CONTENTS

LIST OF TABLES

15. GREENHOUSE GASES AND CLIMATE CHANGE

This chapter summarises the assessment of greenhouse gas (GHG) emissions associated with the construction and operation of the Papua LNG Project – Downstream (the Project) undertaken by SLR Consulting Australia Pty Ltd (SLR) and presented in Appendix F Greenhouse Gas Assessment. The objectives of the study, as described in the environmental inception report approved by the Conservation and Environment Protection Authority in September 2022, were to:

- Compile an inventory of GHG emissions expected to be generated during the construction and operation of the Project.
- Benchmark the GHG emissions from the Project against relevant national, industry or facility emissions.
- Document GHG abatement and energy efficiency measures currently employed on the PNG LNG Project.
- Propose GHG abatement and energy efficiency measures to mitigate the increased emissions if existing measures are insufficient.

This chapter also provides a summary of the predictions for climate change for the region in which the Project is located.

15.1 INTERNATIONAL AND PAPUA NEW GUINEA CONTEXT

Several mechanisms are in place to encourage international cooperation in the management and minimisation of GHG emissions, including the Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. The function of each of these is outlined below. Many are linked to national goals Papua New Guinea seeks to achieve and are therefore relevant context for this chapter. The role of Papua New Guinea's Climate Change Development Authority in the context of the UNFCCC and its related agreements is also outlined. The function of the International Finance Corporation Performance Standards are also outlined.

15.1.1 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Programme and World Meteorological Organization to provide independent scientific advice on climate change. The role of the IPCC (2010) is:

> *…to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.*

The IPCC prepares comprehensive scientific reports about climate change including the IPCC assessment reports. The first IPCC assessment report in 1990 served as the basis for negotiating the UNFCCC. The report underlines the importance of climate change as a challenge with global consequences and requiring international cooperation.

15.1.2 United Nations Framework Convention on Climate Change

The UNFCCC is an international environmental treaty that came into effect in 1994. The objective of the UNFCCC is to stabilise concentrations of GHG in the atmosphere at a level that would prevent dangerous human-induced effects on climate. It is the parent treaty of the Kyoto Protocol (UNFCCC 2014).

Papua New Guinea ratified the UNFCCC in 1993.

15.1.3 Kyoto Protocol

The Kyoto Protocol built upon the UNFCCC by committing signatories set out in Annex I to individual, legally binding targets to limit or reduce GHG emissions. It was adopted in 1997 and entered into force in 2005. The Kyoto Protocol concluded in 2020, with the end of the second commitment period which started in 2013, while the first commitment period ran from 2008 to 2012 (UNFCCC 1998).

The Kyoto Protocol mandated the regulation of seven GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) with nitrogen trifluoride (NF_3) being adopted in the second Kyoto commitment period (Ecometrica 2014).

Papua New Guinea ratified the Kyoto Protocol in 2002 as a non-Annex I signatory.

15.1.4 Paris Agreement

The Paris Agreement to the UNFCCC (Paris Agreement) builds on the Kyoto Protocol and UNFCCC with the aim to limit the increase in global temperature to below 2°C above pre-industrial levels. The Paris Agreement provides a framework for countries to determine and report on emissions and emissions management. It also aims to strengthen developing countries' ability to deal with impacts of climate change and support them in their efforts (UNFCCC 2023).

Papua New Guinea submitted its first Climate Plan and ratified the Paris Agreement in 2016.

15.1.5 Office of Climate Change and Development

The Papua New Guinea Office of Climate Change and Development (OCCD) and National Climate Change Committee (NCCC) were formed in 2010 (OCCD 2010), with the OCCD now referred to as the Climate Change and Development Authority (CCDA).

The CCDA, established under the *Climate Change (Management) Act 2015*, is the designated National Authority under the UNFCCC and is responsible for facilitating and developing policies, and regulatory framework to address climate change in Papua New Guinea (CCDA 2020).

