging in scientific analysis and research of benefit to Papua New Guinea; and*
>
> *(j) providing assistance to the Minister for the purposes of giving effect to the WMO Convention or otherwise for purposes relating to meteorology including participating in the work of the WMO.*[6]

The Act further explains that the other functions of the National Weather Service shall include -

> *(a) providing of quality meteorological services and products to rural, village and city communities, aviation, marine, mining, exploration, agricultural and other users; and*
>
> *(b) advising the Minister on meteorological matters; and*
>
> *(c) conducting meteorological research in support of national development and other essential socio-economic activities; and*
>
> *(d) contributing to the fulfilment of Papua New Guinea's international meteorological obligations.*

The Act makes no explicit mention of climate services, hydrological services (or support for hydrological services), critical sectors, commercial or cost-recovered services, or the criticality of integrated, multi-hazard early warning systems (noting in particular the compound hazards discussed earlier). It may be taken as implicit that a meteorological warning service will include these functions, but the functional description is brief.

Climate services are mentioned to some extent in the Climate Change Management Act 2015 (Amended 2021), and disaster management is covered by the Disaster Management Act 1984 (Amended 1987), which only deals with disaster management and not early warnings.

[6] Civil Aviation Act (2000, amended 2010, 2016)

Flood warnings and river monitoring have historically been handled by the Conservation and Environment Protection Authority, although the river monitoring network collapsed due to lack of maintenance in the mid-1990s, and flood warning services are not mentioned in the Conservation and Environment Protection Authority Act 2014, which establishes the Authority.

Staff of the National Weather Service have expressed frustration over these legislative deficiencies over the past 10 years, and a broad consensus has developed that new, stand-alone legislation is required that clearly articulates the National Weather Service's role in supporting national priorities. The drafting of the new proposed legislation is in its early stages.

Geohazards are managed by the Department of Mineral Policy and Geohazards Management, which operates the Port Moresby Geophysical Observatory (responsible for earthquakes and tsunami warnings) and the Rabaul Volcano Observatory. Like the NWS, the Rabaul Volcano Observatory does not currently receive aviation cost recovery for its services, although it is required to monitor active and potentially active volcanoes and supply information for aviation purposes as well as for the general public and for marine safety.

The National Weather Service sits within the Department of Transport. Although this is a common placement for meteorological agencies[7], staff have expressed strong concerns that the current administrative arrangements inhibit independent budgetary and staffing management and the ability for the National Weather Service to fulfil its functions.

1.2 Existence of Strategic, Operational and Risk Management plans and their reporting as part of oversight and management.

At the highest level, the PNG Government defines a 2050 Vision, which sets out 7 Pillars for development:

1. Human Capital Development, Gender, Youth and People Empowerment;
2. Wealth Creation;
3. Institutional Development and Service Delivery;
4. Security and International Relations;
5. Environment sustainability and Climate Change;
6. Spiritual, Cultural and Community Development; and
7. Strategic Planning, Integration and Control.[8]

Underneath this Vision, PNG defines a rolling series of Medium-Term Development Plans, the latest of which is valid from 2023-27. This sets out the development priorities and related funding allocations for Papua New Guinea, including some that are directly relevant to the NWS (such as transport safety, multi-hazard early warning systems, disaster management, strong economic growth, and climate).

Within this broad framework, the NWS has its own Strategic Plan, developed under the previous Medium Term Development Plan and valid from 2019-2023. The plan articulates

[7] A 2011 survey of 72 National Meteorological and Hydrological Services reported that meteorological service providers were predominantly located in ministries of the environment (38%) and transport (29%). Source: *Guidelines on the Role, Operation and Management of National Meteorological and Hydrological Services. 2017 edition. WMO-No. 1195.*

[8] Government of PNG, Papua New Guinea Vision 2050, 2009, 82pp

a vision for the NWS to be an "organization of strong Regional standing, that is highly valued by the community for our pivotal role in enabling a safe, prosperous, secure and healthy Papua New Guinea." Priorities articulated in the Strategic Plan are:

1. *Improved weather services particularly aviation, marine and public weather services, and establishment of ocean weather services to support the safety and productivity of the sectors.*

2. *Disaster risk reduction including implementing the Framework for Resilient Development in the Pacific 2017-2030 and contributing to the Sendai Framework for Disaster Reduction 2015-2030 to protect life and property of PNG people as well as NWS contribution to reduce the impacts of climate change globally, regionally and nationally.*

3. *Improved climate and hydrological services including implementing the Pacific Roadmap for Strengthened Climate Services (PRSCS) and strengthened collaboration between hydrological and meteorological services.*

4. *Integrated observing and communication systems to support data exchange and processing and the preparation of weather, climate, water and ocean information and services including warnings.*

5. *Coordinated support for NWS to ensure we have resources and access to services to undertake the legislated requirements and service our stakeholders as both a government department or an independent body.*

6. *Develop our people through training in management, meteorology, climatology, tsunami, oceanography, related environmental fields and information technology together with mentoring programs to gain experience from experts through both domestic and international agreements.*[9]

Operational NWS planning occurs within this context and appears to be somewhat fragmented, noting that severe staffing and budgetary constraints and the occurrence of the COVID pandemic have disrupted NWS' business processes. Annual reporting is undertaken through the Department of Transport.

1.3 Government budget allocation consistently covers the needs of the NMHS in terms of its national, regional, and global responsibilities and based, among others, on cost-benefit analysis of the service. Evidence of sufficient staffing to cover core functions

The most recent budget (for 2022-23) is for 4.5 million PNG Kina, with 82% allocated for staffing costs. The long-term budget trend is negative in actual and real terms, and this has resulted in a number of critical decisions including station closures, staffing impermanence, and the cessation of upper air flights. Station inspection trips are rarely performed. A quality manager officer position, present in 2014, has since been made redundant. Training cannot be internally funded and there has been significant deterioration of physical facilities. No currently operational meteorologist staff are qualified to international forecasting standards, although several managers are fully qualified and the operational staff work under their general supervision. Civil Aviation Safety Authority certification for NWS has been reduced to short-term (3 months) certification, representing a critical safety issue for aviation in PNG (the desired and maximum length of certification is 5 years). NWS observations do not currently meet WMO standards in most operational

[9] PNG National Weather Service, 2019. Strategic Plan 2019-2023 (Draft copy examined)

aspects, and the observational network does not meet requirements for nearly all fundamental NMHS service products.

On this basis, it would be reasonable to conclude that the Government budget allocation does not cover the needs of the NWS. Moreover, the NWS does not currently charge fees for its services or have the ability to retain those charges in its budget. This leaves the NWS in a difficult position.

In terms of corporate governance and budgetary management, the 2014 Mini-Diagnostic stated:

> *There are numerous indications that the NWS struggles to manage the complex challenges of being an operational scientific and service delivery organisation within a policy department. For example, the NWS regularly has had difficulty spending its annual maintenance budget, including meeting procurement guidelines and Department of Transport monthly phased funding practices. As a result, some desperately needed housing maintenance and instrument repair and calibration is simply not carried out, and the money (which may have been insufficient) is returned to consolidated revenue.*[10]

This quote highlights the importance of internal processes in terms of ensuring that budget is spent. The senior leadership of the NWS has changed since 2014, and some of the above may no longer apply, but corporate administrative functions within the NWS remain poorly resourced. Direct evidence from observation station reports shows that the state of housing and maintenance at remote locations remains extremely poor.

More positively, the new Medium Term Development Plan allocates 10 million Kina each year for the next four years for the National Weather Service Support Program, which is a significant investment intended to improve NWS infrastructure. An additional 10.2 million Kina is expected to be sourced from the Asian Development Bank Civil Aviation Development Investment Program (CADIP)[11], to be used for improving NWS facilities at provincial airports. This planned government and development partner investment reflects the representations of the NWS and parent Department under the NWS Strategic Plan and its alignment to PNG's broader strategies. However, it does not address the difficulty of operating a sustainable national meteorological service in the current budgetary environment.

Also, a commitment within the forward plan is not a guarantee of receipt of funds. It is very important that this additional funding is received and spent as part of the much-needed rejuvenation of the NWS, and consideration may need to be given in regard to mechanisms to ensure this.

1.4 Proportion of staff (availability of in-house, seconded, contracted- out) with adequate training in relevant disciplines, including scientific, technical, and information and communication technologies (ICT). Institutional and policy arrangements in-country to support training needs of NMHS.

NWS has 74 staff in total, which is an undesirably low number of staff for a country of PNG's population, physical complexity, and forecasting needs. The male:female ratio of 59:15 is not unusual in the region, but is a long-term concern. There are no female forecasters or nightshift observers in the NWS. Women have historically not been able to work 24/7 shift roles in the unsafe and insecure buildings of the NWS (an issue that is also a concern for male staff), severely limiting their career opportunities and contributing to

[10] Tupper, A., Dunda, P, White, P, and Ataia B. A. 2014, NWS Mini-diagnostic
[11] https://www.adb.org/projects/52201-001/main

the gender imbalance. This also makes the NWS a less attractive place to work for female graduates seeking science careers.

Twenty-seven staff of the NWS have university degrees, with seven of those to a Master's level. However, only five have forecasting qualifications to WMO Class 1 standards, and none of those staff are on the current operational forecasting roster. The forecasting staff have only had on-the job training or short-course training, such as the 'Pacific Desk' at the US National Weather Service in Hawaii. There is a backlog of applications to be trained for the 10-month Diploma of Meteorology course in Australia or its equivalent courses elsewhere, with funding being the primary issue. Whilst training scholarships exist within the PNG government portfolio, none are currently suited to supporting meteorological training. Efforts to resolve this issue so far have been unsuccessful. The training situation has worsened since the 2014 'Mini-Diagnostic', and exposes the NWS to the issue of having uncertified staff producing critical operational forecasts. It should be stressed that this is not a criticism of those staff, who are diligent and keen to receive training.

1.5 Experience and track record in implementing internationally funded hydromet projects as well as research and development projects in general.

The NWS has a long-standing relationship with the Australian Bureau of Meteorology, although during the during the 1975-2015 period, assistance through this partnership only occurred in a few areas. More recently, and very positively, there is a 'twinning' partnership in place allowing for staged assistance activities with a focus on sustainable capacity development. A Climate Risk and Early Warning Systems (CREWS) project has recently concluded, which provided some assistance although was affected by the COVID pandemic. A successful partnership with the COSPPac program has allowed for some product development and data rescue. These and other projects have helped the NWS over the years. However, PNG was unfortunately not included in the southwest Pacific instance of the WMO Severe Weather Forecasting Programme, which would have benefited the country. Little research and development takes place outside internationally funded projects.

