Environmental and Social Impact Assessment

June 2017

SOL: Tina River Hydropower Project
(Part 4)

Prepared by the Government of Solomon Islands for the Asian Development Bank.

CURRENCY EQUIVALENTS
(as of 9 June 2017)

Currency unit	–	Solomon Islands dollar (SBD)
SBD1.00	=	$0.1276
$1.00	=	SBD7.8308

NOTE

(i) In this report, "$" refers to US dollars.

Name of Act or regulation	Implication for the Project
Land and Titles Act	The Land and Titles Act establishes the procedure for the registration and acquisition of customary land. The Projectˇs Core Land was acquired through the compulsorily acquisition process set out in Division 2, Part V of the Act. The acquisition included all of the customary land needed for the construction and operation of the project including part of the access road. The process used was a :compulsoryˇ process under the legislation, with acquisition contingent on first obtaining the consent of all identified landowning tribes. This consent was obtained through the negotiation of a written :process agreementˇ. The Land and Titles Act also establishes the procedure for the subdivision and voluntary sale of registered land, relevant to the Projectˇs acquisition of the registered land required for the access road and transmission line corridors. The Lands and Titles Act also made provision for preservation orders to be applied to land of `historic, architectural, traditional, artistic, archaeological, botanical or religious interest¸ and permits the establishment of nature reserves.
Customary Land Records Act	The Act provides a process for the formal identification and recording of customary land ownership and boundaries. Although the Customary Land Records Act is technically in force, the administrative bodies required to administer the Act have not been established. The Act has been piloted informally but never technically used. For this reason, the Project cannot make use of the Act. However, an informal process for recording customary land was undertaken by a land identification committee. The provisions of the Land and Titles Act were used to formally register the land required for the Project.

Name of Act or regulation	Implication for the Project
Mines and Minerals Act	The Act sets out procedures the licence prospecting for, and the extraction of, minerals. The Act will be relevant to the extraction of building materials from the site for use in project construction. The Act requires that the extraction of gravel for use as a building material must have a `Building Materials Permit_(BMP). The BMP is not transferable and royalties must be paid at the prescribed rate per cubic meter for all building materials extracted. However, similar to many of the laws in the Solomon Islands, the Minister can issue an exemption to the building materials permit: building materials for building or road construction for the personal use of the landowner or occupier, or for sale not exceeding a prescribed amount, may be mined without a `Building Materials Permit". The extraction of materials for the TRHDP could require seeking an appropriate permit from MMERE for quarry development to occur. However, the Minister has powers to issue exemptions where a national project, such as TRHDP, is involved.
National Parks 1954	The Minister can make a proclamation declaring certain areas to be a National Park and purchase or acquire any land for such purpose. This Act is outdated and lacks provisions to empower customary landowners to make decisions about their resources. In practice, the Act has been replaced by the Protected Areas Act although not formally repealed.

Name of Act or regulation	Implication for the Project
Protected Areas Act 2010	The Act sets out the process for landowners to formally protect their land. Once protected, land cannot be used for commercial logging or mining, and other uses of the land will be subject to the terms of the management plan established for the land. For an area to become a Protected Area (PA), a community or organization shall prepare an application to the Director of Environment for their site to be declared. The application shall include a PA management plan and scientific studies to show that the areas is of significance to biological diversity and to the community in terms of natural resources. The application will also include an estimated budget for the PA, and evidence of agreement by all customary landowners, as well as a map showing the boundary and size of the site. The director, upon receiving the application, will review the application and make recommendations to the Minister. The Minister shall consider whether: (a) Conservation objectives of the proposed PA are identified and are in accordance with sound conservation practices; (b) Boundaries of the area are accurately identified, or otherwise demarcated and surveyed; (c) Consent and approval are obtained from persons having rights or interests in the area; (d) Appropriate conservation, protection or management plan is developed for the area, to ensure that the conservation objectives of the protected area will be achieved. The Protected Areas Committee has been established and the country˜s first Protected Area was declared in 2016.

Name of Act or regulation	Implication for the Project
Provincial Government Act 1997	Schedule 3 of the Provincial Government Act 1997 provides a list of activities for which the provinces have responsibility, and have the power to pass ordinances; é Trade and Industry - Local licensing of professions, trades and businesses, local marketing. é Cultural and Environment Matters - Protection of wildlife, coastal and lagoon shipping, é Agriculture and Fishing - Protection, improvement and maintenance of fresh-water and reef fisheries. é Land and Land Use - Codification and amendment of existing customary law about land. Registration of customary rights in respect of land including customary fishing rights. Physical planning except within a local planning area é Local Matters - Waste disposal é Rivers and Water - Control and use of river waters, pollution of water é Corporate or Statutory Bodies - Establishment of corporate or statutory bodies for provincial services including economic activity. (Provincial services include "Conservation of the Environment" and "Fishing"). The Guadalcanal Province Wildlife Management Area Ordinance 1990 (GPWMAO) applies to the protection of wildlife. This ordinance applies to TRHDP to ensure that wildlife impacts are understood. Other requirements include a business license during construction and approval under the provincial Town and Country Planning Board.
River Waters Act 1964	The River Waters Act 1964 states that it is an offence to interfere with a river, except in accordance with the terms and conditions of a permit. The Act applies to the section of the river called Ngalibiu (referred to as part of the Ngalimbiu River). A permit will, therefore, be sought from the Minister for MMERE before constructions works proceed. The process for applying for a permit involves submitting details of the proposed construction and diversion that will occur, including maps of the location in which construction will occur. The conditions for issuing a permit include a study of the current use of the river and the potential impact of the proposed interference on the river. In granting any permit, the Minister shall have regard to the existing use of water and shall safeguard such existing use of water as far as it appears to be practicable and consistent with the provisions and purposes of this Act. A practical application would be to submit the ESIA and proposed development plan for a permit to be issued. The law does not provide a timeframe for the permit to be issued.

Name of Act or regulation	Implication for the Project
River Waters Ordinance 1969	Provides measures for watershed control in relation to rivers and regulates the use of designated river water through permit applications.
Public Health Ordinance 1970	This Ordinance authorises inspections to be conducted for the regulation of water pollution.
Solomon Islands Water Authority Act 1992	The Solomon Islands Water Authority (SIWA) is established under this Act and is currently charged with providing the proper management and development of urban water resources and services, and sewerage services in the Solomon Islands.
Safety at Work Act 1982	The legislation codifies the duties of employers to their employees and others responsible for ensuring the safety of workers in various work environments, in particular, safety of workers in dangerous and risky conditions. It provides for the civil and criminal liability of employers who are negligent regarding the safety of their workers.
Town and Country Planning Act 1980	The Act requires developments on registered land to obtain planning consent from the relevant provincial Town and Country Planning Board. The Guadalcanal Board has recently been re-established. The TRHDP will require consent under this Act.
Wild Birds Protection Act 1914	This Act was repealed by the Wildlife Protection and Management Act.
Wildlife Protection and Management Act 1998	The legislation primarily protects wildlife by limiting the import of potentially harmful species, preventing the export of listed protected species and requiring a permit (for scientific research) for others. Schedule I lists the species that are prohibited to export, and Schedule II lists the regulated and controlled species for which a valid permit to export such specimen is required. The Act also empowers the Minister to make an order to approve a management programme which can include measures for the breeding or study of certain species, and the setting aside of reserved areas for their protection. There are no known orders currently in place.

Name of Act or regulation	Implication for the Project
Environmental Health Act 1980 and Environmental Health (Public Health Act 1970) Regulations	In the case of the TRHDP, the Guadalcanal provincial health authority has a duty to take necessary and reasonably practicable measures to enforce the law and request that, at all time, the Project site be in a clean and sanitary condition.
Electricity Act	The Electricity Act sets out in very wide terms the functions and duties of the Solomon Islands Electricity Authority (SIEA). The SIEA (trading as Solomon Power) is generally in charge of all matters related to electricity production and transmission/distribution in Solomon Islands, including ensuring standards of safety, efficiency and economy. It also advises the Government on matters related to electricity and can make recommendations as to regulatory instruments. Relevant to the Project, the Electricity Act empowers SIEA to enter into contracts for the purposes of signing the Power Purchase Agreement. The Act also establishes a licencing regime for an electricity producer and the developer will require a licence under this Act.
Guadalcanal Historic Places Ordinance 1985	This Ordinance provides a means of legally protecting sacred, traditional and archaeological sites. No such sites are present in the Project study areas.

3.3 INTERNATIONAL ENVIRONMENTAL AND SOCIAL TREATIES

Table 3-5 presents and describes international environmental and social treaties signed and ratified by the Solomon Islands, and the relationship between the Project and these treaties is analysed.

Table 3-4 Treaties observed by the Solomon Islands

Multilateral Environment Agreement	Status	Purpose/Aim	Agency Responsible	Relevance to TRHDP
Regional Multilateral Environment Agreements				
Pollution Protocol for Dumping	Ratified 10/9/98	Prevention of pollution of the South Pacific region by dumping.	Marine Div/MECDM	NA

Multilateral Environment Agreement	Status	Purpose/Aim	Agency Responsible	Relevance to TRHDP
Pollution Protocol for Emergencies	Ratified 10/9/98	Cooperation in combating pollution emergencies in the South Pacific region.	Marine Div/MECDM Project: National Pollution Prevention Plan	NA
Natural Resources & Environment of South Pacific Region (SPREP Convention)	Ratified 10/9/98	Protection of natural resources and environment of the South Pacific Region in terms of management and development of the marine and coastal environment in the South Pacific Region.	MECDM	This is relevant for the Project and the ESIA should address the related issues. This a pacific agreement for the management of natural resources and biodiversity
Waigani Convention on Hazardous & Radioactive Wastes 1995	Ratified 7/10/1998	Bans the importation of hazardous and radioactive wastes into Forum Island countries and to control the trans-boundary movement and management of hazardous wastes within the South Pacific region.	MECDM	Any import of hazardous material will require permits to be issued by MECDM. This is a regional version of the Basel Convention.
International Multilateral Environment Agreements				
Chemicals, Wastes and Pollution				
Liability for Oil Pollution Damage	Ratified	Strict liability of ship owner for pollution damage to a coastal state within a certain amount.	Marine Div	NA
Marine Pollution Convention (London)	Ratified	Prevention of marine pollution by dumping of wastes and other matter.	MECDM/Foreign Affairs	NA
United Nations Convention to Combat Desertification (UNCCD)	Acceded 16/4/1999	Agreement to combat desertification and mitigate the effects of drought in countries experiencing drought or desertification.	MAL/MECDM Project: National Action Plan on Land Degradation and Drought	NA

Multilateral Environment Agreement	Status	Purpose/Aim	Agency Responsible	Relevance to TRHDP
POPs Convention (Stockholm)	Acceded 28.7/2004	Protection of human health and environment from persistent organic pollutants (POPs).	MECDM/Environmental Health Div. Project: National Implementation Plan	NA as no POP chemicals will be used during construction.
Biodiversity				
CITES	Instrument of ratification being prepared	Regulations and restriction of trade in wild animals and plants through a certification system of imports and exports.	MECDM	Unlikely to be applicable as applies to import or export of relevant species
World Heritage Convention (UNESCO)	Acceded 10/6/1992	Protection of sites of Outstanding Universal Values. Solomon Islands currently has East Rennell Island as a World Heritage site.[20] Mt. Popomanaseu is on the Tentative list of the UNESCO	National Museum/ MECDM	NA, however, Mount Popomanaseu is at the upper reaches of the Tina Catchment
UN Convention on Biological Diversity (UNCBD)	Ratified 3/10/1995	Conserve biological diversity through the sustainable use of its components and the fair and equitable sharing of the benefits arising out of utilizing genetic resources.	MECDM Project: NCSA; National Biodiversity Strategy and Action Plan; International Waters Program; 3rd National Report	Relevant since the ESIA also aims at protecting species
Cartegena Protocol to the UNCBD	Acceded - 26/10/2004	Protection of human health and the genetic diversity.[21]	MECDM	NA

[20] World Heritage Convention

21 artegena Protocol to the UNCBD

Multilateral Environment Agreement	Status	Purpose/Aim	Agency Responsible	Relevance to TRHDP
Coral Triangle Initiative (CTI) Agreement		Protection and conservation of marine resources within the coral triangle region.		NA
Cultural and Natural Heritage				
World Cultural and Natural Heritage Convention	Acceded in 1992	Protection and management of cultural and natural heritage	National Museum under the Ministry of Home Affairs	Applicable since cultural heritage is valued by local communities
Climate Change Related				
United Nations Framework Convention on Climate Change (UNFCCC)	Ratified - 28/12/1994	Set an overall framework for intergovernmental efforts to tackle the challenges posed by climate change.	MECDM	This is relevant since the Project will reduce the use of fossil fuel for electricity production.
Kyoto Protocol	Ratified - 13/03/2003	Reduce greenhouse gases especially carbon dioxide for the 39 industrial/ developed countries by an average pf 5.2% by 2012.	MECDM	NA- emissions from the construction of the Project are limited in time
Montreal Protocol	Acceded - 17/06/1993	Allows phase out of substances that deplete the ozone layer according to a fixed schedule.	Energy Division	NA
Vienna Convention for the Protection of the Ozone Layer	Acceded - 17/06/1993	-Protection of the ozone layer through intergovernmental cooperation on research. -observation of ozone layer - monitoring of CFC		NA

3.4 WORLD BANK GROUP REQUIREMENTS

To date, the World Bank has provided significant project funds to the Project. The Bank has also proposed that it may provide a partial risk guarantee, as well as concessional and grant financing, towards construction costs. Therefore, the Project must comply with several social and environmental principles. These principles are reflected in the WB Operational Policies, and the WB Performance Standards.

The WB Operational Policies apply to public sector projects and will apply to the land acquisition and livelihood restoration undertaken by the SIG.

The eight Performance Standards, initially developed by the IFC in 2006 and amended in 2012, were adopted by the World Bank in 2013 as the World Bank Performance Standards for Projects Supported by the Private Sector (˝WB Performance Standards˝). They are to be applied where the Bank provides support for projects (or components thereof) that are designed, owned, constructed and/or operated by a Private Entity, in lieu of the World Bank˙s Operational Policies. The developer, the Special Purpose Company (SPC) managed by K-Water as a private sector entity, will abide by WB Performance Standards, all of which, except for PS5 on land acquisition and resettlement, apply to the dam and power plant.

The following sections identify the World Bank Operational Policies and World Bank Performance Standards that will apply to the Project.

The developer/contractor will be responsible for developing an environmental and social management system (ESMS) and for identifying, assessing and managing environmental and social risks and impacts associated with the Private Sector Activity, all in accordance with the WB Performance Standards.

3.4.1 WB Operational Policies

While a private sector agent is taking the lead role in management of environmental and most social impacts, TRHDP-PO, within MMERE, retains the responsibility for land acquisition, livelihood restoration, and benefit sharing, all of which have particular significance to indigenous communities.

World Bank OP 4.12 and OP 4.10 thus apply as safeguards relating to Indigenous Peoples (IP) that are managed in the land acquisition plan (LALRP). WB PS 7 is applicable to the dam and power plant because the Developer must abide by any IP-related mitigation, monitoring, hiring, community engagement, etc. all of which involve IPs.

It is proposed that Solomon Power will construct the transmission line between the powerhouse / switchyard and the main tie-in point at Lungga Generating Station for which WB Operational Policies will apply. Solomon Power as a state owned enterprise is classified as a public sector agency according to OP 4.03 criteria.

The access road, between the Black Post turnoff and Mengakiki, will be upgraded by the Ministry of Mines, Energy and Rural Electrification (MMERE), in part using funding provided by Australian DFAT for which WB Operational Policies will apply.

3.4.1.1 Applicable Operational Policies

Those components of the Project relating to the transmission line and the access road to Mengakiki will be undertaken in accordance with the following applicable World Bank Environmental and Social Safeguard Policies:

- OP4.01 ‒ Environmental Assessment
- OP4.04 ‒ Natural Habitats
- OP4.36 ‒ Forests
- OP4.10 ‒ Indigenous Peoples
- OP4.11 ‒ Physical Cultural Resources

OP 4.01: Environmental Assessment

OP 4.01 (Environment Assessment) sets out the general policies and principles for environmental and social protection and requirements for assessment of impacts and implementation plans and measures to mitigate or manage impacts.

OP 4.01 requires that an assessment evaluate a project's potential environmental risks and impacts in its area of influence; examine project alternatives; identify ways of improving project selection, siting, planning, design, and implementation by preventing, minimizing, mitigating, or compensating for adverse environmental impacts and enhancing positive impacts; and include the process of mitigating and managing adverse environmental impacts throughout project implementation.

The requirements of OP 4.01 for the access road are addressed as part of this ESIA.

OP 4.04: Natural Habitats

OP 4.04 supports the protection, maintenance, and rehabilitation of natural habitats, and a precautionary approach to natural resource management. It provides that the Bank does not support projects that involve the significant conversion or degradation of critical natural habitats unless there are no feasible alternatives for the project and its siting, and comprehensive analysis demonstrates that overall benefits from the project substantially outweigh the environmental costs.

The requirements of OP 4.04 for the access road and transmission line are incorporated into this ESIA. No critical natural habitats are identified as affected by the access road.

OP4.10: Indigenous Peoples

OP 4.10 Indigenous Peoples (Amended 2013) is triggered where a project affects Indigenous Peoples. The vast majority of the people benefiting from and affected by the Project are assessed to be Indigenous Peoples. The Policy will apply to the SIG˘s acquisition of land for the Project, as well as the SIG˘s upgrade and construction of the access road and Solomon Power˘s construction of the transmission line. The Policy requires that SIG engage in free, prior and informed consultation resulting in broad community support. It also requires that SIG avoid potentially adverse effects on Indigenous People and where avoidance is not feasible, minimize, mitigate or compensate such effects. Compensation and benefits must be culturally appropriate and gender and inter-generationally inclusive.

Clause 12 of the Policy indicates that `when Indigenous Peoples are the sole or the overwhelming majority of direct project beneficiaries, the elements of an Indigenous Peoples Plan (IPP) should be included in the overall project design, and a separate IPP is not required._Based on this clause, since the vast majority of citizens of the Solomon Islands are members of one or more Indigenous Peoples, and the entirety of the communities in the project Area of Influence are comprised of members of one or more Indigenous Peoples. Rather, the Social Impact Assessment prepared for the whole project, as part of the overall ESIA, fulfills the needs of what would otherwise be an IPP, and the project design fully accounts for the interest of Indigenous Peoples within the project-affected area. Measures to minimize, mitigate and compensate for land acquisition impacts, and the SIG˘s process of free, prior and informed consent, are set out in the Land Acquisition and Livelihood Restoration Plan.

OP4.12: Involuntary Resettlement

The World Bank˘s policy on involuntary resettlement `is triggered_ in situations involving involuntary taking of land and involuntary restrictions of access to legally designated parks and protected areas. The policy aims to avoid involuntary resettlement to the extent feasible, or to minimize and mitigate its adverse social and economic impacts. The policy prescribes compensation and other resettlement measures to achieve its objectives and requires that borrowers prepare adequate resettlement planning instruments prior to Bank appraisal of proposed projects (World Bank, 2014).

In the case of the TRHDP as it is currently conceived, the Policy is triggered because:

- the proposed project will require the taking of customarily owned land for the dam site, hydro storage reservoir, power station, access roads, quarries and borrow sites, and for power transmission infrastructure, and;
- the taking of such land implies a loss of assets for some, and/or a loss of income sources or means of livelihood.

It is not anticipated that the construction or operation of the TRHDP will result in the loss of residence or shelter of any members of local communities or require any of them to move to another location. While there have been calls during community consultations by some people for their villages to relocate, the project is being designed to avoid relocating and resettling any existing households or communities and, accordingly, will not require any relocations for it to proceed safely.

Avoidance of displacement is consistent with the Bank˘s polices on the protection of indigenous peoples; nevertheless, compliance with OP 4.12 requires the preparation of a Resettlement Action Plan or a Livelihood Restoration Plan for loss of livelihood.

This plan has been prepared as a separate document, the Land Acquisition and Livelihood Restoration Plan. As the SIG is responsible for land acquisition, the plan is prepared with respect to World Bank OP 4.12.

3.4.1.2 OP4.37: Dam Safety

WB Performance Standard 4 will apply to the Project with respect to dam safety. However, OP 4.37 has been used to guide the actions necessary for Performance Standard compliance.

The World Bank˘s policy on dam safety `is triggered_ when the construction of a new dam is proposed. The policy prescribes that the dam be designed and its construction supervised by experienced and competent professionals. It also requires that project adopt and implement certain dam safety measures for the design, bid tendering, construction, operation, and maintenance of the dam and associated works. (World Bank, 2013).

If TRHDP were a Government project, the Policy would be triggered because the proposed TRHDP dam at a height of 53m qualifies as a large (>15m high) dam.

Under the Policy the project proponent is required to engage technical specialists to investigate the site and design the dam, supervise new or remedial construction, advise on initial reservoir filling and start-up operations, and perform inspections and safety assessments. The qualifications of the professionals (e.g., engineers, geologists, or hydrologists) employed by the borrower must be adequate to the complexity of the particular dam.

Project information relevant to dam safety, including: cost estimates; construction schedules; procurement procedures; technical assistance arrangements; environmental assessments; plans for construction supervision and quality assurance, instrumentation, operation and maintenance, and emergency preparedness are to be prepared, along with any other action plans relating to dam safety.

3.4.2 WB Performance Standards

WB Performance Standards (PS) will guide all actions and activities of the Project from design and construction through operations and maintenance, to decommissioning and rehabilitation / restoration of the site. The PS will guide the Project to identify impacts and to avoid, mitigate and manage them in an environmentally and socially acceptable way.

The term `client_ is used throughout the Performance Standards broadly to refer to the party responsible for implementing and operating the Project that is being financed, or the recipient of the financing, depending on the project structure and type of financing. In the case of TRHDP, the client is the developer of TRHDP.

The term `consultant_ refers to the company that is responsible for preparing the ESIA.

TRHDP has delegated the consultant to prepare the ESIA to describe the baseline environmental and social conditions, identify impacts, and propose mitigation measures in accordance with national, World Bank and other IFI standards.

The following sub-sections present the WB PS that apply to the ESIA and highlight what needs to be implemented to comply with the PS.