In March 2016, CCDA released Papua New Guinea's first Nationally Determined Contribution. In December 2020, the Enhanced Nationally Determined Contribution was released which includes a *package of policies and measures, sectorial targets, and sector-specific actions that are tailored towards meeting defined contributions to addressing climate change…*

The key items include maintaining Papua New Guinea's high forest cover and reducing emissions from both land use changes and the energy sector.

15.1.6 International Finance Corporation (IFC) standards

The Project has adopted the International Finance Corporation Performance Standards (IFC PS) on Environmental and Social Sustainability (IFC 2012). The IFC PS are comprised of eight performance standards that detail commitments, roles and responsibilities relating to environmental and social sustainability. In relation to this assessment, IFC PS 3, *Resource Efficiency and Pollution Prevention*, requires that:

> *In addition to the resource efficiency measures described above, the client will consider alternatives and implement technically and financially feasible and cost-effective options to reduce project-related GHG emissions during the design and operation of the project. These options may include, but are not limited to, alternative project locations, adoption of*

renewable or low carbon energy sources, sustainable agricultural, forestry and livestock management practices, the reduction of fugitive emissions and the reduction of gas flaring.

For projects that are expected to or currently produce more than 25,000 tonnes of CO_2-equivalent annually, the client will quantify direct emissions from the facilities owned or controlled within the physical project boundary, as well as indirect emissions associated with the off-site production of energy used by the project. Quantification of GHG emissions will be conducted by the client annually in accordance with internationally recognized methodologies and good practice.

SLR prepared the GHG emissions assessment to meet the requirements of IFC PS 3.

15.2 GREENHOUSE GAS ASSESSMENT

The GHG emissions were estimated for the construction, commissioning, and operation phases of the Project to determine the contribution to Papua New Guinea's GHGs. A brief explanation of the GHG emissions and the relevant project activities is as follows:

- **Scope 1 emissions.** Directly result from project activities including combustion of fuels due to transport, on-site power generation and construction activities.
- **Scope 2 emissions.** Result from the generation of electricity, heating, cooling or steam by a third-party that is supplied to a project, i.e., indirect emissions. As the Project does not consume electricity from the grid, Scope 2 emissions are negligible and were not calculated as part of the assessment.
- **Scope 3 emissions.** Generated in the wider economy as a consequence of a project, i.e., indirect emissions, but not directly generated by the project. Reporting of Scope 3 emissions is not required under UNFCCC methods, nor are IPCC emission factors designed to allow the calculation of Scope 3 emissions; as such, Scope 3 emissions were not calculated as part of the assessment.

Scope 1 GHG emissions will also occur during decommissioning of the Project; however, options for facilities and infrastructure will vary between life extension, upgrading or decommissioning. While decommissioning activities will comply with applicable regulatory requirements at the time, due to the current uncertainty, emissions associated with the end-of-life phase of the LNG Plant and other infrastructure associated with the Project have not been calculated as part of the assessment.

15.2.1 Assessment method

The GHG assessment included the following steps:

- Definition of the boundary for Scope 1 emissions
- Identification of the potential sources of GHG emissions from construction, commissioning and operation activities
- Estimation of the quantities of GHG produced from Project sources
- Comparison of the estimated GHG quantities produced from the Project and most recent available operational emissions data from the LNG Plant as well as national GHG emissions inventory data
- Analysis of expected GHG emissions and comparison against total Papua New Guinea emissions
- Determination of GHG management measures.

As above, due to negligible Scope 2 emissions, and the assessment methods not requiring Scope 3 emissions, only the Scope 1 GHG emission estimates have been calculated.

15.2.2 Boundary for Scope 1 emissions

The Scope 1 boundary covers the Project area comprising the LNG Plant and facilities located within the fence of the LNG Plant to the south of the existing jetty where GHG emissions associated with construction and operation of these infrastructure areas are within the geographical boundary of this assessment.