Summary score and recommendations for Element 1

Papua New Guinea is assessed as being at **Maturity Level 2** (out of 5), expressed as 'Effort ongoing to formalize mandate, introduce improved governance, management processes and address resource challenges' in the Country Hydromet Diagnostic template.

Table 2: CHD maturity ratings for Element 1

Element 1: Governance and Institutional Setting		*Description: The level of formalization of the NMHS mandate and its implementation, oversight, and resourcing.*		
Level one: Weakly defined mandate; serious funding challenges; essential skills lacking; little formalized governance and future planning.	Level two: Effort ongoing to formalize mandate, introduce improved governance, management processes and address resource challenges.	Level three: Moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps.	Level four: An effective service but with a few shortcomings related to its mandate, governance, and resourcing and in the process to address the gaps.	Level five: Strong and comprehensive mandate, highly effective governance, secure funding, and readily available skills base.

This rating reflects a generally declining budgetary situation, infrastructure and observations, and training, and lack of progress in establishing a stand-alone agency and the ability to recover costs. The preparation of a strategic plan and a renewed partnership approach (refer later in this report) have been positive developments, as is the commitment of 40 million Kina by the PNG Government towards infrastructure renewal. However, the situation of the NWS is still a significant concern and affects its ability to support public safety, economic growth, and other aspects of PNG's needs.

In order to improve the current situation, PNG could consider:

- Accelerating work towards legislation and related transitional support arrangements for re-establishing the NWS as an agency with its own budget processes, ability to recover costs and/or charge commercial rates as appropriate, and reinvest monies raised into services. It must be emphasised that this is not simply a matter of passing new legislation, but also of establishing business processes and supporting strong agency governance and increased workload during the redevelopment period.
- As part of this legislative process, considering options for reconfiguring agency arrangements to better support integrated, multi-hazard early warning systems in line with the strategic priorities in the Medium-Term Development Plan 2023-2027, and PNG's commitments to the Sendai Framework for Disaster Risk Reduction 2015-2030. Such a process could also help encourage additional international capacity development support for building early warning systems, and could be timely in terms of high profile international initiatives such as the UN Early Warnings For All initiative. Two options that could be considered could be for:
    - A formal cross-agency (and cross-Departmental) restructure, reflecting new legislation, to create a single multi-hazard agency that covers meteorological, hydrological, geophysical and other natural hazards, with new budgetary arrangements including the ability to retain any cost-recovered or commercial earnings. This would, for example, allow International Civil Aviation Organization (ICAO) deficiencies in volcanic monitoring to be addressed at the same time as deficiencies in meteorological observations and warnings, and in the context of a modernised multi-hazard early warning system for the community. Such a model would be similar to that adopted by Iceland or Vanuatu in recent years.
    - Defined agency partnership arrangements to achieve a similar result, through formal agency agreements. This may be difficult to achieve in terms of financial and quality management processes, but would be less disruptive to existing Departmental arrangements.
- Seeking support for management of the additional PNG-sourced funding from the National Weather Service Support Program, in order to reduce a critical management load on senior staff.
- As part of the National Weather Service Support Program, and also the planned additional CADIP funding for spending on facilities at provincial airports, defining and implementing a physical security standard that will sustainably support the safety of all staff during out-of-hours operations, to ensure that all current and future staff have opportunities to work in all relevant roles as required, and to encourage female science recruits in particular to see the NWS as an employer of choice.
- Urgently seeking further partnership support for critical staff training, including in forecasting and warning functions, to reduce the lack of training as a 'blocker' in operations and staff career progression.

Element 2: Effective partnerships to improve service delivery

2.1. Effective partnerships for service delivery in place with other government institutions.

Since the 2014 Mini-diagnostic, relationships with some other government institutions have noticeably improved, which is attributable to a forward-looking, collegiate approach from current management. An example of NWS' approach here is the building, with support from the PNG Government, of the 'RIMES (Regional Integrated Multi-Hazard Early Warning System) building' as a multi-hazard collaboration space with other agencies. Stakeholders visited during this report process spoke positively about their relationships with the NWS, and efforts to build MOU arrangements.

However, the effectiveness of these partnerships has also been limited by the situation of the NWS, and also that of some of its partners. For example, as noted later in this report, the flood warning network is virtually non-existent in PNG, which impacts the potential effectiveness of the NWS partnership with the Conservation and Environment Protection Authority. As already noted, the Rabaul Volcano Observatory, which is required to provide volcanic eruption information to NWS and the aviation industry under ICAO standards, is limited by some of the same budgetary constraints as the NWS, including the ability to raise money for its operations through aviation cost recovery (this has been a known issue since the 2000s, when the relevant ICAO requirements were first articulated). The RIMES building operates as a collaboration and training space, but with no ongoing staff presence at this stage.

Even where resourcing has been less of an issue, deep operational arrangements and relationships have not necessarily been fully developed. Several examples of lack of data exchange (particularly of relevant observations not being sent to the NWS) were given to the report-writing team. A concerning example noted by the report team is that extensive redevelopment of some airport facilities has been occurring in PNG without provision for the NWS to occupy space on-site, effectively threatening the provision of weather observations critical for aviation purposes, and also impacting the continuity of the climate record at those locations. In one location, it was also reported that NWS staff had not been allowed to access their airport observations site for the past three years.

Despite the positive signs, there is much more work to do in this space. Redevelopment of the NWS role and mandate through legislation (as discussed previously) would do much to help reset some of the relationships required but would not in itself be sufficient to rapidly address the problem without additional attention in this area.

2.2. Effective partnerships in place at the national and international level with the private sector, research centres and academia, including joint research and innovation projects.

Private sector and academic cooperation is very limited at this stage, although there is a strong need for such cooperation given the multitude of challenges that PNG faces in pursuing the 2050 vision. Positive developments include discussions with a telecommunications provider about hosting mobile-phone tower automatic weather stations, following earlier pioneering work from the academic sector. The NWS has also taken on the provision of tailored services for the Ok Tedi mine, although is unable to charge for those services until financial arrangements are in place on the NWS side.

2.3. Effective partnerships in place with international climate and development finance partners.

Like other nations in the southwest Pacific region, PNG has benefited from the long-standing Climate and Oceans Support Programme in the Pacific (COSPPac) program, and

has recently worked to strengthen the broader twinning relationship with Australia. As a generalisation, short-term projects are less effective in PNG (as for elsewhere), and there have been some examples of rapid project failure (for example, by equipment theft or vandalism due to inadequate consideration of security challenges). As part of this, the relative lack of visibility of the PNG NWS has meant that some development assistance in weather or climate-related work has been directed elsewhere (for example, automatic weather stations installed but without the data going to the NWS or out to the global observations system and no consideration given to support for sustainable maintenance), resulting in essentially wasted external investments. A previous visit to Goroka, undertaken by the WMO, Bureau of Meteorology, and NWS, vividly demonstrated this issue with multiple externally funded observations sites in existence but none of them being effective for improving weather forecasts or climate knowledge.

2.4. New or enhanced products, services or dissemination techniques or new uses or applications of existing products and services that culminated from these relationships.

A new drought information product was developed under the CREWS initiative, and is emailed out to key stakeholders. As already noted, weather and climate services for the very large, PNG-owned Ok Tedi mine have recently commenced, taking over this service from the Australian Bureau of Meteorology. This is a progressive development from the NWS, but so far the NWS is not able to charge for this commercial service.

Summary score, recommendations, and comments for Element 2:

Papua New Guinea is assessed as **Maturity Level 2** for this criterion, expressed as *'Limited partnerships and mostly excluded from relevant finance opportunities.'* This rating, although negatively phrased, appears to be more appropriate than the next higher level, '*Moderately effective partnerships but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.'* The rating is made because of the strength of some of the negative examples of NWS exclusion from processes, whether unintentional or not. The NWS's proactive attitude to partnerships is to be applauded and is having an impact, but there is much more to do.

Table 3: CHD maturity ratings for Element 2

Element-2: Effective partnerships to improve service delivery		*Description: The level of effectiveness of the NMHSs in bringing together national and international partners to improve the service offering.*		
Level one: Works in isolation and does not value or promote partnerships.	Level two: Limited partnerships and mostly excluded from relevant finance opportunities.	Level three: Moderately effective partnerships but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.	Level four: Effective partnerships with equal status in most relationships and approaching relevant funding opportunities in a coordinated manner.	Level five: NMHS is regarded as a major national and regional role player. It has extensive and productive partnerships and is viewed as an honest broker in bringing parties together and provide national leadership on relevant finance decisions.

Rejuvenation of the NWS in this area will be assisted by the development of legislation and a 'reset' of some agency relationships, noting that external support for that effort would be highly desirable as discussed in the previous section. Ideally, NWS would also have much higher visibility through its structural positioning as focal point for multi-hazard early warning systems, weather and climate services (see discussion under Element 1), combined with a much stronger communications strategy (see discussion under Element 9). Support from central government agencies in affirming the critical role of the NWS, coincident with the planned investment from the National Weather Service Support Program, will also be very helpful in developing NWS positioning and partnerships.