3.4.2.1 Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts

The requirements of PS1 are presented in Table 3-6

Table 3-5 PS 1 requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	To conduct a process of Environmental and Social Impact Assessment (ESIA) and maintain an effective Environmental and Social Management System (ESMS).	This ESIA includes an Environmental and Social Management Plan
R.2	The client will establish an overarching policy defining the environmental and social objectives and principles that guide the project to achieve sound environmental and social performance	The client will implement such policy based on the ESIA

#	Requirements	How will the Project implementation process comply with requirements
R.3	The client will establish and maintain a process for identifying the environmental and social risks and impacts of the project	ESIA identifies and describes risks and impacts. As required, the ESIA studies the areas likely to be affected directly or indirectly by the Project, studies associated facilities (access roads, camps, quarries, etc.) and cumulative impacts. Monitoring measures will be implemented to enable verification of impact predictions and mitigation measures.
R.4	The client will establish management programs (such as environmental and social action plans) to describe mitigation and performance improvement measures and actions that address the identified environmental and social risks and impacts of the project	The ESIA includes a list of action plans annexed in the ESMP. These plans will be further developed by the developer as it finalises the detailed design.
R.5	The client, in collaboration with appropriate and relevant third parties, will establish, maintain, and strengthen as necessary an organizational structure that defines roles, responsibilities, and authority to implement the ESMS.	The final ESMP will assess the responsible actorˇs capacity to implement environmental and social measures. Capacity building measures to strengthen staff are proposed. The ESMP also assesses the need for external experts to assist the responsible actor in implementing measures.
R.6	The ESMS will establish and maintain an emergency preparedness and response system so that the client, in collaboration with appropriate and relevant third parties, will be prepared to respond to accidental and emergency situations associated with the project in a manner appropriate to prevent and mitigate any harm to people and/or the environment.	To respond to accidents and emergency situations, and to comply with World Bank Operational Policy OP 4.37 Safety of Dams, several reports will be produced that address seismic monitoring of the dam, instrumentation, construction supervision, reservoir loading and flood prediction, emergency preparedness and response, etc., prior to commencement of construction. In addition, the ESMP outlines some safety measures.

#	Requirements	How will the Project implementation process comply with requirements
R.7	The client will establish procedures to monitor and measure the effectiveness of the management program, as well as compliance with any related legal and/or contractual obligations and regulatory requirements.	The ESMS defines a monitoring program for the developer to implement, identifying all monitoring activities, and roles and responsibilities for monitoring and reporting. The developer will also conduct internal audits to ensure measures are implemented. Results will be documented and the monitoring program will be part of the review cycle. The monitoring program will define corrective measures in situations where goals are not achieved.
R.8	The client will develop and implement a Stakeholder Engagement Plan that is scaled to the project risks and impacts and development stage, and tailored to the characteristics and interests of the Affected Communities.	A final Stakeholder Engagement Plan (SEP) will be developed. Some amendments are proposed in the ESMP.

3.4.2.2 Performance Standard 2: Labour and Working Conditions

The scope of application of this Performance Standard depends on the type of employment relationship between the client and workers. It applies to workers directly engaged by the client (direct workers), workers engaged through third parties to perform work related to core business processes of the project for a substantial duration (contracted workers), as well as workers engaged by the client ̀s primary suppliers (supply chain workers).

Since the need for human resources will be concentrated in the construction phase, most employment will be temporary and, therefore, some requirements of PS2 do not apply. In the case of the Project construction, workers will be contracted. Even though only part of PS2 applies for contracted workers, all requirements are presented for the construction contractor to implement. The client, in turn, will have to audit the construction contractor for compliance and will have to ensure that specific requirements are part of tender documents.

The requirements of PS2 are presented in Table 3-7.

Table 3-6 PS 2 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	The construction contractor/client will adopt and implement human resources policies and procedures appropriate to its size and workforce that set out its approach to managing workers. The construction contractor/client will provide workers with documented information regarding working conditions and a written contract.	Through call for tender process, the TRHDP PO will ensure that the developer has a written human resources policy.

#	Requirements	How will the Project implementation process comply with requirements
R.2	The construction contractor will provide reasonable working conditions and terms of employment.	The developer shall develop a health and safety plan, which will be audited by TRHDP PO.
R.3	In countries where national law recognizes workers˘ rights to form and to join workers˘organizations of their choosing, without interference, and to bargain collectively, the construction contractor will comply with national law.	This measure will be presented in the ESMP and will be included in any contracts between the developer and its contractor(s).
R.4	The construction contractor will not make employment decisions on the basis of personal characteristics unrelated to inherent job requirements. The construction contractor will base the employment relationship on the principle of equal opportunity and fair treatment, and will not discriminate with respect to any aspects of the employment relationship.	This measure will be presented in the ESMP and will be included in any contracts between the developer and its contractor(s).
R.5	The construction contractor will provide a grievance mechanism for workers (and their organizations, where they exist) to raise workplace concerns.	The Stakeholder Engagement Plan applies to the developer. Its contract will include specific measures regarding workers˘ conditions.
R.6	The construction contractor will not employ children in any manner that is economically exploitative, or is likely to be hazardous or to interfere with them.	This measure is presented in the ESMP and will be included in any contracts between the developer and its contractor(s).
R.7	The construction contractor will not employ forced labor.	This measure is presented in the ESMP and will be included in any contracts between the developer and its contractor(s).
R.8	The developer will provide a safe and healthy work environment, taking into account inherent risks in its particular sector and specific classes of hazards in the client˘s work areas, including physical, chemical, biological, and radiological hazards, and specific threats to women.	The developer will develop a health and safety plan, which will be audited by TRHDP PO

#	Requirements	How will the Project implementation process comply with requirements
R.9	With respect to contracted workers, the developer will take commercially reasonable efforts to ascertain that the third parties who engage these workers are reputable and legitimate enterprises and have an appropriate ESMS.	Through the call for tender process, the developer will ensure that construction contractors put the ESMP into effect.

3.4.2.3 Performance Standard 3: Resource Efficiency and Pollution Prevention

The requirements of PS3 are presented in Table 3-8.

Table 3-7 PS 3 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	During the project life-cycle, the client will consider ambient conditions and apply technically and financially feasible resource efficiency and pollution prevention principles and techniques that are best suited to avoid, or where avoidance is not possible, minimize adverse impacts on human health and the environment.	The ESIA and ESMP address all impacts and define pollution prevention measures.
R.2	The client will implement technically and financially feasible and cost effective measures for improving efficiency in its consumption of energy, water, as well as other resources and material inputs, with a focus on areas that are considered core business activities.	The ESIA/ESMP addresses water quality impairment issues during construction activities and proposes efficiency measures. The ESIA/ESMP ensures that specific measures are developed to help the client integrate them in the call for tender documents. The client will include an environmental expert on its staff to ensure that processes are efficient (water, energy, etc.)
R.3	The client will avoid the release of pollutants or, when avoidance is not feasible, minimize and/or control the intensity and mass flow of their release.	The ESIA/ESMP addresses pollutant release issues during construction activities and proposes measures to avoid, mitigate, and control release of pollutants.

#	Requirements	How will the Project implementation process comply with requirements
R.4	The client will avoid the generation of hazardous and non-hazardous waste materials. Where waste generation cannot be avoided, the client will reduce the generation of waste, and recover and reuse waste, in a manner that is safe for human health and the environment.	The ESIA/ESMP addresses waste issues during construction activities and proposes measures to avoid release, and reduce, reuse, and recover all types of waste. The construction contractor will use subcontractors that are reputable and legitimate enterprises licensed by the relevant government regulatory agencies and obtain chain of custody documentation for wastes transferred to the final destination. This condition will be included in contracts between the client and its contractor(s).
R.5	Hazardous materials are sometimes used as raw material, or produced as product, by the project. The client will avoid or, when avoidance is not possible, minimize and control the release of hazardous materials.	The client will include conditions regarding use of hazardous materials in call for tender and in contracts. This measure will be presented in the ESMP and will be included in contracts between the client and its contractor(s).

3.4.2.4 Performance Standard 4: Community Health, Safety, and Security

The requirements of PS4 are presented in Table 3-9.

Table 3-8 PS 4 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	The client will evaluate the risks and impacts to the health and safety of the Affected Communities during the project life-cycle and will establish preventive and control measures consistent with Good International Industry Practice (GIIP).	The developer will develop a health and safety plan. A warning system will be developed as part of the Operations Plan to address the peak hour water releases (i.e., sudden releases from $2m^3/s$ to flow of $24m^3/s$).

#	Requirements	How will the Project implementation process comply with requirements
R.2	The client will design, construct, operate, and decommission the structural elements or components of the project in accordance with GIIP, taking into consideration safety risks to third parties or Affected Communities.	The developer will engage one or more external experts with relevant and recognized experience in similar projects, separate from those responsible for the design and construction, to conduct a review as early as possible in project development and throughout the stages of project design, construction, operation, and decommissioning
R.3	The client will avoid or minimize the potential for community exposure to hazardous materials and substances that may be released by the project.	The developer will develop a health and safety plan, and hazardous materials management plan as part of the developer̆s final ESMP.
R.4	The project̆s direct impacts on priority ecosystem services may result in adverse health and safety risks and impacts to Affected Communities, the client will identify those risks and potential impacts on priority ecosystem services that may be exacerbated by climate change.	The ESIA identifies the extent to which the Project affects ecosystem services that contribute to impacts on the health of local communities.
R.5	The client will avoid or minimize the potential for community exposure to water-borne, water-based, water-related, and vector-borne diseases, and communicable diseases that could result from project activities, taking into consideration differentiated exposure to, and higher sensitivity of, vulnerable groups.	The ESIA identifies the extent to which Project construction and operation impact the health of local communities.
R.6	The client will assist and collaborate with the Affected Communities, local government agencies, and other relevant parties, in their preparations to respond effectively to emergency situations, especially when their participation and collaboration is necessary to respond to such emergency situations.	To respond to accident and emergency situations, and to comply with World Bank Operational Policy OP 4.37 Safety of Dams, several reports shall be produced to address seismic monitoring of the dam, construction supervision, reservoir loading and flood prediction, emergency preparedness and response, etc., prior to commencement of construction. These studies will be carried out in close collaboration with project affected communities

#	Requirements	How will the Project implementation process comply with requirements
R.7	When the client retains direct or contracted workers to provide security to safeguard its personnel and property, it will assess risks posed by its security arrangements to those within and outside the project site. The client will make reasonable inquiries to ensure that those providing security are not implicated in past abuses; will train them adequately in the use of force, and appropriate conduct toward workers and Affected Communities; and require them to act within the applicable law.	The ESMP addresses such issues to ensure that local communities are safe.

3.4.2.5 Performance Standard 5: Land Acquisition and Involuntary Resettlement

Option 7C will not necessitate any physical resettlement. It will, however, necessitate land acquisition for the construction area. Land acquisition will be done in compliance with World Bank safeguard policies OP 4.12 on Involuntary Resettlement rather than PS5 since the process is carried out by SIG, which is a public agency.

A land acquisition process was carried out by the TRHDP PO to secure land from its customary tenure. The customary land acquired is referred to as the Core Land (also the Core Area). A memo summarizing the land acquisition process that was prepared at the time the ESIA was being developed, is included as Annex 20 in the Annex Report.

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3.4.2.6 Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources

The requirements of PS6 are presented in Table 3-10.

Table 3-9 PS 6 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	The risks and impacts identification process should consider direct and indirect project-related impacts on biodiversity and ecosystem services and identify any significant residual impacts. The client should seek to avoid impacts on biodiversity and ecosystem services. When avoidance of impacts is not possible, measures to minimize impacts and restore biodiversity and ecosystem services should be implemented.	The ESIA/ESMP addresses such issues. When avoidance of impacts is not possible, measures to minimize impacts and restore biodiversity and ecosystem services will be implemented. The ESIA presents the baseline conditions of natural habitats within the Project areas and describes their services.
R.2	For the protection and conservation of biodiversity, the mitigation hierarchy includes biodiversity offsets, which may be considered only after appropriate avoidance, minimization, and restoration measures have been applied.	The ESIA/ESMP has studied possible ways to offset impacts on natural habitats.
R.3	The client will conduct a systematic review to identify priority ecosystem services: (i) those services on which project operations are most likely to have an impact and, therefore, which result in adverse impacts to Affected Communities; and/or (ii) those services on which the project is directly dependent for its operations	The ESIA/ESMP addresses such issues. Section 4.2 identifies and describes environmental components that play a role for local population (sources of livelihood), Tambu sites, etc.
R.4	Where a client is purchasing primary production, systems, verification practices will be adopted as part of the client`s ESMS to evaluate its primary suppliers	The ESMP develops measures to ensure that suppliers of natural resources (quarry, etc.) will be evaluated regarding their compliance with measures.

3.4.2.7 Performance Standard 7: Indigenous Peoples

The WB Performance Standard (and accompanying procedure) on indigenous peoples is triggered because the peoples and communities likely to be directly or indirectly affected by the construction, and/or operation of TRHDP, can be considered indigenous people according to the Standard. Performance Standard 7 uses the term indigenous people in a generic sense to refer to :a distinct, social and cultural group possessing the following characteristics in varying degrees:

- ¿ Self-identification as members of a distinct indigenous cultural group and recognition of this identity by others;
- ¿ Collective attachment to geographically distinct habitats or ancestral territories in the project area and to the natural resources in these habitats and territories;
- ¿ Customary cultural, economic, social, or political institutions that are separate from those of the mainstream society or culture; or
- ¿ A distinct language or dialect, often different from the official language or languages of the country or region in which they reside (WB, 2012).˘

The baseline sections of the ESIA identify several groups or communities resident within, or in close proximity to, the proposed project area that could be potentially affected by the project, including:

- é Indigenous Teha/Malango-speaking people of the Bahomea district who customarily own and occupy the ˆCore Area˘ for the project;
- é Indigenous Malango people of Malango district, some of whom are customary :shareholders˘ or users of the Core Area;
- é :Settler˘ Guale people in the Bahomea district, who are largely indigenous Talise-speaking people from the Weather Coast of Guadalcanal and do not have customary ownership rights in the project area, though have been granted usufruct rights to certain areas by Bahomea customary owners;
- é Indigenous coastal Lengo-speaking Ghaobata people of the Guadalcanal Plains who have ownership rights over the land and resources of the lower part of the Ngalimbiu catchment, and the adjacent coastal area, and;
- é :Squatter˘ peoples of various origins and language groups, who are living on :unoccupied˘ government/alienated land in the northern part of the project area, without the formal approval of the local indigenous customary tribes, and people who are living and working on the LQQ and GPPOL agricultural estates on the Guadalcanal Plains. These people are Indigenous to other parts of the Solomon Islands or other islands of the Pacific, such as the Gilbertese from Kiribati.

Based on the interpretation of the World Bank (World Bankˇs Lead Social Development Specialist, and the World Bankˇs Lead Safeguards Specialist for the project), for the purposes of the social impacts assessment and social standard compliance, all the groups resident in the project area are considered Indigenous Solomon Islanders since they all have the defining characteristics mentioned above.

As noted elsewhere in the ESIA, compliance with this policy requires that TRHDP preparation include a social impact assessment (see Section 12), the scale of which needs to be proportional to ˋthe nature and scale of the proposed projectˇs potential effects on the indigenous peoples and a process of free, prior, and informed consent (FPIC) with the affected indigenous communities, to ascertain whether there is :broad community support˘ for the Project, or not.

This means that the project must also: involve the development of measures to avoid, minimise and/or mitigate adverse impacts; that the design and provision of benefits and mitigation measures include the consideration of options preferred by the affected indigenous peoples; and that the social and economic benefits for indigenous people are culturally appropriate and gender and generationally inclusive.

Other requirements of WB PS 7 mean that the ESIA must also review the extent to which the project planning has considered:

- Free, prior and informed consent;
- Achievement of broad community support;
- Actions that are taken to achieve the legal recognition of customary rights to lands that are traditionally owned, or customarily used or occupied, and for such land acquisition; and
- Management of the commercial development, if any, of cultural resources.

The requirements of PS7 are presented in Table 3-11

Table 3-10 PS 7 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	The client will identify, through an environmental and social risks and impacts assessment process, all communities of Indigenous Peoples within the project area of influence who may be affected by the project, as well as the nature and degree of the expected direct and indirect economic, social, cultural (including cultural heritage), and environmental impacts on them.	The ESIA achieves this requirement.
R.2	Adverse impacts on Affected Communities of Indigenous Peoples should be avoided where possible. Where alternatives have been explored and adverse impacts are unavoidable, the client will minimize, restore, and/or compensate for these impacts in a culturally appropriate manner commensurate with the nature and scale of such impacts and the vulnerability of the Affected Communities of Indigenous Peoples.	Development of measures is carried out during the ESIA with the full participation of indigenous population to ensure that their opinions are taken into account and to minimize impacts on them.

#	Requirements	How will the Project implementation process comply with requirements
R.3	The client will undertake an engagement process with the Affected Communities of Indigenous Peoples	The client's stakeholder engagement plan will be a dynamic document. Local population concerns and grievances will be gathered throughout the lifespan of the Project. Answers will be formulated to ensure ongoing communication.
R.4	The client will obtain the Free, Prior, and Informed Consent (FPIC) of the Affected Communities of Indigenous Peoples in the circumstances.	Mitigation Workshops prepared the way for the FPIC by presenting local populations with information on the various components and impacts of the Project. Social Surveys has also prepared the way for FPIC and results are presented in Section 7 and annexes included in the Annex Report. The assessment of FPIC is presented in the social baseline section
R.5	The client will consider feasible alternative project designs to avoid the relocation of Indigenous Peoples from communally held lands	The new Project layout, based on Option 7C, avoids any relocation of people. Section 4 (Analysis of Alternatives) of the ESIA studies alternatives, presents each alternative, its strengths and weaknesses, and the reasons for the selection of the preferred option.
R.6	Where a project may significantly impact on critical cultural heritage that is essential to the identity and/or cultural, ceremonial, or spiritual aspects of Indigenous Peoples lives, priority will be given to the avoidance of such impacts. Where significant project impacts on critical cultural heritage are unavoidable, the client will obtain the FPIC of the Affected Communities of Indigenous Peoples.	Section 7.2 focuses on gathering information on cultural heritage in the Project areas from interviews with the local population. It identifies cultural sites that will be affected by the reservoir impoundment or road upgrades. During the mitigation workshops, measures were discussed with local populations, to ensure that their opinions regarding the fate of cultural sites, were taken into account and that compensation will be paid for any losses incurred. The ESMP includes a Cultural Heritage Management Plan.
R.7	The client and the Affected Communities of Indigenous Peoples will identify mitigation measures in alignment with the mitigation hierarchy as well as opportunities for culturally appropriate and sustainable development benefits.	Development of measures are carried out during the ESIA with the full participation of local populations to ensure that their opinions are taken into account (during mitigation workshops).

#	Requirements	How will the Project implementation process comply with requirements
R.8	The nature of the project, the project context and the vulnerability of the Affected Communities of Indigenous Peoples will determine how these communities should benefit from the project. Identified opportunities should aim to address the goals and preferences of the Indigenous Peoples, including improving their standard of living and livelihoods in a culturally appropriate manner, and to foster the long-term sustainability of the natural resources on which they depend.	Development of measures, including measures to ensure safeguarding of livelihoods, are carried out in the ESIA and Land Acquisition and Livelihood Restoration Plan with the full participation of local population. Measures to ensure long-term benefits for local population were proposed.
R.9	The client will prepare a plan that, together with the documents prepared by the responsible government agency, will address the relevant requirements of this Performance Standard	Requirements for an IPP incorporated into Social Impact Assessment of overall ESIA. Specific measures for restoring the livelihoods of indigenous peoples with respect to land acquisition are covered in the Land Acquisition and Livelihood Restoration Plan. This plan is prepared under OP4.12 but has also been drafted to meet FPIC requirements of PS7.

3.4.2.8 Performance Standard 8: Cultural Heritage

The requirements for PS8 are presented in Table 3-12

Table 3-11 PS 8 Requirements

#	Requirements	How will the Project implementation process comply with requirements
R.1	In addition to complying with applicable law on the protection of cultural heritage, including national law implementing the host country̆s obligations under the Convention Concerning the Protection of the World Cultural and Natural Heritage, the client will identify and protect cultural heritage by ensuring that internationally recognized practices for the protection, field-based study, and documentation of cultural heritage are implemented.	Chapter 8 presents information on cultural heritage in the Project areas from interviews with local population.

#	Requirements	How will the Project implementation process comply with requirements
R.2	The environmental and social risks and impacts identification process should determine whether the proposed location of a project is in areas where cultural heritage is expected to be found, either during construction or operations. In such cases, as part of the client՝s ESMS, the client will develop provisions for managing chance finds through a chance find procedure.	Chapter 8 presents information on cultural heritage in the Project areas from interviews with local population. Cultural sites that will be impacted by the reservoir impoundment have been identified. During the mitigation workshops, measures were discussed with local populations to ensure that their opinions regarding the fate of cultural sites were taken into account. The ESMP includes measures regarding chance find procedures.
R.3	The client will consult with the Affected Communities to identify cultural heritage of importance, and to incorporate into the client՝s decision-making process the views of the Affected Communities on such cultural heritage.	The Cultural heritage protocol of the ESMP details this requirement.
R.4	Where the client՝s project site contains cultural heritage or prevents access to previously accessible cultural heritage sites, the client will, based on consultations, allow continued access to the cultural site, or will provide an alternative access route.	The ESIA has studied project alternatives to ensure minimization of impacts on cultural sites
R.5	Where the client has encountered tangible cultural heritage that is replicable, where avoidance is not feasible, the client will implement restoration measures. Where restoration in situ is not possible, restore the functionality of the cultural heritage, in a different location.	As presented in Chapter 8, no replicable cultural heritage sites were identified. Mainly `non-physical_ cultural heritage sites (Tambu sites) may be potentially affected.
R.6	Removal of non-replicable cultural heritage is subject to conditions: there are no technically or financially feasible alternatives to removal; The overall benefits of the project conclusively outweigh the anticipated cultural heritage loss from removal; and any removal of cultural heritage is conducted using the best available technique.	As presented in Chapter 8, no replicable cultural heritage sites were identified. Mainly non-removable `non physical_ cultural heritage sites may be potentially affected. Compensation for losses of cultural heritage sites are described in the ESMP and Land Acquisition and Livelihood Restoration Plan.

#	Requirements	How will the Project implementation process comply with requirements
R.7	The client should not remove, significantly alter, or damage critical cultural heritage. In exceptional circumstances when impacts on critical cultural heritage are unavoidable, the client will use a process of Informed Consultation and Participation (ICP) of the Affected Communities.	As presented in Chapter 8, no critical cultural heritage sites were identified. Most sites are locally valued by population. Consultation with population regarding cultural places (Tambu sites) has been an ongoing process.

4. ANALYSIS OF ALTERNATIVES

4.1 BACKGROUND

This section examines alternative ways that the objective of providing a more reliable source of electricity to Guadalcanal can be met, including potential alternative technologies to hydropower, and alternative ways of delivering a hydropower scheme. This section is based on the feasibility reports prepared by Entura for various phases of project development, between 2010 and 2014, as well as supplementary investigations undertaken since then.

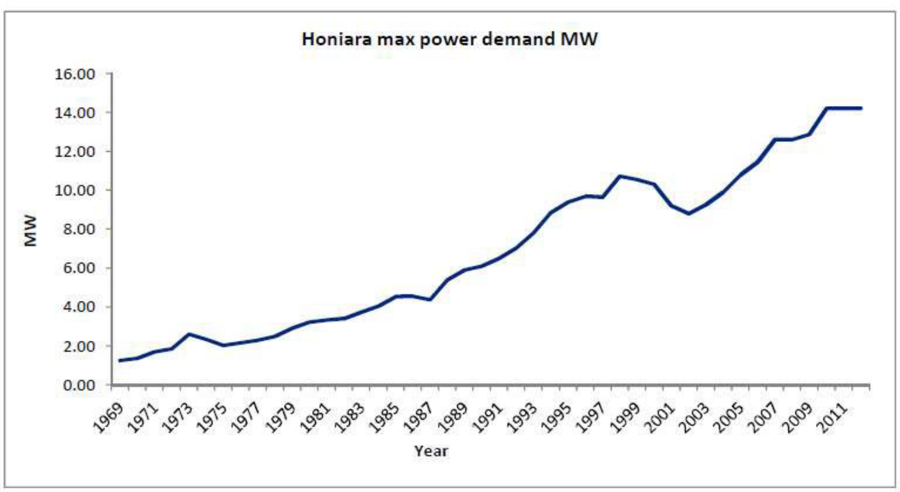
4.2 ENERGY DEMAND AND SUPPLY

4.2.1 Current and Future Energy Demand

Demand growth forecast studies have recently been undertaken by Deb Chattopadhyay for `Solomon Islands Sustainable Energy Project (SISEP)_, commissioned by the World Bank as well as part of the `Energy Contract Modelling_(2014 JACOBS). The figure below is taken from the SISEP report showing demand growth for low, medium and high demand growth scenarios.