Once the Project is operational, the electricity produced by the Combined Cycle Power Plant (CCPP) will be shared with the LNG Plant, which will enable the LNG Plant to either shut down or put on standby its less efficient gas turbine generators. In this estimate, SLR apportioned GHG estimates from the CCPP between the two projects based on the design power needs of the facilities.

15.2.3 Emission estimation method

The annual emission estimates were calculated by the Project design team, and adopted by SLR within the assessment, for the following Scope 1 emission sources:

- Emissions associated with fuel use in stationary engines, mobile equipment, vessels, and vehicles
- Emissions associated with flaring during commissioning and operations
- Operational emissions associated with combustion of fuel gas in the CCPP turbines
- Fugitive emissions during commissioning and operations.

The Project includes processing of up to 2 mtpa of gas from the Papua LNG Project – Upstream in existing trains 1 and 2 at the LNG Plant, and as such, GHG emissions from the existing LNG Plant facilities associated with this processing will be the responsibility of the Project and are included in this assessment:

- Emissions associated with combustion of fuel in mobile equipment, vessels, and vehicles
- Operational emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
- Fugitive emissions during commissioning and operations.

For the purpose of the assessment, estimated GHG emissions from the Project have been calculated in the form of carbon dioxide-equivalents (CO_2-equivalents) based on the global warming potentials. The amount of CO_2-equivalent emissions is calculated by multiplying the mass of gas by the global warming potential of that gas.

The global warming potentials derived from IPCC Sixth Assessment Report (IPCC 2021) for calculation of the GHGs relevant to the Project are presented in Table 15.1.

Table 15.1 Global warming potentials of greenhouse gases used in this assessment

Greenhouse gas	Global warming potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	29.8
Nitrous oxide (N_2O)	273

Source: IPCC Sixth Assessment Report (IPCC 2021).

Further information on global warming potentials, emissions estimation factors and activity data used in the GHG assessment is provided in Appendix I Greenhouse Gas Assessment.

15.3 GREENHOUSE GAS EMISSIONS

This section provides the GHG emissions estimates for construction, commissioning, and operations in kilotonnes (kt) CO_2-equivalents per annum.

15.3.1 Emissions during construction

It is anticipated that the Project infrastructure will be constructed over four years. Scope 1 GHG emission sources associated with construction include the combustion of diesel by plant and equipment, vehicle movements transporting staff and equipment, portable power generators, as well as emissions from solid waste incineration. The Scope 1 GHG emissions are estimated to peak in 2026 at approximately 124 kt CO_2-equivalents, with an average of approximately 57 kt CO_2-equivalents per annum.

The key GHG consideration incorporated into the construction phase is to minimise the use of temporary diesel power generator units by connecting to the existing gas turbine generators for electrical power supply or leverage grid power (which is natural gas sourced from PNG LNG), where practicable.

15.3.2 Emissions during commissioning

The commissioning of Project infrastructure is anticipated to take one year. Greenhouse gas emissions during commissioning include the combustion of diesel for mobile sources, emissions from gas turbines and start-up flaring. The estimated GHG emissions during commissioning is approximately 650 kt CO_2-equivalents.

15.3.3 Emissions during operation

During operation, Scope 1 GHG emission sources are associated with supply of raw gas and condensate, fuel gas combustion, flaring, fugitive emissions, vehicle movements transporting staff and equipment and management of solid waste. The estimated Scope 1 GHG emissions during this phase are approximately 1,067 kt CO_2-equivalents per annum.

15.3.4 Sources of emissions

Table 15.2 presents the estimated annual GHG emissions for different sources by project phase. The major sources of emissions for the Project are flaring and combustion of fuel gas for power and production of liquefied natural gas during commissioning and operations.

An overview of the key GHG considerations incorporated into the current design of the Project is provided below.

15.3.4.1 Native CO_2

CO_2 in gas reservoirs (i.e., native CO_2) is expected to be removed at the Central Processing Facility (CPF) and sent directly from the CPF to a sequestration site. Therefore, no native CO_2 is to be received at the downstream facility and there are no significant or continuous CO_2 vents in the plant design.