Element 3: Observational infrastructure

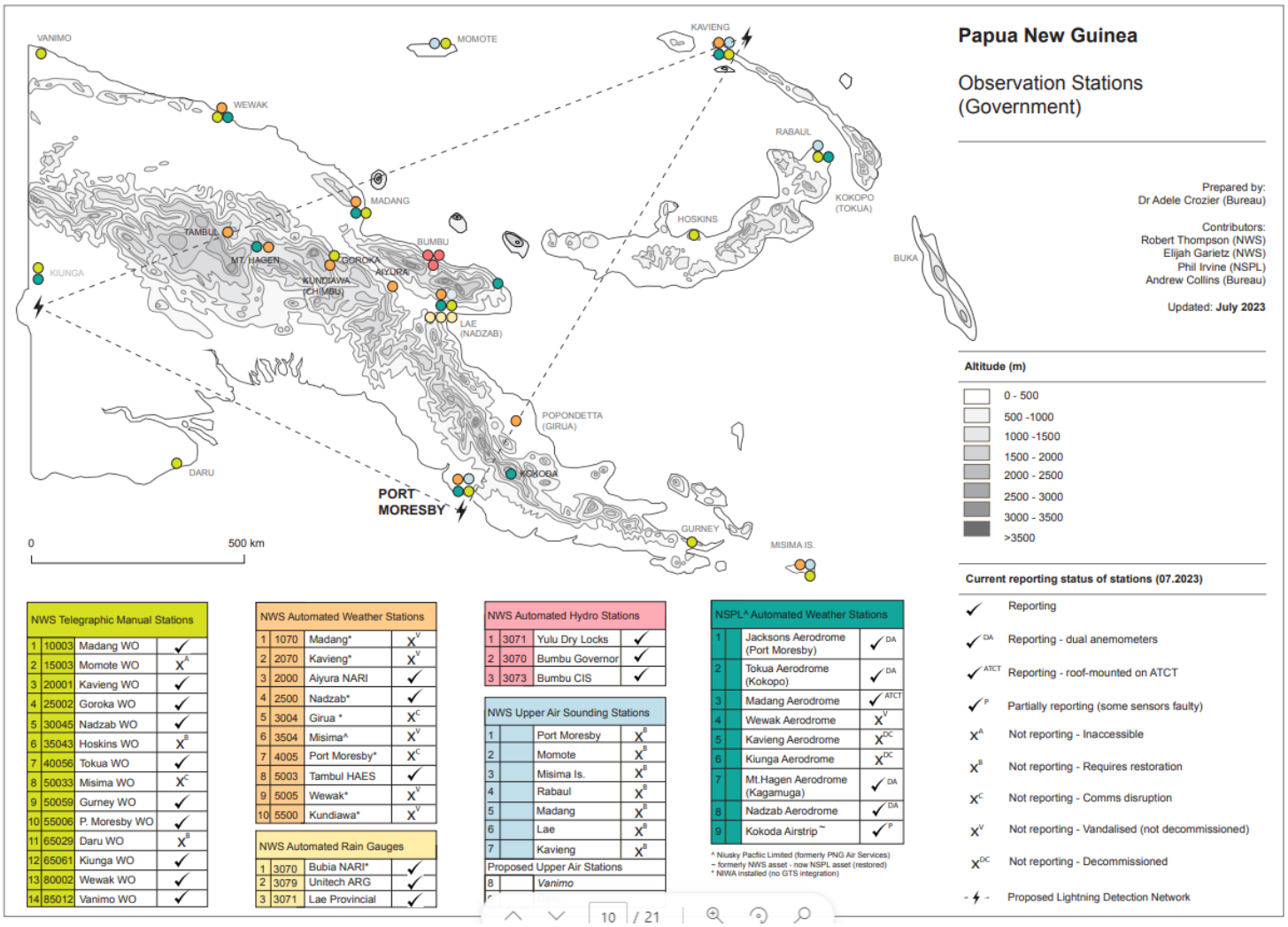

Figure 2 – Map of existing surface stations as of July 2023 (Bureau of Meteorology / NWS / Niusky Pacific Pty Ltd)

3.1. Average horizontal resolution in km of both synoptic surface and upper-air observations, including compliance with the Global Basic Observing Network (GBON) regulations.

Of the fourteen synoptic stations, eight were reporting at the time of the mission visit, although none are fully GBON compliant. The number of operational stations has been decreasing over time. Only Port Moresby operates 24/7, reporting eight 3-hourly observations. The others perform 3-hourly observations during day hours only, with various issues relating to site access and condition, staffing availability, and a range of communications issues frequently reducing the amount of observations received internationally.

The average horizontal resolution over the total surface area of Papua New Guinea (approximately 2.9 million km$^{2)}$ is dependent on the metric used:

- In terms of GBON compliance, the current surface station resolution is undefined (zero fully compliant stations), and
- For stations that are currently operating, the 8 synoptic stations give a resolution of approximately 600 km.

No upper air observations are performed. Seven upper air stations were originally set up for the PNG NWS, performing upper-wind observations via theodolite tracking (see Figure 2). These gradually fell into disrepair. Upper air sondes were ceased at Port Moresby in the 2000s due to budgetary pressures. An externally funded program, the US Atmospheric Radiation Measurement (ARM) program, performed upper air and surface observations at Momote until September 2014, but then ceased operations when the program focus shifted elsewhere.

The existing surface stations are almost exclusively coastal across PNG and the Solomon Islands, with only one synoptic station in the densely populated PNG highlands (Figure 3)

An Australian-funded project plans to install two new upper air stations, at Momote and in Port Moresby.

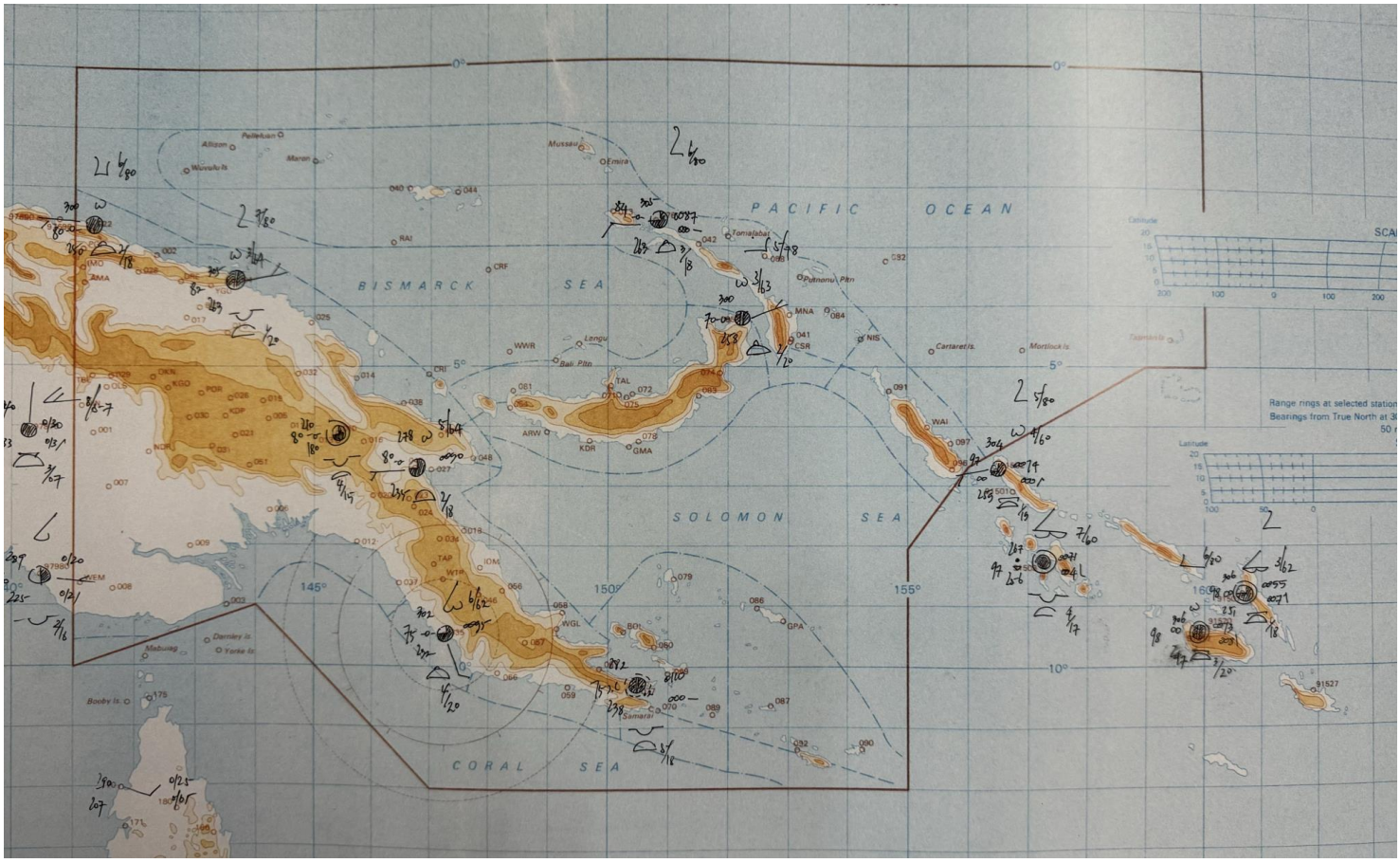

Figure 3 - Hand plotted observations map, 7 November 2023 00 UTC. Map tints show altitude amsl at 500 feet (152m) intervals, with the darkest shade showing 2000 ft (609m) and above. Eight observations are plotted for Papua New Guinea. Note that only one elevated observation (Goroka, altitude 1585m) is available in near-real time on this chart for the entire of Papua New Guinea and Solomon Islands. Given the criticality of the elevated areas for ecosystem health, crop production, river monitoring and weather forecasting in the region, this observations coverage is highly inadequate for PNG's national needs. Courtesy PNG National Weather Service.

3.2. Additional observations used for nowcasting and specialized purposes.

The long-standing observations issues in Papua New Guinea have resulted in various parallel networks being set up at various stages, such as aviation-funded automatic AWS / AWOS (see Figure 2), agricultural and mining stations, and also an extensive network of mobile-phone tower-mounted, proprietarily-owned AWSs set up for climate research and later used for commercial purposes (this network is now largely falling into disrepair). In

general, data from these stations does not reach the NWS in real-time and is not used for forecasting.

A pilot project to operate flood warning stations near Lae has several observations operational. Aside from that, there are no flood warning stations following the collapse of the network in the 1990s.

There are no marine observations currently available, aside from a tide gauge at Lombrum, Manus Island, operated by the Australian Bureau of Meteorology.

3.3. Standard Operating Practices in place for the deployment, maintenance, calibrations and quality assurance of the observational network.