According to JACOBS, the historical annual maximum power demand for the Honiara electricity network dating from 1969 to 2012 is shown in Figure 4-1. The stagnation of demand growth since 2009 in thought to be a consequence of load shedding due to insufficient generation capacity (i.e. consumers are less inclined to buy and use electrical apparatus / appliances when the supply of electricity is unreliable).

Figure 4-1 Honiara historical maximum power demand

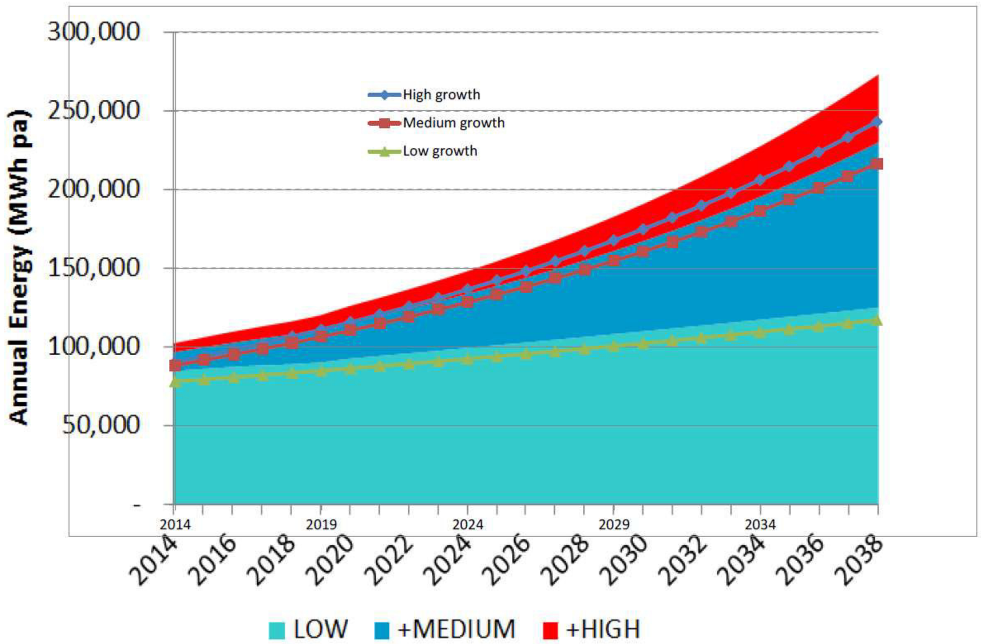


SISEP estimated new generation capacity requirements as 7 MW over the 25 next years for the Low demand growth scenario and an additional requirement for the High demand growth scenario as 25 MW.

The realization of High Demand growth scenario for the Honiara grid here depends on major new and uncertain loads coming on board ´ Gold Ridge, Tenaru, Mamara, Doma. If these loads do not eventuate the least cost generation plan changes (see Figure 4-2).

The SISEP assumed growth rates for the Honiara grid are conservative in that they do not envisage a significant expansion of the grid̆s geographic reach along the north coast of Guadalcanal. If such an expansion were to take place, as part of a national electrification strategy, demand would be higher, possibly requiring additional generation capacity.

Figure 4-2 Honiara Energy Growth Scenarios

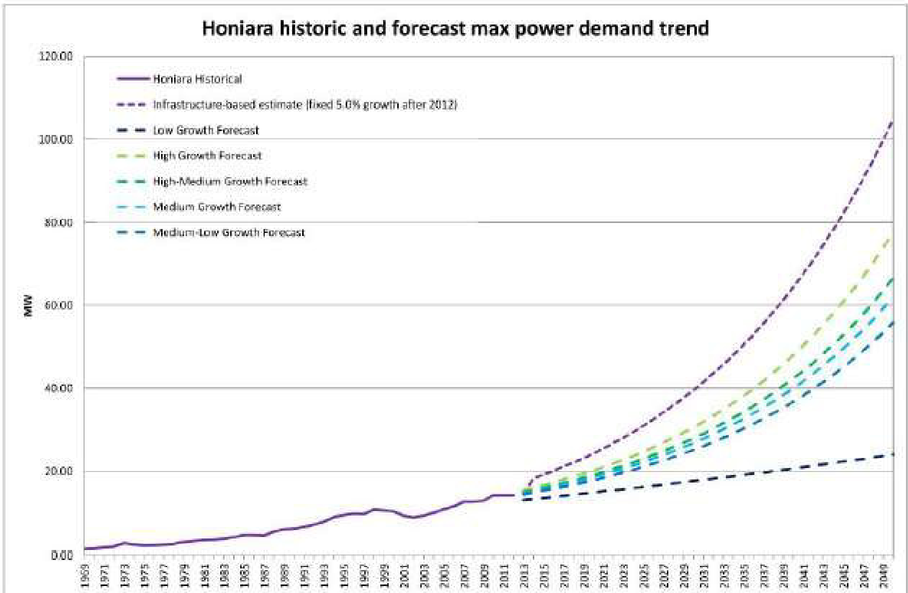


Solomon Power in 2015 predicts the annual growth in demand for energy from the Honiara grid to be 2.5% (compounding on the 2014 base year energy production of 77.6 GWh). This is similar to the SISEP report Low-Growth scenario shown in the figure above.

Solomon Power developed a 5 year demand forecast as part of the recently completed planning study.

Figure 4-3 below shows the extrapolated to demand forecast to 2050 combined with the historical demand records.

Figure 4-3 Combined Historical and Demand forecast to 2050 based on extrapolation of the 5 year forecast



4.2.2 Energy Supply

The Lungga diesel power plant is the main provider of electricity in Guadalcanal. The capital city and key population centre, Honiara, suffers from power shortages, especially during peak demand periods.

4.3 IDENTIFICATION OF POTENTIAL ALTERNATIVES TO THE PROJECT

4.3.1 Screening of Alternatives

Alternatives to the project were divided into four categories for the purpose of initial screening. These include:

1. Energy resources barred from development ;
2. Emerging energy resources;
3. Demand side management (DSM); and
4. Available Energy Resources.

Alternatives to the Project were screened to determine their respective regulatory, technical and financial viability. Only those technologies that made it through the initial screening were further assessed against economic, environmental and social criteria.

4.3.2 Energy Resources Barred from Development

No legislation is barring energy resources from development in Solomon Islands.

4.3.3 Emerging Energy Resources

Wave power is the transport of energy by wind waves, and the capture of that energy to do useful work ¯ for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a wave energy converter (WEC). Wave power is distinct from the diurnal flux of tidal power and the steady gyre of ocean currents. Wave-power generation is not currently a widely employed commercial technology (the first experimental wave farm was opened in Portugal in 2008).

Tidal power, also called tidal energy, is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Tidal power has potential for future electricity generation but is currently not widely used. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, recent technological developments and improvements in design and turbine technology indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels in the future.

Because the technologies for producing power from these resources are still in their early stages and not sufficiently well developed to be employed in the Solomon Islands environment and, therefore, would not provide a reliable source of energy for Guadalcanal, they have been ruled out as alternatives to the Project.

4.3.4 Demand Side Management (DSM)

According to Wikipedia[22], Demand Side Management, or DSM `is the modification of consumer demand for energy through various methods such as financial incentives and behavioural change through education._ DSM was considered, but quickly ruled out for Guadalcanal. This is because electricity costs are already very high and most consumers, having relatively low incomes and, therefore, being price sensitive, are already limiting their use of electricity. Most rural areas are not provided with electricity from the grid, so DSM has no bearing on their use, or not, of electricity produced by Solomon Power.

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[22] https://en.wikipedia.org/wiki/Energy_demand_management

4.3.5 Available Energy Resources

Available energy resources include those for which technologies are sufficiently evolved to provide reasonably reliable generation and transmission and which might be available to Guadalcanal. They include: hydropower, pumped storage, solar, wind, geothermal, gas fired thermal, and transmission of electricity from adjacent islands, where surplus electricity might be available. A portfolio of different energy resources (e.g., combination of solar, wind, geothermal resources) was also considered, as was the status quo diesel generation.

4.3.5.1 Status Quo ‑ Diesel Generator at Lungga

Sticking with the status quo is effectively choosing the `No Project_ alternative.

Grid-connected electricity is generated and supplied in Solomon Islands by Solomon Power (SolPower) which is a state-owned electricity utility. SolPower provides electricity to the national capital (Honiara) and eight provincial centres (Auki, Buala, Gizo, Kirakira, Lata, Malu'u, Noro-Munda, and Tulagi). Installed generation capacity in Honiara is 26 megawatts (MW) with a peak load of 14.3 MW and combined installed capacity in the provincial centres is 4 MW.

The demand for electricity in 2015 in Honiara peaked at 14,425 Kilowatts compared with a figure of 14,100 Kilowatts in 2014.

Figure 4-4 below shows the demand growth for Honiara from 2001 to 2015 (Source: Solomon Power annual Report 2015)

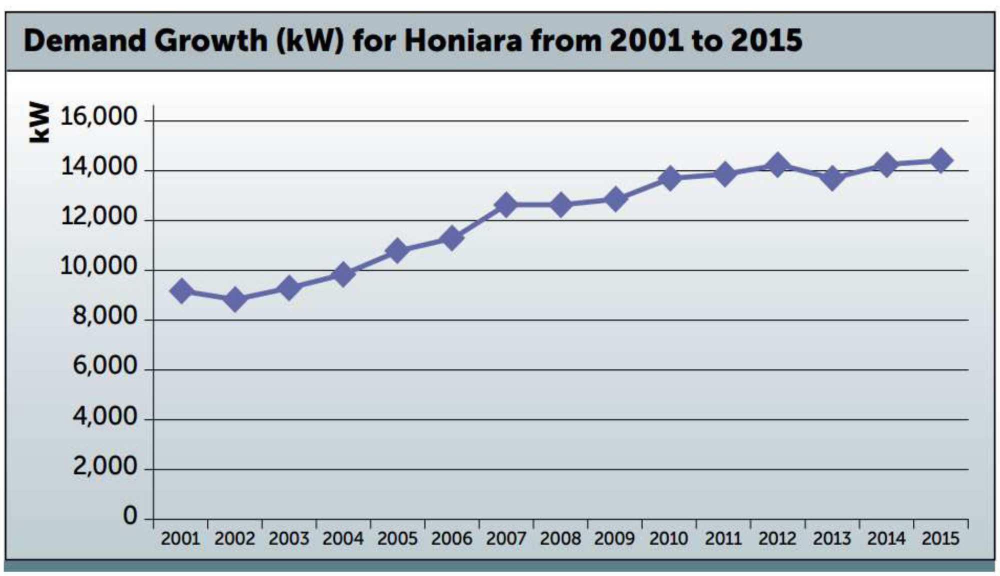


Figure 4-4 Honiara Electricity Demand Growth Solomon Power Annual Report 2015

Lungga and Honiara Solomon Power operations produced a total of 77.91Gwh (89.70%) whilst Solomon Power˘s provincial outstations (Buala, Taro, Auki, Gizo, Noro, Kirakira, Lata, Munda, and Tulagi), Solomon Tropical Products as an Independent Power Producer (IPP) (coconut oil) at Ranadi, and the Ranadi Solar Plant at Solomon Power head office together produced 8.91Gwh (10.3%). There was no energy bought by Solomon Power from its PPA with Soltuna in Noro during the year.

Diesel generation consume fossil fuels and in the long term are not considered a sustainable form of electricity generation. Diesel fuel is a relatively expensive, non-renewable energy source and highly dependent on market price and price changes.

Disadvantages of Diesel power generation:

- ↙ High operational cost
- ↙ High maintenance and lubrication cost
- ↙ Diesel unit capacity is limited
- ↙ Diesel generation is a net producer of the greenhouse gas carbon dioxide
- ↙ Air pollutant emissions
- ↙ Noise emissions
- ↙ Diesel plants are limited when it comes to supplying overloads continuously
- ↙ Diesel power plants are not economical where diesel has to be imported
- ↙ Limited life of a diesel power plant (usually 2 to 5 years)

4.3.5.2 Hydropower

Prior to identifying the Tina River as the site of a potential hydropower project, two hydropower schemes were studied for other sites in Guadalcanal. These were the Lungga Hydroelectric Project, and the Komarindi hydropower Project. Little is known about the characteristics of the Lungga Hydroelectric Project.

The Komarindi hydropower project was studied by Tonkin and Taylor (1993), who completed prefeasibility and feasibility studies, geotechnical investigations, detailed design, and an Environmental and Social Impact Assessment. If constructed, the project would have included a river intake, a tunnel to a penstock connecting to a powerhouse, and a tailrace / outlet back into the river.

The map in Figure 6-1 identifies the respective project areas for the proposed Komarindi, Lungga and Tina hydropower project.

- ¿ Komarindi hydro potential was identified `G-SI-7 Komarindi_with a hydro potential of 6.6MW.
- ¿ Lungga hydro potential was identified `G-SI-4 Lungga_with a hydro potential of 21MW.
- ¿ Tina hydro potential was identified `G-SI-21 Ngalimbiu_with a hydro potential of 17.7MW.

According to the World Bank, `the previous studies highlighted the unsuitability of the Lungga and Komarindi sites. The Lungga and Komarindi schemes failed to proceed for a variety of reasons, including inappropriate scale (both schemes) and poor site selection for the dam wall (Lungga)`. Investigations of the Lungga Gorge, as a site for potential Hydro development, were carried out in the 1980s. After initial optimism and development of a costly road to the proposed construction site, the project was abandoned because of the presence of geological conditions which made the site unsafe for development.

In addition, :The Solomon Islands, Guadalcanal Renewable Development Concept Study˘ (World Bank Project Power Mission, February 2006) studied the hydropower potential of three catchments on Guadalcanal: the Ngalimbiu site on the Tina River; the Nuhu site on the Mbalasuna River; and the Choha site on the Ngheunaha and Kolokumaha Rivers. The study concluded the Ngalimbui site on the Tina River as having the greatest hydropower potential, and the other sites were dropped (Entura, 2012). The present TRHDP is located upstream of the Ngalimbui Site, and has a hydropower potential of 20MW.

Figure 4-5 shows all catchments and rivers that were, at one point, studied for potential hydropower development in Guadalcanal.

As with other forms of economic activity, hydropower projects can have both a positive and a negative environmental and social impact, because the construction of a dam and power plant, along with the impounding of a reservoir, creates certain social and physical changes.

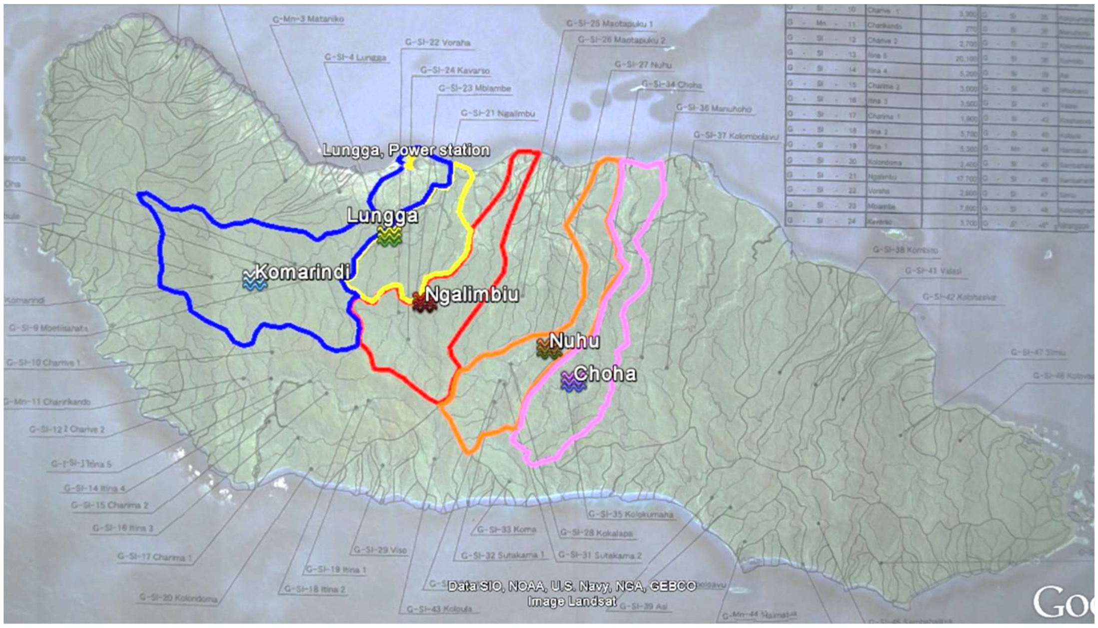
Advantages of hydropower

- Elimination of fuel costs;
- Comparably higher economic lifetime (than diesel generators, for instance);
- Low operation and maintenance (O&M) cost due to a high degree of automation;
- No direct emission of greenhouse gases or air pollutants.
- Potential for multipurpose usage (i.e. irrigation and water supply, fishery);
- River flow and flood regulation;
- Generation of renewable energy.

Disadvantages of Hydropower

- Construction of hydropower projects could introduce local imbalances to ecosystems, landscapes and river flow;
- Impoundment can potentially lead to thermal and chemical changes within the immediate reservoir areas, with possible downstream impacts.
- Sedimentation, deposition, and nutrient enrichment in the reservoir can lead to increased development of aquatic flora (plankton, benthic algae, rooted and floating macrophytes) which in turn, under certain conditions, can reduce the dissolved oxygen content in the water and cause mortality of fish and other aquatic life;
- Construction of hydropower plants in general is expensive (although having low operation & maintenance costs).

Figure 4-5 Studied catchments for hydropower development in Guadalcanal



Source: Photograph provided by MMERE offices and adapted with Google Earth

4.3.5.3 Pumped Storage

Pumped storage facilities use the height difference between two natural bodies of water or artificial reservoirs. At times of low electrical demand (night times), excess generation capacity is used to pump water into a higher reservoir. During times of higher demand (morning, mid-day and late afternoon), water is released back into the lower reservoir through a turbine, generating electricity. Reversible turbine/generator installations can be utilized to act as pump and turbine (usually a Francis turbine design).

A pumped storage system can be economical because it flattens out load variations on the power grid. Capital costs for purpose-built pumped storage are relatively high.

In summary, pumped storage depends on either:

1. Having a `must run_ source of energy such as nuclear or geothermal which has excess capacity at low demand periods and can therefore pump the water to storage at little or no additional cost (other than the capital to establish the storage and hydro facility).; or
2. At least a peak demand price which greatly exceeds the off peak price (I.e. an essential part of the peak generation mix that has a variable cost which exceeds the cost of the pumped storage.

In Honiara, neither of these conditions applies. The pumped facility would cost more than Tina River Hydro per MW to build and more than the diesel generation cost to operate. In addition, there are no identified areas where any suitable hydro storage can be established.

4.3.5.4 Solar

A photovoltaic power station, also known as a solar park, is a large-scale photovoltaic system (PV system) designed for the supply of power into the electricity grid. They are differentiated from most building-mounted and other decentralised solar power applications because they supply power at the utility level, rather than to a local user or users. They are sometimes also referred to as solar farms or solar ranches, especially when sited in agricultural areas. The generic expression utility-scale solar is sometimes used to describe this type of project.

The land area required for a desired power output, varies depending on the location and on the efficiency of the solar modules, the slope of the site and the type of mounting used. Fixed tilt solar arrays using typical modules of about 15% efficiency on horizontal sites, need about 1 hectare/MW in the tropics and this figure rises to over 2 hectares in northern Europe.

Grid connection

The availability, locality and capacity of the connection to the grid is a major consideration in planning a new solar park, and can be a significant contributor to the cost. Most stations are sited within a few kilometres of a suitable grid connection point. This network needs to be capable of absorbing the output of the solar park when operating at its maximum capacity. The project developer will normally have to absorb the cost of providing power lines to this point and making the connection, often also any costs associated with upgrading the grid so it can accommodate the output from the plant.

Operation and maintenance

Once the solar park has been commissioned, the owner usually enters into a contract with a suitable third party to undertake operation and maintenance (O&M). In many cases this may be fulfilled by the original EPC contractor.

Solar plants' reliable solid-state systems require minimal maintenance, compared to rotating machinery for example. A major aspect of the O&M contract will be continuous monitoring of the performance of the plant and all of its primary subsystems, which is normally undertaken remotely. This enables performance to be compared with the anticipated output under the climatic conditions actually experienced. It also provides data to enable the scheduling of both corrective and preventive maintenance. A small number of large solar farms use a separate inverter or maximizer for each solar panel, which provide individual performance data that can be monitored. For other solar farms, thermal imaging is a tool that is used to identify non-performing panels for replacement.

Power delivery

A solar park's income derives from the sales of electricity to the grid, and so its output is metered in real-time with readings of its energy output provided, typically on a half-hourly basis, for balancing and settlement within the electricity market. Income is affected by the reliability of equipment within the plant and also by the availability of the grid network to which it is exporting. Some connection contracts allow the transmission system operator to constrain the output of a solar park, for example at times of low demand or high availability of other generators. Some countries make statutory provision for priority access to the grid for renewable generators

Advantages of Solar Power

Solar energy is a resource that is not only sustainable for energy consumption, it is indefinitely renewable. Solar power can be used to generate electricity, it is also used in relatively simple technology to heat water (solar water heaters).

Solar panels usually require little maintenance. After installation and optimization they are very reliable due to the fact that they actively create electricity in just a few milimetres of material and, unless installed with variable tilt mountings, do not require any type of mechanical parts that can fail. Solar panels are also a silent producer of energy, a necessity if dealing with sensitive neighbourhoods.

Disadvantages of Solar Power

The primary disadvantage of solar power is that it cannot be generated during the night. The power generated is also reduced during times of cloud cover (although energy is still produced on a cloudy day). Advances are being made in battery technology to permit overnight storage, but utility-scale applications are still rare.

Solar panel energy output is maximized when the panel is directly facing the sun. This means that panels in a fixed location will see a reduced energy production when the sun is not at an optimal angle. Many large scale solar "farms" combat this problem by having the panels on towers (above left) that can track the sun to keep the panel at optimal angles throughout the day.

A further disadvantage is the relatively large area required to develop commercial solar farms. For instance, Royalla Solar Farm (Canberra AU) comprises of 83,000 PV panels which are occupying 50 hectares at 20 MW installed capacity. The Royalla Solar Farm is a solar only facility and therefore generating power only during daytime hours.

Even today˘s most efficient solar cells only convert just over 20% of the sun˘s rays to electricity. Besides their low conversion efficiency, solar panels can be a substantial initial investment.