15.3.4.2 Power Generation

Power for the new Papua LNG trains will be supplied by an on-site centralised power plant featuring gas and steam turbines used together to generate more electricity from the same fuel than either could do alone. The gas turbine drives an electrical generator, and the exhaust gas is used to produce steam.

The steam then drives another turbine to create additional electricity. Such a configuration is called a CCPP. With this CCPP, the Project will benefit by requiring less fuel and create fewer GHG emissions when compared to the existing power solutions in the LNG Plant.

The CCPP configuration also seeks to maximise the gas turbine generators’ normal operating efficiency, and consideration has been given to design options that preserve the flexibility to convert the site to a fuel gas supply of up to 100% hydrogen in the future. To this end, the plant design considers the future addition of a hydrogen generation facility to replace the existing fuel gas system. Electric LNG (eLNG) trains were also selected as the design basis to enable the potential for power supply from renewable generation in the future.

The CCPP may allow the existing less-efficient Solar Titans to be on standby or shut down, supplying power to both existing and new plant facilities to optimise fuel gas and reducing GHG emissions under normal operations (power share mode).

Other options for self-generation of power were investigated, but solar, wind and hydroelectric power generation options were all deemed inadequate for the Project at this time. The connection to the external power grid will be maintained to facilitate the possibility of power import in the future, should suitable renewable or other low GHG-intensity electrical power become available through the external power grid.

15.3.4.3 Flaring

The Project design is expected to minimise flaring at the facility via a Flare Gas Recovery System (FGRS). This system is expected to achieve a reduction in GHG emissions from the Project flare system of approximately 13 kt CO_2 per year.

As the plant design is refined, further options to minimise flaring (i.e., during initial plant start up, plant restart and abnormal operating conditions) will be assessed and considered. Flare flow rate measurement will be provided to support flare GHG emissions tracking and reporting.

15.3.4.4 LNG Tank Boil-off Gas (BOG) Recovery System

Given the high methane content of the LNG product, GHG emissions from its storage will be minimised via a boil-off gas (BOG) recovery system. If there is a short-term outage of the BOG system, BOG will be sent to the flare for destruction (i.e., conversion of the methane to CO_2) rather than vented, to minimise GHG emissions.

15.3.4.5 Process Regeneration Gas Heaters

Process regeneration gas heating is currently proposed to be provided by a steam or electrical heating source. As steam and electric heating has not previously been used for this service, if technical issues arise with that option a fired heater will be used instead, which will be designed for compatibility with a possible future fuel gas of up to 100% hydrogen.

15.3.4.6 Mobile Emissions Sources

Material handling studies for the Project will prioritise the use of electrically powered material handling equipment over diesel- or petrol-powered equipment as much as feasible.

15.3.4.7 Energy Efficiency in Design

Most of the energy used in the plant operation will be provided by combustion of fuel gas, so efficient use of energy throughout the plant is aimed at reducing the GHG intensity of the facility and conserving fuel gas. Energy efficient practices incorporated into the plant design include:

- Use of feed/effluent and other heat recovery heat exchangers
- Selection of rotating equipment that operates close to the best efficiency point for normal operation
- Addition of one or more process hydraulic turbines to increase overall plant efficiency
- Fuel gas flow rate measurement on all combustion equipment or devices to support flare GHG emissions tracking and reporting through an automated data management system.