The 2014 Mini-diagnostic review reported severe issues with the quality assurance and maintenance of stations, giving an example from Misima:

> *CASA recently (early 2014) made 170 audit findings of NWS facilities and procedures, many of which were at observation offices. These, supported by NWS management testimony, user evidence and related reports, confirm that the NWS network is in a very poor state. Meteorological instruments are not being calibrated, replaced or repaired with an acceptable frequency and in some cases are missing. For example, the 2014 audit for Misima notes a missing anemometer (for measuring wind), an unserviceable AWS, no boundary fencing, a rotten Stevenson screen (instrument cabinet), no working radio, missing manuals, inadequate staffing and a 'very old and rotten' office building. This is particularly significant because in 2010, an aircraft accident at Misima resulted in four fatalities. Whilst the NWS was not held responsible, the final accident investigation report in 2012 noted some observation issues and included the following:*
>
> > *"4.2.1 Misima wind indicators*
> >
> > *Minor safety issue: The weather station anemometer was giving an incorrect wind indication… The PNG NWS has advised that one of the windsocks at Misima has been replaced. The anemometer was found to be unserviceable and has been taken out of service…. The PNG NWS has advised that five automatic weather stations have been installed in PNG, one of which has been placed at Misima. Pilots will be able to access this information within a 30 NM (56) radius of the stations. At the time of writing, the Misima station had not been commissioned and no date had been advised of a possible commissioning date."*[12]

Since 2014, matters have not improved. The NWS budget has decreased, making funding for maintenance and calibration more difficult – there is effectively no calibration program or equipment. The Quality Management System Officer position has been made redundant from the NWS and moved to a more general position within the Department, making quality management more challenging. The Civil Aviation Safety Authority (CASA) have downgraded their quality certification period of NWS operations to a three-month rolling review, which is very concerning, and (in interview) cited the state of the observations network as a major factor.

In the Misima example given above, an automatic weather station has been installed, but was vandalised. Vandalisation has occurred for many weather stations, including Kokoda (multiple instances), a critical aviation location where high-quality installations

[12] Tupper, A., Dunda, P, White, P, and Ataia B. A. 2014, NWS Mini-diagnostic

were funded by the Australian Government. The Kokoda site is now maintained and operated by Niusky Pacific Ltd due to its criticality for aviation.

Station reports show that many facilities are in a critical state of disrepair. Morale is also low, and at some stations, the observations staff no longer have legal access to their observing site due to an apparent breakdown in arrangements with the PNG National Airport Corporation.

The lack of coastal observations for marine purposes is also a significant concern. Marine safety is a high priority, particularly following the 2012 sinking of the *MV Rabaul Queen* and subsequent inquiry and prosecutions. As noted earlier, many marine fatalities still occur, but NWS staff have no access to real time observations reflective of conditions over the water. Maritime search and rescue staff use numerical modelling to estimate conditions over the water, but without any observational validation. In these circumstances, it is impossible to quality control forecasts and warnings.

3.4 Implementation of sustainable newer approaches to observations.

In the PNG context, newer automated approaches have yet to be proven to be sustainable. Stations are subject to both random vandalization, and also outright theft (particularly of solar panels). Power and communications can still be an issue. The most sustainable solution is thought to be having staffed stations (for community presence and security, as well as manual back-up due to broken or stolen equipment), with 'palisade' security fencing, and an AWS on site to provide 24/7 observations if possible, with scope for manual observations to be added by observers.

A mobile phone tower-mounted AWS network was built prior to 2014 by a research group affiliated with the local university, which is still in partial operation. It is now owned and operated by a private company for commercial purposes. Some further exploration of this approach is occurring.

3.5. Percentage of the surface observations that depend on automatic techniques.

Three NWS automatic weather stations are currently operational (although not transmitted internationally), meaning that about 27% of total available stations are automatic. This excludes the aviation stations, from which data is not received by the NWS.

Summary score, recommendations, and comments for Element 3

Papua New Guinea is assessed as **Maturity Level Two** for this observational criterion, reflecting a 'Basic network, large gaps, mostly manual observations with severe challenges and data quality issues.' The situation has in general deteriorated, and the country risks having a Maturity Level One ('No or limited, basic surface observations and no upper-air observations') maturity rating unless a significant change in circumstances occurs.

Table 4: CHD maturity ratings for Element 3

Element 3: Observational Infrastracture		*Description: The level of compliance of the observational infrastructure and its data quality with prescribed WMO regulations and guidance.*		
Level one: No or limited, basic surface observations and no upper-air observations.	Level two: Basic network, large gaps, mostly manual observations with severe challenges and data quality issues.	Level three: Moderate network with some gaps with respect to WMO regulations and guidance and with some data quality issues.	Level four: Comprehensive mostly automated network providing good traceable quality data fully compliant with WMO regulations and guidance.	Level five: Comprehensive and highly automated advanced network including additional measurements and remote sensing platforms providing excellent data fully compliant with WMO regulations and Guidance.

It is difficult to overstate how serious this situation is from the point of view of services and safety. The extreme topography and energetic, tropical convective climate means that a high-density network of weather observations is absolutely essential for safe aviation and marine operations, public safety, agriculture, industry, and climate monitoring purposes. Without reliable observations, credible forecasting is difficult, and quality-

controlled operations are virtually impossible. That the situation has not improved since 2014 is deeply concerning.

In this context, the planned investment by the PNG government into NWS sites is very welcome, and should be seen as a pre-requirement for enabling the sustainment of externally funded initiatives such as SOFF and the current Australian Government investment. It should particularly be noted that high security installations, and budget for maintenance and consumables, as well as the presence of nearby staff quarters, are necessary for the successful operation of an observations program in PNG. It is likely that much larger investment will be required than is currently planned in order to bring the network to a basic and sustainable operational standard.

In terms of long-term network sustainment, aviation cost-recovery (as recommended in 2014) is still an important option to consider, as it removes some of the cost burden from the Government whilst reasonably drawing on aviation resourcing to service aviation needs. Ongoing funding may be available from SOFF to help sustain operations to a GBON standard, but this would not be enough to service PNG's domestic needs.

Element 4: Data and product sharing and policies

4.1. Percentage of GBON compliance – for how many prescribed surface and upper-air stations are observations exchanged internationally. Usage of regional WIGOS centres.

No surface stations are considered GBON compliant. Eight stations transmit internationally to some degree, although communications issues (including in data-relay nodes) mean that receipt of these internationally is inconsistent. The NWS has no connection to the WMO Global Telecommunication System, meaning that observations are transmitted via a circuitous route (email to Australia).

No upper-air observations are now performed in PNG.

Regional WIGOS centres are still in the process of being established in the region, with Indonesia and Fiji expected to be able to provide some assistance in monitoring of observations.

4.2. A formal policy and practice for the free and open sharing of observational data.

The PNG NWS formally shares data, both internationally and domestically. Some domestic data exists that is not shared with the NWS (such as from aviation sources), although more from practical rather than policy reasons. There is no national WIGOS agreement. Relationships with partners are established, but formal data processes tend not to exist in practice.

The public of PNG has very limited access to NWS data, or data from other sources. The NWS website is under reconstruction and there are few other potential sources.

4.3. Main data and products received from external sources in a national, regional and global context, such as model and satellite data.

Very little data is received from some local external sources, including from the National Maritime Safety Authority (ship observations), or Niusky Pacific (air traffic management, including AWS and pilot reports). Some telegraphic data is received from agricultural research stations. At time of the team visit, an issue with the NWS Aeronautical Fixed Telecommunications Network (AFTN) connection (where NWS had been able to transmit but not receive) was in the process of resolution, and has since been resolved.

The issue of exchange of data is ongoing, and, if anything, the situation has deteriorated. The 2014 Mini-Diagnostic commented about this at length, particularly in the aviation context:

> *As noted in the ICAO report, immediate improved availability of meteorological information could be realised through the establishment of a more functional arrangement between the NWS and Air Services Limited (ASL) for the use of the AFTN for exchange of operational meteorological information for international users. In addition, weather information is passed informally between pilots, flight dispatch, and air traffic services, rather than being forwarded formally to the NWS and to aviation users through the relevant Aeronautical Information Service, as per the relevant ICAO Standards and Recommended Practices and guidance. This is common across the world, but particularly notable in PNG. The problem is that, if weather (including, for example, turbulence, volcanic eruptions, unforecast conditions) is not reported and exchanged in the required manner, then it will not be received by the National Weather Service or by other agencies, including international agencies, meaning that critical observational, safety and verification*

data is missing. It is often assumed by pilots that meteorological information gathering is sufficient without their direct input, but that is not the case – particularly in PNG where the meteorological data network is sparse and where clouds often obscure satellite remote sensing views.

There have been good examples of pilot reporting and forwarding of those reports for critical events in the past (for example the 1994 Rabaul eruption), but not always and particularly not recently. In a review of the major 2004/05 eruptions of Manam, it was found that not one of more than 80 pilot observations of volcanic activity from a single airline, or any reports from any other airline, had been passed on internationally in real time, despite the good will of all involved. It is envisaged that this issue will be effectively addressed by the meteorological authority, but it will require the full support of Air Services Ltd[13] and the airlines to change practices in this regard.[14]

The above referenced situation with pilot reports has not improved at all since 2004, and is also true of marine observations.

Geostationary satellite data is received from the Japan Meteorological Agency through HimawariCast. Model data in image form is used by forecasters and received from international modelling centres.

Summary score, recommendations, and comments for Element 4

Papua New Guinea is assessed at **Maturity Level 2** for data and product sharing and policies, described as *'a limited amount of GBON compliant data is shared internationally. The existing data sharing policies or practices or the existing infrastructure severely hamper two-way data sharing'* in Country Hydromet Diagnostic guidelines.

Table 5: CHD maturity ratings for Element 4

Element 4: Data and Product Sharing and Policies		*Description: The level of data and product sharing on a national, regional and global level.*		
Level one: No observational data is shared internationally, either because not available to be shared or due to the lack of data sharing policies or practices, or the existing	Level two: A limited amount of GBON compliant data is shared internationally. The existing data sharing policies or practices or the existing infrastructure severely	Level three: Moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps.	Level four: Fully meeting GBON data sharing compliance with a data policy and practices and infrastructure in place. These support free and open sharing of	Level five: Exceeding GBON data sharing compliance and additional data (marine, radar, etc.) contributing to regional and international initiatives with policies that promote free and open two-way sharing

The NWS intent is clearly to share data, but procedures and compliance with procedures (including by 3rd parties) have prevented this in practice. In some circumstances, including historically, meteorological observations networks have been set up by 3rd parties that are unaware of the central role of the NWS in taking and sharing observations and maintaining the climate record, and those projects have not allowed for data-sharing in their design and implementation.

Ideally, all projects that could enhance the national observations network should include the strong involvement of the NWS. Data sharing (including international sharing) should be a pre-condition of and built into the design of those projects. Establishing the central role of the NWS under the proposed legislation and supporting the NWS in undertaking the role would be helpful in this regard. Also, guidance could be given through PNG Government that any accepted capacity building project involving meteorological observations must be designed to support PNG's national meteorological observations networks, including for observations sharing.