4.3.5.5 Wind

Economic wind generators require wind speed of 16 km/h (10 mph) or greater. An ideal location would have a near constant flow of non-turbulent wind throughout the year, with a minimum likelihood of sudden powerful bursts of wind. An important factor of turbine siting is also access to local demand or transmission capacity.

Advantages

- Aclean fuel source. Wind energy doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas. Wind turbines don't produce atmospheric emissions that cause acid rain or greenhouse gases.
- Wind is a domestic source of energy.
- It's sustainable. Wind is actually a form of solar energy. Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. For as long as the sun shines and the wind blows, the energy produced can be harnessed to send power across the grid.

- Wind power is cost-effective. It is one of the lowest-priced renewable energy technologies available today, costing between four and six cents per kilowatt-hour, depending upon the wind resource and the particular project˜s financing.
- Wind turbines can be built on existing farms or ranches. This greatly benefits the economy in rural areas, where most of the best wind sites are found.

Disadvantages

- Wind power must still compete with conventional generation sources on a cost basis. Depending on how energetic a wind site is, the wind farm might not be cost competitive. Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires usually higher initial investments.
- Good wind sites are often located in remote locations, far from cities where the electricity is needed. Transmission lines must be built to bring the electricity from the wind farm to the city.
- Wind resource development might not be the most profitable use of the land. Wind farms on land suitable for wind-turbine generation must compete with alternative forms of development for the land that might be more highly valued by the owners.
- Turbines cause noise and aesthetic impact. Although wind power plants have relatively little impact on the environment compared to conventional power plants, concern exists over the noise produced by the turbine blades and visual impacts to the landscape.
- Turbine blades can harm local wildlife. Birds and bats have been killed by flying into spinning turbine blades. These problems can be somewhat reduced through technological development and proper site selection.

To ascertain whether there is a commercial wind resource in useable locations within Solomon Islands would require at least 2 years of meteorological data monitoring prior to construction of a wind farm. A previous attempt to carry out such monitoring with meteorological measuring masts provided by donor funding failed to capture data from the installed equipment due to inadequate funding, and eventually the installed equipment was adapted for other purposes by the local communities.

4.3.5.6 Geothermal

Initial investigations were conducted into a possible geothermal resource on Savo Island, 40 km from Honiara. However, due to financial constraints, no drilling has been undertaken and the potential resource remains unproven. In 2015, Geodynamics, the majority shareholder of the geothermal venture, announced that it did not intend to incur any further significant expenditure on the project due to :market conditions˝.[23] No further activities have been undertaken. High transmission costs from Savo Island to Honiara are a disadvantage of the site, with 16 km of undersea cabling required to the closest point on Guadalcanal, some 60 km from Honiara, depths of Iron Bottom Sound near Savo of 600-1350 metres, and Solomon Power˜s preference for dual transmission lines to provide for n-1 redundancy.

[23] Geodynamics Annual Report 2015. See also :Geodynamics puts expenditure on hold for Pacific Geothermal Projects˝, Think Geoenergy, 16 October 2015: http://www.thinkgeoenergy.com/geodynamics-puts-expenditure-on-hold-for-pacific-geothermal-projects/. Accessed 10 December 2016.

4.3.5.7 Gas Fired Thermal

A gas fired power station is a power station which burns fossil fuel to produce electricity. Central station fossil-fuel power plants are designed on a large scale for continuous operation. In many countries, such plants provide most of the electrical energy used. Fossil-fuel power stations have machinery to convert the heat energy of combustion into mechanical energy, which then operates an electrical generator. The prime mover may be a steam turbine, a gas turbine or, in small plants, a reciprocating internal combustion engine. All plants use the energy extracted from expanding gas, either steam or combustion gases. Heavy fuel oil and other liquid fuels besides diesel could also be used in a thermal plant, but because any fossil fuels would have to be imported and gas is less expensive, only gas is being considered here.

Advantages

- Economy: Natural gas is cheaper compared to other fossil fuels and cheaper than electricity when used for supplying home appliances. Natural gas appliances are also cheaper compared to electrical ones.
- Environment: It does not pollute the ground or the underground water because its by-products are in gaseous form. Another important fact is that natural gas burns without releasing any particulate material or sulphur dioxide. It also emits 45% less carbon dioxide than coal and 30% less than oil per unit of electricity produced.
- Transportation: Transportation is made via sea (tankers) and land (pipelines and small tanks). This fact allows natural gas to be easily transferred from power plants to residential areas surrounding residential areas.
- Multi-uses: Natural gas is a multi-use fuel. It is used inside the house for cooking, heating, drying, etc. It can be used for generating electric power, powering vehicles (by substituting for diesel and gasoline), producing plastics, paints, fertilizers, and many more uses.
- Availability: It is abundant and almost worldwide available.
- Conversion to Hydrogen Fuel: It is currently the cheapest fossil fuel source for producing hydrogen.

Disadvantages

- Flammable: Natural gas leaks can be proven to be extremely dangerous. Such leaks may be the cause of fire or explosions. The gas itself is an asphyxiant. The main risk comes from the fact that it is naturally odourless and cannot be detected by smell, unless an odorant has been added to the gas mixture. In the case of an underground leak, the odorant may gradually become weaker and the gas may go undetected.
- Environmental Impact: When natural gas burns, carbon dioxide, monoxide, and oxides of nitrogen s are emitted in the atmosphere contributing to air pollution and the greenhouse effect. Although it is cleaner than other fossil fuels (oil, coal, etc.) as far as combustion by-products are concerned, natural gas leaks are significant contributors to climate change since methane, its main constituent, has 21 times the global warming potential of carbon dioxide.
- Processing: In order to use it as a fuel, constituents other than methane have to be extracted. The processing results in several by-products: hydrocarbons (ethane, propane, etc.), sulphur, water vapour, carbon dioxide, and even helium and nitrogen.
- Non-Renewable: It is a finite source of energy and cannot be considered a long-term solution to our energy supply problem.

- ¿ Installation: The whole pipe installation may be very expensive to construct since long pipes, specialized tanks, and separate plumbing systems need to be used. Pipe leakage may also be very expensive to detect and fix.
- ¿ Efficiency in Transportation: When natural gas is used as a fuel in cars, the mileage is lower than gasoline.
- ¿ Economics: In addition to the gas fired thermal generating station itself, an onshore compressed gas storage facility and dedicated deep sea terminal to receive LNG or CPG shipments site infrastructure are required.
- ¿ Conversion to Hydrogen Fuel: A drawback in producing hydrogen from natural gas is that efficiency drops to almost 50% compared to the original chemical energy.

4.3.5.8 Transmission of Electricity from Other Islands

Transmission of electricity from one of the other islands within the Solomon Islands archipelago, and from neighbouring island countries like Papua New Guinea (e.g., Bougainville) and Vanuatu, were quickly dismissed on the basis that all of these islands are currently in short supply of cheap electricity and, therefore, do not have surplus energy to sell. More importantly, even if surplus electricity were available for purchase, the great distances involved to connect Guadalcanal using an undersea transmission cable of sufficient capacity to overcome line losses, would cost orders of magnitude more than the next best alternative. Therefore, this option was given no further consideration.

4.3.5.9 Portfolio of Available Energy Resources

Consideration was given to combining the most promising available energy resources ¯ solar, wind and geothermal ¯ into a portfolio of energy generation against which the hydropower option was compared.

A significant percentage of total capacity being provided by hydropower would be favourable to the potential to add other more intermittent energy sources (such as solar, wind or tidal) to provide a portfolio of available energy sources because of the particular characteristics of hydropower generation. The hydro generators are able to provide ancillary services (frequency control, voltage control), spinning reserve and maintenance capacity to the networked generators.

The hydro turbines are able to start or increase output virtually instantaneously, and to maintain the key power quality characteristics of the network (voltage and frequency) even as other elements of the network fluctuate in their production.

A certain percentage of hydropower in the network is an essential feature that will allow for significant penetration to the network of either wind or solar generation. Thus a station like Tina Hydro could be a catalyst to support further construction of solar farms.

4.3.5.10 Preferred Project Alternative

Table 4-1 compares the various available energy project alternatives on the basis of: energy production; economics; reliability and limitations; and environmental and social benefits and constraints Based on a comparative review of the various available energy resources, the best alternative was determined to be that of a hydropower project located on the Tina River. The rationale for this selection is as follows:

¿ Hydropower is a reliable and proven source of renewable energy within local environments such as Solomon Islands

¿ Suitable hydrological conditions

¿ Project locations with minimal social and manageable environmental impact

¿ Availability of natural resource (water)

¿ Relatively long economic lifetime

¿ Low maintenance cost

¿ Reliable base load power supply

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When compared with the status quo or no-project alternative, if the hydropower alternative is not constructed, Honiara would probably continue to experience frequent power outages, as is the case today. Lungga power station would need to be upgraded, or additional diesel plants would need to be constructed to provide electricity during peak hours. Unlike electricity generated from hydro, electricity generated from diesel can contribute to environmental impacts in the form of greenhouse gas emissions, air pollution, risks of oil spills during production, sea transport and transfer. Another advantage of hydropower over diesel is that it allows the Solomon Islands to move toward energy self-reliance, using its own renewable resources, rather than importing non-renewable sources of energy. From an economic perspective, the unit cost of hydro is significantly lower than the unit cost of diesel. As diesel prices increase, this gap will become more significant. Therefore, not implementing the hydropower alternative would have economic consequences for SIG.

According to the TRHDP PO, there is provision in the transmission design for rural electrification, which will include 33kV/415V pole mounted transformers at each of the villages situated along the Tina Village road. Therefore, not implementing the hydropower project would potentially result in the loss of opportunity for rural electrification.

From an employment perspective, more jobs will be created during construction than for any other alternative energy project. Therefore, not developing the hydropower project would eliminate the opportunity for local communities to earn salaries, and gain experience and skills in construction work. Wages paid to construction workers typically represent the single largest social benefit during the construction phase of a dam. In the case of the TRHDP, it is the intention of the PO to engage as many workers as possible from the local communities during the construction phase.

Table 4-1 Comparative summary of energy resource projects

	Status Quo (Lungga Diesel)/No Project	Hydro Project on Tina River	Solar	Wind	Geothermal	Gas Fired Thermal	Transmission from Another Island	Portfolio of Energy Resource Alternatives
Energy Production	71.91 GWh (2015)	78.35 GWh pa	Dependent on size (range 1 to 2.5 ha/MW)	1 average onshore wind turbine (2.5‑3 MW capacity) can produce more than 6 GWh pa given suitable average wind speeds	Depending on available energy stored within geological unit	Approx. 8,000,000 m^3 gas / 81 GWh pa	Not feasible due to lack of suitable energy production facility on other islands	Combination of Hydro + Solar considered feasible to meeting increasing future demand (refer to hydro and solar columns)
Reliability & Limitations	Frequent outages experienced during times of peak energy demand	Reliable power generation option, immediately available energy, long project lifetime	Generation mainly during sunshine hours, difficult to store energy on large scale, suitable in combination with other power generation sources	Dependent on site selection, high initial investment cost	Low operation and maintenance cost once established, potential to run out of steam thus high initial investigation costs, extremely long lead time to install/repair undersea cables	Reliable technology, high efficiency (up to 60%),		
Economics	High cost due to import of diesel and lubricants, high operation and maintenance cost	High initial investment, low operation and maintenance cost	Medium to high initial investment, low operation and maintenance cost, current technology warranty of 25 years, average of 1% per annum of reduction in output	Due to storage limitations for energy, wind farms typically complement hydro power very well. Suitable sites for wind farms are required to operate economically, which may result in high transmission costs	Potentially available geothermal energy at Savo island (unproven), approx. 11MW, thus additional energy source required to meet demand; High initial investment, high transmission cost (undersea cable + transmission line), finite energy source	High cost due to import of natural gas and lubricants, high operation and maintenance cost, added cost for site and storage handling and infrastructure (storage, port facility, etc.)		
Environmental Benefits / Constraints	Fossil fuel, noise, priority air contaminants and GHG emissions, dependency on imported fossil fuels, potential spills	Inundation of land due to reservoir impoundment, requirement to manage reduced river flows between dam and powerhouse tailrace; potential barrier to migration of some fish species; lower net GHG emissions; no air pollutant emissions from operations	Relative large areas of land required for establishment (approx. 1 MW/2.5ha, depending on angle to sun), operation of solar plants has low environmental impacts	Large site required for establishment of wind park, but land can continue to be used for some agricultural purposes. Noise and aesthetic pollution. Bird and bat mortality.	Potential to release poisonous or otherwise harmful gases such as hydrogen sulphide. Potential water pollution from brines,	Fossil fuel, noise, priority air contaminants and GHG emissions, dependency on imported fossil fuels		

	Status Quo (Lungga Diesel)/No Project	Hydro Project on Tina River	Solar	Wind	Geothermal	Gas Fired Thermal	Transmission from Another Island	Portfolio of Energy Resource Alternatives
Social Benefits / Constraints	Local employment opportunities, constraints on locally available skilled maintenance/engineering	Local employment opportunities, constraints on locally available skilled maintenance/engineering	Local employment opportunities, constraints on locally available skilled maintenance/engineering	Local employment opportunities, constraints on locally available skilled maintenance/engineering	Local employment opportunities, constraints on locally available skilled maintenance/engineering	Local employment opportunities, constraints on locally available skilled maintenance/engineering		

4.4 ALTERNATIVE LOCATIONS AND CONFIGURATIONS FOR THE PREFERRED PROJECT - THRDP

4.4.1 History of Project Refinement

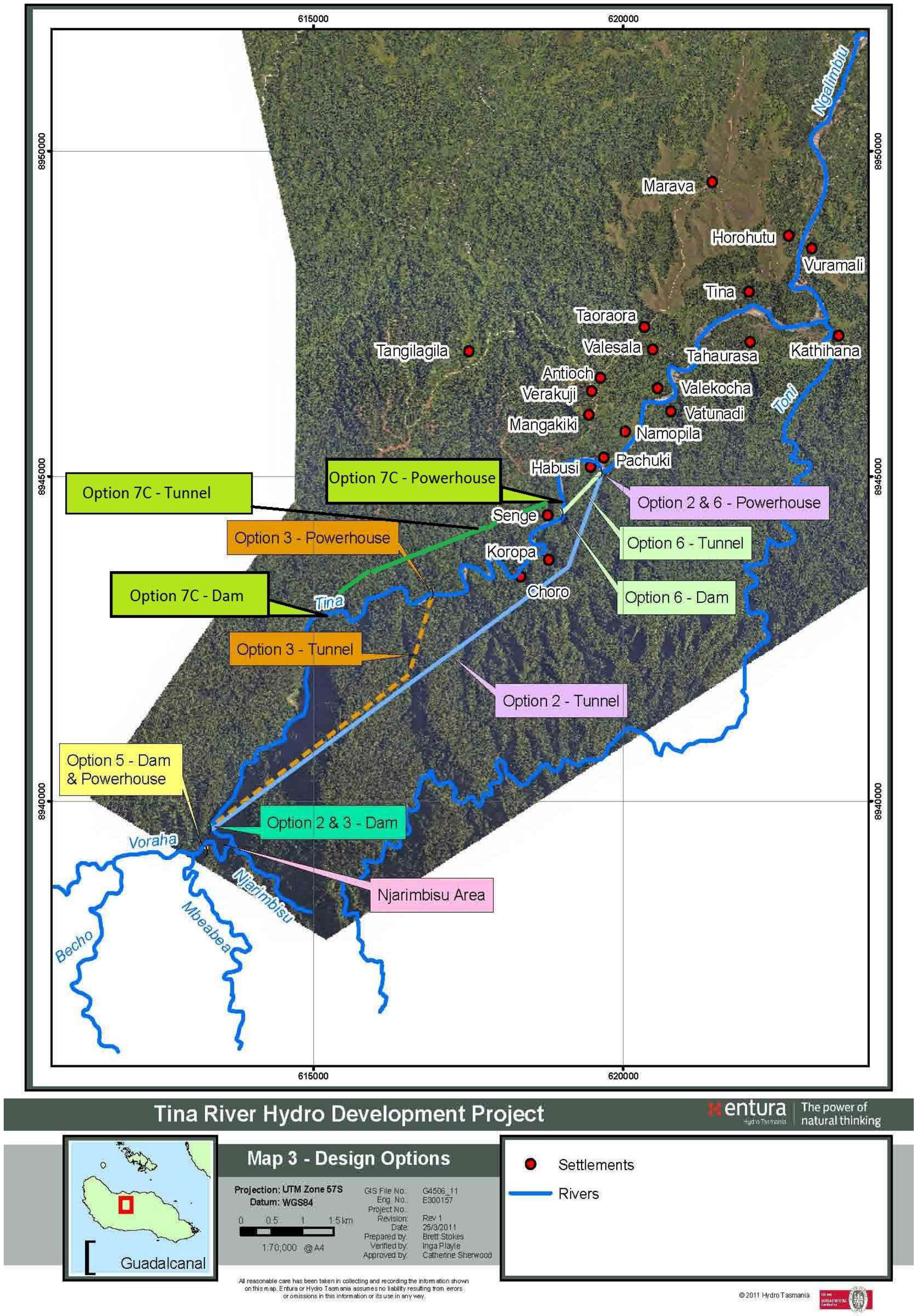
Entura (2010 to 2014) studied several options along the Tina River with the objective of locating the best site to optimize power generation capacity. Options were evaluated based on economic, technical and environmental and social criteria. The key criteria used to select the single best option were financial / economic viability and geological integrity.

Entura carried out a three-phased program to select the preferred site for a hydropower project, as follows (see Figure 4-6):

Phase 1 report studied a series of dams along the stretch of river from the Mbeambea River / Tina River confluence (upstream catchment) to the Toni River / Tina River confluence (Entura, 2010):

- Site 1: Dam located on the Tina River upstream of Njarimbisu and upstream of Mbeambea geological fault, and a powerhouse located upstream of Habusi village. Option 1 was considered not technically viable because of the high geological risk associated with the long tunnel. Option 1 was eventually dropped due to high environmental sensitivities of the upper catchment region.
- Site 2: Dam located on the Tina River downstream of Njarimbisu tributary and upstream of the Mbeambea geological fault, and a powerhouse located upstream of Pachuki, connected by a tunnel of approximately 8.6 km. Option 2 was eventually dropped due to high environmental sensitivities of the upper catchment region.
- Site 3: Dam located on the Tina River downstream of Njarimbisu tributary. Power station located upstream of Koropa, connected by a tunnel of approximately 5.5 km. Option 3 was eventually dropped due to high environmental sensitivities of the upper catchment region.
- Site 4: Dam located on the Tina River upstream of Njarimbisu tributary at the Mbeambea geological fault, and a powerhouse located at the downstream end of Njarimbisu. Option 4 was considered not technically viable because of extremely difficult access and unsuitable geology at the dam site.
- Site 5: Dam located on the Tina River upstream of Njarimbisu tributary and Mbeambea geological fault, and a powerhouse located at the toe-of-dam. Option 5 was eventually dropped due to high environmental sensitivities of the upper catchment region.
- Site 6: Dam located on the Tina River downstream of Senghe, and a powerhouse located upstream of Pachuki connected by a short tunnel. This option was selected for phase 2 report.

Figure 4-6 Sites investigated for the TRHDP



Phase 2 report (Entura, 2012) dropped the Site 6 (also called 6a) option, due to geological risks, and studied several further locations for siting a dam-powerhouse, from Site 6a to Site 6f. Two options were retained for further evaluation (Sites 6e and 6f) by GeoRisk Solutions (2012). The other options were eventually dropped due to potential adverse geological conditions. At the time the ESIA commenced, the Site 6e option was favoured.

Phase 3 report by Entura (2014) evaluated two sub-options for Site 6e, as well as a new site, referred to as Site 7c, for which three sub-options were evaluated.

- Site 6e: Option 1: RCC dam at chainage 11.3km, left bank pipeline to powerhouse at ch11.5km, dam height ranges from 35m to 75m above existing riverbed level (toe of dam solution)
- Site 6e: Option 2: RCC dam at chainage 11.3km, right bank tunnel to powerhouse at ch13.3km, dam height ranges from 35m to 75m above existing riverbed level (mid tunnel solution).
- Site 7c: Option 1: RCC dam at chainage 7km, left bank tunnel to powerhouse at ch12.7km, dam height ranges from 35m to 65m above existing riverbed level (long tunnel solution).
- Site 7c: Option 2: RCC dam at chainage 7km, right bank pipeline to powerhouse at ch7.3km, dam height ranges from 45m to 85m above existing riverbed level (toe of dam solution)
- Site 7c: Option 3: RCC dam at chainage 7km, left bank tunnel to powerhouse at ch8.9km, dam height ranges from 35m to 75m above existing riverbed level (mid tunnel solution)

In its Phase 3 report, Entura (2014) concluded that Site 7c Option 1 had superior economic, social and technical value when compared to Site 6e. A comparative environmental and social alternative analysis was made of Site 6e and Site 7c, the results of which are provided in the following subsection. Site 7c Option 1 is the Project assessed by this ESIA.

4.4.2 Final Selection of the Preferred Project Site and Layout

Table 4-2 presents an analysis of alternatives from Entura's 2014 Phase 3 report, based on social, environmental, technical and economic criteria.

The Phase 2 and Phase 3 feasibility studies by Entura (2014), had selected several options along Tina River, the selection of options was mainly based on geophysical criteria used to select a site that offers stable geological conditions, as well as economic performance in terms of return on investment, and electricity production. In the following analysis, emphasis was placed on environmental and social criteria to complement the technical analysis done by Entura.

Options that were favoured, were those that were best able to address environmental, social or technical/financial criteria, or combination of criteria.

Criteria were selected based on their relevance, and do not necessarily reflect the various existing baseline sections. For example, criteria such as 'reptiles and amphibians' or 'birds' are not dealt with since they represent a level of detail that was not available at the time the overview level of analysis of alternatives was undertaken.

Table 4-2 summarises the results of the evaluation of the two Site 6e and three Site 7c alternatives for the Project. Chainage distances are based on Entura (2010) Phase 1 work, with CH 0km being the confluence of the Mbeambea and the Voraha, and CH 18.7km being the downstream Tina River / Toni River confluence.