Table 15.2 Sources of GHG emissions by Project phase

Project phase	Source of emissions	Estimated annual emissions (kt CO_2-equivalent)						
		2024	2025	2026	2027	2028	2029	2030
The Project (new LNG processing trains)								
Construction	Engines – liquid	4.99	27.16	73.52	25.15	-	-	-
	Mobile sources	4.21	25.08	49.78	16.67	-	-	-
	Waste incineration	0.75	0.75	0.75	0.75	-	-	-
Commissioning	Mobile sources	-	-	-	-	4.12	-	-
	Waste incineration	-	-	-	-	0.75	-	-
	Turbines – gas	-	-	-	-	337.26	-	-
	Flaring	-	-	-	-	77.27	-	-
Operation	Mobile sources	-	-	-	-	-	4.12	4.12
	Waste incineration	-	-	-	-	-	0.75	0.75
	Turbines – gas	-	-	-	-	-	637.50	637.50
	Flaring	-	-	-	-	-	30.00	30.00
	Subtotal	10.0	53.0	124.1	42.6	419.4	672.4	672.4
LNG Plant (existing trains 1 and 2 processing for the 2 mtpa of Project gas)								
Commissioning	Engines	-	-	-	-	0.02	-	-
	Flaring	-	-	-	-	6.74	-	-
	Fugitives	-	-	-	-	0.07	-	-
	Heaters / boilers / reboilers	-	-	-	-	2.22	-	-
	Turbines	-	-	-	-	220.38	-	-
	Mobile sources	-	-	-	-	0.66	-	-
Operation	Engines	-	-	-	-	-	0.04	0.04
	Flaring	-	-	-	-	-	11.55	11.55
	Fugitives	-	-	-	-	-	0.13	0.13
	Heaters / boilers / reboilers	-	-	-	-	-	3.81	3.81
	Turbines	-	-	-	-	-	377.79	377.80
	Mobile sources	-	-	-	-	-	1.12	1.12
	Subtotal					230.1	394.4	394.4
	Total Project Emissions	**10.0**	**53.0**	**124.1**	**42.6**	**649.5**	**1,066.8**	**1,066.8**

15.3.5 Comparison of estimated integrated LNG Plant emissions with current emissions

The total Scope 1 emissions for the existing LNG Plant in 2022 was estimated to be approximately 1,742 kt CO_2-equivalent per annum. During construction, the total Scope 1 emissions are expected to increase by up to approximately 124 kt CO_2-equivalent per annum from 2022 emissions (7% increase). Once the Project is fully commissioned, the integrated LNG Plant Scope 1 emissions are predicted to increase by approximately 470 kt CO_2-equivalent per annum from 2022 emissions (27% increase). This increase is largely attributable to the combustion of fuel gas in the CCPP providing power to both the Project and existing LNG Plant.

Notably, upon commencement of operation of the Project, SLR has forecast an improved emissions intensity for the integrated LNG Plant, with an estimated reduction of around 1.6 tonnes CO_2-equivalent per 100 tonnes of product available to market (i.e., 18.7 down to 17.1 tonnes CO_2-equivalent per 100 tonnes of product available to market).

15.3.6 Total Project-generated greenhouse gas emissions

In April 2019, the Papua New Guinean Government released Papua New Guinea's First Biennial Update Report to the UNFCC (CCDA 2018) which presents an overview of the nation's GHG emissions. In May 2022, an updated National Inventory Report 2000 – 2017 (CCDA 2022) was submitted to the UNFCCC. Project emissions will be included in the nation's future national GHG emission inventory as part of the energy sector emissions.

The updated report found that in 2017 the total energy sector emissions were 8,673 kt CO_2-equivalent (the most recent year presented in the report). SLR estimated the Scope 1 emissions in 2022 for the LNG Plant as approximately 1,742 kt CO2-equivalent, which is 20% of the 2017 reported total energy sector emissions. From 2029, when the Project is fully commissioned, Scope 1 emissions for the integrated LNG Plant are predicted to be 27% higher than Scope 1 emissions in 2022, whereby the Project is predicted to increase energy sector emissions by around 5%, and Papua New Guinea's national emissions from 2017 by approximately 4%.

15.3.7 Greenhouse gas abatement initiatives

This section describes the proposed GHG abatement and management initiatives of the Project.