Data sharing is also a critical element to geohazard and flood warning needs. Regardless of which agencies are responsible for warnings for these hazards, the production of multi-hazard early warnings typically requires free sharing of relevant data as well as the pooling

[13] Air Services Ltd is now NiuSky Pacific Ltd
[14] Tupper, A., Dunda, P, White, P, and Ataia B. A. 2014, NWS Mini-diagnostic

of professional expertise. In the framing of any new legislation relating to the NWS or multi-hazard early warning systems, consideration could be given to ensuring that all relevant data is shared freely.

Element 5: Numerical model and forecasting tool application

5.1. Model and remote sensed products form the primary source for products across the different forecasting timescales.

PNG NWS uses a methodical forecast process, derived from classical meteorological training, consisting of:

1. Hand-plotting observations from PNG and surrounding countries onto a chart
2. Streamline analysis of chart
3. Consideration of forecasting models (from websites, or from 3rd party web-based displays such as 'Windy') in the light of current forecast policy and analysis, update of policy as required. Data manipulation is not performed in-country
4. Preparation and issuance of forecasts and warnings
5. Monitoring of situation, amendment of forecasts as required, and repeat of cycle.

The NWS staff are compromised by the state of the surface observations network, and the impact of that on their own analyses and model analyses and forecasts. They also receive very few user-sourced observations such as pilot reports or ship reports. However, they are also able to use satellite observations (although with limited training in this and all meteorological techniques) to provide a basic service.

5.2. a) Models run internally (and sustainably), b) Data assimilation and verification performed, c) appropriateness of horizontal and vertical resolution.

Locally-run modelling can be problematic for small NMHSs due to the heavy burden associated with computing resources, quality control mechanisms, observations ingestion, training and retention of staff.

PNG NWS has used the Weather Research & Forecasting model (WRF), variously in collaboration with Indonesia and with RIMES, at 9 km resolution (a comparable resolution to the highly sophisticated ECMWF global model). WRF is not currently in operations.

In this context, the World Meteorological Organization has recently issued Guidelines on High-resolution Numerical Weather Prediction (World Meteorological Organization-No. 1311, June 2023)[15], defining six levels of appropriateness of NWP use according to country capacity:

Level 1 - Use of NWP products from Regional Specialised Meteorological Centres (RSMCs)

Level 2 – Enhanced use of NWP products from RSMCs through post-processing

Level 3 – Downscaling regional model implementation

Level 4 – Regional NWP including data assimilation

Level 5 – Regional Ensemble Prediction Systems

Level 6 – Regional coupled Earth system modelling or rapidly updated NWP

These guidelines highlight the complexity of running models in country with full data assimilation. In operational terms, the NWS is currently closest to Level 1 in this scale.

[15] World Meteorological Organization Guidelines on High-resolution Numerical Weather Prediction (World Meteorological Organization-No. 1311, June 2023 Available at https://library.World Meteorological Organization.int/doc_num.php?explnum_id=11654

The WMO Guidelines suggest that for a Level 4 system (regional NWP with data assimilation), a country would need an ICT administrator, High Performance Computing Centre administrator, scientific software engineer, data assimilation scientist, model scientist, verification expert, product developer, meteorologist, increasing staff to a total of 5-7 Full Time Equivalent positions (FTEs) for NWP, 2-3 FTEs for Scientific Software Engineering, and 2-3FTEs for ICT (i.e. 7-13 positions). The Guidelines also note that "for many NMHSs at any level of this process, it can be beneficial to join a consortium of partners and work together to develop and implement NWP capabilities, rather than going it alone."

These considerations very much apply to Papua New Guinea, noting that complexities of topography also tend to make numerical modelling more challenging. In this light, it may be most sustainable for PNG to reach partnership agreements with numerical weather prediction centres, preferably in the region, to provide high resolution numerical modelling as part of ongoing joint arrangements. Such modelling, if reliably produced and shown to be strongly credible (through verification with an improved observations network), could be co-branded and feature prominently on external facing output from the NWS.

5.3. Probabilistic forecasts produced and, if so, based on ensemble predictions.

PNG NWS uses probabilistic forecasts produced for climate purposes through regional and global centres, and also for tropical cyclone forecasting purposes in partnership with the Brisbane Tropical Cyclone Warning Centre.

Summary score, recommendations, and comments for Element 5

Papua New Guinea is assessed as **Maturity Level 2** for this criterion, expressed as *'Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range'.*

Table 6: CHD maturity ratings for Element 5

Element 5: Numerical Weather Prediction Model and Forecasting Tool Application		*Description: The role of numerical weather prediction model output and other forecasting tools in product generation. Whether local modelling is sustainably used to add value to model output from WMO Global Data-processing and Forecasting System (GDPFS) centres.*		
Level one: Forecasts are based on classical forecasting techniques without model guidance and only cover a limited forecast time range.	Level two: Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range.	Level three: Prediction based mostly on model guidance from external and limited internal sources (without data assimilation) and remoted sensed products in the form of maps, figures and digital data and cover nowcasting, short and medium forecast time ranges.	Level four: Digitized model output from internal (with data assimilation) and/or external (regional) sources and remote sensed products and data used and value-added through post-processing techniques extended into longer ranges.	Level five: Optimal combination of global, regional and local models, remote sensed data, post-processing techniques and automated probabilistic product generation over weather and climate time scales with minimal human intervention supported by up-to-date verification statistics.

It is not necessarily appropriate for the country to pursue a strong local modelling capability due to the large overhead associated with numerical modelling, but the skill and use of model data could be significantly improved through enhanced forecast production systems being available to forecasting staff, combined with improved local observations being contributed to GBON, and agreements with partners and within the context of the World Meteorological Organization Integrated Processing and Prediction System to ensure that the highest possible resolution NWP is made available to the country, both in graphical form and through database availability.

Further discussions are recommended, particularly within the context of the Severe Weather Forecasting Programme (which PNG has so far been excluded from due a lack of external capacity within the original Severe Weather Forecast Demonstration Project) and the Weather Ready Pacific initiative, to explore whether one or more of the Regional Specialised Meteorological Centres or World Meteorological Centres in the region could assist the NWS in a partnership arrangement to help provide the maximum achievable and sustainable NWP implementation.

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

As noted earlier, PNG is exposed to a variety of hydrometeorological and geological hazards, including compound and multi-disciplinary hazards (for example, landslides and volcanic ashfall).

PNG NWS operates 24/7, with a recently established 'watch' shift providing a higher level of coverage for high priority issues.

Out-of-hours operations of partner agencies are less robust. The Port Moresby Geophysical Observatory (for tsunami warnings) or Rabaul Volcano Observatory do not operate 24/7, although the Rabaul Volcano Observatory does work extended hours when required, and the National Disaster Centre does operate 24/7 and has the ability to consider externally generated tsunami advice from the Pacific Tsunami Warning Center in Pearl Harbor. There is no effective flood warning system, as discussed later. There are also few operational options for distributing urgent warnings in real time. In that sense, PNG overall struggles to maintain a 24/7 multi-hazard warning system.

6.2. Hydrometeorological hazards for which forecasting and warning capacity is available and whether feedback and lessons learned are included to improve warnings.

Warnings are issued to the public for heavy rain, strong winds and gales (including for coastal waters), tropical cyclones including storm surges, thunderstorms, high tides that can lead to coastal inundation, and drought. Marine incidents are common, with weather frequently a strong contributing factor. Attention usually focuses on major incidents, such as the 2012 sinking of the Rabaul Queen, but the (unacceptable) death toll from major incidents is likely well exceeded by the combined volume of small craft incidents. Over one-hundred lives are considered still lost at sea from September 2023 alone (Figure 4)[16].

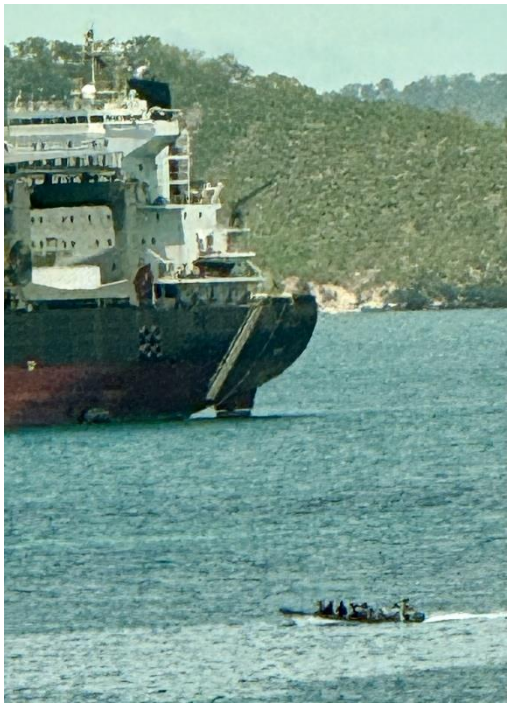

Figure 4 - a heavily laden 'banana boat' (foreground) moves across the harbour at Port Moresby, with very little freeboard. In September 2023 alone, over 100 crew and passengers from banana boats went missing in PNG waters. Photo: Authors.

There is little operational integration of warning systems, with responsibility for warnings divided as noted earlier. The NWS has taken leadership in seeking to address this through the creation of the multi-hazard early warning centre (the previously mentioned RIMES building) located at the NWS headquarters. At the moment, this largely functions as a collaboration space and the review team did not have the chance to observe it as an operational area.

No formal process is in place for obtaining feedback and undertaking service improvement from lessons learned. No systematic warning verifications are performed. As noted earlier, a quality management position was made redundant several years ago.

Discussions with the National Disaster Centre leadership suggested that the focus of their

[16] PNG National Maritime Safety Authority, Personal Communication, 2023

activities is more towards national resilience and response. However, separate conversations with a provincial disaster manager and with an operational coordinator from a leading humanitarian organization demonstrated that within Papua New Guinea there is a keen appreciation of the value of early warnings for driving effective anticipatory actions, reducing the cost and casualties from hazard impacts. The need for improved services in this area was clearly articulated from these points of view. It appears that the NWS is likely best placed to drive future service improvements under a refreshed mandate and organisational structure.

6.3. Common alerting procedures in place based on impact-based services and scenarios taking hazard, exposure and vulnerability information into account and with registered alerting authorities.