Table 4-2 Comparison of siting options

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
Location (Chainage in km)	Dam: 11.3 Powerhouse: 11.5 Reservoir: 11.3 - 7 Toe of dam option (no by-passed river reach)	Dam: 11.3 Powerhouse: 13.3 Reservoir: 11.3 - 7 Mid tunnel option (mid by-passed river reach)	Dam: 7 Powerhouse: 12.7 Reservoir: 7 ¯ 4.5 Long tunnel option (long by-passed river reach)	Dam: 7 Powerhouse: 7.3 Reservoir: 7 ¯ 4.5 Toe of dam option (no by-passed river reach)	Dam: 7 Powerhouse: 8.9 Reservoir: 7 ¯ 4.5 Mid tunnel option (mid by-passed river reach)
Catchment size (150 km^2)	Upstream of dam: 135 km^2 Downstream of dam: 15 km^2		Upstream of dam: 125 km^2 Downstream of dam: 25 km^2		
Social and cultural					
Number of people/villages to relocate and land acquisition	For this criteria, the best option would be the one that involves the least number of inhabitants to resettle and the smallest Core Area to acquire (to alienate from customary land ownership)				
	Choro (CH 9km), ~4 inhabitants to be resettled due to the reservoir Senghe (CH 11.5km), ~16 inhabitants to be resettled due to the powerstation Koropa (CH 11 km), ~19 inhabitants to be resettled due to quarries Habuchi (CH 13.3 km), ~33 inhabitants, no foreseen physical resettlement Pachuki (CH 13.8 km), ~65 inhabitants, no foreseen physical resettlement		Choro (CH 9km): no foreseen physical resettlement Senghe (CH 11.5km): no foreseen physical resettlement Koropa (CH 11 km): no foreseen physical resettlement Habuchi (CH 13.3 km): no foreseen physical resettlement Pachuki (CH 13.8 km): no foreseen physical resettlement Villages along the access road: no foreseen physical resettlement		

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
	Villages along the access road: no foreseen physical resettlement				
	Since this option will physically relocate people, some of their sources of livelihood will also be affected such as garden and river uses. However, this option would require a relatively small Core Area because the powerhouse would be at the toe of the dam	Since this option will physically relocate people, some of their sources of livelihood will also be affected such as garden and river uses. In addition, the Core Area to be acquired would include the powerhouse 2 Km downstream of the dam	Although this option does not necessitate relocation of people, the Core Area to be acquired would be relatively large to include the powerhouse 5.7 Km downstream	In terms of livelihood, this option would probably be the best since it would not require any resettlement of people and it would require a relatively small Core Area because the powerhouse would be at the toe of the dam	Although this option does not necessitate relocation of people, the Core Area to be acquired would need to include the powerhouse 1.9 Km downstream
				Best Options	
Sacred sites and cultural heritage	For this criterion, the best option would be the one that would affect the least number of sacred sites or safeguards the most important ones.				
	Each community has numbers of cultural heritage sites (tambu site); most of their localizations are unknown to outsiders, therefore all options have to be considered equally good for this criteria. However, the sacred site identified as `Tulahi_ would be unaffected by 7c and it has been excluded from Land Acquisition				
			Best option		
Infrastructure, school, clinic, churches to displace	None of the options affect infrastructure or buildings				
River uses	For this criterion, the best option would be the one that would affect the fewest villages along the Tina River (and the fewest river users), and affect the shortest river section.				

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
	Fishing is carried out along the length of the Tina River, though nowadays it is focused on the river holes and pools in the upper catchment, upstream of Choro and as far as the Mbicho and Mbeambea rivers. All options will modify river use around Choro-Koropa because of the presence of either the reservoir or the by-passed river reach. River uses will evolve due to the presence of a reservoir creating new opportunities such as sustainable, non-commercial fisheries. At the reservoir location, local topography and distance from villages will determine whether the reservoir will be easily accessible for new uses or not.				
	This option will modify river use due to the presence of a reservoir	This option will modify river use due to the presence of a reservoir, in addition to the 2 km affected river reach with modified flow between the dam and powerhouse that would potentially affect Koropa, Senghe, Habusi and Pachuki villages.	The 5.7 km affected river reach with modified flow will pass through Choro, Koropa and Senghe potentially affecting river uses.	This option will not affect river uses outside of the infrastructure rights-of-way since it is located outside any human settlement and has no by-passed river reach with modified flow.	The 1.9 km affected river reach, with modified flow, will not pass through any villages.
	Local topography around Site 6e is less steep, and the reservoir will be easily accessible for pedestrians, access to the reservoir will, therefore, most likely be easier, allowing for local people to develop new uses of the reservoir		Steep gorge around site 7c will restrain access to the reservoir (especially during day-time low water level). In addition, being located approximately 5 km upstream from Mangakiki, access for pedestrians will be more difficult.		
	Best option in terms of potential for developing new opportunities around the reservoir			Best option in terms of limitation of actual river uses	
Natural resources use (on a livelihood perspective)	For this criterion, the best option would be the one that would be located the farthest away from villages and valuable natural resources, thereby limiting impacts on natural resources (timber, game wildlife, etc.)				
	These options will affect natural resource uses by the local population since they are close to Choro, Senghe and Koropa. Hunting and timber products will be affected locally.		Natural resources close to Option 7C dam and the reservoir are poorly utilized by local population as the site is difficult to access and is located upstream from villages.		

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
			Regardless of the location of the powerhouse, any of Options 1, 2, 3 have the same low impact on actual natural resources use.		
			Best option		
Local population wellbeing and safety	For this criteria, the best option would be the one that would be located the farthest away from villages (including access road).				
	Regardless of the option, the access road through villages would be the same, according to TRHDP PO, the final road alignment is being designed to limit disturbances and ensure the safety of villagers.				
	All options will necessitate heavy machinery and truck traffic during construction, so villages nearby the access road will be disturbed. Villagers will be at risk of collisions with trucks and will be subjected to noise and vibration from passing trucks. Health and safety precaution will be developed.				
	Noises and vibration from dam construction could affect some nearby villages		Noise and vibration from dam construction will probably not affect villagers thanks to the site῾s remote location		
	The powerhouse is relatively far from settlements. This helps reducing flow related safety hazards (since the powerhouse outlets release flows after a night῾s storage (sudden flows))	The powerhouse is the closest of all options to settlements, this could lead to flow related safety hazards (since the powerhouse outlets release flows after a night῾s storage (sudden flows))	The powerhouse is close to settlements, this could lead to flow related safety hazards (since the powerhouse outlets release flows after a night῾s storage (sudden flows))	The powerhouse is the farthest of all, this significantly reduces flow related safety hazards (since the powerhouse outlets release flows after a night῾s storage (sudden flows))	The powerhouse is relatively far from some settlements, this helps reducing flow related safety hazards (since the powerhouse outlets release flows after a night῾s storage (sudden flows))
				Best option	
Effect on downstream communities due to modified flow and water quality	Regarding water quality impairment during construction and modified flow, any options will have the same effects on communities downstream of the dam. There is a slight difference between Sites 6e and 7c, that benefits 7c: the size of the reservoir and the volume of usable storage is less for 7c than with 6e, thus limiting the ability to hold back and manage flows.				

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
	Regardless of the option, supply of potable water to affected communities will be necessary during construction, and during the first years of post-impoundment reservoir filling.				
Gender aspects	There is no difference between options regarding gender aspects.				
Best option based on socio cultural criteria				Site 7c- Option 2 is the best option based on social criteria	
Environment					
Plant and wildlife habitat during construction	For this criteria, the best option would be the one that would necessitate the smallest surface of natural habitat to be cleared and the option that is located the farthest away from primary forests, as upstream area are more intact and would require longer access roads				
	With a toe-of-dam powerhouse and a location closer to the existing access road (Black Post Road), the access road will encroach on limited area of habitats. Moreover, the site is located closer to anthropogenically altered areas, which limits the losses of forested areas.	The site is located closer to anthropogenically altered areas and closer to the existing access road (Black Post Road), which limits the losses of forested areas. However, the powerhouse, located away from the dam, would lead to greater impact on habitats.	Due to the great distance between the dam and powerhouse, this option will necessitate more forest clearing than any other options, especially for access roads, leading to greater negative impacts on wildlife (collision, disturbances, noise, vibration, etc.).	Due to a toe-of-dam powerhouse, disturbed areas will be limited	Due to the distance between the dam and powerhouse, this option will necessitate forest clearing for access roads leading to greater negative impacts on wildlife.
	Best option				
Plant and wildlife habitat during reservoir impoundment	For this criteria, the best option would be the one that inundates the smallest volume of habitat (in m^3)				
	At reservoir full supply level, 25.2 x 10^6 m^3 of habitat would be inundated		At reservoir full supply level, 7.0 x 10^6 m^3 of habitat would be inundated		
			Best option		

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
Long term changes to habitat	For this criteria, the best option would be the one that would lead to the least long term pressure on natural resources and the least habitat fragmentation. This criteria is important since it deals with long terms effects.				
	Being located closer to already disturbed areas, with shorter access roads, these options will better preserve upstream natural resources from increased pressure.		These options are located at the edge of a pristine area with undisturbed forests which can shelter more wildlife than disturbed or remnant forests, especially mammals and birds (wildlife surveys have shown that mammals and bird diversity is higher in pristine habitats of the study area). As determined from plant surveys, undisturbed forests located upstream also shelter more vulnerable or threatened plant species than downstream areas. The access road that will lead to the dam will probably be used by local populations to access remote areas. This will inevitably increase hunting and logging pressure on wildlife in pristine areas, and potentially attract new settlers into these areas. Habitat fragmentation is also more pronounced with Site 7c.		
	These options are the best ones				
Fish	For this criteria, the best option would be the one that would lead to the smallest affected length of the Tina River and that would limit aquatic habitat fragmentation. The further upstream a dam is, and the shorter the by-passed section is, the less the fragmentation of aquatic habitat will be. This criteria does not weight much since the habitat gain from one location to the other is rather small (10 km^2).				
	Unless a fish pass is installed, the dam will block the migration of fishes, regardless of the option				
	With a toe-of-dam powerhouse, there will be no reduced flow reach on the Tina River, thus reducing negative impacts on the length of affected river	This option has a 2 km by-passed river reach with reduced flow	This option has a 5.7 km by-passed river reach with reduced flow	With a toe-of-dam powerhouse, there will be no reduced flow reach on the Tina River, thus reducing negative impacts on the length of affected river	This option has a 1.9 km by-passed river reach with reduced flow
	Being located the farthest downstream, these options lead to greater aquatic habitat fragmentation		Being located the farthest upstream, these options lead to less aquatic habitat fragmentation		

<table>
<tr><th>Criteria</th><th>Site 6e- Option 1</th><th>Site 6e- Option 2</th><th>Site 7c- Option 1</th><th>Site 7c- Option 2</th><th>Site 7c- Option 3</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Best option</td><td></td></tr>
<tr><td>Endemic species</td><td colspan="5">Wildlife surveys and data obtained from the literature have shown that endemicity is common in the Solomon Islands. However, regardless of the location, endemic species could be affected to the same extent.</td></tr>
<tr><td>Downstream water quality for aquatic life</td><td colspan="5">All options will lead to water quality impairment during construction especially turbidity (suspended solid). Diminished water quality could disturb aquatic life</td></tr>
<tr><td rowspan="3">Sediment continuity</td><td colspan="5">For this criterion, the best option would be the scheme that leaves the largest river bank volume unaffected, allowing for more natural erosion/deposition processes to take place. The difference between sites is, however, small given the small difference in affected (upstream) catchment size, regardless of the site. This criteria does not provide much weight in the assessment, since the gain between one location and the other is rather small (10 km^2).</td></tr>
<tr><td colspan="2">Being located the farthest downstream, more sediment will be trapped by the dam.
Trap efficiency of the Tina River catchment is 750 tons/km^2/year (Entura, 2014). Therefore, this site will trap 101,250 tons per year of sediment (mostly bed load).</td><td colspan="3">This site will trap 93,750 tons per year of sediment (mostly bed load).</td></tr>
<tr><td colspan="2"></td><td colspan="3">Best option</td></tr>
<tr><td rowspan="2">Amount of spoils</td><td colspan="5">For this criterion, the best option would be the one that generates the least amount of spoils (topsoil during road construction and subsoil during tunnel excavation).</td></tr>
<tr><td>With a dam and powerhouse located close to the existing Black Post Road, and with a toe of dam scheme, this option will generate the least amount of spoils</td><td>The dam and powerhouse are located close to the existing Black Post Road. However, tunnel excavation will generate spoils</td><td>With a dam and powerhouse located far from the existing black post road, and with the longest tunnel of all options, this scheme will generate the greatest amount of spoils</td><td>The dam and powerhouse are located far from the existing Black Post Road. Therefore, a great amount of topsoil will be excavated for road construction</td><td>With a dam and powerhouse located far from the existing Black Post Road, and with the tunnel, this scheme will generate a large amount of spoils</td></tr>
</table>

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
	Best option				
Protected area	There are no protected areas				
Risk of cumulative impact	During construction, all options may result in cumulative water quality impacts with Gold Ridge Mine potential extension project in the Toni River catchment (also called SPL 194), with Oil palm industry drainage discharged, and with logging activities.				
Best option based on environmental criteria	Site 6e ¯ Option 1 is the best option based on environmental criteria				
Technical and Financial*					
Net Present Value ($US) (based on 15m^3/s flow)	$25m ¯ 38m (35m dam ¯ 75m dam)	$53m ¯ 57m (35m dam ¯ 65m dam)	$90 ¯ 103m (35m dam ¯ 65m dam)	$28 ¯ 47m (45m dam ¯ 85m dam)	$55 ¯ 69m (35m dam ¯ 75m dam)
			Best option		
Unit cost of energy ($US/MWH) (based on 15m^3/s flow)	$ 222 ¯ 314 (35m dam ¯ 75m dam)	$ 189 ¯ 285 (35m dam ¯ 65m dam)	$158 ¯ 193 (35m dam ¯ 65m dam)	$ 218 ¯ 312 (45m dam ¯ 85m dam)	$ 186 ¯ 248 (35m dam ¯ 75m dam)
			Best option		
Annual energy (GWh/a) (based on 15m^3/s flow)	26 ¯ 57	38 ¯ 69	59 ¯ 82	34 ¯ 65	39 ¯ 70
			Best option		
Geological features	At the time the Phase 3 report was prepared, some elements of geology were still to be confirmed. Preliminary comparison was made between Site 6e- Option 2 and Site 7c ¯ option 2.				
Best option based on technical and financial criteria			Site 7c ¯ Option 1 is the best option based on technical and financial criteria		

Criteria	Site 6e- Option 1	Site 6e- Option 2	Site 7c- Option 1	Site 7c- Option 2	Site 7c- Option 3
Overall conclusion	Preliminary Project optimization (optimization of dam height and position, tunnel size and route, powerstation size and location, etc.) has lead TRHDP PO to select Site 7c with its superior economic performance. The site was also trending to fewer social impacts, especially in terms of resettlement.				

*this only present a few relevant technical and financial criteria, for the full scope please read the Phase 3 report

4.4.3 Evaluation of Selected Ancillary Facilities for Preferred Alternative 7C

4.4.3.1 Fish Passage

4.4.3.1.1 Comparison of Select Ancillary Works and Construction Methods for Preferred Project

The following comparisons have been made for some of the key elements of ancillary facilities or construction methods with a view to selecting alternatives offering the best value for money, while at the same time lessening potential direct and indirect environmental and social impacts.

4.4.3.1.2 Comparison of Fish Pass Options

Hydropower dams present a barrier to upstream migrating fish and, as a result, can reduce the number of fish species and their numbers in upstream areas. Consideration was, therefore, given to methods for enabling fish to move past the dam and access upstream areas of the Tina River watershed. These included:

- Fish pass structures – these are of two basic designs depending on whether the fish that would use them are free swimming or climbing species, both of which are found in the Tina River. Free-swimming fish require fish pass structures (e.g., fish ladders) with sufficient water depth and reduced velocities to enable fish to freely swim up and over a dam. They are generally comprised of inclined ramps with pool/weir or baffle elements to moderate flow velocities and maintain water depth. Climbing fish may also use pool/weir fishways, but some will require fish pass structures comprised of ramps with wetted rough surfaces (e.g., carpet or roughened concrete) up which they can pass. For both types of fishway, sufficient flow of water is required at the base of the structures to attract fish to enter and continue upwards through the fishway.
- Trap and haul facilities – these consist of an area of attraction water into which fish are either attracted to climb the roughened surface of a wetted ramp to enter a tank in which they are trapped (e.g., for climbing species), or swim via a short pool/weir structure into a tank where they are trapped by a screened cage with a one-way entry. The fish are then brailed or pumped out of the trap into a tanker truck, which is then driven to a location upstream of the dam where the fish are released. Alternatively, swimming species can be netted where they congregate in the attraction waters at the base of the dam or powerhouse tailrace, transferred into tanks, then transported upstream of the dam.

Consideration has been given to include two forms of trap-and-haul. An engineered trap-and-haul system to accommodate climbing fish species, plus, a system involving netting and hauling for swimming species, as part of an adaptive management approach to monitor their migrations and congregations with a view to designing an effective but inexpensive engineered structure, should the results of monitoring support this. Each type of system will need to be monitored during operation to determine whether changes to design or operation are required to ensure fish passage over the dam.

Table 4-3 presents the pros and cons of the two approaches for moving fish upstream past the dam.

Based on this analysis, the trap-and-haul facility was selected as the preferred means of ensuring upstream fish passage for the TRHDP, as it offers potentially greater effectiveness, better opportunity for adaptive management, lower capital cost, and provides ongoing social benefits in the form of employment to operators of the facility.

Table 4-3 Pros and Cons of two primary means of fish passage

	Facilities			
	Fish Pass Structures (i.e., pool/weir/baffle fish ladders for swimmers and friction ramp fishways for climbers)		Trap and Haul Facilities for both swimmers and climbers	
Parameter	Pros	Cons	Pros	Cons
Effectiveness (environmental)	- operates with minimal human intervention - effective at moving species for which it is designed up and over dam	- requires potentially significant volume of water to be effective - a given design of fishway may not serve all species due to different swimming capabilities in the case of free swimming fish - considerable research may be needed to design fishways for target fish species - not effective for climbing fish attracted into tailrace	- trap-and-haul facilities are capable of moving multiple species of fish, if properly designed - relative simplicity of trap-and-haul systems facilitates use at multiple locations - facilities are effective for moving both free swimming and climbing species of fish	- will require that trap-and-haul facilities be installed at least at two locations ¯ at dam site, and at tailrace - requires that ongoing monitoring be undertaken such that trapping and hauling fish be carried out on time and not miss periods when schooling fish are congregating at trap locations
Compatibility with Adaptive Management	- it may be possible to adapt fishway operations to multiple species that might use the fishway at different times of the year by adjusting fishway flows	- costs of changing fishway designs once constructed, or having to add additional fishways of a different design as an adaptive management technique can be very costly and would require additional research to justify - changing operating flow parameters of fishways can have a significant cost on a project especially if this	- relatively easy to change design and operation of trap-and-haul to suit different species and different migration patterns and timing - can add an additional trap and haul system at the mouth of the Ngalimbiu River when certain species school for upstream migration, if this is later	- minimal when compared to fishway structure

	Facilities			
	Fish Pass Structures (i.e., pool/weir/baffle fish ladders for swimmers and friction ramp fishways for climbers)		Trap and Haul Facilities for both swimmers and climbers	
Parameter	Pros	Cons	Pros	Cons
		removes flow from power generation	determined to be advantageous	
Capital Cost	- issue of capital cost is less of an issue if multiple species can be served by the same fishway design	- high cost relative to trap-and-haul system, especially since two systems, one for free swimmers, the other for climbers, would likely be required	- relatively low capital cost	
Operating and Maintenance Costs (direct and indirect), including social costs	- relatively low if fishway design and operation does not have to be altered	- potentially high cost to ongoing project operations if monitoring determines that adaptive management requires retrofitting fishway, or additional flows that take away from power production	- provides steady employment for a small number of persons within the local community	- ongoing costs of labour, and fuel, maintenance and eventually replacement costs of the tanker truck

4.4.3.2 Quarries and Borrow Sites

Based on the Feasibility Study carried out by Entura, the quarry / borrow sites selected are the closest to the proposed location of the concrete batch plant and are within the Core Area, the land that has been acquired for the project. No other suitable quarry / borrow sites are located within the Core Area. If additional stone is required, it will be purchased from commercial suppliers.

4.4.3.3 Access Roads

The parameters for siting access roads included: using existing permanent alignments that could be upgraded for project purposes, and serve local villages as improved roadways during and after construction; avoiding relocating houses and villages; and, where roads did not exist, use former logging roads providing they could be developed as stable access roads, or routes along ridge-tops that could provide stable roadways. Based on these criteria, the main access road was chosen as it follows the existing alignment from the highway to Managakiki Village with a diversion to minimise physical and economic displacement. From Managakiki to the powerhouse and damsite, the road alignment chosen provides for optimum stability.

4.4.3.4 Drilling and Blasting

A variety of drilling methods were examined, including the use of pneumatic and hydraulic drills. Hydraulic drills were chosen due to their lower noise profile.

Standard blasting methods were chosen since, for the most part, blasting will occur 2 or more kilometres from the nearest settlements. Notwithstanding, for safety purposes, blasting mats will be employed to minimise the spread of shot rock from the blasts.

4.4.4 Conclusions

Under the proposed Site 7c Option for the TRHDP, no villages or households in the Tina River Valley will need to be physically resettled. There will be some loss of resources in the upper catchment, especially fishing and forest materials, due to creation of the reservoir, access road clearing, and in the `low-flow_ section of the river between dam and powerhouse. The latter is of central importance to the people living at Choro, Koropa, and Senghe, and to those engaged in timber milling alongside the river.

Development of Site 7c will generate significantly fewer social impacts on local communities than the other options previously advanced and assessed (Site 6a and Site 6e). Site 7c is, therefore, a significant improvement from a social and cultural point of view. The main issue, loss of clean fresh water supplies for all riverside communities located downstream during the projectˇs construction, will need to be addressed by the Project.

In terms of environmental impacts, development of Site 7c will generate greater disturbance in the long term due to the presence of a 5.7 km by-passed stretch of river, which will be affected by reduced night-time flows, and the presence of an upgraded all-season road that passes close to undisturbed forested areas along the reservoir. This access road can be a strong agent of change, as new settlers could arrive, placing additional pressure on natural resources. To mitigate the potential impact of the access road, the original core land owners have been included in the process by the establishment of a core land company which will make decisions with respect to the use and access of the core land, including the access road to the dam. Further mitigation will be the closure of the dam access road for public traffic except operation and maintenance vehicles. A minimum environmental flow will be a requirement for dam operation to mitigate environmental impacts in the low-flow section, and the project's monitoring program will provide information to allow the effectiveness of the flow to be evaluated and appropriate adjustments to be made.

To mitigate impacts on upstream fish passage, a trap and haul system is proposed, combined with an adaptive management approach to monitor and adjust the scheme.

Of the two options that made it to final review, Site 6e and Site 7c, Site 7c is the superior option from both a technical and economic perspective, with the best NPV, best unit cost of energy and best annual energy production.

Based on more favourable expected technical and economic outcomes, fewer social impacts, and environmental impacts that, while not as favourable, should be manageable, Site 7c was chosen as the preferred project alternative to carry forward for a full environmental land social impact assessment.

5. PHYSICAL ENVIRONMENT BASELINE

5.1 INTRODUCTION

This section describes the existing baseline physical environmental conditions within the project-affected area. Biological environmental baseline conditions are discussed in Section 6 (Terrestrial) and Section 7 (Aquatic).

The information on the environmental baseline is based on detailed on-site environmental studies and field-surveys carried out by the ESIA team from August to September 2013, for the purposes of preparing the initial ESIA. Additional, supplementary studies were conducted in the field to address follow-up review comments. The regional information on the study areas is based on a review of secondary literature, supported by field studies, interpretation of available topographic imagery, and review of the Environmental Scoping Report (Entua, 6 June 2012) and the Feasibility Study Report Phase 2 (Entura, June 2012).

The objective of the environmental baseline was to assess the present state of the environmental conditions in the project area, and to provide a basis for evaluating environmental impacts and issues related to project design and construction, operations and maintenance, and decommissioning and rehabilitation.