15.3.7.1 The Project's GHG Initiatives

The Project's proposed design incorporates energy efficiency measures that support the minimisation of GHG emissions and is consistent with engineering, design and procurement approaches set out in the EMPNG *Environmental Management Plan: LNG Plant and Marine Facilities* for the LNG Plant. Specifically, the following priorities were identified for the Project's plant design in relation to GHG emissions mitigation:

- Identifying design choices that have the potential to improve the GHG performance of the operating LNG Plant, with design choices that change the projected GHG emissions by 5 kt CO_2-equivalent per annum or greater to be communicated to management for further investigation.
- Providing a plant design that does not preclude subsequent projects at the site that may reduce GHG emissions intensity.

Optimisation of energy use and minimisation of GHG emissions will be a key consideration throughout the detailed design phase of the Project. Refer to Section 15.3.1 and 15.3.4 for key design considerations.

15.3.7.2 Management measures

In addition to key design considerations to improve GHG performance (see Section 15.3.4), the management measures identified for the Project that will further assist in reducing GHG emissions are provided in Table 15.3. In addition, standard energy efficiency practices relating to mobile plant and equipment to reduce GHG emissions include:

- Reducing vehicle speed limits on site

- Reducing idling times of trucks at construction sites through efficient traffic management
- Maintaining roads to avoid meandering of vehicles on roads
- Reducing gradients of haul roads to reduce fuel consumption
- Optimising vehicle tyre pressures.

Table 15.3 Management measures that reduce GHG emissions

Number	Management Measure
MM192	Maintain vehicles and equipment to limit air emissions, and maximise fuel efficiency, and remove from service any vehicles or equipment from which emissions are excessive.
MM74	Avoid the use of chemicals and hazardous materials subject to international bans or phase-outs consistent with the following agreements: • Stockholm Convention on Persistent Organic Pollutants. • Montreal Protocol on Substances that Deplete the Ozone Layer. • Rotterdam Convention of Prior Informed Consent for Certain Hazardous Chemicals and Pesticides in International Trade.
MM78	Consider the GHG implications of modularisation during the construction planning process.
MM76	Minimise the use of temporary diesel power generator units by connecting to the existing gas turbine generators for electrical power supply or leverage grid power (which is natural gas sourced from PNG LNG), where practicable.
MM193	Minimise waste to minimise GHG emissions from treatment, disposal and/or transport of waste. Sort waste to minimise quantities landfilled and to maximise recycling and reuse as far as practicable.
MM84	Track and report on GHG emissions and associated activity data (i.e., fuel consumption) to assist in identifying key emission sources and appropriate targeting of mitigation measures.

GHG emissions are tracked and reported to internal and external stakeholders as part of EMPNG's environmental performance reporting requirements for the existing LNG Plant. Site emission sources are accounted for, including generators, turbine compressors, flares, process vents and mobile sources such as vehicles. Direct process fuel usage is used with approved emission factors to calculate the final GHG emissions.

Year-on-year trends in the estimated GHG emissions are reviewed and differences noted are used to understand potential changes in operations.

In addition to management measures presented in Table 15.3, the management and monitoring measures included in the PNG LNG Project ESMP will be leveraged, and updated where necessary, for the integrated LNG Plant once the Project has been constructed and commissioned. GHG allocation procedures will be identified as part of the commercial arrangements for sharing gas and utilities between the joint sites, with measurement facilities to be provided consistent with those agreements.

A fugitive emissions monitoring program will also be implemented at the site.

15.4 CLIMATE CHANGE

The greenhouse effect is a naturally occurring process by which gases in the atmosphere, such as carbon dioxide and methane aid in retaining heat in the atmosphere. Atmospheric uptake and GHG generation is influenced by environmental temperature and moisture (IPCC 2007).