The development of impact-based warnings and implementation of common alerting procedures in PNG is in its very early stages. At the time of the review visit, two staff were about to attend a training conference on the Common Alerting Protocol. Hazard, exposure and vulnerability information is not available to the NWS in a systematic way.

Summary score, recommendations, and comments for Element 6

The PNG NWS is assessed as being at **Maturity Level 2** for Warning and Advisory Services, which is described in the Country Hydromet Diagnostic guidelines as being '*Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions and services'.*

Table 7: CHD maturity ratings for Element 6

Element 6: Warning and Advisory Services		*Description: NMHS' role as the authoritative voice for weather-related warnings and its operational relationship with disaster and water management structures.*		
Level one: Warning service not operational for public preparedness and response.	Level two: Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions and services.	Level three: Weather-related warning service with modest public reach and informal engagement with relevant institutions, including disaster management agencies.	Level four: Weather-related warning service with strong public reach and standard operational procedures driving close partnership with relevant institutions, including disaster management agencies.	Level five: Comprehensive, impact-based warning service taking hazard, exposure and vulnerability information into account, with strong public reach. It operates in close partnership with relevant national institutions, including disaster management agencies and registered Common Alerting Protocol alerting authorities.

This rating is judged to be more appropriate at this stage than Maturity Level 3, or higher. However, noting the NWS' constructive strategy and efforts to promote collaboration, it is feasible for the agency, and PNG more generally, to develop through Maturity Level 3 and beyond given enough sustained support. Building better multi-hazard warning and advisory services is an important challenge and is a global priority to address under the Sendai Framework and related initiatives such as the UN Early Warnings for All effort, and sustained effort will make an important difference.

Element 7: Contribution to Climate Services

7.1. Where relevant, contribution to climate services according to the established capacity for the provision of climate services.

For ranking climate services, the Country Hydromet Diagnostics uses a six-point rating scale, ranging from 'Not Applicable', through 'Less than Basic', 'Basic', 'Essential', 'Full' and 'Advanced'. The scale is applied across six core data points, in alignment with the WMO Checklist for Climate Services Implementation.

In terms of Climate Services **Governance**, Papua New Guinea has inadequate legislation in place for climate services. Climate services are not mentioned in the Civil Aviation Act, which establishes the NWS, although it might be reasonably argued that climate services are implicit in the NWS role. However, the Climate Change Management Act 2015 (Amended 2021) requires the Climate Change and Development Authority to:

- *facilitate and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system as a precautionary measure to reduce the uncertainties regarding the causes, effects, magnitude and timing of climate change (Section 11 as amended (h));*
- *provide for and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change; (Section 11 as amended (i));*
- *strengthen climate observation and support research towards proved understanding, modelling and prediction of the climate system and climate impacts (Section 11 as amended (m)).*

In practice, the Climate Change and Development Authority cooperates with the National Weather Service, which provides climate services to the best of its ability. It would also make little organisational sense for the Climate Change and Development Authority to run a separate climate observation service (nor is this required by Climate Change Management Act). However, given the importance of both climate and climate change to Papua New Guinea, it is unfortunate that the National Weather Service does not have a clearly legislated mandate to provide these services to a stronger level.

The **Basic Systems** element of climate operations in PNG is compromised by the poor quality of the observations network, and relatively basic data management, monitoring and forecasting systems. However, assistance by Australia and through COSPPac over a long period have helped with data rescue, observations management, and product preparation, allowing PNG to maintain a basic level of functionality. It should be emphasised however that the observational network for PNG is very poor when considered against PNG's national needs.

The **User Interface** for Climate Services is provided only through email and paper requests, and in-person discussions. The NWS is redeveloping its website, and currently no climate services are provided on the site.

The **Provision and application of Climate Services** from the NWS addresses principal country needs in terms of monitoring and forecasts, including for drought and seasonal forecasting purposes. Recently, for example an external project (the CREWS initiative) helped introduce a new Drought Update product (Figure 5), which is professionally presented and draws on international modelling and support.

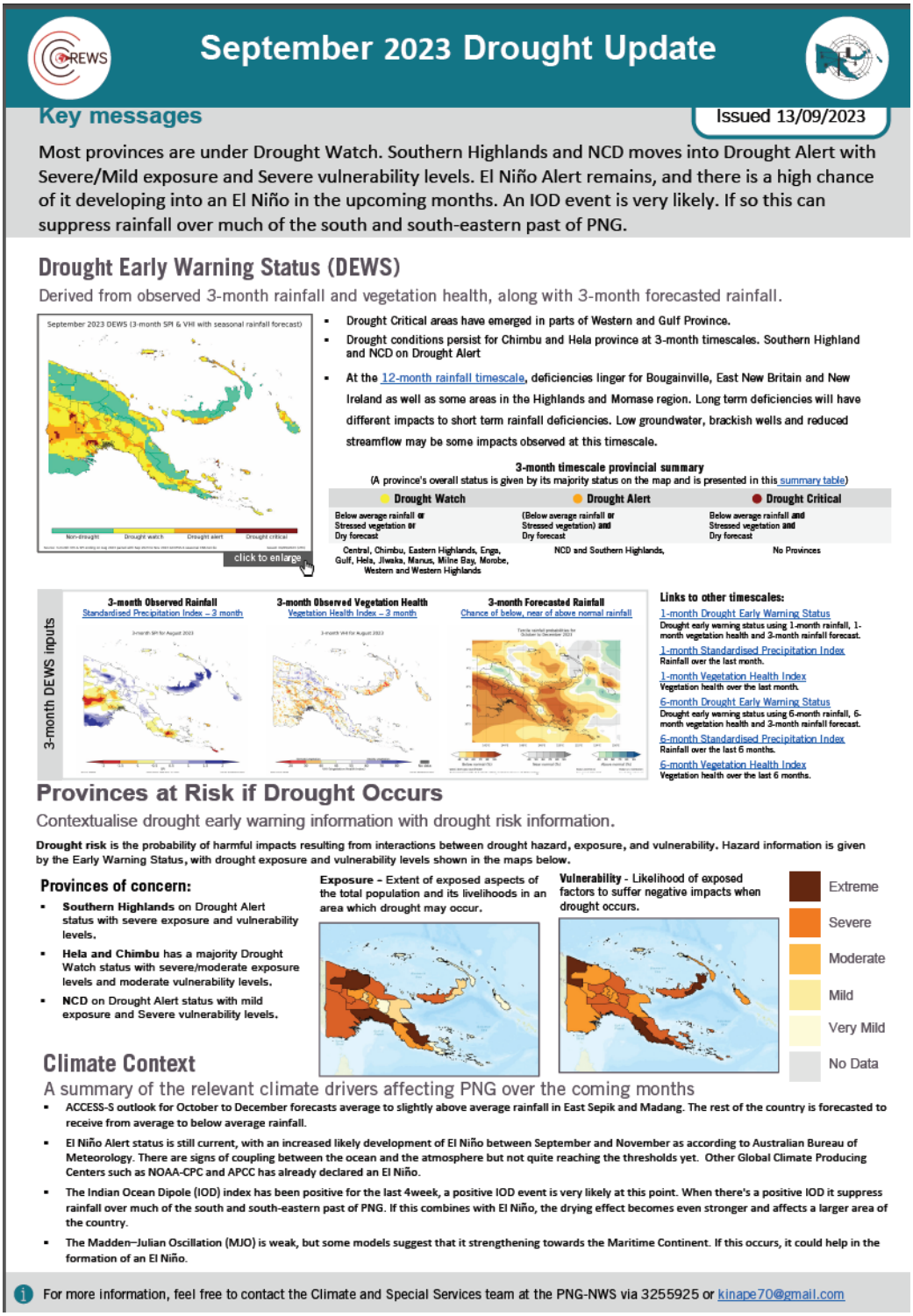

Figure 5 – Example Climate Services Product – the September 2023 Drought Update (distributed through email)

There is no **monitoring and evaluation of the socio-economic benefits** of climate or related services, making it more difficult to articulate the value of climate and weather services to the PNG economy.

Consultative services are provided on a cost-recovery basis, although no commercial charges are levied. Recently, the Climate Services section has taken on an ongoing role in assisting a major mining customer, although they are unable to charge for those services at this stage. Because the section cannot readily reinvest customer services into capacity,

there is little capability for the NWS to take on extra climate services clients to a major extent.

Summary score, recommendations, and comments for Element 7

In terms of formal climate services evaluation, Papua New Guinea rates at **Maturity Level Two** for contribution to climate services, or 'Basic Capacity for Climate Services Provision', noting the support provided by COSPPac and others for services and the dedication of local staff.

Table 8: CHD maturity ratings for Element 7

Element 7: Contribution to Climate Services		*Description: NMHS role in and contribution to a national climate framework according to the established climate services provision capacity.*		
Not Applicable: Climate Services provided by another party Level one: Less than basic Capacity to provide Climate Services	Level two: Basic Capacity for Climate Services Provision	Level three: Essential Capacity for Climate Services Provision	Level four: Full Capacity for Climate Services Provision	Level five: Advanced Capacity for Climate Services Provision

Climate services provision would benefit from broader support of the NWS, including the observations network and communications strategy. In addition to this, improvements can be made through ensuring that climate services are emphasised in new legislation and in support of the Medium-Term Development Plan, by providing for commercial and partnership arrangements to be enabled, and by ensuring that any relevant external capacity building activities for climate-service related purposes are inclusive of the NWS as a key partner in the activity.

Element 8: Contribution to hydrology

8.1. Where relevant, standard products such as quantitative precipitation estimation and forecasts are produced on a routine basis according to the requirements of the hydrological community.

Qualitative warnings for heavy rain are produced by PNG NWS. Aside from this, there are no requirements set by the hydrological community, as the community is not active in Papua New Guinea despite PNG's strong needs. No quantitative precipitation estimation is provided.

An externally-funded global project, the Flash Flood Forecast Guidance System[17], does provide numerical prediction and some remote sensing guidance to the National Weather Service (Figure 6), but the forecasts and information given are difficult to verify and use without ground-truthing. The project is essentially treated as useful guidance at this stage, but does not form part of formal NWS operations.