The description of the physical environment is based on secondary and primary data sources, including the report entitled `Engineering Geological Assessment of Tina River Hydro Project, Guadalcanal, Solomon Islands_(GeoRisk Solutions, 2012); Entura˘s feasibility study (2014); and site visits made by the ESIA team involved in preparing the initial ESIA.

5.2 TOPOGRAPHY AND GEOMORPHOLOGY

The Ngalimbiu River is a large river draining in a northerly direction from some of the highest peaks (2000+ m) on the island of Guadalcanal. The river has two main tributaries, the Tina and Toni rivers. The Tina River catchment is more than three times larger than the Toni River. The catchment area of the Tina River is about 150 km^2 compared to 45 km^2 for the Toni River. The Tina River contains a diverse fish community and is unaffected by human development in its upper reaches. The gradient of the river increases with distance upstream (Table 5-1). Downstream of the Tina/Toni confluence the gradient is 2.3 m/km. This increases to about 5 m/km between the Tina/Toni confluence and the powerhouse site. Upstream of this the gradient continues to increase and is an average of about 9.3 m/km through the reach between the dam and powerhouse, and is steep (19 m/km) between the dam and the head of the proposed reservoir.

Table 5-1 Distance, elevation and gradient of key sections of the Tina River

Location	Distance from sea (km)	Elevation (m amsl)	Gradient (m/km)
Estuary	0	0	0.0
Tina/Toni confluence	19	43	2.3
Powerhouse site	24.7	73	5.2
Dam site	30.1	123	9.3
Proposed reservoir reach	32.7	172	18.8

The changes in gradient with distance upstream are reflected in the substrate and morphology. In the lower reaches downstream of the Tina/Toni confluence, the river is relatively wide and the substrate is dominated by sand and gravel. The bars and braiding are evidence of bedload movement during floods. From the Tina/Toni confluence to approximately 1 km upstream of Tina Village the river gradient is low, and the river unconfined with a substrate comprised of cobble, gravel and sand. The aquatic habitat comprises mainly wide runs and riffles. Upstream of this, the river becomes steeper and more confined and boulders are present, as well as cobbles, gravel and sand. The runs and riffles are generally narrower, with occasional rapids and places where the river splits into two channels. There are also pools which form where the river flows against a bedrock bank and changes direction. Upstream of the powerhouse site, the river becomes even more confined and steeper (50 m in 5.4 km).

Some villages (e.g., Mangakiki and Marava) are located on flat, low elevation ridges, connected by Black Post Road. The elevation of this road ranges from 23masl at Kukum Highway junction, to 235masl at its terminus at Mangakiki village, a distance of 12km. Black Post Road grades are less than 10%, with the average grade around 2%. Other villages (e.g., Koropa, Choro, Sengue, Habusi, Pachuki, etc.) are situated along the edge of the Tina River. These villages are separated from one another by steeply sloped ridges. The Ngalimbiu River runs through flat coastal plains, where human settlements are more numerous.

The dam site is located in a narrow valley comprised of steep slopes and narrow ridge crests. The valley sides at the site of the dam abutments are very steep (30é to 45é slope), and rise to the ridgeline that crests at approximately 200masl.

5.3 GEOLOGY AND SOILS

The Tina River is located within five key lithological units, as follows (Entura, 2014):

é Conglomerate (Tpn: Lower and Upper Toni Conglomerate members)

é Limestone (Tmb: Mbetilonga Limestone)

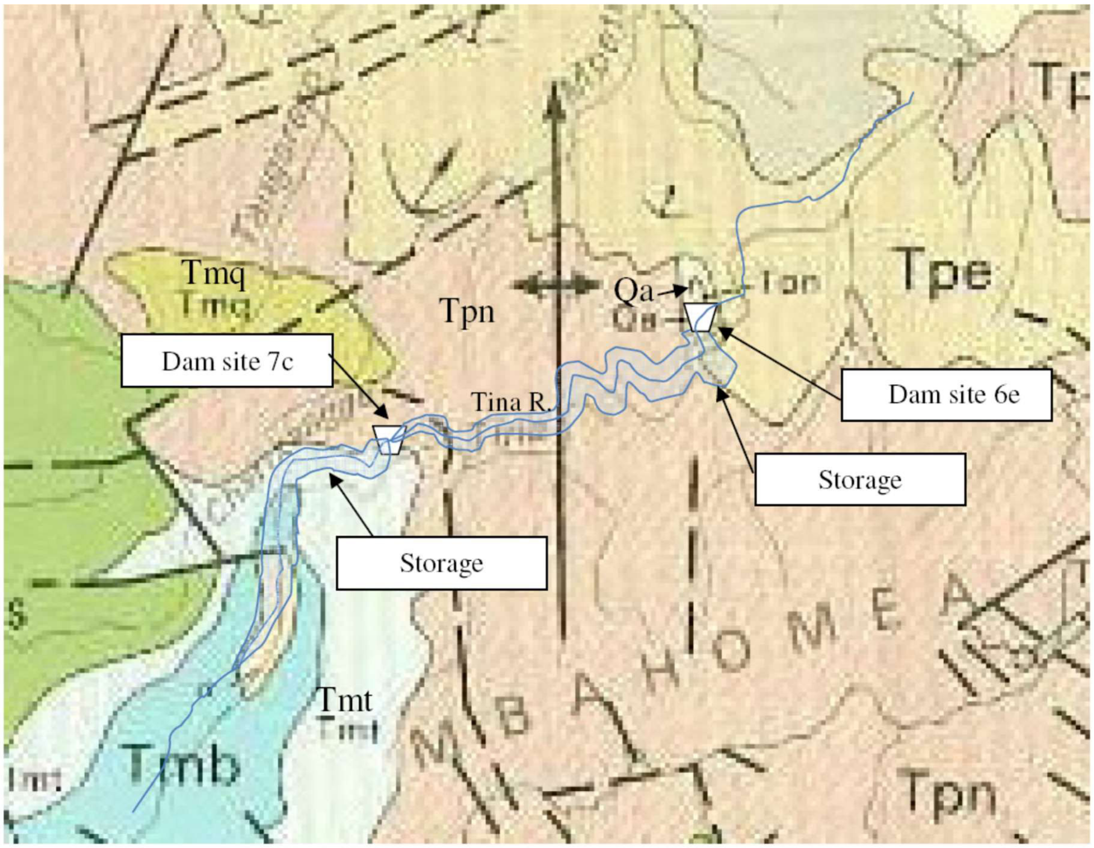
é Sandstone (Tpe: Mbetivatu Sandstone)

é Calcarenite (Tmt: Tina Calcarenite)

é Suta Volcanics

Figure 5-1 includes a map of the local geology found within the Project area. Dam site 7c is the relevant site.

Figure 5-1 Local Geology



Source: Entura (2014)

In addition to these formations, faults and karst are present in the project area. The presence of karst means that sandstone and conglomerate beds have a significant, soluble calcareous content. Entura (2014) considered it most likely that karst features are relatively minor and unlikely to lead to significant geotechnical concern. The proposed Site 7c location for the dam lies within the Toni Conglomerate Formation. This site is composed mostly of sandstone beds, interbedded with conglomerate beds (Entura, 2014). The majority of the proposed reservoir area lies within limestone, overlain by calcarenite. The proposed headrace tunnel and powerhouse are also located within the Toni Conglomerate.

Soils that cover the steep slopes of the construction area, adjacent to the Tina River, are shallow and unstable. They are comprised of colluvial rock debris. However, in stable areas, soils are deep and leached. Based on field observations, topsoils close to the proposed access road that will connect to the dam site are primarily composed of organic red-brown clay loam, or clay silt, with underlying weathered sandstone. Organic matter is primarily restricted to the first 10cm of the topsoil. These soils possess moderate to high fertility, resulting in rapid regeneration of vegetation following disturbance, as long as the topsoil remains undisturbed. Conversely, weathered soils observed in disturbed forested areas often become lateritic, are poor in nutrients, and do not facilitate rapid plant regeneration.

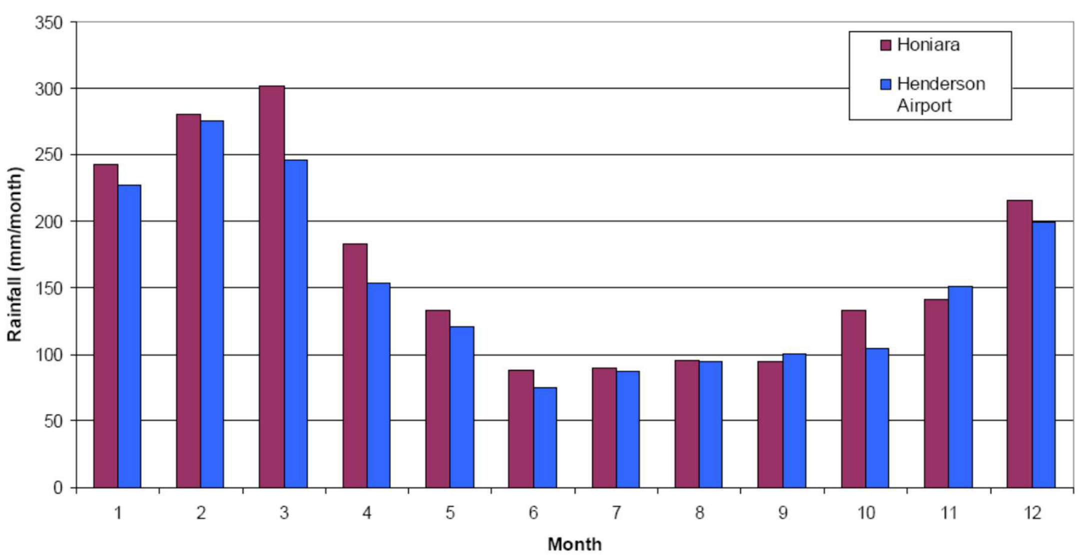
Along Black Post Road, soils are sandy and have low organic matter content, which does not allow for rapid regeneration. In the Solomon Islands, surface soil horizons are usually rich in organic-matter, while underlying mineral horizons contribute poorly to plant growth (SOPAC, 2007). In Guadalcanal, most soils are acidic (pH 3 to 5) (SOPAC, 2007).

5.4 CLIMATE AND METEOROLOGY

Average daily temperatures in Guadalcanal range from 22éC to 31éC throughout the year, with a yearly average of 26.6éC in Honiara. The island has a tropical moist climate with regular rainfall. Rainfall increases with altitude and is higher on the windward coast (South shore). Annual rainfall at both Honiaria, and Honiara International Airport (also known as Henderson Airport), is 1972mm, with summer months being the driest. Figure 5-2 (Entura, 2013) shows the trend in rainfall.

Historic rainfall records for Tina River do not exist. However, based on modeling undertaken by Entura (2012), it was estimated that annual rainfall at the dam site exceeds 2500mm. The same model predicts in excess of 3500mm of total annual rainfall in the headwater reaches of the Tina River.

Figure 5-2 Average monthly rainfall at Honiara and Henderson Airport



Month 1 is January

In Guadalcanal, cyclones are most likely to occur between November and April, and are associated with extreme rainfall events.

In May 1986, cyclone Namu contributed 1200mm of rainfall over a period of a few days, causing rivers to overflow their banks. Water depth at the project site was said to be 7m. The Ngalimbiu River depth reached 7.2m, with a peak discharge of 2,460 m^3/s (Baines & Danitofea, 1987). The extreme rainfall associated with Cyclone Namu contributed to major floods, mudflows and landslides that, in combination, transported logs down the rivers destroying villages and the bridge spanning the Ngalimbiu River.

The floods and mudflows precipitated by Cyclone Namu reshaped the course of the Tina River, and deposited highly fertile silt. The deposited silt has improved soil fertility for the communities that plant crops, and has permitted sustained intense market gardening.

An analysis of a map of sediment deposit patterns from Baines & Danitofea (1987) shows that following Cyclone Namu, communities downstream from Habusi received up to 50cm of deposited sediments. Sediment plumes at the mouth of the Ngalimbiu River mouth extended almost one kilometer offshore.

Meteorological events are important element in people˙s lives, as they have influenced decisions to move from one location to another. People that currently reside in the project area were originally from the upper Tina River catchment area. Landslides, floods such as those caused by Cyclone Namu, and heavy rains were often mentioned during social surveys, as reasons for moving to downstream areas where the effects of these events are less severe. Heavy rain often brings floods that destroy gardens along Ngalimbiu River. Fear of extreme meteorological events is still very strong among villagers.

5.5 LANDSLIDES, ROCKSLIDES AND SEISMICITY

5.5.1 Landslides and Rockslides

A significant number of landslides occur within the Tina River catchment, particularly on the steeper slopes. However, they remain relatively small, and are primarily associated with rockslides along bedding planes. Slope instability is an active and ongoing process within the proposed reservoir area (Entura, 2014).

A rockslide of $2Mm^3$ to $3Mm^3$ volume is visible at the upstream end of the proposed reservoir. A historic rockslide of $0.3Mm^3$, caused by an earthquake, blocked the Tina River in the proposed reservoir area creating a 20m high dam. One year later, the natural dam failed, and caused one causality downstream (anecdotal).

Other slope failures are located in the upstream end of the proposed reservoir, in Suta Volcanics. Large-scale landslides are unlikely to directly affect the dam.

5.5.2 Seismicity

The damsite is located in an area of significant seismicity (GeoRisk Solutions, 2012).

The U.S. Geological Survey (USGS) notes that along the South Solomon trench, the seismicity is predominantly related to subduction tectonics, and large earthquakes are common. Fourteen earthquakes having a magnitude of greater than 7.5, have been recorded since 1900. On 01 April 2007, an inter-plate megathrust earthquake of a magnitude of 8.1 occurred at the western end of the trench, that generated a tsunami that killed at least 40 people. This was the third megathrust event associated with this subduction zone in the past century; the other two having occurred in 1939 and 1977 (GeoRisk Solutions, 2012).

GeoRisk Solutions (2012) recommended that a site-specific seismic hazard evaluation be undertaken for the Project. This evaluation was undertaken by the Seismology Research Centre in February and October 2014. The evaluation employed probabilistic seismic hazard assessment (PSHA) using an earthquake recurrence model that considered the seismicity and geology of the area.

Peak Ground Acceleration (PGA), a measure of the amplitude of the earthquake motion, has been calculated for the TRHDP as being 0.286 g, based on an earthquake of Richter magnitude ML 4 or greater, and 0.273g, based on earthquakes of Richter magnitude ML 5 or greater. This is based on a return period of 475 years, with a 10% chance of exceedance in 50 years, and assumes a Vs30 value of 1000m/s.

During feasibility studies, a pseudo-static seismic stability analysis was undertaken to assess the potential damage caused by the earthquake and a post-earthquake analysis was undertaken to assess the stability of the dam after earthquake events. Conclusions of this evaluation will assist in the final design of the dam.

5.6 RIVER (FLUVIAL) GEOMORPHOLOGY

The Tina River is a single channel meandering river. It has a torrential behavior with regular flash floods. The texture of its bed includes gravel, cobbles and boulders, and fine and coarse-grained sand. In the higher elevation headwaters of the Tina River, very large boulders are intertwined with logs, attesting to the power of its water velocity during floods. Along its banks, some areas have large fluvial deposits.

The River flows through three main geological areas:

- Volcanics, upstream of the Study area and upstream of the Njarimbisu bend area;
- Limestone from the Njarimbisu to the middle reaches of of the Tina River;
- Sandstone, where the Tina River flows through villages upstream of the Toni River.

The following sections describe the Tina River from its upper catchment to its mouth. Figures 5-3 through 5-8 uses Google Earth imagery to identify morphological features of the River. In addition, Annex 1: Description of the Aquatic Survey Stations (see Annex Report) describes the riverˇs morphology at each fish sampling station.

5.6.1 Upper Catchment Area

Figure 5-3 presents an aerial view of the Tina River headwaters (270masl), which are comprised of the junction of two main rivers: Vohara River (1) and Mbeambea River (2) and a minor tributary: Njarimbisu River (3). Becho River (4), a tributary of the Vohara is located further upstream.

This section is characterized by sequences of pools and rapids and sharp meanders. Major boulders, some greater than 3 m diameter, have accumulated along the channel bars. These large boulders indicate that intense floods occasionally occur within this reach. Boulder clasts are predominantly volcanic in origin.

This reach of the Tina River flows along a north-south orientated thrust fault (GeoRisk Solutions, 2012).

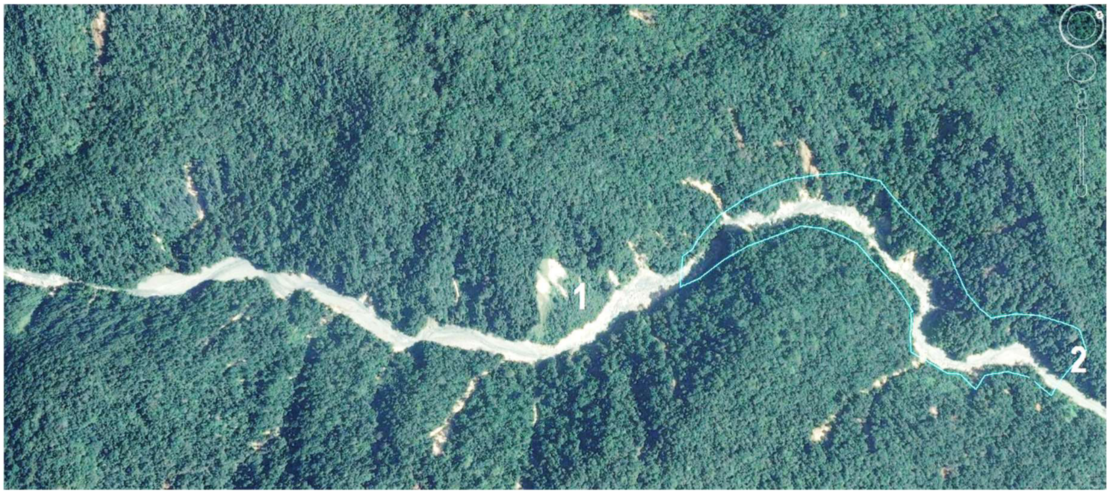
Figure 5-3 Tina River headwaters

Source: Google Earth, 2014

5.6.2 Tina River Gorge

The Tina River enters steep limestone gorges (Figure 5-4) where its course is more confined and less meandering. At this location most of the river˘s course is made of rapids. In many areas, river banks are dominated by rock outcrops. This area is the site of a major historic landslide (1) of around 200,000m^3. The dam and reservoir site are located in this area (2). At the dam site, the river lies at an altitude of approximately 122masl.

Figure 5-4 Tina River Gorge with dam site (Site 7c) and reservoir



Source: Google Earth, 2014

5.6.3 Meandering River Toward the Plain

Figure 5-5 illustrates the river reach downstream of the dam site (1), the river gradually flows through an area having shallower slopes and many meanders. The powerhouse (2) will be located in this area. The density of human settlements also gradually increases as the river flows through villages, until it is joined by the Toni River (3).

Figure 5-5 Tina River between damsite (7c) and Toni River confluence

Source: Google Earth, 2014

Figures 5-6 and 5-7 illustrate the sharp meander bends, channel braiding, and other deposition-erosion features associated with intense flash floods that have the capacity to rapidly shape the river. The inside curves of the meander bends show large point bars of alluvial deposits comprised of cobbles and boulders, while the outside curves show marked cut banks in sandstone. In this area, both size and position of meanders have changed throughout time, and sometimes quickly as a result of weather related events, such as Cyclone Namu. One example of rapid river channel migration is the behaviour of the Tina River (3) at ‘Tina’s old meander (1)’ adjacent to Tina Village (2) where the channel quickly shifted from a straight line channel to a large meander channel before its junction with Toni River (4). The following example shows the evolution of the Tina River channel within one year.

Figure 5-6 Tina River before channel shifted

Source: Google Earth, 2013

Figure 5-7 Tina River after channel shifted

Source: Google Earth, 2014

The riverbed and the adjacent terrace are comprised of rounded cobbles and boulders, predominately less than 0.5m in diameter, within a matrix of silty sand.

5.6.4 Tina and Toni River Confluence: Ngalimbiu River

Figure 5-8 illustrates the flat coastal plain, located downstream of the confluence of the Toni and Tina rivers, where they give rise to the Ngalimbiu River. The Ngalimbiu River flows across an area characterized by denser human settlement, and other anthropogenic human activities, such as gravel extraction. Drainage from agricultural lands, such as oil palm plantations, enters the river. During Cyclone Namu, sediments from the Ngalimbiu River extended across this coastal plain in a path more than 6km wide (Baines & Danitofea, 1987). The Ngalimbiu River also shows intense deposition-erosion processes at work, as illustrated by sharp meanders and fluvial deposits.

At the confluence of the Tina and Toni rivers, the elevation is approximately 40masl.

A small delta has formed at the mouth of the Ngalimbiu River where it enters the Solomon Sea at Lasa Point (close to Tenaru Bay).

Figure 5-8 Ngamimbiu River flood plain

Source: Google Earth, 2014

5.7 RIVER HYDROLOGY

The Tina River catchment covers an area of approximately 150km^2. Upstream of the dam site, the catchment covers an area of about 125km^2.

The Tina River is comprised of three rivers: the Mbeambea, the Voraha and the Njarimbisu rivers. The Tina River's catchment area is delineated by: Chupu Kama to the East; Mount Mbutohaina (1649m) to the West; and a chain of mountains to the South, including Mount Tambunanguu (1902m), Mount Popohanatungga (1877m), and Mount Turipukumahi (1636m). Mount Popomanaseu (2310m), the highest mountain of the Solomon Islands, is located just outside of the Tina River catchment.

The Tina River meets the Toni River 17.8km downstream from the Tina River's headwaters. The Toni River is a much smaller river with a catchment of approximately 45km^2, and a flow roughly 1/3 that of the Tina River.

To model the flow of the Tina River, a river level and rainfall gauging site was installed upstream of the proposed dam site. Another rainfall-gauging site was installed in the upper catchment at Chupu Kama. Hourly rainfall data has been collected since mid-June 2010. River water levels and flows were collected until April 2014 when equipment was destroyed by flooding. The levels and flows have been obtained to allow development of a rating curve for the site (Entura, 2014).

According to Entura (2014), the lack of long-term rainfall data within the upper Tina River catchment is a major constraint to estimating the catchment rainfall and flow at the proposed dam site.

Two years of additional data have been acquired and this has allowed Entura to develop a hydrological model and synthesise a long-term flow data series for the Tina River. One of the conclusions from the additional data and the long-term (29 years) flow analysis is a reduction of the fully absorbed energy of the scheme from 84.7 Gwh to 80.6 Gwh.

5.7.1 Duration Curves of Specific Yield

According to Entura (2014), the duration curves of specific yield for the Tina River is 0.097m^3/s/km^2, which means that, on average, when moving downstream, for every additional km^2 of Tina River catchment, the yield increases by 0.097m^3/s.

5.7.2 Average Flow

Flow data were taken from the Feasibility Study prepared by Entura (2014). Tina River gauging station is located in the upper catchment area between the confluences of the Tina River and the Voraha and Mbeambea rivers (see location at A3 in Figure 5-3). Flow data has been collected by automatic gauging and telemetry from 15 June 2010 to April 2014. Plans are underway to reinstate the gauging station.