The sun is the primary energy source for Earth's climate. When solar radiation reaches the Earth's atmosphere, some is reflected into space and the rest is absorbed by the Earth's surface and atmosphere

(CSIRO 2011). Much of this absorbed solar energy is re-emitted by the Earth's surface as heat (longwave or infrared radiation). Greenhouse gases in the atmosphere absorb this radiation from Earth and emit the radiation back into the atmosphere. The increase in trapped energy results in keeping the Earth's surface and lower atmosphere warm. Without the greenhouse effect, the average temperature of the Earth's surface would be more than 30 degrees cooler (CSIRO 2011). Any disturbance to the balance of incoming and outgoing solar energy will affect the Earth's climate (The Royal Society 2014).

The enhanced greenhouse effect is a phenomenon in which the concentration of GHGs (including carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4)) in the atmosphere has increased due to human activities (The Royal Society 2014). The increased concentration of GHGs in the atmosphere has reduced the amount of heat escaping into space causing an increase in the amount of radiation trapped in the Earth's lower atmosphere where the weather we experience is generated.

The predicted changes in climatic conditions due to the enhanced greenhouse effect are discussed in the following sections.

15.4.1 Intergovernmental Panel on Climate Change predicted effects of climate change

The IPCC releases reports describing the state of scientific, technical and socio-economic knowledge on climate change, with comprehensive review of its impacts and future risks predicted in the latest climate models. The IPCC Sixth Assessment Report (IPCC 2021) presents climate predictions divided into regions, both land and sea. Papua New Guinea is described in the South-east Asia climate region.

A summary of the IPCC findings includes the following:

- **Temperature.** The intensity and frequency of days of extreme heat are projected to increase, while intensity and frequency of cold extremes will decrease. The likelihood of these changes ranges from likely to virtually certain depending on the modelled scenario.
- **Rainfall.** The frequency and intensity of rainfall are projected to increase, with the report stating there is high confidence in these projections.
- **Cyclones.** The number of extreme cyclones is projected to increase by at least 20%, with these increases in strong cyclones appearing to be robust across models and for most seasons, although they show strong regional variations.
- **Sea level.** Rise in sea level of approximately 10 to 40 cm by 2050 predicted with high confidence.

15.4.2 Pacific-Australia Climate Change Science and Adaptation Planning Program

The Pacific-Australia Climate Change Science and Adaption Planning Program (PACCSAP) undertook a range of science, communication, and capacity building activities to improve the understanding of the current and future climates of Pacific Islands, including Papua New Guinea.

According to the modelling, the projected changes to the climate of PNG will likely be as follows (PACCSAP 2014):

- **Temperature.** The predicted annual increase in temperature by the end of 2030 ranges from 0.4 to 1.1°C depending on the emission scenario.
- **Rainfall.** Average rainfall is projected to increase in most areas, along with more extreme rain events. Drought events will decline in frequency.

- **Cyclones.** Tropical cyclones are projected to be less frequent; however, the intensity is predicted to increase.
- **Sea level.** Sea levels are expected to continue to rise. By 2030, sea levels are projected to rise by 7 to 17 cm depending on the emission scenario, which may result in coastal flooding in low-lying areas.

15.4.3 Considerations for the Project

The predicted effects of climate change may increase in frequency and/or severity over time. These effects may manifest in many ways, with their local and subregional scale intensity and severity influenced by terrain, local variation in meteorological conditions, uncertainty about the relationship between El Niño Southern Oscillation activity and climate change, land use and natural phenomena, e.g., volcanic eruptions. Potential implications for the Project resulting from climate change effects could include:

- Enhanced erosion and runoff from increased rainfall and storm intensity
- More frequent and intense coastal and inland flooding
- More frequent heat waves
- Changed seawater to freshwater interface due to sea level rise leading to possible regression of freshwater environments
- Changed land use due to drought, inundation and enhanced productive capacity (higher rainfall)
- More favourable (humid) conditions for outbreak and spread of water-borne and vector diseases (e.g., malaria), plant pathogens and pest plants and animals.

The effects and potential impacts of climate change have been considered in designing project infrastructure.