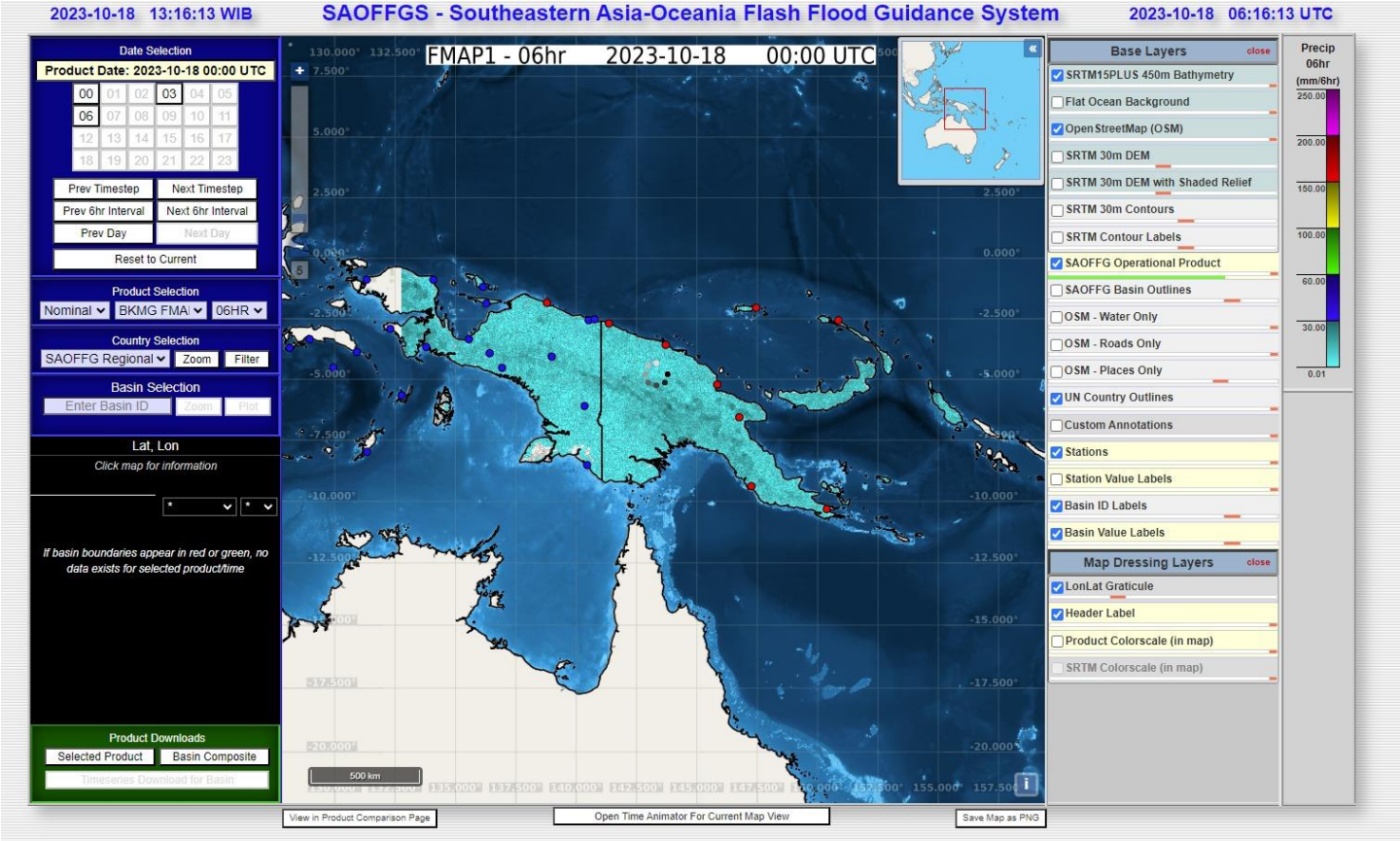

Figure 6 - New Guinea information from Flash Flood Guidance System (courtesy WMO)

Flood warning responsibility is currently nominally with the Conservation and Environment Protection Authority in view of their historical role in maintaining a river gauging network and their statutory role in water management. However, the river gauging network collapsed in the mid-1990s when the former Bureau of Water Resources was dissolved, and apart from a pilot project near the provincial capital of Lae, there are no gauges in place. This is an undesirable situation in the light of PNG's exposure to flooding issues.

[17] https://public.wmo.int/en/projects/ffgs

8.2. SOPs in place to formalize the relation between Met Service and Hydrology Agency, showing evidence that the whole value chain is addressed.

A review of flood warning needs and current arrangements in PNG was conducted in 2014[18] . The report noted the importance of flash flooding and riverine flooding to Papua New Guinea, as well as coastal floods, but noted that:

'Currently, PNG's capacity to generate and disseminate warning information for inland and coastal flooding is almost non-existent due to a lack of adequate technical facilities, capacities and systems in place…. Real forecasting capacity only exists at the NWS for weather services. No hydrological or flood forecasting is currently operational.'

The report also made an assessment of NWS' forecasting ability at the time, stating that:

- *The NWS does not currently forecast rainfall levels. An analysis of the hind-casts, held in the publicly available S2S archive, shows that the forecasts have little skill.*
- *While the capacity to downscale forecasts to a point is in place, an analysis of skill suggests that rainfall amount cannot be accurately forecasted at the spatial scales of relevance for a functioning flood early warning system.*
- *The NWS issues forecasts of rainfall occurrence with a lead time of up to seven days. The forecasts issued by the international modelling centres are no more reliable than if a climatological estimate is issued. The chief reason for the lack of forecast reliability is the challenge of modelling the complex PNG climate.*
- *An assessment of publicly available forecasts showed that the skill for forecasting rainfall intensity is poor – even at a lead time as short as 24 hours. Nevertheless, there is capability for reliable provision of aviation forecasts, which could, in principle, be adapted for a flood early warning system.*
- *Forecasting floods with a sufficient level of detail* ***is the mandatory prerequisite for the successful operation of a flood early warning system*** *in PNG* (emphasis added)*.*

The forecast skill of global models has increased considerably since 2014, but the quality of the observations network in Papua New Guinea has not, and the challenges of convective rainfall forecasting within a parameterized model context remain. Improvement of observations and modelling for rainfall in PNG remains a mandatory prerequisite for a flood early warning system in PNG.

Based on this assessment, and the lack of progress since, there is no evidence that the flood warning value chain is addressed in PNG, notwithstanding the pilot project near Lae.[19]

8.3. Data sharing agreements (between local and national agencies, and across international borders as required) on hydrological data in place or under development.

[18] UNDP and partners, 2014, 'An assessment of early warning systems for inland and coastal flooding in Papua New Guinea'. 143 pp

[19] In 2023, WMO issued guidance on Operational Flood Forecasting Needs from Numerical Weather Prediction, as an annex to the WMO Guidelines on High-resolution Numerical Weather Prediction. The guidance emphasises the requirement for validated, high resolution NWP to support flood forecasting. The surface meteorological and riverine observations network in Papua New Guinea is in no sense sufficient to validate NWP in support of operational flood forecasting.

There is very little hydrological data to share, and certainly not data sufficient for meeting PNG's needs.

8.4 Joint projects/initiatives with hydrological community designed to build hydrometeorological cooperation.

As noted, a pilot project is in operation near Lae, where three river water-level stations and five automatic rain gauges were installed in the Bumbu catchment, as well as automatic weather stations in five surrounding provinces, and some of those stations are in operation. This is positive, but does not substantially address PNG's flood warning needs.

Summary score, recommendations, and comments for Element 8

Papua New Guinea is assessed as having **Maturity Level 1** in this area: *No or very little meteorological input in hydrology and water resource management*. This reflects that there are good relationships, but there is little in the way of a functional flood warning system other than qualitative heavy rain warnings.

Table 9: CHD maturity ratings for Element 8

Element 8: Contribution to Hydrology			*Description: NMHS role in and contribution to hydrological services according to mandate and country requirements.*	
Level one: No or very little meteorological input in hydrology and water resource management.	Level two: Meteorological input in hydrology and water resource management happens on an ad hoc basis and or during times of disaster	Level three: There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but	Level four: The meteorological, hydrological and water resources sectors have a high-level formal agreement in place and an established working relationship and data sharing take place, but	Level five: The meteorological, hydrological and water resources sectors have robust SOPs and agreements in place to work closely in developing new and improved products and providing seamless and advanced services.

In order to address this, a legislative mandate is required for an agency to take the lead in flood warning, paired with sustained funding, recruitment and training to create a hydrological capability in PNG. Without that, externally driven investment is unlikely to be effective in the long term. In support of flood warning, it is also necessary to improve PNG's basic observations network, including for rainfall stations on topography, and make arrangements for the highest quality meteorological modelling to be operationally available and verified for flood warning purposes.

These are all long-term actions, but given PNG's climate, topography, and population vulnerability, they are necessary for developing a capability for flood warning in PNG.

Element 9: Product dissemination and outreach

9.1. Channels used for user-centred communication and ability to support those channels (for example, does the NMHS operate its own television, video or audio production facilities? Does it effectively use cutting-edge techniques?).

PNG NWS distributes its forecasts through traditional media (television, radio, newspaper) and via Email. There are currently no effective coastal radio arrangements for marine warnings. NWS has a website that is currently under redevelopment using internal resources, and at this stage contains little in the way of real time information. In terms of social media, there is an NWS Facebook page with a small number of followers (6.5K from a population of 10M+), which was last updated in December 2022. There is no policy for operational staff to provide updates on real-time events, and no supporting procedures or communications strategy. There are no broadcast text messages.

Internet and mobile phone coverage has been expanding relatively rapidly in Papua New Guinea, with Internet access moving from less than 3% of the population in 2011 to 31% of the population in 2021[20]. So far, the distribution of information from the NWS has not substantially adjusted to this growth.

Slow progress in communications following the Rabaul Queen disaster

The 2014 Mini-Diagnostic referred to the *Commission of Inquiry into the capsizing and sinking of the MV Rabaul Queen*.