According to Entura (2014), the average monthly flow at dam, estimated from extended records, was 11.5 m^3/s. This flow was used in the estimating energy production for the TRHDP scheme.

Using available data from the gauging station upstream of the proposed dam site, for the period 15 June 2010 to 21 September 2013, the average flow at dam site in the wet season (December first to March 31) was estimated to be 19.40 m^3/s, and the average flow at dam site in the dry season (April 1 to November 30), was estimated to be 12.72 m^3/s. This data shows that the average flow appears higher than the average flow obtained from the extended records.

Table 5-2 shows the average flow on a monthly basis, based on the same data. January shows abnormally low values. Although the wet season, this could be the result of abnormally dry conditions that occurred in January 2011, 2012 and 2013. Alternatively, this may have been the result of an error in recording measurements at the gauging station. There is considerable variation around the average flow, as illustrated by the figures in the minimum and maximum columns.

Table 5-2 Monthly flow at damsite (15 June 2010 to 21 September 2013)

Months	Average monthly flow at dam site (m^3/s)	Minimum recorded (m^3/s)	Maximum recorded (m^3/s)
January	13.87	5.97	120.94
February	21.48	4.96	342.38
March	21.94	6.55	233.54
April	18.23	5.04	141.84
May	14.27	4.53	201.50
June	8.69	3.83	185.64
July	10.55	3.42	222.93
August	10.81	3.01	234.85
September	11.62	2.85	220.06
October	12.90	3.91	176.93
November	17.12	3.26	445.62
December	20.46	4.83	298.33

The Phase 3 addendum report based on the 29 years of river flow modelling shows a dry season flow (between June and September) of 7.5 m^3/s with increasing flow in September and a wet season flow up to 20 m^3/s occurring in December to January. This is shown in Figure 5-9 below.

Figure 5-9 Seasonal river flows

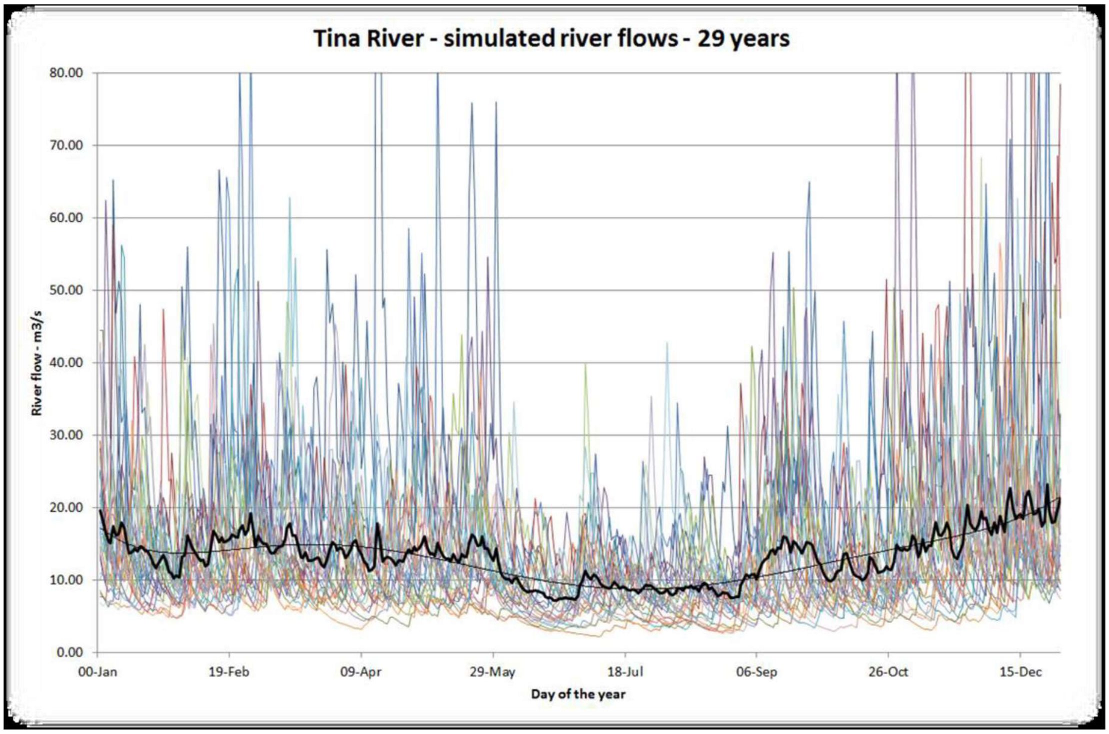


Table 5-3 identifies flow percentiles of long-term estimated flow at the dam site. Flow percentiles provide precise information about occurrences of flows.

Table 5-3 Flow percentiles for long-term estimated flow at damsite

Flow Percentile	Average daily flow transposed to dam site (m^3/s)
10	5.1
25	8.0
50	11.8
75	17.0
90	25.4

Source: Entura (2014)

Table 5-3 is interpreted as follow:

- On an annual basis, average daily flow is less than 5.1m^3/s, 10% of the time. This also means that for 90% of the time, flow is greater than 5.1m^3/s.
- On an annual basis, average daily flow is less than 25.4m^3/s, 90% of the time. This also means that for 10% of the time, flow is greater than 25.4m^3/s.

5.7.3 Flow Difference Between Toni River and Tina River

A rapid comparison (Table 5-4) of flows between the Tina River and Toni River was made during the rainy season to quantify the flow input of the Toni River on the Ngalimbiu River. The following table shows that the Toni River has a flow roughly 1/3 that of the Tina River. At approximately 45km^2, the Toni River catchment covers an area approximately 1/3 that of the Tina River catchment, which covers roughly 150km^2.

Table 5-4 Comparison of flows between Tina and Toni rivers

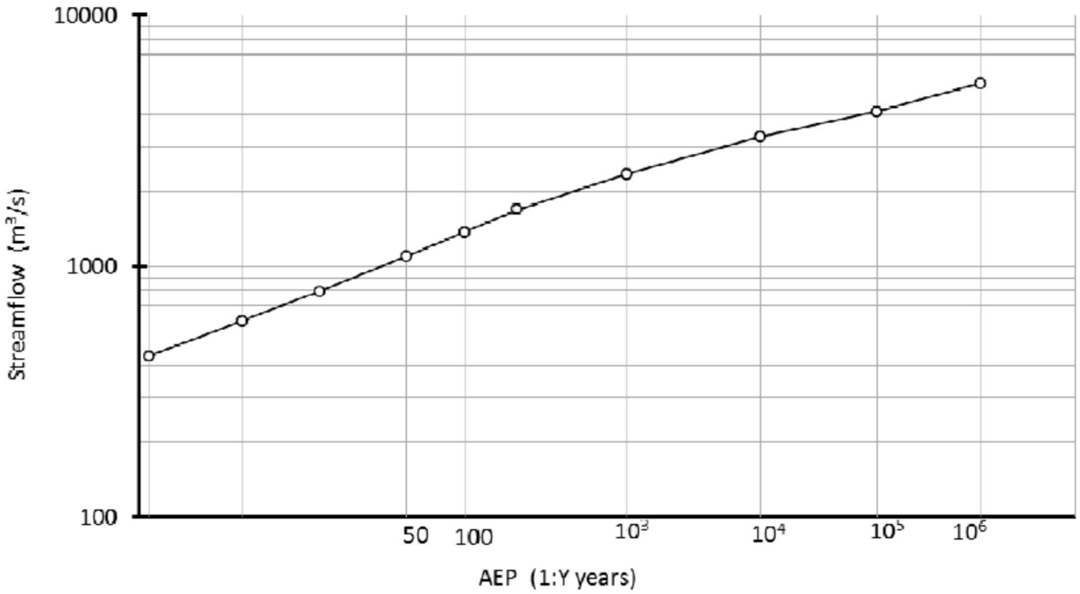
Station	Location	Date	Width (m)	Water level (m) at different locations	Water Velocity (s) for 20 m	Water Velocity (m/s)	Estimated flow (m^3/s)
A5B	Tina River (before its confluence with Toni)	11/02/14	46.40	0.28	35	0.57	28.99
				0.28	20	1	
				1.10	11	1.82	
A6B	Toni River (before its confluence with Tina)	11/02/14	19	0.50	42	0.48	7.16

5.7.4 Flood Frequency

The Tina River flood frequency curve is derived from the Lungga River flood frequency curve, as measured at Lungga Bridge. The Lungga frequency curve, with up to 1:200 Annual Exceedance Probability (AEP), was scaled to the Tina River catchment using catchment area and rainfall scaling.

The maximum observed flow over a period of three years in the Tina River is 445m^3/s, which is close to the 1:5 AEP event. This means that, statically, this AEP event could take place every 5 years, or that there is a 1 in 5 chance that it will occur every year). Figure 5-10 and Table 5-5 show the preliminary estimate of flood frequency curve at the dam site.

Figure 5-10 Preliminary estimate of flood frequency curve at damsite



Source: Entura (2014)

Table 5-5 Preliminary peak inflow estimates for Tina River damsite

AEP (1 : Year)	Peak Flow (m^3/s)
1.01	60
2	245
5	460
10	610
20	800
50	1100
100	1375
200	1690
1,000	2340
10,000	3290
100,000	4140
1,000,000	5050

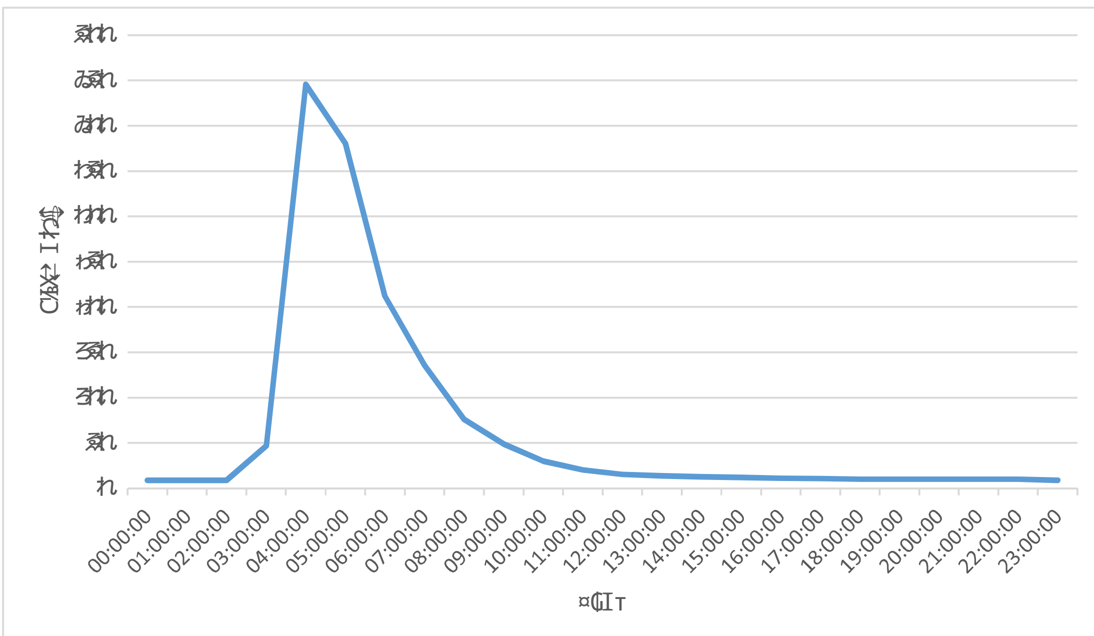
Source: Entura (2014)

The spillway has been designed to pass a Maximum Flood Level of an AEP equals to 1:10,000, which is 3,290 m^3/s. In comparison, according to Entura, 2014 Cyclone Namu was approximately a 1:50 event, meaning that, statistically, it can occur once every 50 years, or that it has a 1 in 50 chance of occurring every year. This compares to data provided in Baines & Daitofea (1987), which indicated that cyclone Namu had a peak discharge at the Ngalimbiu River mouth of 2,460 m^3/s, meaning that it was a 1:1,000 event.

5.7.5 Flash Floods

The Tina River experiences flash floods almost immediately after heavy rainfall events occur in the upper catchment. Flow and water level can change rapidly during such events. Heavy rainfalls in the upper catchment are visible from afar, and people use this visual cue as a warning of an impending flash flood. On 11 November 2010, a spectacular flood occurred that increased the flow from 8.7m^3/s to 445.65m^3/s in only four hours (see graph in Figure 5-11).

Figure 5-11 Example of a significant flash flood that occured on 11 November 2010



Data based on Tina River gauging station

In area where the Tina River runs through gorges, water can quickly rise up to 2 meters in elevation. Whereas, elsewhere these flash floods briefly inundate riparian areas and replenish wetlands.

A dam at 7C can become a means of controlling flash flood for the downstream communities. The Hydro powerstation will have accessories to monitor flow installed and this can be used to advise the downstream communities about possible flooding and the level of flooding can be more easily determined. The downstream communities can access this information to take appropriate actions if required. The downstream communities should not experience any significant changes to the current flooding characteristics as the volume of water flowing down the Tina river after the power station will not be impacted after the power station.

5.7.6 Tina River Tributaries in the Reduced Flow Reach

A number of small, seasonal tributaries enter the Tina River between the dam and powerhouse sites (i.e., `reduced flow reach_). These streams are valuable aquatic resources that will need to be protected during road construction.

These small left and right bank tributaries cover an area of 1,042ha (+/- 10 km^2). Given the specific yield of 0,097$m^3/s/km^2$, calculated for the watershed upstream of the dam, with its higher elevation and rainfall, the run-off supply from the smaller tributaries entering the reduced flow reach is estimated to be less than 0.97m^3/s (~1m^3/s) on average. Hence, this represents only a small proportion of Tina River flow. Table 5-6 identifies the length of the tributaries that enter the reduced flow reach.

Table 5-6 Left and right bank tributary streams

Small left bank tributaries of Tina River	Length of the tributary (m)
Vurahairauha	1149
Vurapokola	1088
Valemalamala	362
Choro	250
Hainalovo	511
Senge	314
Nembo	607
Small right bank tributaries of Tina River	
Kakaʻuha	3044
Jarikela	757
Puaka	3760
Valebou	3113
Valepohopoho	509
Mbabakoechir	273
Aho	406
Chongo	853
Chanbaulo	446
Pihu	645
Koeropa	705
Lotulotu	583

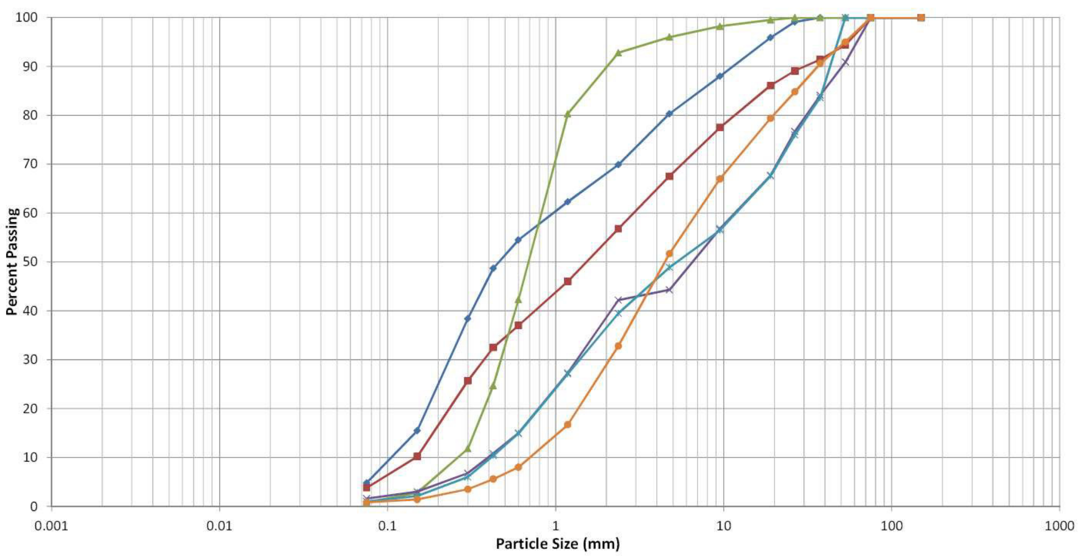
5.8 RIVER SEDIMENT TRANSPORT

According to Entura (2014), alluvial deposits are the predominant river-bed material. It is assumed that the depth of alluvium reaches approximately 10 m within the river channel. Although, alluvium deposits within the Option 6 area extended to a depth of 25m. Alluvial terraces occur adjacent to the current river course and bars. Terraces vary from 1.5m to 5m above the current river level. They are comprised of cobbles and boulders, predominately less than 50cm in diameter, with a matrix of silty sand. At some locations, large boulders up to 3m in diameter are found, indicating that intense floods occasionally occur.

Bed load sediment ranges in size from silts and sands in low flow area, to large boulders in very high flow areas. Bed load sediments are materials likely to be deposited into the storage reservoir because of reduced water velocity, and will accumulate over time in the dead storage zone of the reservoir and are, therefore, unlikely to be transported downstream. In addition to bed load, additional material may be transported into the reservoir from landslides, and from surficial materials eroded from the land as a result of upstream logging and construction activities.

According to Entura (2014), bed load sediments deposited in the Tina riverbed and alluvial bars range from 0.1mm to 100mm in size, as shown in Figure 5-12 (sample taken in the vicinity of Site 7c).

Figure 5-12 Particle size distribution of bed load sediment and alluvial bars in the Tina River



Source: Entura (2014)

By opposition to bed load sediments, suspended sediment are material transported by the river that remain in suspension even when water velocity is reduced. These materials are likely to be transported downstream through the headrace tunnel and turbines. Sand, silt and clay make up suspended sediments. Based on field surveys by Entura (2014), total suspended solids in Tina waters range from 8mg/L to 157mg/L.

Based on trap efficiency for the suspended sediment of 50% and 100% for bed load, Entura (2014) has estimated that the amount of material (both suspended sediment and bed load) that will be trapped would be of 750t/km^2/year (93,750 tons per year or 45,000m^3) would be deposited in the reservoir. It would therefore take about 65 years until the reservoir fills to the intake invert level at 162.5masl.

Despite the dam acting as a barrier for sedimentation transport to the downstream areas, the over topping of the dam during flooding will continue to carry sediments from tributaries downstream of the dam and this will continue to supply sediments to the downstream communities which will allow them to continue with their livelihood activities such as gardening on fertile land along the river bank.

5.9 AIR QUALITY

Air quality is generally excellent in the Project area and there are no air quality non-attainment areas in the vicinity. Construction activities can be sources of dust pollution during wind events in the general region.

Impacts: There would be short-term dust impacts during excavation work although this would be limited to fugitive dust emissions and emissions from machinery and vehicles used and dust control would be followed during construction. There would be no negative long-term adverse impacts on air quality due to operation and maintenance of the hydropower facilities. As with other hydropower projects, there would be an offset of emissions of carbon dioxide and other green house gases.

5.10 WATER QUALITY

5.10.1 General Water Quality

Tables 5-7 and 5-8 include water quality results for both dry and rainy seasons, respectively. The locations of water quality sampling stations are set out in Table 5-9, at the end of this section. Dry season water sampling was carried out in July and August 2013 and rainy season sampling was carried out in February 2014.

Generally speaking, the water quality in the upper Tina River, upstream of inhabited areas, is assumed to be good owing to there being no anthropogenic sources (i.e., no domestic use, no gold panning, etc.) of pollution. Natural peaks in turbidity following flash flood events are considered to be the primary cause of degraded water quality. Current water quality in the Tina River does not appear to be a limiting factor for aquatic life, given this low level of pollution.

Table 5-7 Dry season surface water quality monitoring results

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*Norms for Rivers in tropical Australia

ADWG: Australian Drinking Water Guidelines; WHO: World Health Organization

Stations A10C, A10 D and A10E are not mapped, they were taken in the river mouth at the shore line about 20m upstream inland and about 20m downstream in the river outflow outside of the shoreline. The conductivity measurements clearly show that, at the time of the observation, there was no estuarine effect: the freshwater flows directly to the sea. No salinity gradient inland. This was confirmed by the presence of fresh water helophytes and can toad tadpoles at the river mouth.

Table 5-8 Rainy season surface water quality sampling results

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*Norms for River in tropical Australia

ADWG: Australian Drinking Water Guidelines; WHO: World Health Organization

Table 5-9 Table of location of water quality sampling sites

Station	Area	River	Location	Chainage*	WQ sample
A1	Upper catchment	Bicho-Voraha Riv.	confluence	CH -1km	X
A2	Upper catchment	Mbembea River	confluence	CH -1km	X
A3	Upper Tina	Tina River	Gauging st	CH 1km	X
7C	Middle Tina	Tina River	Dam	CH 7km	
A4	Middle Tina	Tina River	Koropa	CH 11km	
A5	Middle Tina	Tina River	Sengue	CH 11.5km	
A6	Upper Ngalimbiu	Toni River	Horohutu	CH 19km	X
A7	Upper Ngalimbiu	Ngalimbiu Riv.	Kathihana	CH 20km	X
A8	Lower Ngalimbiu	Ngalimbiu Riv.	Ngalimbiu	CH 28km	X
A9	Lower Ngalimbiu	Ngalimbiu Riv..	Saele	CH 34km	X
A10a	Mouth area	Old Ng. mouth	Komporo	CH 36 km	X
A10b	Mouth area	New Ng. mouth	Komporo	CH 37 km	X

*Based on Entura Phase 1 chainage, starting at Tina River between the upstream confluence of the Mbeambea and the Voraha (chainage 0km)

For further details on the location of the water quality sampling sites see Section 7.3.3.

5.10.2 Specific Water Quality Parameters

5.10.2.1 Turbidity

During the dry season water quality sampling (August 2013), the water was very clear in the vicinity of the gauging station (turbidity of 1 NTU or less). In the Toni River, a high turbidity (9.7 NTU) was observed on a rainy day. In the Ngalimbiu section (Horohutu to Saele), turbidity values were significantly higher, ranging from 5NTU to 9NTU (5NTU is considered as noticeable when observing). The maximum turbidity (12NTU) was observed at the mouth of the River.

During the rainy season water quality sampling (February 2014), the water was less clear than it had been at the same location during the dry season water quality sampling. In all river stations, turbidity was higher than the World Health Organisation`s (WHO) recommended norm of 5NTU for drinking water. At the time the rainy season sampling was conducted, frequent heavy high rainfall events were generating silt and soil laden runoff originating from within the large catchment area.

Turbidity in downstream reaches of the Tina River (16.1NTU) was higher than in the downstream reaches of the Toni River (2.52NTU). As would be expected by these NTU levels, visually, the Toni River was also much clearer than the Tina River. The difference between the water clarity in the two rivers could be explained by the fact that Toni River catchment does not extend to the same higher elevations as the Tina River catchment.

In Guadalcanal, rainfall is directly related to altitude, the higher the altitude, then the higher the amount of rainfall. In addition, The Toni River catchment is much smaller than the Tina River catchment. During the dry season water quality survey, according to laboratory results, the mouth of the river was less turbid than at other stations. During the rainy season water quality survey, the river mouth appeared more turbid. This difference could be explained by the slower currents in the vicinity of the river mouth, where the water is also deeper, versus the stronger currents observed at the upstream sampling stations (Tina, Toni and Ngalimbiu).