The Rabaul Queen had sunk with great loss of life on 2 February 2012, and although the great majority of the proportion of criticism and recommendations had been reserved for the ship's owner and master, the Inquiry had also looked at the National Weather Service forecasts and warnings, and had concluded essentially that they were correct, although not as accessible as they could be. The Owner of the Rabaul Queen had not sought to obtain NWS forecasts and had written his own, based on sources that were not suitable for the purpose. Concerning the distribution of products, the Commission had noted:

> *The Service does not have a website which can be easily updated with the latest forecasts and warnings. Consequently, forecasts and warnings are sent by standard facsimile to a list of interested parties. These parties include the coastal radio station, shipping line offices and interested individuals. Copies are also sent to a number of FM radio stations and to EMTV (Media Niugini Limited), the national television service.*
>
> *However, despite Rabaul Shipping's head office in Rabaul being on the automated facsimile list, records from PNG Telikom show that no faxes were sent to Rabaul Shipping in late January/early February got through (Transcript page 310 - 311). Furthermore, Captain Sharp stated that he had never received any faxes and had never requested any information from the Service.*
>
> *If a shipping company is seeking a copy of the latest forecast or wind warning, they can contact the forecasting office at any time and a copy should be sent to them. However, if a member of the public wants a copy of the latest forecast or warning, they can only contact the forecasting office during office hours to request a copy[21].*

And then recommended:

> *The National Weather Service should take steps to improve the reliability of its weather facsimile service. The Service should also ensure that appropriate and up*

[20] Source: worlddata.info

[21] Report of the Commission of Inquiry into the sinking of Rabaul Queen, 28 June 2012, page 71

to date weather information is available on a publicly accessible website and investigate the feasibility of the dissemination of weather information through social media like Facebook and Twitter.[22]

During the missions for this report, it was reported to us that the distribution of marine forecasts through coastal radio was currently not operational, due to technical problems at the National Maritime Safety Authority. The weather facsimile service is operational, but (as for the rest of the world) is used less than it used to be. As noted above, the website is under redevelopment and does not currently contain real time forecasts and warnings, and NWS social media is inactive.

Based on this, some related commentary in the 2014 Mini-Diagnostic, and more recent observations, the communications strategies of the NWS and (in relation to the coastal radio service) its partners have not substantially improved in response to the Inquiry recommendations.

9.2. Education and awareness initiatives in place.

PNG NWS has many requests from schools to visit, and engages with these where possible. There are no funds available for community visits, and no staff have communications or engagement functions. The NWS does participate in externally funded initiatives where possible.

9.3. Special measures in place to reach marginalized communities and indigenous people.

The NWS recognises traditional knowledge. All products are issued in English, one of the official languages of PNG, which the NWS deem to be the most appropriate language for written communication. Translation into other languages can be done by third parties. For example, a humanitarian agency coordinator noted that they first simplify the language in NWS warnings, then distribute to community volunteers for local translation. They requested that NWS seek to issue products in simpler, non-technical language. This feedback was also reflected in a discussion with a government provincial disaster manager.

Summary score, recommendations, and comments for Element 9

The PNG NWS is assessed as being at **Maturity Level One**: *Dissemination using only limited traditional channels such as daily newspapers and the national broadcaster and with little control over messaging and/or format.*

Table 10: CHD maturity ratings for Element 9

Element 9: Product Dissemination and Outreach		*Description: The level of effectiveness of the NMHS in reaching all public and private sector users and stakeholders.*		
Level one: Dissemination using only limited traditional channels such as daily newspapers and the national broadcaster and with little control over messaging and/or format.	Level two: Traditional communication channels and a basic dedicated website is used to disseminate forecasts and basic information.	Level three: A moderately effective communication and dissemination strategy and practices are in place, based only on in- house capabilities and supported by user-friendly website.	Level four: A large fraction of the population is reached using various communication techniques and platforms, in collaboration with partners, and a user-friendly and informative website and apps. Outreach and education activities occur regularly.	Level five: Advanced education, awareness and communication strategy, practices and platforms in place using various technologies tailored to reach even marginalized communities and in close cooperation with several partners.

This is a critical issue given the poor visibility of the NWS in some areas, and the direct commentary from the Commission of Inquiry and other sources.

To improve this rating, it is important to consider developing a communications strategy, using early warnings communications experts to articulate how the NWS can achieve a step-change in population engagement. This may include seeking external support with redeveloping the website from a user-friendly perspective, developing updated media and

[22] Report of the Commission of Inquiry into the sinking of Rabaul Queen, 28 June 2012, recommendation 24.

social media protocols to empower staff to distribute products in new mediums, considering the language of forecasts and warnings, particularly in the context of impact-based warnings and the implementation of the Common Alerting Protocol.

Element 10: Use and national value of products and services

10.1. Formalized platform to engage with users in order to co-design improved services.

There is no formalised, regular consultation platform, but engagement of the NWS with some key users has improved since the 'Mini-diagnostic' was performed in 2014. This was reported by several interviewees (for example, in discussions related to river monitoring, disaster management, and marine services) and appears be a direct result of proactive engagement from current management.

10.2. Independent user satisfaction surveys are conducted, and the results used to inform service improvement.

Independent user satisfaction surveys are not conducted. Several staff members noted that PNG citizens have a tendency to not give solicited feedback unless there is a complaint, so proactive user surveys would be a very useful way of mitigating against complaint-driven mechanisms.

With that noted, there was also evidence that NWS efforts to provide critical warnings and products, including climate products, are appreciated. The newly introduced drought outlook from the NWS Climate Section, distributed by email, is an example of such a new product.

10.3. Quality management processes that satisfy key user needs and support continuous improvement.

Quality management standards have dropped in recent years, following the deletion of the Quality Management Officer position from the NWS. This position had a focus on aviation. There is little evidence of continuous improvement processes, although there is strong desire from NWS staff and management to produce quality products. As a general comment, NWS staff appear demoralised in their efforts to produce quality services in a declining budgetary environment. The morale situation in this respect has not improved since 2014.

Summary score, recommendations, and comments for Element 10

Based on the evidence available, a **Maturity Level Two** rating is given for Papua New Guinea, reflecting that *Service development draws on informal stakeholder input and feedback.* This is a marginal rating and the NWS is at risk of being rated at Maturity Level One 'Service development lacks any routine stakeholder feedback practice', but the lower rating is less appropriate for now because of the NWS' more recent efforts to engage with key stakeholders.

Table 11: CHD maturity ratings for Element 10

Element 10: Use and National Value of Products and Services			*Description: Accommodation of public and private sector users and stakeholders in the service offering and its continuous improvement.*	
Level one: Service development lacks any routine stakeholder feedback practice.	Level two: Service development draws on informal stakeholder input and feedback.	Level three: Services development draws on regular dialogue with major stakeholders.	Level four: Service development draws on survey data and regular dialogue based on formal relationships with major stakeholders to ensure continuous improvement.	Level five: The meteorological, hydrological and water resources sectors have robust SOPs and agreements in place to work closely in developing new and improved products and providing seamless and advanced services.

NWS' poor resourcing and lack of public visibility are key factors in this area. A significant improvement in the value of the NWS to the PNG community could be achieved with a moderate level of investment and legislative improvement, resulting in strong benefits to the PNG economy and public safety.

Annex 1 Consultations (including experts and stakeholder consultations)

Papua New Guinea Government:

- National Weather Service
- Department of Transport
- Civil Aviation Safety Authority
- Maritime Safety Authority
- National Disaster Centre
- Bougainville Emergency Management Directorate
- Conservation and Environment Protection Authority
- Climate Change and Development Authority

Niusky Pacific Ltd

Papua New Guinea Red Cross Society

United Nations Development Programme

Australian High Commission

Annex 2 Urgent needs reported

PNG NWS staff reported urgent needs across virtually every category of discussion, including for:

- Training (support for staff for professional training, particularly including the one-year Diploma of Meteorology in Australia). It is urgent to seek further partnership and procedural support for critical staff training, including in forecasting and warning functions, to reduce the lack of training as a 'blocker' in operations and staff career progression.;
- Upgraded facilities, particularly at remote offices, some of which are in a very degraded state;
- Prompt payment of allowances;
- Support for the observations network, including for surface and upper air observations;
- Improved security at all locations including Port Moresby, particularly for women working out-of-hours, but also more generally for all staff;
- Access to observations sites at specific airport locations; and
- Assistance with ensuring that observations are received in the WMO Integrated Observing System (some issues were identified in message forwarding through the Australian Bureau of Meteorology).

As indicated at various places in the text, the complexity of the challenges that PNG NWS deals with means that there are relatively few 'quick fixes' for some of these issues. Rather, long term partnership approaches are most useful in this context.

Annex 3 Information supplied through World Meteorological Organization

- World Meteorological Organization Monitoring System Data
- World Meteorological Organization Hydrology Survey
- Data from Checklist for Climate Services Implementation

Annex 4 List of materials used

Bureau of Meteorology, Australia, internal visit reports

Center for Excellence in Disaster Management and Humanitarian Assistance, 2022 Disaster Management Reference Handbook - Papua New Guinea 102 pp

Civil Aviation Act (2000, amended 2010, 2016)

Climate Change Management Act 2015 (Amended 2021)

Commission of Inquiry into the sinking of Rabaul Queen, 2012, Final report, 250pp

Conservation and Environment Protection Authority Act 2014.

Climate Risk and Early Warning Systems (CREWS) Project Reports, 2018-2021

Disaster Management Act 1984 (Amended 1987)

Johnson, R. Wally, 'Roars From The Mountain', ANU Press. http://doi.org/10.22459/RM.2020 https://press.anu.edu.au/publications/series/pacific/roars-mountain

Government of PNG, 2009, Papua New Guinea Vision 2050, 82pp

Government of PNG, 2023, Medium-Term Development Plan 2023-2027, 332 pp

PNG National Weather Service, 2019. Strategic Plan 2019-2023 (Draft copy) 19 pp

PNG National Weather Service Observations Station condition reports, 2023

Tupper, A., Dunda, P, White, P, and Ataia B A, 2014. Mini-diagnostic report, Papua New Guinea National Weather Service. 84 pp

UNDP and partners, 2014, 'An assessment of early warning systems for inland and coastal flooding in Papua New Guinea'. 143 pp

Weather Ready Pacific – A Decadal Program of Investment. Pacific Meteorological Council, May 2021

World Meteorological Organization Guidelines on High-resolution Numerical Weather Prediction (World Meteorological Organization-No. 1311, June 2023 Available at https://library.World Meteorological Organization.int/doc_num.php?explnum_id=11654

World Meteorological Organization Operational Flood Forecasting Needs from Numerical Weather Prediction. Annex to WMO Guidelines on High-resolution Numerical Weather Prediction (World Meteorological Organization-No. 1311, June 2023

World Meteorological Organization Guidelines on the Role, Operation and Management of National Meteorological and Hydrological Services. 2017 edition (World Meteorological Organization-No. 1195). Available at https://library.World Meteorological Organization.int/doc_num.php?explnum_id=4221