People residing next to the rivers extract water from small holes dug into the river gravels adjacent to the shore, to obtain water that has been filtered through the sand, before drinking it. Water sampled from a hole dug into the gravel showed reduced turbidity (2.34NTU), compared to water taken directly from an adjacent location in the river (14.6NTU).

The increase in turbidity in the Ngalimbiu River is likely the result of both anthropogenic (high population with increasing water usage, and agricultural drainage in the coastal plain), and natural causes (increase of primary productivity in the lower reach of the river due to the degradation of organic matter from the upper reach, `spiral effect_).

The level of turbidity observed indicates good quality of water for aquatic life.

5.10.2.2 pH

During the dry season, the water had a slightly basic pH (7.8 to 8.2) with no particular variation along the river. During the wet season, the water had a pH that ranged from 6.6 to 7.89.

The observed pH levels indicate good water quality for aquatic life.

5.10.2.3 Conductivity

During the dry season, conductivity readings on the upper Tina River were relatively low (136 ıS/cm to 155ıS/cm), compared to isolated pools, where readings were roughly double (271ıS/cm). Conductivity appeared to increase slightly in the Ngalimbiu River (173ıS/cm to 215 ıS/cm) for the same reasons that dry season turbidity was higher in this reach.

At the mouth of the river, conductivity readings (191ıS/cm to 242ıS/cm) were not significantly higher (319ıS/cm) than in the Ngalimbiu reach, even at the point where freshwater was pushing the ocean outwards. No salinity gradient was observed during the survey (i.e., no brackish water estuary). During flood tides, ocean waters can intrude upstream as a salt wedge beneath the freshwater for a distance of roughly 500m.

During the rainy season, the river mouth shows a significant increase in conductivity (995.1ıS/cm) when compared to the upstream river reaches (155.2ıS/cm to 239.3ıS/cm). Total Dissolved Solids (TDS) exhibited the same trend as conductivity.

5.10.2.4 Other parameters

Regarding nutrients (nitrate, phosphate), during both the rainy and dry seasons, nutrient concentrations were found in low concentrations in the upper Tina River, and were slightly elevated in the Ngalimbiu reach.

Nutrients are more a concern for drinking water quality for humans, than for aquatic life.

5.10.2.5 Faecal Coliform Bacteria Levels

During dry season, the level of faecal coliform contamination was low in the upper Ngalimbiu reach and in the Toni River, where few riparian settlements occur. Faecal coliform levels increased within the lower reaches, especially downstream of Ngalimbiu village.

During the rainy season, the level of total coliform contamination was high in all sampled stations. Total coliform indicates the presence of coliform derived from both vegetative, and human and animal sources. The presence of Escherichia Coli (E. Coli) bacteria indicates faecal contamination from human or animal origin. Sample results exceeded WHO standards but, surprisingly, remained lower than during the dry season. These results were counter-intuitive, as it would have been expected that, due to heavy rains and the volume of runoff from nearby villages, higher levels of E. Coli would have occurred during the rainy season.

5.10.2.6 Water Temperature

Water temperatures were obtained using a Hanna HI 9146 dissolved oxygen and temperature meter. River water temperatures increase in a downstream directly from higher elevation to lower elevation. At the river mouth water temperatures decrease, somewhat, due to the moderating influence of the ocean. During the rainy season, water temperatures ranged from 24.5éC in the Tina River to 32.0éC in the Ngalimbiu River.

Anthropogenic processes have no influence on water temperatures in the sampled rivers.

5.10.2.7 Dissolved oxygen

Dissolved Oxygen (DO) measurements were made using a Hanna HI 9146 dissolved oxygen and temperature meter. Sampling was conducted during the rainy season, at depths of 20cm and 40cm, to obtain a range of results. Along the Tina, Toni and Ngalimbiu rivers, DO ranged from 6.00mg/L to 7.24mg/L, levels that are considered good aquatic life. At the mouth of river, DO decrease to between 5.71mg/L and 5.84mg/L, indicating poorer conditions for aquatic life. According to ANZECC, DO levels below 6mg/L result in conditions that are stressful for aquatic organisms. No DO measurements were obtained during the dry season.

The source of DO is aquatic plants that expel oxygen into the water during photosynthesis, or from the atmosphere through turbulent mixing (entrainment) and diffusion. In the river system, DO comes from entrainment and atmospheric diffusion rather than from aquatic plants, since high water velocities and frequent flash flooding does not facilitate the establishment of aquatic plants. DO is affected negatively by the amount of soil and vegetation debris (organic matter) that enters the river system, both of which consume oxygen through adsorption and decomposition. The presence of fast moving water over rapids and riffles positively affects the amount of oxygen that diffuses into water. Temperature also influences DO, with the higher the temperature the lower the oxygen content of the water. Warm, slow moving water, as observed at the mouth of the river, negatively influences oxygen content.

Erosion caused by human activities, such as agriculture or forest clearing, runoff that occurs during the rainy season, and natural landslide events, all contribute to reducing DO levels in the river, thereby affecting aquatic life. However, notwithstanding the negative effects on DO, floodwaters rich in organic material from the Tina River's large catchment area are valuable for some aquatic species.

5.10.2.8 Dissolved Metal Concentrations at Ngalimbiu River Bridge (2006)

Water quality at the Ngalimbiu River Bridge has been monitored by Golder Associates (August 2006, November 2006, March 2007 and September 2007) as part of a water quality baseline survey. The Ngaliumbiu site was used as a reference site for the Matepono River, which is effected by mine activities. Results were obtained from the Gold Ridge Mine Environmental Audit report (Golder Associates 2008).

The report focuses on metal concentrations in surface water, and includes analyses for aluminium, copper, arsenic, cadmium, manganese, nickel, lead and zinc. Concentrations of dissolved metals were below the ANZECC trigger thresholds for drinking water with the following exceptions: Aluminum (August 2006 and September 2007), Copper and Cadmium (August 2006), Zinc (September 2007).

5.10.2.9 Pesticides Associated with Oil Palm Cultivation

Pesticides, including Glyphosate CT, Basta, 2-4-D Amine, Ally (Metsulfuron Methyl), Kamba 500 selective herbicide (present as the dimethlyamine salt), and Gramoxone Tropical (Paraquat), are most likely present in the Ngalimbiu River, since they are used by the oil palm industry in the area. Since 2011, Paraquat is no longer used (New Britain Palm Oil Limited, 2011) but is most likely still present in the sediments of the Ngalimbiu River.

No water quality data were available for these parameters, and it is suspected that they have never been analysed in the Ngalimbiu River. National laboratories do not have the capabilities to analyse pesticides.

5.10.3 Water Quality Study Limitations

The three main study limitations regarding water quality sampling are:

- Limited capacity of the Solomon Islands Water Authority (SIWA) laboratory;
- Lack of national laboratories with the capability to analyze heavy metals and pesticides; and
- Sampling was undertaken as unique events, rather than as recurring events over a period of time.

The quality of analyses by SIWA Laboratory could not be verified, since blank samples needed for quality control, were lost by the laboratory.

The river system is highly variable, with sudden flash floods rapidly changing turbidity, dissolved oxygen, temperature and Total Suspended Solids (TSS). With the exception of logging, the Tina and Toni rivers are not affected by other anthropogenic disturbances, (e.g., no gold panning, no other major sources of TSS, no agriculture activities, etc.). Therefore, heavy metal and pesticide pollution are not likely to affect the Tina River system. It is, however, likely that the Ngalimbiu River, downstream of the Tina River, is affected by pollution resulting from drainage of oil palm plantations that use fertilizers and pesticides. National laboratories do not have the capability to analyze these sources of pollution. To establish a benchmark for aquatic organisms and the aquatic environment, it is recommended that a program of water, sediment and fish tissue sampling for heavy metal and pesticide toxicity be implemented for the river system, prior to construction of TRHDP (as presented in Section 6). Samples could be sent to Brisbane, Australia.

5.11 Ambient Noise Levels

5.11.1 Ambient Noise – Baseline

Ambient noise monitoring was not undertaken for the TRHDP. This is because the Project will be located in a rural setting in which ambient or background noise is consistent with a largely un-mechanised society. Night time noise levels for undeveloped rural settings typically range from 30dBA to 40dBA, and 40dBA to 50dBA during day time hours. Occasional spikes up to 75dBA to 80dBA may occur close to villages when chainsaws, petrol powered electrical generators or petrol powered water pumps are in use.

5.11.2 Noise Emissions – Construction and Operation

Impact Identification and Rating

During project construction, noise levels will increase considerably at the dam site and powerhouse site over a period of up to three years. However, as the dam site is approximately 2km from the nearest village, only minimal impacts will accrue to local inhabitants as a result of dam construction. Noise disturbance from powerhouse construction will affect Habusi village, which is located across the river and approximately 400m away from the site.

Noise levels will also increase close to villages during the period that access road improvements are underway. This noise disturbance will be transient, extending over a matter of days or weeks, as the road construction progresses. Transient noise levels will also increase within villages located along the access road as a result of truck / vehicle movements, which are estimated at almost 10 transits per hour during the daytime construction period (7:00am to 5:00pm). Heavy truck movements will also generate vibrations that may affect any buildings located in close proximity to the road.

Overall, noise impacts will be significant adjacent to the dam. However, as there are no villages within 2km of the dam site, the effects on villages will be low-moderate. Noise impacts from access road construction and operation, and powerhouse construction will be moderate during the daytime construction period, and low during nighttime.

During project operation, noise disturbance will be minimal and primarily related to occasional vehicle movements to/from the dam and/or powerhouse.

Typical noise levels associated with machinery used to construct a hydropower project are included in Table 5-10.

Typical levels of noise disturbance are shown in Figures 5-13 and 5-14.

Table 5-10 Equipment Noise Emission Levels

Equipment Description	Impact Device?	Actual Average dBA Measured L_{max} @ 50 feet or Spec (where actual not available)
All Other Equipment > 5 HP	No	85 (spec)
Auger Drill Rig	No	84
Backhoe	No	78
Bar Bender	No	80 (spec)
Blasting	Yes	94 (spec)
Boring Jack Power Unit	No	83
Chain Saw	No	84
Clam Shovel (dropping)	Yes	87
Compactor (ground)	No	83
Compressor (air)	No	78
Concrete Batch Plant	No	83 (spec)
Concrete Mixer Truck	No	79
Concrete Pump Truck	No	81
Concrete Saw	No	90
Crane	No	81
Dozer	No	82
Drill Rig Truck	No	79
Drum Mixer	No	80
Dump Truck	No	76
Excavator	No	81
Flat Bed Truck	No	74
Front End Loader	No	79
Generator	No	81
Generator (<25KVA, VMS Signs)	No	73
Gradall	No	83
Grader	No	85 (spec)

Equipment Description	Impact Device?	Actual Average dBA Measured L_{max} @ 50 feet or Spec (where actual not available)
Grapple (on backhoe)	No	87
Horizontal Boring Hydraulic Jack	No	82
Hydra Break Ram	Yes	90 (spec)
Impact Pile Driver	Yes	101
Jackhammer	Yes	89
Man Lift	No	75
Mounted Impact Hammer (hoe ram)	Yes	90
Pavement Scarifier	No	90
Paver	No	77
Pickup Truck	No	75
Pneumatic Tools	No	85
Pumps	No	81
Refrigerator Unit	No	73
Rivit Buster/Chipping Gun	Yes	79
Rock Drill	No	81
Roller	No	80
Sand Blasting (single nozzle)	No	96
Scraper	No	84
Sheers (on backhoe)	No	96
Slurry Plant	No	78
Slurry Trenching Machine	No	80
Soil Mix Drill Rig	No	80 (spec)
Tractor	No	84 (spec)
Vacuum Excavator (Vac-Truck)	No	85
Vacuum Street Sweeper	No	82
Ventilation Fan	No	79
Vibrating Hopper	No	87
Vibratory Concrete Mixer	No	80
Vibratory Pile Driver	No	101
Warning Horn	No	83
Welder/Torch	No	74

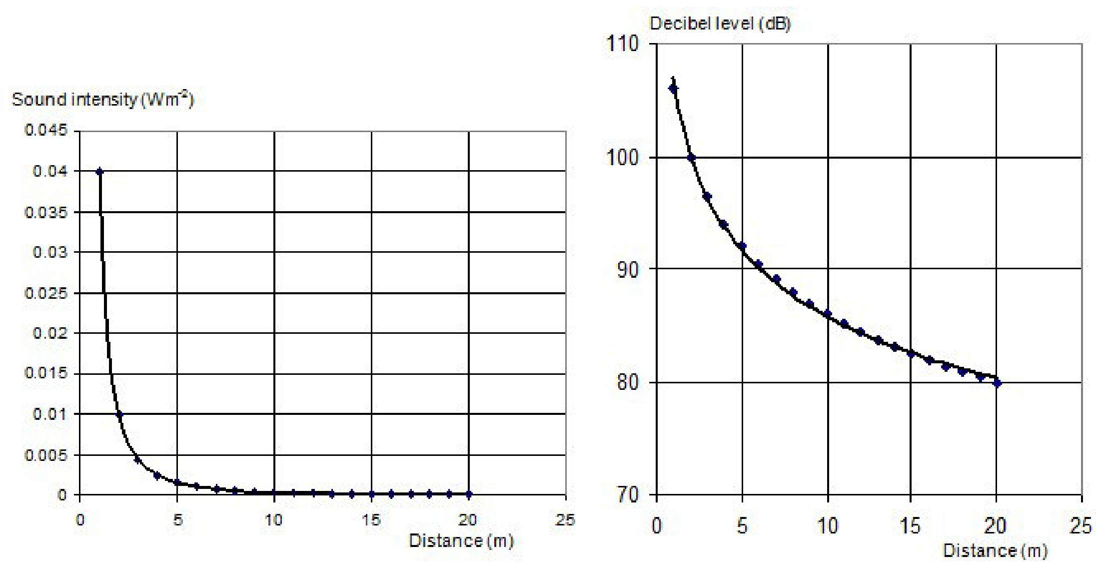
Source: US Federal Highway Authority - Construction Noise Handbook
(https://www.fhwa.dot.gov/environment/noise/construction_noise/handbook/handbook09.cfm)

For each generic type of equipment listed in Table 5-10, the following information is provided:

- an indication as to whether or not the equipment is an impact device;
- the acoustical usage factor to assume for modelling purposes;
- the measured "Actual" emission level, or the specification "Spec" limit for each piece of equipment (where actual not available) expressed as an Lmax level in dBA at 50 feet
- Data obtained from a number of construction projects over the period beginning in the 1970s through 2006

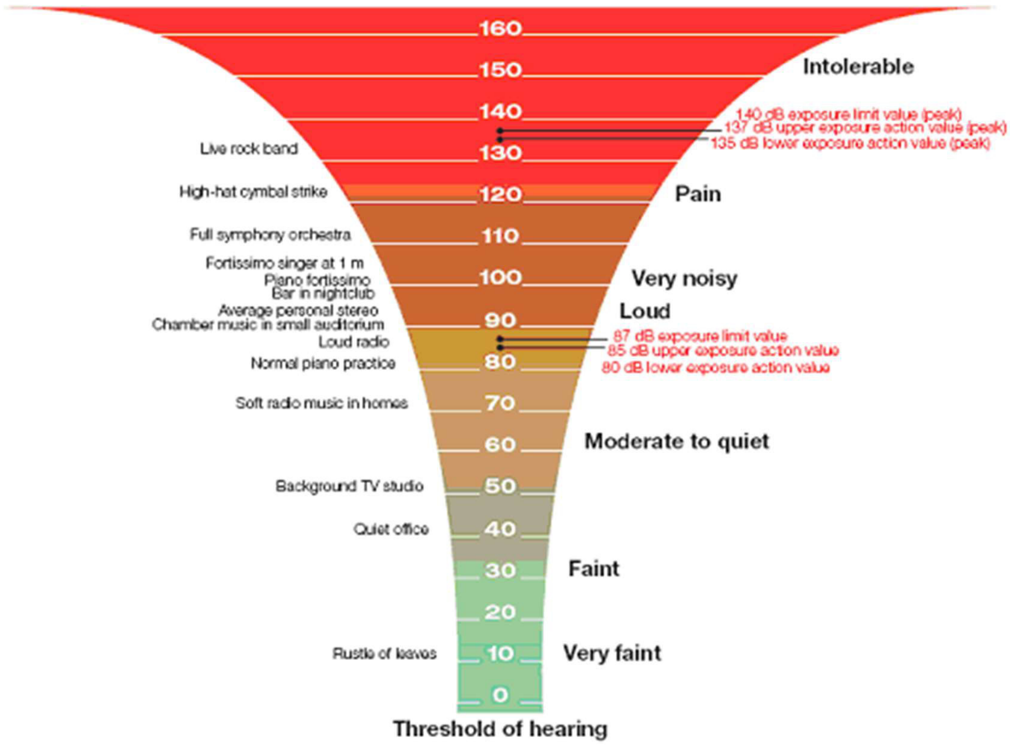
Sound intensity decreases by the inverse square of the distance.

Figure 5-13 Variation of sound level intensity and the decible level with distance from the source of sound (decibel level of 80 dB at 200 m)



Source: http://www.schoolphysics.co.uk/age16-19/Sound/text/Sound_levels_and_distance/index.html

Figure 5-14 Noise disturbance levels



Source: Sound Advice. http://www.soundadvice.info/thewholestory/san1.htm

Mitigation Measures

Noise emissions and vibration effects will be mitigated through best practice, including:

- Restricting construction in areas close to villages (access road and transmission lines, powerhouse) to the period 7:00am to 5:00pm;
- Restricting blasting at the dam site or other locations that require blasting to the period 7:00am to 5:00pm;
- Restricting movement of heavy vehicles through villages to the period 7:00am to 5:00pm;
- Requiring that all mobile and stationary equipment be equipped with fully functioning noise mufflers and baffles.

Residual effects and their significance

By implementing best practices to control noise emissions, including restricting construction work adjacent to villages to daytime hours, noise impacts will be moderate during daytime hours, and low during night time hours and, therefore, are considered to be not significant. http://www.soundadvice.info/thewholestory/san1.htm

6. BASELINE BIOLOGICAL ENVIRONMENT - TERRESTRIAL

6.1 INTRODUCTION

This section presents baseline information on the fauna and flora found within the study area.

According to UNESCO (2013), no other areas of comparable size support more unique bird species than the Solomon Archipelago. Solomon Islands has about 4500 species of plants and is recognized as being rich in plant diversity, and endemism (MECM, 2008). Solomon Islands supports breeding populations of 47 endemic bird species. The country has 4 Endemic Bird Areas (EBAs), one of which is located on Guadalcanal. An EBA is an area of less than 50,000km^2 that encompasses breeding range for two or more restricted-range land birds (Bird Life International, 2013).

Solomon Islands and Guadalcanal are rich in biodiversity and endemicity, not only for birds, amphibians, reptiles and mammals, but also invertebrates. The degree of variation in bird species between islands is very marked. Guadalcanal is home to many small mammals mostly bats, rats and possums, some of which are rare (MECM, 2008). As it is the case with other islands that make up Solomon Islands, Guadalcanal˜s interior mountain species have been poorly studied, and much more scientific information is needed (MECM, 2008; McCoy, 2008). The mountains of Guadalcanal reach elevations up to 2,310 meters, and are uninhabited by humans. They provide pristine wildlife habitats.

6.2 METHODOLOGY

Field surveys to inventory fauna were undertaken by Edgar Pollard, an expert on fauna of the Solomon Islands. Field surveys to inventory flora were carried out by Myknee Sirikolo, an expert on the flora of Solomon Islands. Eric Deneut, biologist and assistant team leader, provided additional observations and discussion concerning terrestrial fauna. Field visits and sampling were carried out from 5 to 17 August 2013. A total of 24 flora stations and 22 fauna stations were studied for the purpose of characterizing the environmental baseline.

Sampling locations were selected to reflect potentially project-affected areas. Prior to conducting the field visits, the location of fauna and flora stations was presented to the TRHDP PO and fauna and flora experts, for discussion and approval. To enable experts to precisely locate each station and to facilitate the process of data gathering in the field, special field maps were prepared using BaseCamp (Garmin). These maps were then printed on waterproof sheets. An example of one of these field maps is included in Annex 9 of the Annex Report. Maps used in recording aquatic environment data show the exact location of each sampling station. Three categories of sampling area were selected:

é Upper Stream sampling area - a typical upper stream area within undisturbed lowland forest (primary forest).

é Middle Tina River sampling area - a large area that represents the main location of potential impact generating activities (e.g., access road, powerhouse, tunnel, and dam).

- Transmission line sampling area - these stations represent the future location of the transmission line. All sampling stations were located along the road that connecting to Tina River village (Black Post Road). This will be the access road used by trucks and machinery to connect to the construction site.

6.3 TERRESTRIAL FLORA

6.3.1 Survey Locations and Methodology

The upper catchment of the Tina River provides important terrestrial habitat, consisting of areas of Montane forest spread across the high peaks of Guadalcanal (see Figure 6-1). The ESIA team accessed this upper catchment to sample flora and fauna, using a helicopter. However, due to issues of limited access and availability of scientific data, many questions remain regarding the flora and fauna assemblages in the upper catchment˜s montane forest. Notwithstanding, the ecosystem of this area will not be directly affected by the Project.

Fauna and flora surveys were carried out at specific survey sites across the project area of influence as shown in Figure 6-1, and further described in Appendix A. Flora species at each station were identified within circular plots having a radius of 10m to 20m from their centre point (see Annex 8 in the Annex Report for a list of identified plant species). In some cases, the radius was increased to reflect the need to sample the diversity of plant species. Although the flora survey was undertaken at one specific time, timing of the surveys is irrelevant since species were identified regardless as to whether they were flowering at the time of the survey, or not. Survey results also confirmed the presence of plants and wildlife that were identified from previous studies.

To ensure that no major rare or protected plant communities will be affected as a result of construction activities, a ground level reconnaissance survey will be done at the time the final road and transmission line alignments are identified, with the purpose of identifying potential threatened or vulnerable plant species that would need to be avoided. This reconnaissance survey would serve as the baseline for monitoring the construction of the access road to ensure that no threatened or vulnerable flora is destroyed.

A constraint for undertaking the flora survey was the lack of site-specific information on the Project area.

6.3.2 Flora Survey Results

From the flora survey, the floral expert identified a total of 159 plant species. Among the species identified, 5 are listed as vulnerable, and 19 are listed as threatened. A total of 66 species of trees, fern trees and palm trees were identified. They are classified in the `tree stratum_. Many species are regrowth and secondary trees species and are, therefore, good indicators of past disturbances, whether from natural events (e.g., cyclones; landslides) or anthropogenic activities (e.g., timber harvest). At least 23 identified tree species are of commercial timber value. A total of 36 shrubs and vines, and a total of 57 herbaceous plants were identified.

The ESIA flora baseline survey was supplemented by information obtained from the Feasibility Study rapid flora assessment, which had identified 23 additional species of plants, including: 2 trees, 3 palms, 4 shrubs (including bamboo) and 14 orchids (herbaceous plants). Many plants are used by local communities as medicinal plants, as a source of building materials, and for food.

Disturbed areas such as Black Post road, and the proposed access road and transmission line corridor, are colonized by invasive plant species. The level of disturbance increases from upstream to the downstream in the catchment. Disturbance is the result of human activity, mainly logging and human settlements (garden, houses, etc.)